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Front-of-pack nutrition labelling schemes: an update of the evidence

Addendum to the JRC Science for Policy report "Front-of-pack nutrition labelling schemes: a comprehensive review", published in 2020

Nohlen, H.U.*, Bakogianni, I.*, Grammatikaki, E., Ciriolo, E., Pantazi, M., Dias, J., Salesse, F., Moz Christofoletti, M.A., Wollgast, J., Bruns, H., Dessart, F., Marandola, G., van Bavel, R.

* joint first authorship

Joint Research Centre

EUR 31153 EN

Contact information
Name: Jan Wollgast
Address: Joint Research Centre, Directorate F, Health, Consumers and Reference Materials, Unit F.1: Health in Society
Via Enrico Fermi 2749, TP 127, 21027 Ispra (VA), Italy
Email: Jan.Wollgast@ec.europa.eu

EU Science Hub
https://joint-research-centre.ec.europa.eu

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Abbreviations

AHEI	Alternate Healthy Eating Index
BMI	Body Mass Index
BOP	Back-Of-Pack
CARP	Category average reference point
DFLF	Dynamic label with real-time feedback
DRI	Daily Recommended Intake
EU	European Union
fMRI	Functional Magnetic Resonance Imaging
FOP	Front-Of-Pack
FOPNL	Front-Of-Pack nutrition labelling
FSA	Food Standards Agency
FSANZ	Food Standards Australia New Zealand
GDA	Guideline Daily Amount(s) (now Reference Intakes)
HCSP	Haut Conseil de la santé publique
HEI	Healthy Eating Index
HSR	Health Star Rating
JRC	Joint Research Centre
MTL	Multiple Traffic Light(s)
NPSC	Nutrient Profilling Scoring Criterion
Ofcom	UK Office of Communications
PACE	Physical Activity Calorie Equivalent
PAHO	Pan American Health Organization
PICO	Population, Intervention, Comparator, Outcome
PME	Perceived message effectiveness
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analysis
RCT	Randomised, Controlled Trial
RIs	Reference Intakes
SENS	Système d'Etiquetage Nutritionnel Simplifié
SFA	Saturated fat
SSB	Sugar-Sweetened Beverage
TL	Traffic Light(s)
WHO	World Health Organization

Abstract

This addendum of the JRC Science for Policy report "Front-of-pack nutrition labelling schemes: a comprehensive review" provides an update of the former publication regarding the effects of front-of-pack nutrition labelling (FOPNL) schemes on consumers' understanding, food purchases, diet and health, as well as food reformulation. This addendum was produced to further inform the Commission's proposal for harmonised mandatory FOPNL announced in the Farm to Fork Strategy.

The previous report provided a review of the scientific literature regarding the effects of FOPNL on consumers, and food business operators. Emphasis was placed on consumer attention, preferences, and understanding of diverse FOPNL schemes, as well as FOPNL schemes' effects on food purchases and their implications for diet and health. The report also discussed whether and to what extent the introduction of FOPNL schemes may affect producer efforts on food reformulation and innovation, highlighted potential unintended consequences of introducing FOPNL, and described knowledge gaps and directions for future research. The literature review was complemented by an overview of FOPNL schemes. In addition to an update and extension of the previous report with recent literature (published between May 2018 and 1 February 2021), the current report additionally addresses the effects of different labelling aspects (e.g. use of reference quantities, voluntary vs. mandatory implementation, combination of front-of-pack nutrition labels and claims on consumer understanding and consumer behaviour).

Executive summary

Background

As of December 2016, Regulation (EU) No 1169/2011 (European Union, 2011) on the provision of food information to consumers requires the vast majority of pre-packed foods to display a nutrition declaration in order to allow consumers to make informed and health-conscious choices. This declaration is often provided on the back of food packaging. As a minimum, this mandatory nutrition declaration needs to include the energy value as well as the amounts of total fat, saturated fat, carbohydrate, sugars, protein and salt, expressed per 100 g or per 100 ml (and optionally per portion).

Front-of-pack nutrition labelling (FOPNL) aims to help consumers with their food choices by providing at-a-glance nutrition information. It is seen as a tool to support the prevention of diet-related, non-communicable diseases.

Under the current EU rules, the indication of nutrition information on the front-of-pack (FOP) is possible on a voluntary basis in line with the requirements of Union law (European Commission, 2020b). A variety of FOPNL schemes have been developed by public institutions, health non-governmental organisations and/or the private sector.

In 2018, the European Commission's Joint Research Centre (JRC) was asked by the Directorate-General Health and Food Safety (DG SANTE) to use its expertise in nutrition and consumer behaviour science to provide a detailed analysis of current FOPNL schemes regarding consumer understanding, their use, and their effect on consumers' behaviour, dietary choices and health. The comprehensive review by Storcksdieck genannt Bonsmann *et al.* (2020a) on FOPNL schemes includes schemes from within and outside the EU.

Furthermore, in May 2020, the European Commission published a report on FOPNL (European Commission, 2020b). The report presents the main FOPNL schemes implemented or developed at EU level, as well as some of the schemes implemented at international level. The report also looks into consumer understanding and impacts on purchasing behaviour, food reformulation and the internal market. It builds upon literature gathered and analysed in the above mentioned report, as well as a consultation carried out by the Commission with national competent authorities and relevant stakeholders.

As part of the Farm to Fork Strategy (European Commission, 2020a), adopted by the Commission on 20 May 2020, the Commission is proposing actions to empower consumers to make healthy food choices, including the introduction of a harmonised mandatory FOP nutrition label. Europe's Beating Cancer Plan (European Commission, 2021b) also lists a proposal for harmonised mandatory FOPNL as one of the actions for improving health promotion through access to healthy diets. The action is also referenced in the New European Union Strategy on the Rights of the Child (European Commission, 2021a).

To better support these EC initiatives, the present report provides an update to the review by Storcksdieck genannt Bonsmann *et al.* (2020a), covering the scientific evidence published after the time limit set for the previous report (May 2018) until February 1st 2021.

Aim

The aim of this report is to:

1. Update the previous literature review with recent evidence, published since 31 May 2018, on the effect of FOPNL on:
    - *consumer awareness, acceptance, understanding, food purchases; diet and health; food reformulation and innovation;*
    - *the understanding by and impact of the various FOPNL schemes on lower socio-economic groups;*
2. Collect relevant scientific publications published after 1990, focusing on the following aspects:
    - *The effects of FOPNL schemes on consumer understanding and impacts on consumer behaviour with regard to:*
        i) the effect of the reference quantities used in a FOPNL scheme (100 g/ml or portions/servings);
        ii) the impact of a voluntary vs. mandatory implementation;
        iii) the combined presence of different types of FOPNL;
        iv) the combination of FOPNL with nutrition and health claims;
        v) highly processed vs. single-ingredient products, as well as traditional products and products with protected geographical indications.

Methods

Two independent systematic searches were carried out across several online databases (PubMed, Web of Science, ScienceDirect, Scopus, Google Scholar, Open Grey and AgEcon). Each article was first screened by title and abstract to assess its relevance before reviewing the full text. Only peer-reviewed scientific articles, written in English, were included in the review process. Two reviewers independently evaluated the included articles. Conflicts on whether to include an article were resolved by discussion, and where necessary by a third reviewer. More than 2 450 unique publications were identified and screened, of which more than 750 articles were read and assessed for eligibility. Additional (grey) literature was identified through stakeholder input and hand searching the reference lists of identified review articles. Finally, 245 articles were included in the analysis. The articles were categorised by topic, from consumer attention and understanding of FOPNL schemes to the impact of FOPNL on purchases, diet, health, and food product reformulation.

Description of the literature

There is a large number of FOPNL schemes varying widely in complexity, colour, and amount of information. Some schemes are purely numerical and repeat some of the information contained in the nutrition declaration (so-called reductive schemes), are colour-coded or monochrome, some represent summary scoring schemes that are graded indicators or dichotomous endorsement logos. Taken from and updated since the previous report, we have included a table (see page 7) summarising different proposed classifications of FOPNL systems that is meant to help make sense of the different aspects on which these labels are categorized in

the literature as well as in this report. Storcksdieck *et al.* (2020b) have overviewed in detail FOPNL schemes in the EU and worldwide.

In recent years, the number of published studies on FOPNL schemes has increased extensively, in particular the number of articles investigating the effects of the Nutri-Score and nutrient-specific warning labels, which have both been used widely in the past decade.

The existing literature largely covers studies on the effectiveness of FOPNL schemes in terms of consumers' attention to the labels, preference, understanding, and purchase as well as their impact on diet and health. Methods vary widely from qualitative studies such as focus groups, to eye-tracking measures, surveys, studies on sales data, as well as field, online, and laboratory experimental studies.

Important to note when interpreting the literature is that consumer behaviour is largely variable and influenced by multiple factors – situational and personal. Consumers differ by age, education, health consciousness, cognitive capacities, culture, and many other attributes. At the same time, the same consumer may behave differently under varying circumstances, whether making purchases under time pressure, in stressful situations, when preoccupied, or when making purchases for oneself or for others. Any FOPNL scheme should thus be conscientiously tested in varied and large samples, and in different settings. This is also important with respect to the fact that familiarity with different FOPNL schemes varies between countries, which may be a key explanation for an observed better performance of a specific label.

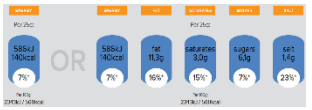
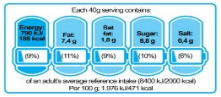
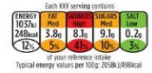
Findings

We considered several aspects to evaluate the effectiveness of FOPNL in shaping healthier diets: a) consumers' attention and awareness of labels; b) determinants of consumer liking and acceptance of labels; c) understanding of labels and inferences regarding healthfulness made from labels; d) the extent to which labels inform purchase decisions; e) effects of labels on diet and health, and f) potential effects of FOPNL on reformulation of food products. Many external and personal factors can affect each of these aspects such as consumer motivation, design, format and placement aspects of the label scheme and a consistent implementation of a label scheme.

Capturing attention is a prerequisite for any FOP nutrition label to inform consumers' product choices. *Attention to FOP nutrition labels* varies depending on features of the labels themselves as well as characteristics of the person and the situation. Visual design aspects (e.g. colour, size, position, complexity, contrast, amount of information, 'visual clutter') can influence consumers' attention. This may be especially relevant for consumers who are under time constraint, have less capacity to process the information, or are less interested in health-related information. Evidence suggests that colours stimulate attention paid to labels and that less complex labels require less attention to be processed. As noted in the previous JRC report, FOPNL awareness may also be facilitated by public information campaigns. Education and promotion campaigns would thus be useful to accompany any initiative to adopt a FOPNL scheme.

FOPNL typologies and examples of corresponding FOPNL schemes in the EU

FOPNL studies and their proposed terminology

Feunekes *et al.* (2008)	Hodgkins *et al.* (2012)	Newman *et al.* (2014)	Savoie *et al.* (2013)	Julia & Hercberg (2017)	Muller & Ruffieux (2020)						
					Directiveness	Scope	Gradation	Set of Reference	Signs		
More complex schemes	Non-directive	Reductive (non-interpretative)	Nutrient-specific labels	Numerical	Non-directive	All foods	Cardinal	Across-category	Numbers	*Reference Intakes label*	
									Numbers Ideograms	*NutrInform*	
	Semi-directive	Evaluative (interpretative)		Colour-coded	Diet-directive		Ordinal		Colours Words Numbers	*UK MTL label*	
Simple schemes	Directive	Evaluative (interpretative)	Summary indicator labels	Graded indicators	Food-directive				Colours	*Nutri-Score*	
				Endorsement schemes *('positive logos')*		Recomm-ended Food	Binary	Within-category	Ideograms	*Keyhole* *Heart/Health logos* *Healthy Choice*	

Binary, expresses opinion by presence or absence; cardinal, expresses information in units; FOPNL, front-of-pack nutrition labelling; MTL, Multiple Traffic Lights; ordinal, divides nutritional score into classes

Overall, consumers seem to *appreciate FOP nutrition labels*, which they see as a quick and easy way to acquire nutritional information related to their purchase decisions and make them feel more empowered in their choices. Studies show that consumers are in favour of having FOP nutrition labels in addition to the more detailed back-of-pack (BOP). Coloured and directive FOP nutrition labels seem to be preferred to monochrome and non-directive ones. While there is no unanimous evidence for a predominant preference for one over other FOPNL schemes, overall, evaluative FOPNL schemes with colour coding tend to do well in assessments of consumer liking. However, it must be noted that consumers' self-reported preferences are not always commensurate to their respective understanding and use of the various FOP nutrition labels.

Consumers tend to *understand* simpler, evaluative, colour-coded labels more easily than more complex, reductive, monochrome labels. Consistently used, simple reference quantities that require less "mental math" to process achieve better understanding. Less mental math is also beneficial for consumer understanding of nutritional information in general. Simplicity, consistency, and salience may be especially relevant in the shopping environment when consumers tend to make decisions quickly. Familiarity with the label also increases understanding.

Field studies assessing the link between FOPNL and *real-life purchasing behaviours* are difficult to design and conduct. Instead, laboratory or online experimental studies are often conducted to collect data on purchasing behaviours and intention to purchase. The latter evidence therefore prevails in the available literature on purchasing behaviours. Experimental studies looking at the intention to purchase show that FOPNL, especially colour-coded labels, can improve the nutritional quality of food choices and shopping baskets, especially for individuals displaying a strong motivation to eat healthily. The available evidence on actual shopping behaviour suggests a small beneficial effect of FOPNL on 'on-the-spot' purchasing. The impact of FOP nutrition labels is estimated to be substantially smaller in real-life compared to in laboratory settings. A possible reason is that real-time purchasing decisions are influenced by a multitude of other factors (price, brand, time pressure, taste, habit, cognitive depletion, etc.) which may be difficult to isolate, making evidence on actual shopping behaviour difficult to obtain. Also the type of FOPNL scheme may influence the effect on purchasing favourably depending on the type of consumer: evaluative labels may be processed faster and reductive labels may be processed slower due to their complexity. Some empirical studies give account of limited or not statistically significant impact of FOP nutrition labels on 'on-the-spot' purchasing behaviour. There is also evidence of FOP nutrition labels boosting purchase of the healthiest products while not discouraging the purchase of products with medium or low nutritional value to the same extent. "High-in" warning labels seem to be more effective than other types of labels in discouraging purchase of less healthy products as they specifically indicate the less healthy choices and not the healthier choices. Other FOPNL schemes, such as (Multiple) Traffic Lights, Health Star Rating and Nutri-Score, seem to work better at improving overall healthiness of choices – i.e. combining both increase of the healthy and decrease of the unhealthy products- rather than effecting changes on purchases of specifically the healthy or the unhealthy products alone. Overall, Reference Intakes/Guideline Daily Amounts also work in the same direction, i.e. to increase overall healthiness when compared to no label condition but to a lesser degree of magnitude. When it comes to the impact on shopping costs, the majority of the evidence reviewed does not relay the existence

of any correlation between FOP nutrition labels and consumers' expenditure. In addition, several *sociodemographic factors* play an important role when it comes to consumers' attention, preferences, purchases, and understanding. Higher income is generally correlated with a higher interest in FOPNL. Older adults and those with lower income and/or education, and lower nutritional knowledge struggle the most to interpret FOP nutrition labels correctly. Consumers from lower socio-economic groups seem to favour simpler, evaluative FOP nutrition labels. Most but not all studies suggest that the presence of FOP nutrition labels, especially directive and semi-directive labels, can help children and lower socio-economic groups in making more healthful choices. Overall, results highlight the importance of choosing the appropriate scheme that could impact consumer choices, especially those of vulnerable populations. Evidence suggests that the traffic-lights and Nutri-Score schemes are particularly effective among consumers of lower socio-economic status in helping them identify the healthier option.

Aspects of the *implementation of labelling* have also been found to affect consumer understanding, preferences, and influence consumer behaviour. Some evidence points to the suggestion that mandatory labelling may be beneficial for consumers' understanding of labels as well as their trust in the labels, and that consumers also prefer a mandatory implementation. There is some preliminary indication that combinations of summary and nutrient-specific information seem to perform relatively well in some studies regarding consumer preferences, purchase intentions, perceived healthiness, or healthiness of the shopping basket. However, even though too early to draw conclusions, it seems that combined labels do not perform as well as well-performing individual labels. While the evidence on the effect of adding voluntary claims to FOP nutrition labels on food products is mixed, there seems to be a tendency that voluntary claims and marketing images can interfere with the efficacy of FOP nutrition labels.

There is some data indicating a potential beneficial impact of FOPNL on *the reformulation of food and beverages* towards a more nutritious food supply and improvement in the nutritional content especially for nutrients such as sugars and sodium. More empirical data is needed to understand the causality as well as the true effect size of improvements in nutritional content of the food supply on consumers' dietary intake.

Given the difficulty in setting up real-life studies that causally examine the impact of FOP nutrition labels on *dietary intake and health outcomes*, there is not enough empirical evidence to draw conclusions regarding FOP nutrition labels' actual effect on diet and health. Experimental and modelling studies are generally used instead. These suggest that the presence of FOPNL, and especially evaluative schemes, could help in reducing the consumption of energy and nutrients of concern such as saturated fatty acids, sugars and sodium, while improving the intake of protein and dietary fibre. Additionally, theoretical modelling studies agree that the introduction of FOPNL could be associated with better dietary intake for the population as well as with a decrease in mortality from diet-related non-communicable diseases.

Knowledge gaps

Some of the knowledge gaps identified in the JRC 2020 report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) still remain, in particular a) the magnitude of the effect of FOPNL schemes on actual purchasing behaviour, as well as purchasing behaviour over time; and b) the extent to which FOPNL schemes may lead to improvements of the overall diet and health. Data from mainly experimental and modelling studies show that the presence of FOP nutrition labels is associated with improvements in the intake of some nutrients. However, more real-life evidence would help corroborate the findings and better quantify the magnitude of the influence of FOP nutrition labels.

Additionally, only limited studies are available regarding the effect of combining several FOP nutrition labels on the same packaging. Also limited studies exist regarding how consumers understand FOP nutrition labels for highly processed compared to foods with single or few ingredients.

1 Background and aim of the report

In 2018, the European Commission's Joint Research Centre (JRC) was asked by the Directorate-General Health and Food Safety (DG SANTE) to use its expertise in nutrition and consumer behaviour science to provide a detailed analysis of current front-of-pack nutrition labelling (FOPNL) schemes regarding consumer understanding, their use, and effect on consumers' behaviour, dietary choices and health. This was done in support of a Commission report on FOPNL.

The current report is an update of the comprehensive review on FOPNL schemes published by the JRC in 2020 (Storcksdieck genannt Bonsmann et al., 2020a) and takes the form of an addendum to that report. It covers the scientific evidence published after the period covered by the previous report, i.e. from May 2018, and until February 1, 2021. The update is produced to further inform the Commission's proposal for harmonised mandatory FOPNL announced in the Farm to Fork Strategy.

As part of the Farm to Fork Strategy (European Commission, 2020a), the Commission is proposing actions to empower consumers to make healthy food choices, including the introduction of harmonised mandatory FOPNL. Europe's Beating Cancer Plan (European Commission, 2021b) also lists a proposal for harmonised mandatory FOPNL as one of the actions for improving health promotion through access to healthy diets.

The objectives of this literature review update are to:

1. Update the previous literature review with recent evidence, published since 31 May 2018, on the effect of FOPNL on:
    - *consumer awareness, acceptance, understanding, food purchases; diet and health; food reformulation and innovation;*
    - *the understanding by and impact of the various FOPNL schemes on lower socio-economic groups;*

2. Collect relevant scientific publications published after 1990, focusing on the following aspects:
    - *The effects of FOPNL schemes on consumer understanding and impacts on consumer behaviour with regard to:*
        i) the effect of the reference quantities used in a FOPNL scheme (100 g/ml or portions/servings)
        ii) the impact of a voluntary vs. mandatory implementation
        iii) the combined presence of different types of FOPNL
        iv) the combination of FOPNL with nutrition and health claims;
        v) highly processed vs. single-ingredient products, as well as traditional products and products with protected geographical indications.

2 Introduction

In the EU, the vast majority of pre-packed foods are required to display a nutrition declaration in order to allow consumers to make informed and health-conscious choices (Regulation (EU) No 1169/2011 (European Union, 2011) on the provision of food information to consumers). This mandatory nutrition declaration is often provided on the back of food packaging. As a minimum, it must include the energy value as well as the amounts of total fat, saturated fats (SFA), carbohydrate, sugars, protein and salt, expressed per 100 g or per 100 ml (and optionally per portion).

Front-of-pack (FOP) nutrition labelling provides at-a-glance nutrition information with the goal to help consumers with their food choices. It is seen as a tool to support the prevention of diet-related non-communicable diseases. Under the current EU rules, the indication of nutrition information on the FOP is possible on a voluntary basis in line with the requirements of Union law (European Commission, 2020b).

The use of FOPNL is considered to significantly help tackle non-communicable diseases, and the World Health Organization lists FOPNL as one of the measures for improving population diets (Kelly & Jewell, 2018; WHO, 2013, 2019). Various FOPNL schemes have been proposed by public institutions, health non-governmental organisations and the private sector. Many schemes have been implemented worldwide, and their characteristics are listed in the previous report from the JRC (Storcksdieck genannt Bonsmann et al., 2020a).

Taken from and updated since the previous report, we have included a table summarising the various proposed classifications of FOPNL systems that is meant to help make sense of the different aspects on which these labels are categorized in the literature as well as in this report (Table 1). Storcksdieck *et al.* (2020b) have overviewed in detail FOPNL schemes in the EU and worldwide.

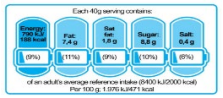
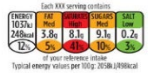
In line with the previous report (Storcksdieck genannt Bonsmann et al., 2020a), in the current report we define FOPNL as nutrition information displayed in the principal field of vision on food and drinks packaging that:

a) either repeats some or all of the numerical information from the mandatory nutrition declaration in a non-evaluative way (so called reductive systems, e.g. Reference Intakes (RIs) label or the NutrInform Battery label developed by Italy) or in an evaluative way (e.g. by using traffic-light colours or wording 'high, medium, low');

b) or expresses the overall nutritional value of a food, by using some or all of the information from the nutrition declaration and/or other nutritional elements, to be applied on all products (e.g. graded scores, such as Nutri-Score or the Australian Health Star Rating (HSR) scheme) or only on products complying with certain nutritional criteria (e.g. positive/endorsement logos/symbols, such as the Nordic Keyhole).

Warning signs neither repeat numerical information from the nutrition declaration nor express the overall nutritional value of a food. However, they are covered in this report where relevant and informative.

Table 1 Front-of-pack nutrition labelling typologies and examples of corresponding schemes in the EU

Overview of studies and their proposed terminology											
Feunekes *et al.* (2008)	Hodgkins *et al.* (2012)	Newman *et al.* (2014)	Savoie *et al.* (2013)	Julia & Hercberg (2017)	Muller & Ruffieux (2020)						
					Directiveness	Scope	Gradation	Set of Reference	Signs		
More complex schemes	Non-directive	Reductive (non-interpretative)	Nutrient-specific labels	Numerical	Non-directive	All foods	Cardinal	Across-category	Numbers	*Reference Intakes label*	
									Numbers Ideograms	*NutrInform*	
	Semi-directive	Evaluative (interpretative)		Colour-coded	Diet-directive		Ordinal		Colours Words Numbers	*UK MTL label*	
Simple schemes	Directive	Evaluative (interpretative)	Summary indicator labels	Graded indicators	Food-directive				Colours	*Nutri-Score*	
				Endorsement schemes *('positive logos')*		Recomm-ended Food	Binary	Within-category	Ideograms	*Keyhole* *Heart/Health logos* *Healthy Choice*	

Binary, expresses opinion by presence or absence; cardinal, expresses information in units; MTL, Multiple Traffic Lights; ordinal, divides nutritional score into classes

3 Impact of FOPNL – a review of the evidence

3.1 Literature search methodology

For this review, two separate literature searches were carried out, one on the effect of FOPNL on diet and health, and the other on consumer behaviour and perceptions of FOPNL.

To identify relevant articles on the effect of FOPNL on diet and health, we applied the search strings defined in Table 2 to the online databases PubMed, Web of Science, Google Scholar, OpenGrey and AgEcon. The search covered the period from 1st June 2018 up to 1st of February 2021.

Table 2 Databases and search strings used for literature search on the effect of front-of-pack nutrition labelling on diet and health.

Database	Search string
PubMed	"nutrition*[Title/Abstract] AND label*[Title/Abstract] AND front[Title/Abstract] AND pack*[Title/Abstract]"
Web of Science, Google Scholar, AgeCon and OpenGrey	"food AND nutrition AND labelling OR label AND front-of-pack OR front of pack OR FOP AND health"

To identify relevant articles on consumer responses to FOPNL, we searched ScienceDirect, Scopus, and Web of Science. Search strings are described in Table 3. Since we addressed different research questions and several questions were added for this review update, separate search terms were defined for each research question. Identified articles were considered for all defined research questions. Searches were conducted between January 26th 2021 and February 1st 2021 and focused on articles published between May 2018 and the date of the search. Articles published after 1990 were considered for the newly added research questions that were not covered by the original literature review. Articles were included if the search terms were found in titles, abstract, or keywords (and keywords+ for Web of Science). Because Science Direct imposes a more stringent limit of Boolean characters, the searches ran on this database are more general and thus more inclusive (Table 3). The searches reported in Table 3 resulted in over 1 000 initial articles that were considered for the review.

Table 3 Databases and search strings used for literature search on consumer responses to front-of-pack nutrition labelling.

Goal: Consumer responses to	Database	Search string [on Title/Abstract/Keywords(+) unless otherwise indicated]
Update of 2018 search	Science Direct	"Front-of-pack/age" AND "behaviour/behavior"
		"Front-of-pack/age" AND ("purchas*" OR "perception" OR "consum" OR "understand" OR "accept" OR "aware" OR "attitude")
	Web of Science, Scopus	(Front-of-pack* OR FOP) AND (behavio* OR purchas* OR perception OR consum* OR understand* OR aware* OR attitude)
FOP on highly processed foods (after 1990)	Science Direct	1.("Front-of-pack" OR FOP OR "Front-of-package") AND (composite OR "highly processed" OR "single ingredient"
		OR traditional OR protected OR "energy-dense food")
		2.("Front-of-pack" OR FOP OR "Front-of-package") AND ("geographical indication" or "geographical indications")
	Web of Science, Scopus	(Front-of-pack* OR FOP) AND (composite OR * processed OR
		single ingredient OR traditional OR protected OR energy-dense food or geograph* indication*) AND
		(behavio* OR purchas* OR perception OR consum* OR understand* OR aware* OR attitude OR impact OR knowledge OR sensitivity)
Voluntary vs. mandatory implementation of FOP (after 1990)	Science Direct	("Front-of-pack" OR FOP OR "Front-of-package") AND (voluntary or mandatory or compulsory or required or obligatory)
	Web of Science, Scopus	(Front-of-pack* OR FOP) AND (voluntary or mandatory or compulsory or required or obligatory) AND (behavio* OR purchas* OR perception OR consum* OR understand* OR aware* OR attitude OR impact OR knowledge OR sensitivity)
Combining FOP labels, and FOP labels with claims (after 1990)	Science Direct	(Front-of-pack OR Front-of-package OR FOP OR Front-of-package) AND (combination OR combined OR "labelling scheme" OR "labelling schemes")
	Web of Science, Scopus	(Front-of-pack* OR FOP) AND (combin* OR labelling scheme*) AND (behavio* OR purchas* OR perception OR consum* OR understand* OR aware* OR attitude OR impact OR knowledge OR sensitivity)
The use of different reference quantities on FOP (after 1990)	Science Direct	(Front-of-pack OR Front-of-package OR FOP OR Front-of-package) AND ("reference quantity" OR "reference amount" OR "portion size" OR "energy intake" OR "reference quantities" OR "portion sizes")
	Web of Science, Scopus	(Front-of-pack* OR FOP) AND (reference quantit* OR reference amount or portion size* OR energy intake) AND (behavio* OR purchas* OR perception OR consum* OR understand* OR aware* OR attitude OR impact OR knowledge OR sensitivity)

For both searches, only peer-reviewed, scientific articles published in English were considered. Conference proceedings, working papers, and PhD theses were excluded. Qualitative and quantitative research was considered (focus groups, online, lab and in-store experiments and observations, surveys, impact modelling). We also received input through stakeholder consultations. All provided input was read, but inclusion was limited to scientific articles that fit the specified inclusion criteria. Using the PICO[1] question approach, studies were included without any limitation on the population (P) that assessed the provision or application of FOPNL in any form (I) against other schemes or no FOP nutrition information as a comparator I, with one or more of the following reported outcomes (O):

- *O-1: Consumer awareness of FOPNL*
- *O-2: Consumer preferences for FOPNL*
- *O-3: Consumer understanding of FOPNL*
- *O-4: Consumer use of FOPNL*
- *O-5: Impact of FOPNL on purchasing*
- *O-6: Impact of FOPNL on diet & health*
- *O-7: Impact of FOPNL on food reformulation / innovation*

In addition, we focused on:

- *O-8: Understanding by and impact of the different FOPNL schemes on lower socio-economic groups;*
- *O-9: The effects of FOPNL schemes on consumer understanding and impact on consumer behaviour for composite products/highly processed food versus single-ingredient products, as well as for traditional products and products with protected geographical indications;*
- *O-10: Effects on consumer understanding and impact on consumer behaviour of voluntary versus mandatory FOPNL schemes;*
- *O-11: Effects on consumer understanding and impact on consumer behaviour of the combined presence on labels of FOPNL and nutrition and health claims;*
- *O-12: Effects on consumer understanding and impact on consumer behaviour of the combined presence of different types of FOPNL schemes on the front of the package;*
- *O-13: Effects on consumer understanding and impact on consumer behaviour of the reference quantities used in a FOPNL scheme (100 g/ml or portions/servings).*

Figure 1 presents the PRISMA[2] flowcharts of the study selection process from the number of initial hits to the number of full-text studies included in the review. The review of the literature was carried out in parallel by two different teams of, respectively, nutritional and behavioural experts. Some of the scientific articles were identified by both teams resulting in partial overlap of reviewed articles.

[1] PICO = Population, Intervention, Comparator, Outcome
[2] PRISMA = Preferred Reporting Items for Systematic reviews and Meta-Analysis http://www.prisma-statement.org/

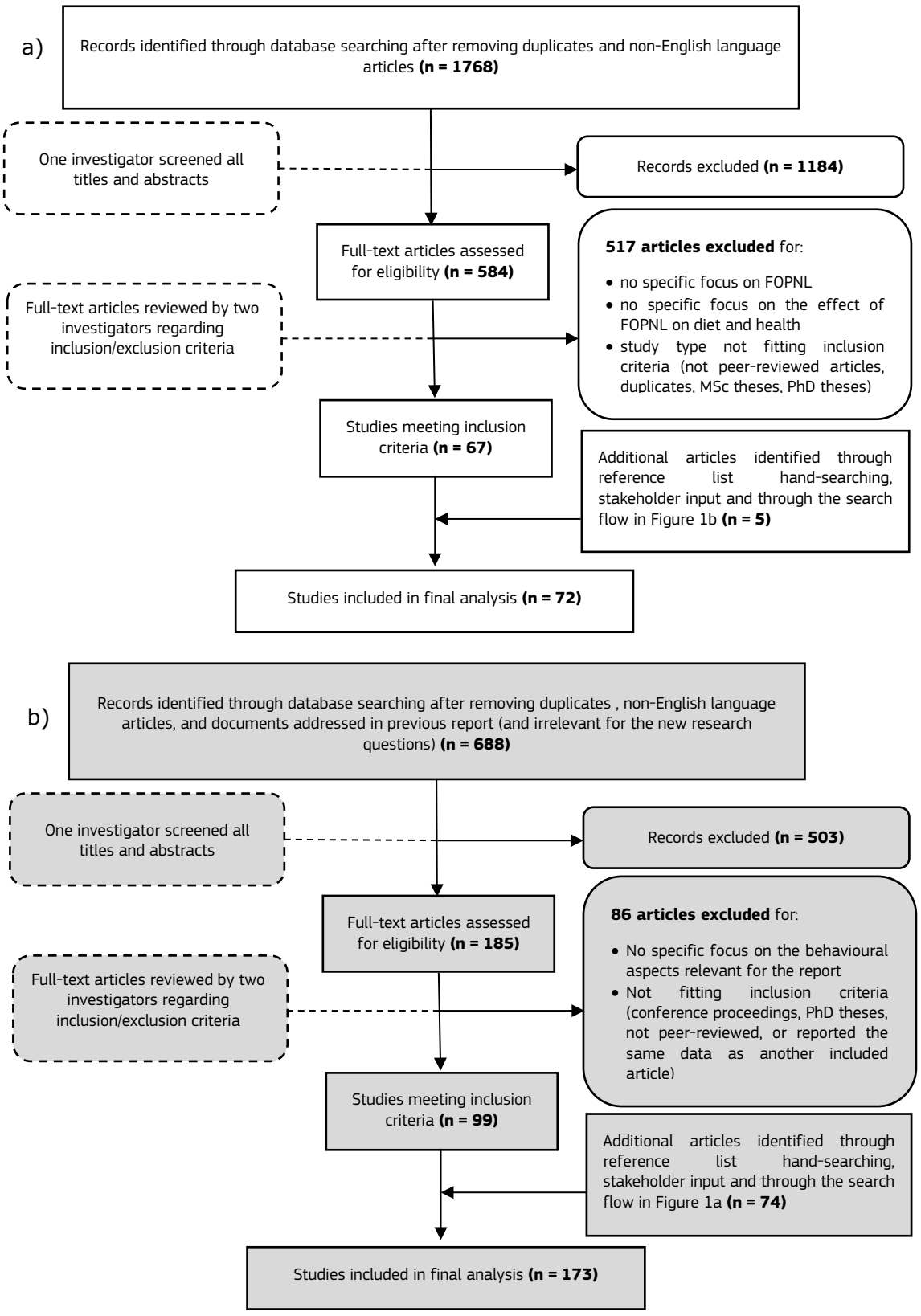


Figure 1 PRISMA flowchart for the screening and selection process of studies included in the final analysis concerning a) nutritional aspects (databases searched: PubMed, Google Scholar, Open Grey, Web of Science and AgEcon); and b) consumer responses to front-of-pack nutritional labelling (FOPNL) (databases searched: Web of Science, ScienceDirect, and Scopus).

Several types of studies are included in this report, such as focus groups, surveys, online experiments, lab experiments, and field studies. Each of these has advantages and disadvantages, and we can draw different conclusions from the study findings based on the study type:

- *Focus groups and interviews* belong to the qualitative research methods. They provide in-depth information on people's views and experiences on a given issue. Evidence from these studies is often used to generate hypotheses for subsequent quantitative research. It is important to note that due to the usually small sample size and lack of statistical testing, the findings do not offer population-level information.
- *Surveys* may provide population-level information and are informative about how participants interpret, understand, and portray information. Surveys are commonly used to assess attitudes and can also be used in experiments (i.e. experimental surveys). When surveys are used in experiments, we can identify causal relationships. Important to note is that they provide self-reported responses. In cases in which participants report on attention, awareness, or behaviour, these responses may not always reflect participants' behaviour in real-life settings.
- *(Behavioural) Experiments* are designed to identify causal relationships between the manipulated variables (e.g. FOP elements) and respondents' reaction. They compare results between groups (or experimental conditions). It is important to take into account that some experimental studies artificially draw attention to FOP nutrition labels and only measure intentions rather than behaviour. Whereas experiments let us identify causal relationships, these studies usually create a simplified choice context in order to identify the relevant elements and participants are often instructed to focus on a specific piece of information by asking them to complete a particular task (e.g. ranking product by healthfulness). Therefore, FOP nutrition labels' effectiveness risks being overestimated in these settings compared to real-life. Nevertheless, experimental studies are a robust way to test the effects of (elements of) a particular FOP nutrition label on respondents' reaction.
- *Field studies* are carried out in a less controlled environment. They can be experimental or observational. Whereas these studies provide greater ecological validity, there is also a greater risk of uncontrolled variables influencing the results.
- *Non-experimental empirical studies* are studies based on observations that do not involve any experiment, i.e. any manipulation of an independent variable (e.g., the presence or the absence of a FOP nutrition label). In the discussion of the results, funding of the research and the declaration of interest of the study authors is considered and reported where this information was provided or easily derived.

In line with the previous report, we distinguish between consumers' attention and attitudes toward different FOP nutrition labels, consumer understanding of the different labels, the impact of labels on purchasing behaviour as well as their impact on diet and health. While these will be related, they address different aspects of the decision-making process and thus different questions. From a policy-making perspective, understanding of FOP nutrition labels as well as purchasing behaviour (and thus diet) may be particularly important. However, each of these aspects is by itself a relevant piece of information. A FOPNL scheme will

not affect behaviour unless noticed and trusted as a reliable source of information. At the same time, without understanding the FOPNL scheme, purchase and consumption behaviour may not be beneficially impacted. Nevertheless, even if a FOPNL scheme is understood, it may not influence purchase and consumption if the information is disregarded or if consumers are not willing to use the FOPNL scheme.

In this report, the effectiveness of FOPNL to facilitate healthier diets is evaluated taking into account the following aspects: a) consumers' attention and awareness of labels; b) determinants of consumer liking and acceptance of labels; c) understanding of labels and inferences regarding healthfulness made from labels; d) the extent in which labels inform purchase decisions; e) effects of labels on diet and health, and f) potential effects of FOPNL on reformulation of food products.

3.2 Evidence on consumers' attention to FOP nutrition labels

Awareness of and attention to FOP nutrition labels are crucial for these labels to be successful in guiding healthier food choices. People need to be aware of the label and its purpose, and nutrition labels need to draw attention in order to facilitate healthier food choices.

In the analysis of the collected evidence on consumer attention to FOP nutrition labels, we will therefore first look at whether consumers are aware of and pay attention to FOP nutrition labels (3.2.1). Second, we will identify aspects that influence the degree to which attention is paid to particular labels in order to draw conclusions on features that can increase the noticeability of FOP nutrition labels by consumers (3.2.2).

3.2.1 Awareness of and attention paid to FOP nutrition labels

Regarding consumers' attention to FOP nutrition labels, we can distinguish between studies relying on self-reported awareness or attention paid to nutrition labels (Table 4), and studies that record eye movements of participants or consumers when looking at different product packages in order to provide an objective measure of attention (Table 5).

Indications of self-reported awareness and attention to nutrition labels have to be interpreted with caution (Storcksdieck genannt Bonsmann et al., 2020a), because socially desirable behaviour is often overestimated. For example, some studies have shown that people are likely to over-report their use of nutrition information (Grunert *et al.*, 2010). Such over-reporting may also be possible when it comes to self-reported awareness of and attention paid to nutrition information (Storcksdieck genannt Bonsmann et al., 2020a).

Eye-tracking studies provide a partial answer to the challenge of respondents potentially over-estimating their attention to FOP nutrition labels. Eye-tracking measures directly follow participants' eye gaze and can tell us whether participants have looked at a label, how long it took them to notice the label (i.e. Time to first fixation), how often a label was looked at (i.e. number of fixations), and for how long (i.e. dwell time, fixation duration). These indicators provide various insights. Whereas the time it takes individuals to fixate a label reflects the attention-grabbing ability of a label, the number of fixations as well as the average fixation duration relate to information processing. Important to note is that a higher number of fixations or longer durations can be interpreted as both, increased relevance of the label for the consumer, as well as the

difficulty to comprehend or process the label (Centurión *et al.*, 2019; Geisen & Romano Bergstrom, 2017; Tullis & Albert, 2013).

Studies on self-reported awareness or attention

Many recent studies, especially on self-reported awareness of and attention paid to FOP nutrition labels have been conducted in South America, likely due to the recent implementation of warning labels in several countries in the region (e.g. Chile, Peru, Uruguay). Based on the identified studies, self-reported awareness of various nutrition labels in the shopping context seems to be high on average, ranging from ~58-90% depending on the labels assessed (Cole *et al.*, 2019; Sarda *et al.*, 2020; Teran *et al.*, 2019). For example, Ares and colleagues (2021) report that 77% of their participants indicated to have seen warning labels when making food purchases in Uruguay, which is similar to Cole and colleagues (2019), who found that ~75% of their UK respondents declared to have noticed traffic light (TL) nutrition information. Two studies suggest that self-reported attention to labels is higher when consumers purchase products for the first time (Correa *et al.*, 2019; Koen *et al.*, 2018).

Large-scale awareness campaigns can help improve awareness of FOP nutrition labels. Sarda and colleagues (2020), for example, report an increase in awareness of the label of 17.2 percentage points after a first communication campaign, and awareness of the tested label increased from 58.2% to 81.5% over the course of 13 months.

Table 4 Studies of self-reported consumer awareness of or attention to front-of-pack nutrition information

Study (most recent first)	Population	Intervention/Comparator	Outcome
Dubois *et al.* (2021)	1 844 observations (1st wave) and 1 737 observations (2nd wave) in France	Study exploring whether FOP nutrition labels improve food purchases in a real-life setting. The nutritional quality of 1 668 301 purchases was analysed. Products in 60 supermarkets were labelled with either no label (20 supermarkets), SENS nutrition label (coloured pyramid with information on how often you should eat the food product), Nutri-Score, Nutri Repère (uncoloured GDA expressed through numbers and bars chart), or Nutricouleur (GDA expressed with numbers and colours). A survey was administered to shoppers before the labelling and during the labelling	Nutri-Score and SENS drew attention to a similar degree and substantially more so than Nutri-Repère and Nutricouleur.

Table 4 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Dubois *et al.* (2021) *(cont.)*		phase to measure the labels' ability to attract attention and the perceptions of their healthfulness.	
Ares *et al.* (2021)	Study 1: 855 participants in Uruguay Study 2: 917 participants in Uruguay	Two surveys were conducted before (May-June 2019) and after (March 2020) the implementation of nutritional warnings in Uruguay to assess awareness, self-reported use and understanding of nutrition information. Participants' task was to identify the healthiest option among various alternatives.	Awareness: 90% of participants indicated they had seen the warning labels in the tasks (Study 2). 77% of participants indicated to have seen warning labels on food products when making purchases. The participants who reported that they had seen the warnings on a product they intended to buy corresponded to 67 %.
Mabotja *et al.* (2021)	403 South African consumers (only those responsible for household shopping)	Online survey measuring participants' use and understanding of food labels of several FOP systems: Nestlé Know Your Serving; GDA; Teaspoon Nutritional Illustration; Nutritional Information Table; and TL Labelling.	The survey indicated that a majority (83%) considers food labels important. 29% said they always read nutritional information on food labels, 27% often and 26% occasionally. Only a minority reads food labels rarely (12%) or never (6%). 67% of those not reading the labels are not interested in them, while quite a few said the information appears in small fonts (28%) or is hard to understand (8%).
Sarda *et al.* (2020)	4 006 French adults across three waves (from April 2018, before the implementation of a national awareness campaign, to May 2019)	An online survey over three successive waves, with questions on awareness of the Nutri-Score, support of the measure, and change of behaviour following the implementation of the Nutri-Score.	Awareness of the logo significantly increased after a national communication campaign (+17.2% points, and then +6.1% points).
Cole *et al.* (2019)	237 participants in the UK	Survey study contained two questions to determine current awareness and use of existing FOP TL information. It also required respondents to compare existing FOP TL information to a novel "till receipt system" summarising the	75.1% of respondents declared that they have noticed existing TL information and understand its meaning. 3.8% of respondents said that they had either never seen TL information or that they did not understand it. 16.5% of

Table 4 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Cole *et al.* (2019) *(cont.)*		nutritional information of the entire food purchased.	respondents reported that they never used TL information to make their purchasing decisions.
Correa *et al.* (2019)	84 mothers in Chile	Nine focus groups were held to explore mothers' response to the 2016 Chilean law of food labelling and advertising. In particular, they assessed perceptions and knowledge about warning labels on food packaging.	In general, participants were aware of the warning labels and reported that more products bearing more labels were less healthy than those with fewer labels. Attention and use of the labels varied. Some say they only pay attention to the labels when buying new products or not at all, whereas others (mostly from middle & upper-socioeconomic levels) said they use them as shortcuts ("I don't read them [..] (very closely) but when I see too many, I don't buy it.").
Teran *et al.* (2019)	73 participants in a supermarket in Ecuador	Observational and survey data looking at awareness (knowledge) and use of the TL nutrition label in a supermarket context.	About 88.7% indicated to know the TL nutrition label and 27.4% indicated to use the label. Observational data suggest that 28.4% of participants actually used it.
Koen *et al.* (2018)	67 adult consumers in South Africa	9 focus group discussions were held to explore whether nutrition information influences purchase behaviour, which reasons consumers mention for reading or ignoring provided nutrition information, and to assess expectations about food/nutrition labelling.	Participants indicated that they spent more time reading nutrition information when they were purchasing a product for the first time. Participants also indicated that they primarily looked at the FOP for information on the nutrient content or health properties.

FOP, Front-Of-Pack; GDA, Guideline Daily Amount(s); SENS, Système d'Etiquetage Nutritionnel Simplifié; TL, Traffic Light(s).

Studies on awareness or attention using eye-tracking or other physiological measures

Overall, eye-tracking studies show some variation in participants' tendency to attend to FOP nutrition labels (Table 5). For example, Centurion and colleagues (2019) reported that 90-91% of participants in their study looked at nutritional warning labels or the Guideline Daily Amount (GDA) system. However, percentages are much lower in other studies, reporting that only 50% of participants looked at the warning label for at least one of the presented products (Machín *et al.*, 2019).

In the majority of studies, the attention-grabbing ability of different FOP nutrition labels is compared, or the presence (vs. absence) of a particular label is tested. A small number of studies compared the time to first fixation for a subset of FOP nutrition labels (Alonso-Dos-Santos *et al.*, 2019; Gabor *et al.*, 2020). Gabor and colleagues (2020) reported that Nutri-Score, Multiple Traffic Light (MTL), and monochromatic GDA drew attention similarly based on the time until first fixation. In their study, Alonso-Dos-Santos *et al.* (2019) found that GDA, nutrition table, and (black and white) warning messages were also similarly quickly looked at. In a study that presented products with nutritional warnings, GDA system, nutrient claims, and images of fruit, participants tended to first fixate the fruit image, followed by the nutrient claim and nutritional warnings, before fixating the GDA system (Centurión *et al.*, 2019).

It has to be noted that time to first fixation is different from the both the amount of time participants spend looking at the label (i.e. dwell time and fixation duration) as well as how often (i.e. number of fixations) participants looked at the label. These indices can relate to how difficult is it is to comprehend or process the label or increased relevance of the label for the participant. Two studies suggest that warning labels received less and shorter fixations than GDA and nutrition tables (Alonso-Dos-Santos *et al.*, 2019) or fewer fixations than the Facts-Up-Front system (Tórtora *et al.*, 2019). In another study, participants looked longer at GDA labels than TL labels (Rramani *et al.*, 2020). In a study comparing attention to MTL, Nutri-Score, and monochromatic GDA during a task to evaluate snack healthfulness, least time was spent on the Nutri-Score (lowest dwell time, least number of fixations, average fixation duration).

Direct comparisons between FOP nutrition labels regarding time to first fixation and time spent looking at the label are difficult to make since none of the reported studies included all available nutrition labels. However, there seems to be a tendency for simpler labels to require fewer and shorter fixations in order to be processed (see 3.2.2). It is important to take into account that factors such as participants' familiarity with the label, design features, the size of the label, or how it fits with the surrounding background may vary between labels and studies, and influence time to first fixation and the time spent. For example, changes to salience, size, and positioning of nutrition labels may be useful to increase attention and impact on choice (Orquin *et al.*, 2020).

Table 5 Studies of consumer awareness of or attention to front-of-pack nutrition information using eye-tracking or other physiological measures

Study (most recent first)	Population	Intervention/Comparator	Outcome
Bialkova *et al.* (2020)	Study 1: 30 students in Germany Study 2: 120 participants in a grocery store in Germany	Two eye-tracking studies (Study 1: lab; Study 2: field) explore gaze behaviour and purchase decision as a function of nutrition label (monochrome vs. TL colour-coded GDAs), brand, and product flavour. Participants in Study 1 were either asked to choose the healthiest product or the product they preferred.	Study 1 shows that products carrying colour-coded GDA labels received more fixations than monochrome GDA labels with no effect of the label on fixation duration. There was no interaction effect between the label type (monochrome vs. colour-coded) and goal of the

Table 5 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Bialkova *et al.* (2020) *(cont.)*		In study 2, all participants chose the product of their preference.	choice (healthiest vs. preferred product) on eye gaze. Study 2 found no main effect of the type of label on the number of fixations, duration of fixations, and product choice. Some interactions were reported between label and brand, and between label and product flavour on fixations.
Gabor *et al.* (2020)	76 students in Croatia	Eye-tracking study on how different FOP nutrition labels (MTL, monochromatic GDA, Nutri-Score) affect visual attention and perception of nutritional quality of eight snack bars.	The study suggests that all labels draw attention similarly based on the time until first fixation. Least time was spent on the Nutri-Score (lowest dwell time, least number of fixations, average fixation duration), when the task is to evaluate healthfulness.
Orquin *et al.* (2020)	Study 1: 123 participants in Denmark (final sample: 91) Study 2: 76 participants in Denmark (final sample: 72)	Two eye-tracking studies to assess the visual ecology of product packaging elements and their effect on attention. The authors discuss 3 relevant bottom-up factors: salience, relative surface size, and position. In Study 1, participants saw several sets of 4 or 6 products, could inspect each product in detail (turn around, see sides) and then chose their preferred product. Salience, size, and positioning of packaging elements were analysed and related to participants' attention (eye-tracking). Study 2 was a choice experiment manipulating health motivation (Between-subject: control, health goal, health priming), label salience (within-subject: high, low), label surface size (within-subject: small, large), and label distance to centre (within-subject).	Both studies suggest that attention (what participants see) influences choices. Study 1 showed that packaging elements that were more salient (colour/contrast to surrounding), larger, and more centrally positioned on the package are more likely to be looked at. Study 2 built on that showing that attending to a target label such as Keyhole positively affected choosing the product.

Table 5 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Orquin *et al.* (2020) *(cont.)*		attract more attention than GDA labels. Additionally, they tested whether attention shifts more toward healthy foods because of TL labels compared to GDA, and whether food choices are more influenced by attention to the label in the case of TL labels. Participants chose between a healthy and an unhealthy food product that were either both presented with GDA or with TL nutrition labels. In an earlier part, participants indicated self-reported liking, and after the choice task indicated their willingness to pay for each of the 100 products.	On average, participants looked longer at GDA labels than TL labels. However, there was a difference in the amount of dwell time for healthy and unhealthy items, only for TL labels: Results suggest that participants pay less attention to unhealthy items in the presence of TL labels. Additionally, the influence on TL labels on healthier food choices are suggested to operate via increasing the effect of attention to the label on choice.
Potthoff *et al.* (2020)	51 women in Austria (mainly students).	Study 1: participants were instructed to gaze at different pictures of sweet foods (e.g., cakes, ice cream) presented in combination with either a positive label (green circle with "+" sign), a negative label (red circle with "-" sign) or neutral label (grey circle with "?" sign). Their eye movement was recorded. Participants were given prior instructions regarding the meaning of the labels.	Study 1: the saccadic latency (i.e. how long it took participants to actively relocate their gaze away from a food item) was significantly lower for food with a positive label compared to food with a negative label, and to food with a neutral label. The saccadic latency did not differ between the neutral and the negative label. The dwell time was shorter for food with a positive label compared to food with a negative label. Dwell time did not differ between neutral label and red label.
Winarno *et al.* (2020)	Study 1: a questionnaire with 110 students in Indonesia Study 2: Eye tracking, 80 (main study) and 20 (validation study) students in Indonesia.	Study 1 relied on a conjoint analysis of a questionnaire; respondents were asked to rank their preference for eight package combinations. Study 2 was an eye-tracking study with participants shown a picture of a label in MTL form and Percent Daily Intake for 10 seconds. The outcome variable was attention.	In Study 1, the upper left-hand position with the MTL was preferred. In Study 2, there was some evidence that upper left and lower right positions received longer fixations than upper right and lower left. Specifically, longest fixations were on the Percent Daily Intake in the upper left-hand position.

Table 5 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Alonso-Dos-Santos *et al.* (2019)	180 participants of a convenience sample in Chile (university campus)	Eye-tracking study on ease of processing of different FOPNL schemes (GDA, nutrition table, black and white warning messages) on food packaging of three product categories.	There is no difference between the tested FOP schemes regarding time until first fixation. Warning messages received less and shorter fixations than GDA and nutrition tables.
Centurion *et al.* (2019)	100 participants in Uruguay, recruited among students and workers of the University of Psychology, aged between 18 and 56 years, 75% of which were female.	Lab experiments assessing the combination of images of fruit (with/without), nutrient claims (with/without) and nutritional warnings (with/without) on attention (eye-tracking) and healthfulness perceptions of cereal bars.	90-91% of participants fixated the fruit image, GDA system, and nutritional warnings; 81% fixated the nutrient claim. Including a nutrient claim or fruit image did not reduce the number of consumers who paid attention to the warning labels. Time to first fixation: Overall, participants first fixated the fruit image, followed by the nutrient claim and nutritional warnings, before fixating the GDA system. Fixation count: The GDA system was fixated most often, followed by nutritional warnings. Fruit image and nutrient claim received least fixations.
Machín *et al.* (2019)	199 participants of a convenience sample in Uruguay	Experiment on the influence of nutritional warning labels (present/absent) on consumers' choice of a snack. Additionally, they measured attention to warning labels with mobile eye-tracking.	50% of participants who were presented with nutritional warnings fixated the warning labels for at least one of the products.
Tórtora *et al.* (2019)	124 participants in Uruguay	Choice-conjoint and eye-tracking study in which FOP nutrition information (nutritional warnings vs. Facts-Up-Front panel), nutrient claim (present vs. absent) and type of product (conveying health vs. hedonic associations) were manipulated.	Eye-tracking data revealed that a majority of participants paid attention to nutritional warnings (e.g. 'high in total fat'). Nutritional warnings were less often fixated than the Facts-Up-Front panel. The authors suggest that warnings thus require fewer fixations to process than the Facts-Up-Front system.

Table 5 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Vidal *et al.* (2019)	201 Uruguayan adults	Eye-tracking study in which participants, before choosing a snack product, were exposed to a) non-nutrition related message, b) loss-framed ("excessive consumption [..] can increase likelihood of early death") nutritional messages combined with warning labels, or c) gain-framed ("Reducing your consumption [..] can increase your quality of life [..]") nutritional messages combined with warning labels.	Both types of nutritional-related messages were found to be more attractive than the control treatment, and they also led to healthier snack choices. Loss-framed messages managed to attract participants' gaze the longer, but had a minor effect on its efficacy, compared to the gain-framed ones.
Zerbini *et al.* (2019)	32 Italian undergraduate students; half with normal weight, half with overweight	fMRI study testing FOP nutrition labels. In addition to some well-known FOPNL, it introduces the "body label", which is a stylised figure of a human body, either of regular shape or with overweight. It uses a 2x4x2 factorial design: regular vs. light product; four labels (text, TL, star rating, and body label); and 2 groups of people (normal weight vs. with overweight). Participants were exposed to the products and asked to (a) observe them and (b) indicate how much of it they would consume.	Results suggest that for participants with overweight, light "body labels" generated greater brain activation in reward-related brain areas than all other labels (including the body label for a regular product). The fact that the star rating led to strongest activity in the right lateral prefrontal cortex, possibly reflecting attentional load, suggests that the star rating is less intuitive and more cognitively demanding compared to the other labels. This may be due to the counterintuitive rating: more stars reflecting lower calorie intake.
Bartels *et al.* (2018)	60 grocery shoppers (convenience sample) in the USA	Product choices were assessed in combination with visual data from a mobile eye-tracking device in a real shopping environment. (data from 2014)	Eye-tracking data revealed that 1/3 of participants viewed nutrition information at least once. 8% of the viewing time was on nutrition information (i.e. Nutrition Facts label, ingredient list, claims on package fronts, Facts-Up-Front symbol, nutrition signage). 25% of participants looked at the Facts-Up-Front symbol at least once. 42% of participants viewed 1 or more of the provided

Table 5 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Bartels *et al.* (2018) *(cont.)*			nutrition information elements immediately before selecting product for purchase.
Fenko *et al.* (2018)	48 adults recruited at a University canteen in the Netherlands.	Field experiment with mobile eye-tracking devices, aiming at studying the relative effect of Choices logos and TL labels (compared to a no-logo condition) on consumers' visual attention and food choice. Half of the participants made their choice under a time constraint.	TL labels were fixated longer and more often than the choices logo. Even though the TL label was less familiar to their participants, familiarity did not explain this difference in attention to the labels. However, visual attention to health labels did not predict the subsequent choice well.

FOP, Front-Of-Pack; GDA, Guideline Daily Amount(s); MTL, Multiple Traffic Light(s); TL, Traffic Light(s).

3.2.2 Factors that influence attention to FOP nutrition labels

The differences in attention that individuals have for different nutrition labels may be explained by the fact that attention to FOP nutrition labels varies according to features of the labels themselves as well as according to features of the situation and the person (Table 6). In general, two types of attention are differentiated: goal-directed (top-down) attention and stimulus-driven (bottom-up) attention (Fenko *et al.*, 2018; Katsuki & Constantinidis, 2014; Yantis, 2000).

Goal-directed, or top-down attention to nutrition labels is thought to occur when consumers have a reason to pay attention to the label (Bialkova & van Trijp, 2010). Top-down factors refer to individuals' goals (e.g. select the healthiest/cheapest product alternative), preferences (e.g. interest in a healthy lifestyle), or mood.

Bottom-up factors refer to visual design aspects (e.g. colour, shape, complexity, contrast, amount of information) that influence whether a stimulus grabs and captivates attention. Key attributes of products and product packages such as brand names or product pictures are often placed prominently on packages to draw consumers' attention and influence choice (Florack *et al.*, 2020; Gidlöf *et al.*, 2017; Janiszewski *et al.*, 2013).

Top-down factors influencing attention to labels (Table 6)

Some studies report that people attend to nutrition labels more often when they are purchasing an unfamiliar product (Correa *et al.*, 2019), or they use labels because they would like to follow a healthy diet (Bryla, 2020; Mabotja *et al.*, 2021; Zerbini *et al.*, 2019). For consumers who are under time constraints (Fenko *et al.*, 2018), have less capacity to process the information, or are less interested in health-related information, attention to nutrition labels may be more stimulus-driven, and thus rely on bottom-up factors (Fenko *et al.*, 2018).

Table 6 Studies on top-down, i.e. situational and consumer characteristics related to attention to front-of-pack nutrition labelling (these studies are also reported in other tables in this section)

Study (most recent first)	Population	Intervention/Comparator	Outcome
Mabotja *et al.* (2021)	403 South African consu mer (only those responsible for household shopping)	Online survey measuring participants' use and understanding of food labels of several FOP systems: Nestlé Know Your Serving; GDA; Teaspoon Nutritional Illustration; Nutritional Information Table; and TL Labelling.	A majority (83%) consider food labels important. Of those reading the labels, many (71%) do so to improve their food choices or to be informed (52%). Quite a few participants read the labels to manage lifestyle diseases (42%) or to control their body weight (40%). Some respondents (15%) appear to read the labels to keep their eating plans, while 8% do not have a particular reason for reading the labels.
Bryla (2020)	1 051 participants in Poland	Survey study that aims to find predictors of which consumers read labels, including FOP and BOP labels, and in different situations: in the shop and at home. Demographic (e.g., age, gender, household size), socioeconomic (e.g., education, income), behavioural (e.g., habits), and psychographic (e.g., importance attached to various types of information) aspects were assessed.	Regarding FOP nutrition labels specifically, the size of one's household correlated positively with reported FOPNL reading, both at home and in the shop. Demographic or socioeconomic variables did not correlate with reading food labels. Only one predictor (self-rated knowledge about healthy diet) correlated with all four measures of label reading, meaning that people who consider themselves knowledgeable about a healthy diet read more labels.
Correa *et al.* (2019)	84 mothers in Chile	Nine focus groups were held to explore mothers' response to the 2016 Chilean law of food labelling and advertising. In particular, they assessed perceptions and knowledge about warning labels on food packaging.	Attention and use of the labels varied. Some said they only pay attention to the labels when buying new products or not at all, whereas others (mostly from middle & upper- socioeconomic levels) said they use them as shortcuts ("I don't read them [..] (very closely) but when I see too many, I don't buy it.").
Zerbini *et al.* (2019)	32 Italian undergraduate students; half with normal weight, half with overweight	fMRI study testing FOP nutrition labels. In addition to some well-known FOPNL, it introduces the "body label", which is a stylised figure of a human body, either of regular shape or with overweight. It uses a 2x4x2	Results suggest that for participants with overweight, light body labels generated greater brain activation in reward-related brain areas than all other labels (including the body label for a regular product).

Table 6 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Zerbini *et al.* (2019) *(cont.)*		factorial design: regular vs. light product; four labels (text, TL, star rating, and body label); and 2 groups of people (with normal weight vs. with overweight). Participants were exposed to the products and asked to (a) observe them and (b) indicate how much of it they would consume.	Based on their finding that the HSR led to strongest activity in the right lateral prefrontal cortex, possibly reflecting attentional load, they suggest that the HSR is less intuitive and more cognitively demanding compared to the other labels. This may be due to the counterintuitive rating: more stars reflecting lower calorie intake.
Fenko *et al.* (2018)	48 adults recruited at a University canteen in the Netherlands.	Field experiment with mobile eye-tracking devices, aiming at studying the relative effect of Choices logos and TL labels (compared to a no-logo condition) on consumers' visual attention and food choice. Half of the participants made their choice under a time constraint.	TL labels were fixated longer and more often than the choices logo. Even though the TL label was less familiar to their participants, familiarity did not explain this difference in attention to the labels. Participants who were put under time constraints paid less attention to the health labels in general. The authors suggest that participants need to be motivated to process health information and should have sufficient time to process the information in order for labels to be effective.

BOP, Back-Of-Pack; FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; TL, Traffic Light(s).

Bottom-up factors influencing attention to labels (Table 7)

Orquin and colleagues (2020) suggest that (nutritional) labels need to be placed prominently on a product package to draw people's attention. They discuss three bottom-up factors of labels they consider especially relevant for capturing attention: salience, relative surface size, and position of the label. In their studies, they show that packaging elements that were more salient (e.g. in terms of contrast to the surrounding, or colour of the label), larger, and more centrally positioned on the package are more likely to be looked at. The authors suggest that changes to salience, size, and positioning (centrality) of (nutritional) labels may be useful to increase attention and their impact on product choices.

Similarly, in their review of the literature, Fenko *et al.* (2018) suggested that combining colour schemes with bold text and familiar, accessible wording may also increase salience (study reported in Table 6). In their study (conducted in the Netherlands), they compared attention allocated to the Choices logo or to a TL Label. In line with the idea that TL labels are more salient because they combine colour schemes with familiar, simple wording ("low", "medium", "high"), they found that TL labels were fixated longer and more often than

the Choices logo. Even though the TL label was less familiar to their participants, familiarity did not explain the difference in attention to the labels.

Other studies have also reported a tendency for colourful labels (Table 7) to be more attention capturing. Bialkova and colleagues (2020) found in one of their studies that colour-coded GDA labels were more often looked at than monochrome GDA labels. Similarly, TL labels were also more likely to be looked at than (monochrome) GDA labels in a study by Rramani and colleagues (2020). However, in the same study, participants looked longer at the (monochrome) GDA labels than they did at the colourful TL labels. This underlines that time spent looking at a label can be interpreted as both, interest or relevance of the information for the individual as well as difficulty to process and extract information. In the case of the latter study, the authors found that less attention was paid to unhealthy items in the presence of TL labels, and that TL labels led to healthier food choices than (monochrome) GDA labels despite attracting less dwell time.

Important to note, and in line with suggestions by others (Bialkova *et al.*, 2020; Orquin *et al.*, 2020), (colourful) labels may be more or less salient depending on the background on which they are placed. 'Visual clutter' surrounding the nutrition label can reduce attention to the label (cf. review by Ma & Zhuang, 2021). For example, the TL labels in Rramani and colleague's study (2020) were placed on a black background and thus relatively salient. However, colourful labels placed against a multi-colour background may be less salient as there is less contrast between the label and the package.

Table 7 Studies on bottom-up factors, i.e. the impact of label colour or other label attributes on consumer attention to front-of-pack nutrition information (these studies are also reported in other tables in this section)

Study (most recent first)	Population	Intervention/Comparator	Outcome
Bialkova *et al.* (2020)	Study 1: 30 students in Germany Study 2: 120 participants in a grocery store in Germany	Two eye-tracking study (Study 1: lab; Study 2: field) explore gaze behaviour and purchase decision as a function of nutrition label (monochrome vs. TL colour-coded GDAs), brand, and product flavour. Participants in Study 1 were either asked to choose the healthiest product or the product they preferred. In Study 2, all participants chose the product of their preference.	Study 1 showed that products carrying colour-coded GDA labels received more fixations than monochrome GDA labels with no effect of the label on fixation duration. There was no interaction effect between the label type (monochrome vs. colour-coded) and goal of the choice (healthiest vs. preferred product) on eye gaze. However, products with a colour-coded GDA were more often chosen when participants had to choose the healthiest product; this was seemingly independent of the information provided on the label.

Table 7 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Bialkova *et al.* (2020) *(cont.)*			Study 2 found no main effect of the type of label on the number of fixations, duration of fixations, and product choice.
Deliza *et al.* (2020)	Study 1: 62 participants; Study 2: 1 932 participants in Brazil	Two studies (one experiment and one online survey) explored the efficacy of the nutrition warning scheme (the Chilean labels), GDA and TL label. Study 1 consisted of a visual search to see how quickly participants identified whether a product had a high nutrient content. Study 2 assessed participants' ability to use the FOP schemes to identify the most healthful product in a set as well as high nutrient content. They also looked at the effect of FOPNL on perceived healthfulness.	Study 1: High nutrient content was quicker detected when products were labelled with black octagon or black triangle warning schemes compared to GDA. Regarding colour, participants detected black signs faster than red signs, when these were included in a food label with other colours.
Gabor *et al.* (2020)	76 students in Croatia	Eye-tracking study on how different FOP nutrition labels (MTL, Nutri-Score, monochromatic GDA) affect visual attention and perception of nutritional quality of eight snack bars.	All labels draw attention similarly based on the time until first fixation. Least time is spent on the Nutri-Score (lowest dwell time, least number of fixations, average fixation duration), when the task is to evaluate healthfulness.
Orquin *et al.* (2020)	Study 1: 123 participants in Denmark (final sample: 91) Study 2: 76 participants in Denmark (final sample: 72)	Two eye-tracking studies to assess the visual ecology of product packaging elements and their effect on attention. The authors discuss 3 relevant bottom-up factors: salience, relative surface size, and position. In Study 1, participants saw several sets of 4 or 6 products, could inspect each product in detail (turn	Whereas brand elements are often conspicuous on a product package, nutrition labels are not. Changes to salience, size, and positioning (centrality) of nutrition labels may be useful to increase attention and their impact on choice. Study 1 showed that packaging elements that were more salient

Table 7 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Orquin *et al.* (2020) *(cont.)*		around, see sides) and then chose their preferred product. Salience, size, and positioning of packaging elements were analysed and related to participants' attention (eye-tracking). Study 2 was a choice experiment manipulating health motivation (control, health goal, health priming), label salience (high, low), label surface size (small, large), and label distance to centre.	(colour/contrast to surrounding), larger, and more centrally positioned on the package are more likely to be looked at.
Rramani *et al.* (2020)	50 participants in Germany	Eye-tracking study conducted in a lab in Germany to assess whether TL labels attract more attention than GDA labels. Additionally, they tested whether attention shifts more toward healthy foods as a consequence of TL labels compared to GDA, and whether food choices are more influenced by attention to the label in the case of TL labels. Participants chose between a healthy and an unhealthy food product that were either both presented with GDA or with TL nutrition labels. In an earlier part, participants indicated self-reported liking, and after the choice task indicated their willingness to pay for each of the 100 products.	Eye-tracking data revealed that TL labels were more likely to be looked at than (monochrome) GDA labels. On average, participants looked longer at GDA labels than TL labels. However, there was a difference in the amount of dwell time for healthy and unhealthy items, only for TL labels: Results suggest that participants pay less attention to unhealthy items in the presence of TL labels. Additionally, the influence on TL labels on healthier food choices are suggested to operate via increasing the effect of attention to the label on choice. Participants showed a greater inclination to choose healthy when presented with TL labels compared to GDA labels.
Acton *et al.* (2018b)	234 participants above 16 years old at a shopping mall in Canada	Consumers rated their perception of five FOP nutrition label design characteristics: border, background presence, background colour, 'caution' symbol	FOP nutrition labels with a border, solid background and contrasting colours increased noticeability. A solid background increased readability, while a

Table 7 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Acton *et al.* (2018b) *(cont.)*		and government attribution. Ratings included noticeability, readability, believability and likelihood of changing the participant's beverage choice.	contrasting background colour reduced it. Both a 'caution' symbol and a government attribution increased the believability of the labels and the perceived likelihood of influencing beverage choice. In sum, label design characteristics, such as the use of a border, colour and symbols can enhance the salience of FOP nutrition labels and may increase the likelihood that FOP nutrition labels are used by consumers.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); MTL, Multiple Traffic Light(s); TL, Traffic Light(s).

Similarly, less complex labels (e.g. Nutri-Score and nutritional warnings in the mentioned studies) seem to require less and shorter fixations in order to be processed (Alonso-Dos-Santos *et al.*, 2019; Gabor *et al.*, 2020; Tórtora *et al.*, 2019). For example, Gabor and colleagues (2020) found that in their comparison of time spent on the MTL, Nutri-Score, and monochromatic GDA, least time was spent on the Nutri-Score (lowest dwell time, least number of fixations, average fixation duration), when individuals' task was to evaluate the healthfulness of products. Tórtora, Machín, and Ares (2019) reported that warning messages (i.e. less complex information) are less often fixated than the Facts-up-front panel. Similar results were also reported by Alonso-Dos-Santos *et al.* (2019), who observed that warning messages receives less and shorter fixations than GDA and nutrition tables.

3.2.3 Conclusions regarding consumers' attention to FOPNL

The JRC report on FOPNL published in 2020 (Storcksdieck genannt Bonsmann et al., 2020a) highlighted that:

I. FOP nutrition labels generally receive more attention than more detailed BOP nutrition information;
II. Colour increases attention to FOP schemes, as long as contrast between the label and the package is achieved and the label is clear and big enough to be easily legible;
III. Attention is greater when the type of label and its location on the package does not change;
IV. Attention to the nutritional information is higher if there is less other information on the food package.

On the basis of the literature reviewed for this report, we can add the following conclusion:

V. Less complex labels require less attention to be processed.

With the literature reviewed for this update, the conclusions drawn in the JRC report on FOPNL (2020) remain unchallenged. Conclusion II is strengthened by new evidence that suggests including colours in FOPNL stimulates attention paid to the labels (Table 7). Insights were also extended regarding the ideal position of the label on the package (Orquin *et al.*, 2020; Winarno *et al.*, 2020). Whereas Winarno *et al.* (2020) suggest that the upper left corner is a beneficial position for a label, Orquin *et al.* (2020) suggest that central positions usually receive more attention. Earlier research suggested that more attention is paid to labels when they always appear in the same position (cf. conclusion III Storcksdieck genannt Bonsmann et al., 2020a).

3.3 Evidence on consumers' preferences and acceptance regarding FOP nutrition labels

In this section, we provide an overview of the findings on consumers' general attitudes and preferences regarding FOP nutrition labels, that is on whether consumers *say* they like FOP nutrition labels as well as on whether *they prefer* products exhibiting FOP nutrition labels.

Overall, people seem to prefer packages with FOP nutrition labels compared to ones without, because they make them feel in control of their food choices (Acton & Hammond, 2018a). As the studies included in Table 8 show, people prefer products exhibiting FOP nutrition labels to those that do not (Cooper *et al.*, 2020; McCrickerd *et al.*, 2020), and find FOP information important (Bartels *et al.*, 2018) as they believe that the most important nutritional information should be displayed on the FOP (Koen *et al.*, 2018). In fact, studies reveal that consumers support FOP nutrition labels being mandatory (Talati *et al.*, 2019b) and prefer mandatory FOP nutrition labels to other harder obesity-prevention regulations (cf. zoning restrictions to prohibit fast food outlets near schools; taxes on unhealthy high fat foods; and taxes on sugar-sweetened beverages; (Farrell *et al.*, 2019).

The main reason why consumers prefer FOP nutrition labels is to improve their food choices (71%) or to be informed (52%), followed by managing lifestyle diseases (42%) or body-weight control (40%). In addition, consumers prefer information on FOP compared to on BOP or, ideally, a combination of the two (Gomes *et al.*, 2020; Mabotja *et al.*, 2021). This may be because people on the one hand like to have access to FOP nutrition labels that display aggregated and easy to process nutritional information (de Morais Sato *et al.*, 2019; Koen *et al.*, 2018) but on the other hand also like to be provided with additional, more detailed nutritional information, especially on bad nutrients like sugar, SFA and sodium/salt (Dana *et al.*, 2019). However, FOP nutrition labels are thought to be more useful and educative for others than oneself (Farrell *et al.*, 2019).

In general, FOP nutrition labels are preferred if the information contained in them is overseen by government agencies as consumers do not fully trust the information that food manufacturers could provide without wider governmental regulations and supervision (Pulker *et al.*, 2019).

Studies have shown that preference for FOP nutrition labels depends on a number of individual-level characteristics. In some studies, sugar-conscious, diet-related health-conscious individuals with a high level of

physical activity, women, and dieters, have a higher preference for FOP nutrition labels (de Sousa *et al.*, 2020; Hagmann *et al.*, 2018). On the other hand, one study suggests that respondents with overweight and those that generally consume higher amounts of sugar-sweetened beverages (SSBs) appear more strongly opposed to their adoption (Hagmann *et al.*, 2018). A Swiss study also suggested geographical variability in FOPNL preferences (probably related to local cultural differences), with residents from the French-speaking and urban areas being more in favour (Hagmann *et al.*, 2018). However, another study failed to find significantly different preferences by populations of different Body Mass Index (BMI) or gender (Dana *et al.*, 2019).

Despite the high preference that consumers express for FOP nutrition labels, when asked about the frequency with which they *actually use* them to support purchase decisions, few (16.7%-29%) say they always use them, while most (29.9%-38%) appear to use them occasionally (Gomes *et al.*, 2020), or infrequently (de Sousa *et al.*, 2020; Farrell *et al.*, 2019; Mabotja *et al.*, 2021). Few consumers (6%-16%) say they never use FOP nutrition labels (Cole *et al.*, 2019; Gomes *et al.*, 2020; Mabotja *et al.*, 2021). Interestingly, use of FOP nutrition labels seems not directly predicted by trust in the information they contain: a study by de Sousa *et al.* (2020) showed that people using FOP information are critical about its content, while those that do not use it paradoxically trust it.

Table 8 Studies of consumer preference and acceptance of front-of-pack nutrition labelling

Study (most recent first)	Population	Intervention/Comparator	Outcome
Mabotja *et al.* (2021)	403 South African consumers (only those responsible for household shopping)	Online survey on participants' use and understanding of several FOP nutrition labels: Nestlé Know Your Serving; GDA; Teaspoon Nutritional Illustration; Nutritional Information Table; and TL Labelling.	The survey indicated that a majority (83%) considers food labels important. 29% said they always read nutritional information on food labels, 27% often and 26% occasionally. Only a minority reads food labels rarely (12%) or never (6%). 67% of those not reading the labels are not interested in them, while quite a few said the information appears in small fonts (28%) or is hard to understand (8%). Of those reading the labels, many (71%) do so to improve their food choices or to be informed (52%). Quite a few participants read the

Table 8 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Mabotja *et al.* (2021) *(cont.)*			labels to manage lifestyle diseases (42%) or to control their body weight (40%). Some respondents(15%) appear to read the labels to keep their eating plans, while 8% do not have a particular reason for reading the labels.
Medina-Molina *et al.* (2021)	240 Spanish university students (129 in the control and 111 in the treatment)	An experimental survey that measures participants' brand attitudes and purchase intentions, without (control) and with FOPNL, specifically, Nutri-Score (A-E ranking) on the products. Participants respond to five items measuring brand attitude and three items measuring purchase intentions. They evaluate five products (yogurt) with A-E ranking either with or without seeing this Nutri-Score ranking (depending on the assigned treatment). Respondents gave information about their gender, age, etc.	The findings suggest that brand attitudes predict purchase intentions irrespective of the presence or absence of FOPNL. The authors claim that the relation between attitudes and purchase intentions is affected by FOPNL only for men. They do not provide detail on this finding however, or explain its direction, making it difficult to evaluate this claim.
Cooper *et al.* (2020)	1 024 participants in Australia (Data were collected in 2014 and 2015.)	Online survey assessed how much consumers valued the HSR by looking at their willingness to pay for a packaged food product with the HSR label.	The study suggests that almost 2/3 of the participants were willing to pay more for products that contain a HSR (on average ~3.7% of the product price). HSR seems to be valued by all socio-demographic groups.
Gomes *et al.* (2020)	Study 1: 1 127 consumers in Portugal Study 2: 33 participants in 4 focus groups	Study 1 (survey) included questions regarding label format, consumers' responses to food labelling (search, understanding, liking, and use), and a choice task, where respondents were asked to make the healthier choice using two alternative food labels.	Liking: 26% of the respondents prefer information on FOP while 22% prefer BOP. 30% of the consumers prefer a combination. Use: 16.7% of the respondents claim to always use food labels to support purchase

Table 8 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Gomes *et al.* (2020) *(cont.)*		Study 2 (focus groups) explored interest and importance attributed to food options in the definition of healthy lifestyles, the importance of food labelling in food choices; and knowledge, understanding, liking, and use of food labels.	decisions, 29.9% declare occasional use while11.2% refer to not using labels at all or rarely.
De Sousa *et al.* (2020)	536 Brazilian students of the Curitiba region.	Interview using the face-to-face method or self-answering the questionnaire. This included socio-demographic data, nutritional and health status, and use of nutritional information.	Food labels and nutritional information overall was reported to not be used often, and mostly by women and by those practicing physical activities. Others reported not using them because they were less concerned with the composition of the food items they were buying. They found mixed results in terms of trust: those that used the info, were critical about its content, and those that did not use it were paradoxically trusting the information.
McCrickerd *et al.* (2020)	Study 1: 123; Study 2: 48; Study 3: 94 participants in Singapore	Three studies explored whether sensory characteristics influence label-generated biases on calorie estimation and portion selection. Various labels were tested, including an organic label, a "healthier choice", a reduced sugar or a monosodium glutamate. Participants indicated their willingness to pay for the product, estimate calories, and how much they would consume of the product.	Participants were willing to pay more for products with added labels, estimated that products with "healthier choice" and "reduced sugar/sodium" have fewer calories, and selected larger portions for "healthier choice" products. The impact of FOP health and nutrition labels on portion selections depends on the taste of the products. Consumer portion selections made in the absence of product tasting are likely to over-estimate the influence of FOP nutrition labels on these behaviours.

Table 8 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Cole *et al.* (2019)	237 participants in the UK	Survey study contained two questions to determine current awareness and use of existing TL FOP nutritional information. It also required respondents to compare existing TL FOP nutritional information to a novel "till receipt system" summarising the nutritional information of the entire food purchased.	When asked to compare the existing FOP TL to a till receipt system, 54.4% of respondents indicated that the new system could have some value either as a stand-alone system or alongside the current FOP system. 16.5% of respondents reported that they never used TL information to make their purchasing decisions. Qualitative data suggest that respondents want to know about nutritional information when they select the product, rather than after on a receipt.
Dana *et al.* (2019)	1 558 adults in Australia	Survey to explore consumers' perspective on the importance of energy and nutrients information on FOP. Socio-demographic variables, BMI, (perceived) healthiness of own diet, and self-reported nutrition knowledge were taken into account in a latent profile analysis to identify different groups of consumers.	Participants perceived it as at least "somewhat important" to receive information about specific nutrients on the FOP. This preference was even more pronounced for "risk" nutrients (i.e. sugar, SFA, sodium/salt). Five different segments of consumers were identified ranging from low preference to very strong preference for nutrition information on the FOP. The authors note that there were no differences according to gender or BMI.
Farrell *et al.* (2019)	2 732 South-Australian adults	Face-to-face interviews collecting views about four obesity prevention regulations: mandatory FOPNL for packaged foods; zoning restrictions to prohibit fast food outlets near schools; taxes on unhealthy high fat	Among the four obesity prevention regulations, support was strongest for the softer intervention that is mandatory FOPNL for packaged food. Most respondents believed this would help educate *others* about nutrition, while

Table 8 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Farrell *et al.* (2019) *(cont.)*		foods; and taxes on sugar-sweetened beverages.	fewer expected to use such information themselves.
Pulker *et al.* (2019)	37 parents (33 mothers and 4 fathers) of children aged 2-8 years	Five 90-min focus groups exploring the way marketing via packaging information influences Australian parents' ability to select healthy food items for their children. As the study was conducted in Australia, the main focus was on the HSR.	Inductive thematic content analysis suggested that there is a desire to speed up shopping, and to avoid hedonic costs. Also, the views expressed highlighted a lack of certainty in packaging information, trust for government and a demand for it to take charge, while food manufacturers' health messages are not trusted.
De Morais Sato *et al.* (2019)	96 participants in Brazil	Focus groups were held to explore opinions about nutrition labels and barriers for using them. Specific focus was placed on warning labels.	Participants highlighted the need for highly visible (e.g. highlighted, letter size), clear, and easily understandable information when it comes to nutrition labels, thus pointing to reduced complexity of labels. The most often mentioned intention when seeing warning labels was to reduce the amount of the product consumed.
Talati *et al.* (2019a)	12 015 participants in 12 countries (Argentina, Australia, Bulgaria, Canada, Denmark, France, Germany, Mexico, Singapore, Spain, UK, USA)	Respondents were asked to provide their perceptions of five different FOPNL schemes (HSR, MTL, Nutri-Score, RIs and warning labels) in an online survey. "Perception" was a 9-item scale that included items measuring liking, trust, comprehensibility, salience and desire for the label to be mandatory.	Respondents indicated a strong preference for mandatory FOPNL regardless of label condition.

Table 8 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Acton & Hammond (2018a)	1 000 respondents aged 16 to 32, recruited in Canada.	The subjects completed a between-group experimental task in an online survey were they were asked to indicate the "harshness" of four FOP nutrition labels (text-only, octagon, triangle, or HSR) on a beverage, and whether they made them feel more or less "in control" of their healthy eating decisions.	The vast majority of respondents indicated that all labels were either about right or not harsh enough, and indicated that the labels made them feel more in control of their healthy eating decisions.
Bartels *et al.* (2018)	60 grocery shoppers (convenience sample) in the USA	Product choices were assessed in combination with visual data from a mobile eye-tracking device in a real shopping environment. FOP information included the Facts-Up-Front icon. (data from 2014)	42% of participants reported that they find nutrition information "extremely" or "very" important on the front of packages. 62% of participants indicated that the importance of FOP information was different depending on whether they were buying a new or routine product.
Hagmann *et al.* (2018)	5 238 adults in Switzerland	Panel survey (first two waves) on eating habits and behaviour, that also compared the acceptability of several state interventions to reduce sugar intake.	A FOP nutrition label making the sugar content of foods high in sugar clearly visible was rated as the most acceptable intervention (5.92 on a 7-point acceptance scale). Acceptance for any intervention was higher for sugar-conscious, diet-related health conscious individuals, women, dieters, residents from the French-speaking areas and people living in urban areas. Respondents with overweight and those that consume higher amounts of SSBs were more strongly opposed.
Koen *et al.* (2018)	67 adult consumers in South Africa	Nine focus group discussions were held to explore whether nutrition information influences purchase	Participants indicated that the most important information should be displayed on the FOP. Most

Table 8 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Koen *et al.* (2018) *(cont.)*		behaviour, which reasons consumers mention for reading or ignoring provided nutrition information, and to assess expectations about food/nutrition labelling.	preferred products that contained nutrient content claims, health claims and health endorsement logos on the FOP. In order not to have to consult the nutrition information table, some of the participants preferred a summary of the nutrients (similar to the TL label) on the front of pack.

BMI, Body Mass Index; BOP, Back-Of-Pack; FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; SFA, Saturated fat; SSB, Sugar-Sweetened Beverage; TL, Traffic Light(s).

3.3.1 FOP nutrition label features related to consumer preference

Of course, not all FOP nutrition labels are expected to be equally preferred by consumers, and studies have tried to unpack the specific FOP nutrition label characteristics that may make them more or less preferred. The most salient characteristic that has also received most scientific attention is colour.

Table 9 summarizes all identified studies looking at whether use of colour may increase FOP nutrition labels appeals to consumers. In several countries (e.g. Australia, India, New Zealand, UK, USA, Iran), consumers have a higher preference for coloured FOP nutrition labels, although there are some cross-country differences in this respect, as this effect appeared to be reversed in Canada and smaller in China (Pettigrew *et al.*, 2021). A study ran in Iran found that mothers and nutritionists preferred the coloured TL FOP nutrition label to the monochromatic BOP nutrition facts table, mainly because of the impact of the colour red in the former (Seyedhamzeh *et al.*, 2020). At the same time, food quality control experts and food industry experts, while recognizing the privilege of the coloured nature of TL recommend the BOP nutrition facts label as, in their opinion, this will be more suitable in guiding toward healthier food choices (Seyedhamzeh *et al.*, 2020).

Despite the self-reported preference for coloured over uncoloured FOP nutrition labels by consumers, two studies using behavioural and electrophysiological measures (with 78 and 31 Brazilian students each) suggest that the precise colour included in a coloured FOP nutrition labels (i.e. red, green and amber) could potentially play an implicit role in affecting consumers' preferences toward some sweetened foods (Lemos *et al.*, 2020). Specifically, the results of their experiments showed that sweetened food items preceded by a red circle may elicit more arousing and positive affective reactions toward the sweetened food items, which according to the authors could make consumers prefer them.

Table 9 Studies on consumer preferences regarding certain characteristics (especially use of semantic colours) in front-of-pack nutrition labelling schemes

Study (most recent first)	Population	Intervention/Comparator	Outcome
Lemos *et al.* (2020)	Study 1: 78 students in Brazil Study 2: 31 students in Brazil	Two experiments testing participants' emotional reactions to TL coloured scheme with self-report (Study 1) and using electroencephalography (Study 2). Participants' hedonic and arousal reactions to 45 ultra-processed sweet and salty products were tested when preceded by either green, amber or red coloured circles. Study 1 used SAM (a nonverbal pictorial assessment method measuring affective reactions to stimuli), and Study 2 assessed Early Posterior Negativity.	Participants' affective reactions were more positive when they saw sweet products preceded by a red circle compared to a green or amber circle. For salty products, pictures were more arousing when preceded by green than an amber circle, while no difference was observed between the red and amber. Nevertheless, participants rated food healthiness correctly (less healthy when preceded by red compared to green colour). Study 2 reported a reduced Early Posterior Negativity (hypothesized to be a response to more arousing and hedonic stimuli) for the sweet taste products relative to salty when primed with the red circle. The difference in Early Posterior Negativity amplitude between sweet and salty products disappeared when primed with a green circle.
Pettigrew *et al.* (2021)	7 545 in seven countries (Australia, Canada, China, India, New Zealand, UK, USA)	In an online survey experiment, participants were exposed to several breakfast cereals with four HSR variations, resulting from a combination of 2 types of FOPNL: summary HSR vs. hybrid HSR (summary and nutrient-specific information); and 2 types of colour condition: coloured (red/orange/green) vs. black & white) design. In each trial one product had no rating, one had 1.5 star, one had 3 stars and one had 4.5 stars. Participants indicated purchase intentions and rated the	Across countries, purchase intentions and healthiness ratings were higher when the products were labelled with the coloured, summary HSR and with the coloured hybrid FOPNL. However, there were noticeable country differences: while in most countries a coloured version performed significantly better than the monochrome hybrid on at least one of the two measures, it was the monochrome summary version that performed better in Canada and the positive effect of colours was significantly smaller in

Table 9 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Pettigrew *et al.* (2021) *(cont.)*		perceived healthfulness of the products.	China than in the other countries.
Seyedhamzeh *et al.* (2020)	63 Iranian mothers + 6 nutritionists, 8 food industry experts and 3 policymakers	Qualitative approach with focus group discussions and semi-structured interviews.	Different groups expressed different views: mothers and nutritionists found coloured TL labels clearer than BOP monochrome Nutrition Facts labels, mainly thanks to the impact of the red colour. However, food quality control experts and food industry experts believed Nutrition Facts labels to be more suitable to guiding consumers toward healthy food choices.

BOP, Back-Of-Pack; FOPNL, Front-of-pack nutrition labelling; HSR, Health Star Rating; TL, Traffic Light(s).

Another element of FOP labels that has received attention as possibly determining consumers' preferences for the labels is their level of directiveness, namely whether the FOP label provides an assessment of the nutritional quality of the product (see Table 10). Evaluative FOP labels seem to be preferred over reductive labels (Talati *et al.*, 2016), as the latter are reported as complex (Vargas-Meza *et al.*, 2019b).

Table 10 Studies of consumer preferences regarding directiveness and complexity of front-of-pack nutrition labelling schemes

Study (most recent first)	Population	Intervention/Comparator	Outcome
Vargas-Meza *et al.* (2019b)	120 Mexican adolescents (13-15y), young adults (21-23y), mothers of children (3-12y), fathers of children (3-12y) and older adults (55-70y).	Ten focus groups with 12 participants each, aimed at exploring the awareness, acceptability and subjective understanding, of seven different FOP nutrition labels (HSR, Warning labels, Warning labels in red version, TL, GDA, Healthy Choice, and a (fictitious) 5-colour nutrition label) by low- and middle-income Mexican consumers.	Participants were aware of GDAs but found them complex and rarely used them. Directive and semi-directive labels (such as warning labels, HSR and MTL) may be more effective in encouraging healthier food choice for low- and middle-income groups. The study reported a low subjective understanding for a fictitious 5-colour nutrition label; participants questioned the meaning of the colours and the letters of the labels.

Table 10 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Talati *et al.* (2016)	50 adults and 35 children aged 10-17 years in Australia, divided into ten groups.	Focus group discussions in which participants were shown the three FOP schemes: Daily Intake Guide, MTL, and HSR. Food packages featured different combinations of FOP nutrition labels and health claims. The relationship between the FOP nutrition labels and health claims was designed to be somewhat contradictory in that the health claims promoted a positive aspect of the food while the FOP nutrition labels provided a negative overall picture of the food.	The two evaluative FOP schemes MTL and HSR were preferred over the reductive Daily Intake Guide. The two main considerations were trust and ease of interpretation. The FOP schemes were also more likely to be considered in the product evaluation than health claims (this was especially true of the HSR and MTL labels). Of the two evaluative FOP schemes, participants preferred the one with the summary indicator (namely the HSR).

FOP, Front-Of-Pack; FOPNL, GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); TL, Traffic Light(s).

3.3.2 Consumer preference for and acceptance of specific FOPNL schemes

Given the multitude of FOPNL, several studies have compared consumers' preferences for the various schemes. In general, consumers appear to prefer simple labels (Vargas-Meza *et al.*, 2019b) and trust and expected easiness to process labels explains consumers' willingness to use them (Karamanos *et al.*, 2019). Regarding preference for specific type of schemes, while several studies reveal an overall positive attitude towards FOP nutrition labels, they do not reveal a clear preference for specific schemes (Egnell *et al.*, 2019c; Nieto *et al.*, 2020; Talati *et al.*, 2019b; Vandevijvere *et al.*, 2020). For example, Egnell and colleagues (2020a) compared 5 different FOP nutrition labels (MTL, RIs, Warning Labels, Nutri-Score and HSR) amongst Swiss consumers and did not detect major differences in preference. This study corroborates older studies, where each of the FOP nutrition labels appeared to have advantages and disadvantages according to consumer preferences (Maubach & Hoek, 2010).

Other studies suggest that consumers may have differential preferences for various labels, but their results are not always consistent. One study shows that consumers prefer evaluative labels that use interpretative colours, symbols and text (Hutton & Gresse, 2020). Among the RIs, MTL label, Nutri-Score, Health Endorsement Logo and warning labels, the health endorsement logo received most positive responses followed by the Nutri-Score; RIs on the other hand was evaluated rather negatively. The MTL was most often chosen as trustworthy and as providing the nutritional information needed while the Health Endorsement Logo and the Nutri-Score were most often seen as the easiest to understand.

Other studies suggest a preference for colour-coded TL and MTL over other FOP nutrition labels, including %GDA, Nutri-Score, HSR, or Guiding Stars (Carter *et al.*, 2011; Karamanos *et al.*, 2019; Santos *et al.*, 2020; Vargas-Meza *et al.*, 2019a).

Warnings also show very high levels of preference by consumers (Vargas-Meza *et al.*, 2019a) mainly because they are simple and easy to understand (Ares *et al.*, 2018b), confirming the general finding that FOP nutrition labels that contain simple visually enhanced information may be preferred (Maubach & Hoek, 2010).

One study reports that the HSR label appears to have lower general acceptance, as, despite being appreciated for its simplicity, and for facilitating across-products comparison, consumers may have little confidence in it due to the lack of transparency in the criteria underlying the choice on the number of stars (Pelly *et al.*, 2020). In addition, consumers think that the HSR may portray highly processed foods too positively, possibly because of its lack of negative imagery that would correspond to low-rated foods (Pelly *et al.*, 2020).

Lastly, a study by Mantzari *et al.* (2018) tested acceptability of a label with a rotting tooth vs. a sugar teaspoon image as a means of reducing consumption of sweetened drinks in adolescents, and found that the rotten tooth image was not considered acceptable or at least was considered less acceptable than the sugar teaspoon image.

Table 11 Studies of consumer preferences for specific front-of-pack nutrition labelling schemes

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2021)	Study 1: 855 Study 2: 917 participants in Uruguay	Two surveys were conducted before (May-June 2019) and after (March 2020) the implementation of nutritional warnings in Uruguay to assess awareness, self-reported use and understanding of nutrition information. Participants' task was to identify the healthiest option among various alternatives.	Acceptance of warning labels: 94 % of participants responded that the warning signs policy was good or very good. Only 1 % of the participants indicated that the policy was bad or very bad, whereas the remaining 5 % rated the policy as regular.
Mazzù *et al.* (2021)	200 participants in Italy The study was funded by the Italian Federation of Food Industry.	Participants either evaluated products marked with NutrInform Battery or Nutri-Score labels. The food products, with the labels, were delivered by the interviewers through a home visit at two points in time: at the start of the trial and then approximately 15 days later.	NutrInform Battery performed better than Nutri-Score in terms of liking at the beginning and at the end of the test period, after four weeks of label utilisation.

Table 11 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Mazzù *et al.* (2021) *(cont.)*		The family member responsible for food purchases rated subjective understanding (Complexity; Comprehensibility/ design; Help to shop) and liking of the NutrInform Battery or Nutri-Score associated to each of the 10 products.	
Egnell *et al.* (2020a)	1 088 participants in Switzerland	Consumer study assessing Swiss' preference and understanding of five FOP nutrition labels: (HSR system, MTL, Nutri-Score, RIs and Warning symbols) and their effects on food choices. Participants were asked to make three purchase choices from three products of one category, and asked to rank the products regarding their healthiness.	The MTL tended to be perceived as "likeable", "providing the information needed" and "easy to understand", while the Nutri-Score tended to be perceived as "standing out" to a greater extent than the RIs and the Warning symbols, monochromatic formats. Nevertheless, these differences were not meaningful, since, as the authors mention, the differences in perceptions among FOP nutrition labels were of very low magnitude and not statistically significant.
Hutton & Gresse (2020)	359 participants in South Africa	Cross-sectional exploratory survey (with an interviewer) conducted at 12 retail food locations assessed consumer perceptions of the RIs, MTL label, Nutri-Score, Health Endorsement Logo and Warning Labels. Participants received a brief explanation of each FOP nutrition label before objective understanding and preferences (liking, trustworthiness, usefulness, feelings of coercion, perceived ease of identification, use) were measured (participants had to choose one label for each item).	Participants preferred evaluative FOPNL using interpretative colours, symbols and text. The Health Endorsement Logo (evaluative summary indicator) received the most positive responses (n = 833), ahead of the Nutri-Score (n = 813). RIs were evaluated negatively most often (n = 437). The MTL was most often chosen as trustworthy (n = 139) and as providing the nutritional information needed (n = 141). Health Endorsement Logo and Nutri-Score were seen as the easiest to understand.

Table 11 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Nieto *et al.* (2020)	78 participants in Mexico	12 focus groups in which participants discussed their perceptions, use and comprehension of nutrition labelling. The specific labels were GDA, Nutrition Facts Table (on BOP, not on FOP), and nutritional stamps. Additionally, claims on the front of the package were included in the study. In the focus group studies, participants discussed, in a semi-structured way aspects (mentioned above) related to labelling.	Overall, participants had an unfavourable perception towards current nutrition labels on foods. Participants did not acknowledge any positive effects from reading them or reported they did not read them. On the other hand, participants acknowledged the importance of having clear information on foods to make healthy choices. Participants also identified some barriers related to nutrition labels (GDA and Nutrition Facts Table), specifically complex language, the font size, information amount, and lack of trust. All these findings were irrespective of participants socio-economic background.
Pelly et al. (2020)	15 Australian grocery shoppers	Four focus groups were conducted to discuss and explore four different features: simplicity and clarity of the HSR, transparency and trust, ratings of processed and ultra-processed food, and effectiveness in discouraging purchase of low-rated products.	The HSR was found to be easily understood, to be appreciated for its simplicity, and to facilitate comparison across products. Still, there was little confidence in the HSR due to the lack of transparency in the criteria underlying the choice on the number of stars. Highly processed foods were found to be portrayed too positively by the HSR. Finally, the HSR is found to lack negative imagery, which limits its dissuasive impact for low-rated foods.
Santos *et al.* (2020)	357 participants in Portugal	An online questionnaire aimed to a) assess the preferences of consumers for different FOPNL and b) evaluate the impact of those	TL was the most preferred FOP nutrition label and Nutri-Score was the least preferred one, according to the individual preferences' questionnaire

Table 11 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Santos *et al.* (2020) *(cont.)*		FOPNL on the selection of food products according to perceived nutritional quality. Each choice scenario contained one out of four FOPNL systems (TL, %GDA, Nutri-Score or HSR) or a no-nutrition label control. Participants were also asked to select the healthiest food product from a set of three alternatives.	previously developed by Julia *et al.* (2017). The option "not able to decide" was more frequent for Nutri-Score than for any of the other FOP nutrition labels.
Vandevijvere *et al.* (2020)	1 007 adult Belgian consumers	Online survey to assess objective understanding and perceptions of five FOP nutrition labels: HSR, MTL, Nutri-Score, GDA, and warning symbols. Participants were randomized to see products with one of the FOP nutrition labels. They then had to 1) choose between products of the same categories; 2) rank products according to their nutritional qualities; 3) express their perceptions regarding the label to which they were exposed.	Perceptions of consumers were favourable for all FOP nutrition labels (no significant differences between the FOP nutrition labels). Food choices also did not differ significantly between the different FOP nutrition labels. However, Nutri-Score performed best for ranking products according to nutritional quality.
Egnell *et al.* (2019c)	1 032 adult Dutch consumers	Online survey to compare HSR, MTL, Nutri-Score, RIs and warning symbols regarding perception and understanding. Participants had to 1) choose between products of the same categories; 2) rank products according to their nutritional qualities; 3) express their perceptions regarding the label to which they were exposed.	The MTL seemed somewhat preferred although there were no significant differences observed across FOP nutrition labels in terms of consumers' perceptions.
Karamanos *et al.* (2019)	242 participants in Western Canada (data collected in November/December 2016)	Survey to investigate consumers' use of nutrition information and their attitudes towards nutrition facts tables, TL system, and Guiding Stars shelf labels.	Price, nutrition, and taste were considered the most important factors influencing purchase decisions. More participants (~30%)

Table 11 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Karamanos *et al.* (2019) *(cont.)*			indicated the TL label provided the nutrition information to choose food products (11.5%: Guiding Stars, 18%: Nutrition Facts Table). Survey results indicate that both trust and expected difficulty to use are relevant factors for consumers' willingness to use each labelling scheme.
Talati *et al.* (2019a)	12 015 participants in 12 countries (Argentina, Australia, Bulgaria, Canada, Denmark, France, Germany, Mexico, Singapore, Spain, UK, USA)	Respondents were asked to provide their perceptions of five different FOPNL schemes (HSR, MTL, Nutri-Score, RIs and warning label) in an online survey. "Perception" was a 9-item scale that included items measuring liking, comprehensibility, trust, salience and desire for the label to be mandatory.	Respondents indicated a strong preference for mandatory FOPNL regardless of label condition. The MTL label was evaluated most favourable in this study. There were no substantial differences between countries regarding label preference.
Vargas-Meza *et al.* (2019a)	2 105 Mexican adults	Participants were randomly assigned to either GDA, MTL or Warning labels condition. They were asked to detect, among 3 products, the one with the lowest nutritional quality.	Most participants liked the MTL and the Warning Labels more than the GDA, finding them more attractive and clearer. GDA had the lowest acceptability among the labels tested.
Ares *et al.* (2018b)	1 416 Uruguayan citizens aged 18-75 years	Online survey: participants had to answer a series of questions (open ended and multiple-choice) related to their perception of warnings as a FOPNL scheme (i.e. the Chilean warning labels).	Participants had a positive attitude towards nutritional warnings, which were regarded as easy to understand and to identify on food packages. A high level of public support for nutritional warnings was observed.
Mantzari *et al.* (2018)	2 002 parents of 11–16-year-olds living in the UK, with a total household consumption of SSBs of at least 500 ml each week	Online experiment in which participants had to indicate the extent to which they accepted government policy requiring a safety label to be placed on drinks. The SSBs	The rotting teeth image label was judged less acceptable than the calorie information label alone. The rotting teeth image label was seen as

Table 11 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Mantzari *et al.* (2018) *(cont.)*		displayed an image warning or not following a between-subject factorial design: 3 (image-based warning label: no image, picture of rotting teeth, picture of a teaspoon of sugar) × 2 (calorie information label: absent, present).	less acceptable than the sugar content image.
Hoefkens *et al.* (2012)	1 735 University canteen users in Ghent, Belgium	Online choice experiment aimed at studying individual preferences (and the factors explaining them) for alternative nutrition labels on canteen meals, not products. A typical past dish was presented with either one of two versions of GDA (energy-only or detailed with percentages) or with either one of two versions of star rating (with or without verbal descriptor).	This non-incentivised choice experiment explored preferences for information (as opposed to product, as usual) attributes. Participants were ready to pay a 43% price premium to have detailed GDA label, and significantly less to have basic GDA information or star rating. Also, participants elicited a negative preference towards a combination of two simple label formats, and of two detailed formats, too. This signals both information insufficiency and information overload.
Maubach & Hoek (2010)	15 parents in New Zealand	Qualitative study in which parents' view of four different FOP nutrition labels (Percentage Daily Intake, TL, MTL, Wheel TL) were assessed in semi-structured, in-depth interviews.	All FOP nutrition labels appeared to have advantages and disadvantages but those containing simple visually enhanced information (i.e. visual heuristics) seemed to be preferred by parents.
Carter *et al.* (2011)	58 participants in Australia	Participants rated three food packages, alternatively labelled with Daily Intake Guide for kJ, full Daily Intake Guide (with thumbnails), and TL systems, for the following dimensions (7-point scales): 'interpretable', 'noticeable', 'useful' and 'a deterrent to purchasing unhealthy snack	Daily Intake Guide for kJ was the least favoured labelling system of the three, being rated the lowest along all four attributes of 'interpretability', 'noticeability', 'usefulness' and as 'a deterrent to purchase of unhealthy snack foods'. TL was

Table 11 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Carter *et al.* (2011) *(cont.)*		foods'. After, they discuss the merits of each system in focus groups of 7-8 participants.	ranked as best.

BOP, Back-Of-Pack; FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; TL, Traffic Light(s).

3.3.3 Conclusions regarding consumer preferences and acceptance

The previous JRC literature review on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) reported that:

I. Most people seem to appreciate FOP nutrition labels.

II. Older adults and people with overweight/obesity are more likely to report a need for a FOP nutrition label.

III. Self-reported acceptance of FOP nutrition labels does not automatically entail that the label will be effective. However, if labels are not accepted, their message may be ignored even though they are noticed.

IV. FOPNL schemes that use colours, are typically preferred to monochrome ones. The limited evidence, mostly coming from focus group studies, supports the idea that consumers prefer evaluative FOPNL schemes.

V. When comparing different FOPNL schemes, different studies show a preference for different schemes, where the most preferred label tends to be the one implemented in the country where the study is conducted.

The present report largely confirms these past findings by providing additional evidence for the wide acceptance of FOP nutrition labels by consumers (cf. conclusion I above). With respect to conclusion II, some, but not all of the studies reviewed here also suggest that consumers' support and preference for FOP nutrition labels depends on their individual-level characteristics, including socio-demographic characteristics (like gender and region) and dietary habits or preferences. Nevertheless, the findings reviewed here suggest that it is sugar-conscious, health-conscious individuals with a high level of physical activity, and dieters, who report higher preference for FOP nutrition labels, while both respondents with overweight and those that consumed higher amounts of sugar-containing products appear more strongly opposed to their adoption. The discrepancy between the results reported in this and the previous report as for the relationship between obesity and consumers' preferences on FOPNL may be, indeed, attributed to demographic or cultural differences since the studies reported here were conducted in different countries (Switzerland; Brazil) than those reported in the previous report (mainly EU countries). Another potential explanation is that the two related studies in the previous report measured perceived obesity while the studies reported here relied on BMI calculations. It is possible that respondents who self-identified as having obesity are those who are more

concerned with their weight and more aware of their eating habits, which would make the past results aligned with those reported in this study.

Conclusion III is further supported by evidence that self-reported preference for and self-reported use of FOP nutrition labels for making food choices are not always commensurate. Conclusion IV remains unchallenged with all reviewed studies suggesting consumer preference for coloured and directive FOP nutrition labels. A field experiment suggested that directive FOP nutrition labels may be preferred when they provide an overall food assessment rather than independent assessment of the various nutrients (Muller & Ruffieux, 2020). Lastly, with respect to conclusion V, several studies do not reveal any clear preferences for specific FOP nutrition labels. Nevertheless, a significant number of other studies tend to suggest some preference for the TL or the MTL FOP nutrition label over other schemes (Carter *et al.*, 2011; Hutton & Gresse, 2020; Karamanos *et al.*, 2019; Santos *et al.*, 2020; Vargas-Meza *et al.*, 2019a).

3.4 Evidence on consumers' understanding of FOP nutrition labels

Front-of-pack nutrition labels are meant to empower consumers by providing visible, understandable, and accessible information on the nutritional quality of food products. In order to be effective, a FOP nutrition label needs to attract attention, be accepted and understood by the consumers before it can potentially guide their food choices (Grunert & Wills, 2007).

Food choices of consumers are generally thought to be guided by heuristic processing due to limited time, motivation, and cognitive resources (Fenko *et al.,* 2018). To help consumers even when they have limited time and cognitive resources, **FOP nutrition labels should require little time and effort to be interpreted correctly when making food choices**.

Understanding of FOP nutrition label information can be measured objectively (by asking consumers to identify, rate or rank products according to healthfulness) or subjectively (by asking consumers to report how easy or useful they find a particular FOP nutrition label). Whereas subjective understanding can provide in-depth information on the aspects of a FOP nutrition label that consumers find more or less clear, objective measures provide insights into how consumers use the provided label to derive the nutritional quality of a food product.

A related aspect is that consumers should understand the concept behind the specific FOPNL scheme (e.g., does the label compare nutritional quality within or across product categories; JRC report on FOPNL, 2020). Some studies have shown that FOP nutrition labels can be interpreted incorrectly, leading consumers to draw inaccurate conclusions regarding a product's healthfulness (Ikonen *et al.*, 2020).

Several aspects influence the ease with which the information provided by FOP nutrition labels is interpreted, such as specific features of the FOP nutrition label (section 3.4.1, e.g. reference quantities, colour coding). Much research has also directly looked at understanding of specific FOPNL schemes or compared consumer understanding of different FOPNL schemes (section 3.4.2).

3.4.1 FOP nutrition label features related to consumer understanding

The previous sections have shown that some labelling scheme features can influence attention to and preferences for different FOP nutrition labels. Some features of FOPNL schemes may also have implications for objective and subjective consumer understanding. In the following, we will first focus on the impact of providing different reference quantities for consumers' understanding of FOP nutrition labels (3.4.1.1), followed by implications of using colour to facilitate understanding of FOP nutrition labels (3.4.1.2).

3.4.1.1 Implications of using different reference quantities for consumer understanding

Reference quantities represent the unit on which the nutritional information of the FOP nutrition label is based. In some labelling schemes, this information is visibly presented on the label (e.g. MTL, GDA, RIs), whereas for others it is not (e.g. Nutri-Score, warning labels). References can be given 'per serving/portion', 'per 100 g/ml', 'per 100 kcal', or 'per container/package'. Different reference quantities provide consumers with information that can support them in evaluating the nutritional quality, either by making it easier to compare between products (e.g. per 100g/ml, per 100kcal) or by receiving an indication of what one is actually buying or consuming (e.g. per container/package, per serving/portion) (Gomes *et al.*, 2020; van Kleef *et al.*, 2008). The energy value of the foods, which is explicitly stated on some labels, can be represented in kJ and kcal. Mentioned in the literature are also more interpretative alternatives such as a physical activity equivalent (PACE), which shows the extent of physical activity that is necessary to burn off the energy in a serving of the food (Hartley *et al.*, 2018).

Clarity and granularity of reference quantities seem to be relevant factors for consumers' understanding and interpretation (Baxter *et al.*, 2018; Lewis & Earl, 2018). In general, there seems to be a tendency for participants to **understand nutritional information better when it requires less "mental math"** (Table 12). For example, Baxter and colleagues reported that participants made more errors in evaluating a Nutrition Facts Table when food packages contained multiple servings but information was provided on single servings, compared to when information on serving size and content of the package matched (Baxter *et al.*, 2018). Stating smaller serving sizes on packages than are typically consumed in one sitting and thereby potentially indicating lower calories than expected by consumers, may result in consumers misinterpreting, and specifically underestimating the energy and nutrient content of a particular food (Tangari *et al.*, 2019). **Salient, consistent, and simple reference quantities** thus seem preferable (Gomes *et al.*, 2020; Kerr *et al.*, 2015; Roberto & Khandpur, 2014).

Table 12 Studies of the impact of specific reference quantities used in front-of-pack nutrition labelling schemes on consumers' subjective and objective understanding

Study (most recent first)	Population	Intervention/Comparator	Outcome
Gomes *et al.* (2020)	Study 1: 1 127 consumers in Portugal Study 2: 33 participants in 4 focus groups	Study 1 (survey) included questions regarding label format, consumers' responses to food labelling (search, understanding, liking, and use), and a one-shot choice task, where respondents were asked to make the healthier choice between two TL food label indicating either a reference level of 30g (1 portion) or 100g with similar salt levels. Study 2 (focus groups) explored interest and importance attributed to food options in the definition of healthy lifestyles, the importance of food labelling in food choices; and knowledge, understanding, liking, and use of food labels.	Choice task: 59% of respondents correctly made the healthier choice when presented with two TL labels, one of which presented as "per 30g", and one "per 100g". Focus Groups: Concerned consumers stated that information on nutrition labels is often unclear. When labels present different units of measurement, participants find it difficult to compare nutritional values.
Tangari *et al.* (2019)	Study 1: 140 students in the USA Study 2: 403 participants (online) Study 3: 106 students in the USA Study 4: 76 students in the USA Study 5: 115 students in the USA	Five studies assessed how calories-per-serving information on labels influences snack consumption. Expectations regarding the calories per serving were manipulated across studies to confirm or disconfirm expectations. Intentions to eat the snack (quantity) was assessed in Study 2. Consumption was assessed in studies 1, 3, 4, and 5.	Stating lower calorie value than expected by providing smaller serving sizes are suggested to result in misinterpreting energy and nutrient content by consumers.
Baxter *et al.* (2018)	60 participants in Canada (convenience sample)	Lab study to explore the effect of package size on serving size assumptions that individuals make from a nutrition facts table.	When packages contained multiple servings but information was provided on single servings, participants made more errors compared to when information

Table 12 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Baxter *et al.* (2018) *(cont.)*		Between participants, products either appeared as single serving on the table & the package contained a single serving, product contained multiple servings, or they appeared and contained multiple servings.	on serving size and content of the package matched.
Hodgkins *et al.* (2015)	2 068 participants from four European countries: 513 in the UK, 525 in Germany, 500 in Poland and 530 in Turkey.	Online survey to test the extent to which inclusion of the most prevalent FOPNL systems: GDA, TL, GDA-TL hybrid, and health logos – impact consumer perceptions of healthfulness over and above the provision of a FOP basic label containing numerical nutritional information alone. To test the effect of portion size on health inferences, portion size on the label was manipulated with either a typical portion size as used on the market, or a 50% reduction of the typical portion size.	The FOP schemes tested resulted in small improvements for objective understanding under some conditions. However, there was not much difference from a FOP scheme containing basic numerical nutritional information alone. Portion size on the label had little effect on participants' subjective health ratings. These conclusions (from the authors) derive from the observation of very small effect sizes, although differences are statistically significant given the large sample. This may be because people believe that portions are larger when portion size labels are fine-grained.

FOP, Front-Of-Pack; GDA, Guideline Daily Amount(s); TL, Traffic Light(s).

3.4.1.2 Implications of using colour coding for consumer understanding

Several studies suggest that labels that make use of colour coding facilitate consumer understanding (Table 13). With some exceptions (Bialkova *et al.*, 2020), healthiness ratings of food products were often more accurate with colour-coded labels than without (Acton *et al.*, 2018b; Kunz *et al.*, 2020; Pettigrew *et al.*, 2020, 2021). Some studies have shown that healthiness ratings were also made quicker with colour-coded labels (e.g. Prevost *et al.*, 2018). This is in line with the idea that perceiving and processing colour information requires little time and effort for the average consumer (Muller & Prevost, 2016) .

Table 13 Studies of the impact of colour coding on consumer understanding of front-of-pack nutrition labelling

Study (most recent first)	Population	Intervention/Comparator	Outcome
Pettigrew *et al.* (2021)	7 545 in seven countries (Australia, Canada, China, India, New Zealand, UK, USA)	In an online survey experiment, participants were exposed to several breakfast cereals with four variations of the HSR, resulting from a combination of 2 types of FOP: summary health-star rating vs. hybrid health-star rating (summary and nutrient-specific information); and 2 types of colour condition: coloured (red/orange/green) vs. black & white) design. In each trial one product had no rating, one had 1.5 star, one had 3 stars and one had 4.5 stars. Participants indicated purchase intentions and rated the perceived healthfulness of the products.	Across countries, healthiness ratings were higher when the products were labelled with the coloured, summary health-star rating and the hybrid coloured FOP. However, there were noticeable country differences: while in most countries a coloured version performed significantly better than the monochrome hybrid on at least one of the two measures, it was the monochrome summary version that performed better in Canada and the positive effect of colour was significantly smaller in China than in the other countries.
Mabotja *et al.* (2021)	403 South African consumers (o nly those responsible for household shopping)	Online survey measuring participants' use and understanding of food labels of several FOP systems: Nestlé Know Your Serving; GDA; Teaspoon Nutritional Illustration; Nutritional Information Table; and TL Labelling.	Concerning ease of understanding of the individual FOP systems, 76% of the participants said that 'Nestlé Know Your Serving' was easy to understand, while the respective percentages were 67% for GDA, 69% for Teaspoon Nutritional Illustration, 68% for Nutritional Information Table, and only 52% for TL labelling. An extra understanding question included for TL labelling showed that between 74%-52% of the participants correctly interpreted the colour coding (green, amber and red) of the TL labelling.
Anabtawi *et al.* (2020)	858 for the Choice Based Conjoint Analysis and 901 for	Online Choice Based Conjoint Analysis technique: Each screen presented three	People tend to avoid food products that had a red label and give the red label

Table 13 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Anabtawi *et al.* (2020) *(cont.)*	the survey on knowledge	options of the same food item with different nutrition TL label combinations.	a higher importance than presence of a green label. Notably, the aversion to red labels was stronger for sugar than for other nutrients.
Bialkova *et al.* (2020)	Study 1 (lab study): 30 students in Germany Study 2 (field study): 120 participants in a grocery store in Germany	Two eye-tracking studies explored gaze behaviour and purchase decision as a function of nutrition label (monochrome vs. TL colour-coded GDAs), brand, and product flavour. In Study 1, participants were either asked to choose the healthiest product or the product they preferred. In study 2, all participants chose the product they preferred.	Study 1 showed that products with a colour coded GDA were more often chosen when participants had to choose the healthiest product. This effect is seemingly independent of the information provided on the label. Study 2 found no main effect of the type of label on product choice.
Kunz *et al.* (2020)	173 adults in Austria	Online study showing pictures of unknown desserts, and varying sugar levels and the presence of FOP nutrition label, to estimate the impact on tastiness expectations and purchase intentions.	MTL (as opposed to uncoloured sugar info) helped participants estimate products' healthiness based on sugar content. On the contrary, MTL did not affect perceived products' tastiness and did not reduce purchase intentions for higher sugar products.
Pettigrew *et al.* (2020)	1 033 adults in Australia	Online survey study to investigate the effect of adding colour and excluding nutrient icons as a way to improve the 'interpretativeness' of the HSR. Participants chose the healthiest breakfast cereal (+ product preference) out of 4. Healthiness was indicated by HSR. Between participants, HSR was 1) black & white full, 2) colour full, 3) black & white star rating only, 4) colour star rating only.	The study provides preliminary support that an HSR version that includes TL colours without nutrient-specific information would enhance HSR's effectiveness. HSR variations with colour were better understood than black & white variations. The star only versions performed better than the full versions including nutrient icons. The coloured star-only HSR led to most correct (healthy) choices and was the most preferred.

Table 13 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Sundstrom *et al.* (2020)	1 026 participants, representative sample of the online adult US population	Survey-based experiment, using three treatment groups with alternative FOPNL of nutritional content to assess their effect on healthfulness perceptions. The treatment groups presented the information with different degrees of salience. Specifically: one label just gave nutrient information/ serving, the second added whether the product was "high" or "low" in a specific nutrient, and the third added colours (traffic-light type) to the second label. The outcome measure was participants' subjective assessment of the healthfulness of the food they were shown.	The study reports that most individuals changed their health rating of products according to the FOP nutrition labels. Results suggest that salience of nutrition information on FOP influences health perceptions only when people have nutrient-specific concerns that motivate them to attend to the provided information. This would suggest that FOP nutrition label formats should provide personally meaningful information. The authors suggest that labels that provide easily interpretable information on whether a particular key nutrient is low or high (e.g. green or red) fulfils this objective.
Prevost *et al.* (2018)	50 participants in France	fMRI study to test the neural correlates of evaluating food healthiness according to GDA and the TL labels. GDA and TL labels were simplified in that, per nutrient, GDA was represented by circles with numeric information and TL by colourful circles.	Healthiness evaluations were faster on the basis of TL information than GDA (numeric) information, and if less information had to be combined rather than more. Interestingly, participants recruited brain regions involved in arithmetic in both TL and GDA regions if more than one piece of information was presented. This suggests that integrating several pieces of information requires some complex, likely analytical processing.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition Labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); TL, Traffic Light(s).

3.4.2 Consumers' understanding of specific FOPNL schemes

FOP nutrition labels vary in terms of how easily they are understood by consumers. We have categorized this section according to studies that focus on one specific FOP nutrition label (3.4.2.1) and those that compare different labels with each other (3.4.2.2).

3.4.2.1 Studies focusing on consumer understanding of one particular FOP nutrition label

Many studies have focussed on consumer understanding of **one particular FOP nutrition label** and the methodology used in these studies varies widely, from qualitative studies such as focus groups to experimental tasks in which one feature of a label was changed and its impact on understanding was investigated (Table 14).

Most of these studies suggest that FOP nutrition labels increase the accuracy of consumers to identify healthier products. The studies suggest that more directive labels, those including colour (see also 3.4.1.2), interpretative text (Ares *et al.*, 2021; Goodman *et al.*, 2018; Nobrega *et al.*, 2020), graded indicators (De Temmerman *et al.*, 2021) or those that are simpler lead to better consumer understanding (Pettigrew *et al.*, 2020; Pongutta *et al.*, 2019). Additionally, some studies suggest that information and education campaigns can increase understanding of specific labels (Miller *et al.*, 2019; Retno & Fatmah, 2019).

Next to accuracy of identifying healthier products (e.g. objective understanding), some studies focus on perceived healthfulness of food products. Most studies report an effect of the presence (vs. absence) of a label as well as gradations within the label on perceived healthfulness of products (Ares *et al.*, 2021; De Temmerman *et al.*, 2021; Mantzari *et al.*, 2018; Nobrega *et al.*, 2020). Only a limited number of studies report no effect of FOP nutrition labels on perceptions of product healthfulness (Lima *et al.*, 2019c). However, results on perceived healthfulness remain difficult to interpret because it is not always clear from the studies whether the perceived difference in healthfulness corresponds with an actual difference in healthfulness of the product.

Table 14 Studies of objective and subjective consumer understanding of specific front-of-pack nutrition labelling schemes

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2021)	Study 1: 855 participants in Uruguay Study 2: 917 participants in Uruguay	Two surveys were conducted before (May-June 2019) and after (March 2020) the implementation of nutritional warnings in Uruguay to assess awareness, self-reported use and understanding of nutrition information. Participants' task was to identify the healthiest option among various	In both tasks, percentage of participants who correctly identified the healthiest option significantly increased with the inclusion of nutritional warning labels. There were some differences identified

Table 14 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2021) *(cont.)*		alternatives (Task 1: most healthful product; Task 2: excessive content of critical nutrient)	corresponding to different nutrient contents in task 2.
De Temmerman *et al.* (2021)	Study 1: 292 respondents in Belgium Study 2: 415 respondents in Belgium	Two online studies that investigated the effect of the presence (vs. absence) and the effect of the five categories of the Nutri-Score on perceived healthiness of products as well as purchase intentions. Study 1 followed a 3 (meal Nutri-Score category: A, B, C) x 2 (Nutri-Score presence: present vs. absent) between-subject design. Study 2 followed a 2 (Nutri-Score between participants: present vs. absent) × 2 (brand between participants: manufacturer brand vs. private label) × 5 (Nutri-Score within participants: A, B, C, D, E) mixed design.	There was an overall effect of the presence of Nutri-Score, and of the Nutri-Score category on perceived healthiness. More specifically, the data suggest an interaction effect in that products with better Nutri-Score score are perceived as healthier in the presence of a label, but perceived healthiness of products with lower Nutri-Score are not affected by the presence of the label (Study 2).
Pettigrew *et al.* (2021)	7 545 participants in seven countries (Australia, Canada, China, India, New Zealand, UK, USA)	In an online survey experiment, participants were exposed to several breakfast cereals with four variations of the HSR, resulting from a combination of 2 types of FOP: summary HSR vs. hybrid HSR (summary and nutrient-specific information); and 2 types of colour condition: coloured (red/orange/green) vs. black & white) design. In each trial one product had no rating, one had 1.5 star, one had 3 stars and one had 4.5 stars. Participants indicated purchase intentions and rated the perceived healthfulness of the products.	Across countries, purchase intentions and healthiness ratings were higher when the products were labelled with the coloured, summary health-star rating and the hybrid, coloured FOP. While in most countries a coloured version performed significantly better than the monochrome hybrid on at least one of the two measures, it was the monochrome summary version that performed better in Canada and the positive effect of colour was significantly smaller in China than in the other countries.

Table 14 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2020)	163 participants in Uruguay (high proportion of highly educated participants)	Before and after the implementation of nutritional warnings, this study assessed associations with food products without (pre-implementation) and with (post-implementation) warning labels on ultra-processed products.	Compared to pre-implementation, responses relating to excessive content of a particular unhealthy ingredient, associations regarding unhealthfulness and diseases increased when warning labels were presented on the package.
Gomes *et al.* (2020)	Study 1: 1 127 consumers in Portugal Study 2: 33 participants in 4 focus groups	Study 1 (survey) included questions regarding label format, consumers' responses to food labelling (search, understanding, liking, and use), and a one-shot choice task, where respondents were asked to make the healthier choice between two TL food label indicating either either a reference level of 30g (1 portion) or 100g with similar salt levels. Study 2 (focus groups) exploredinterest and importance attributed to food options in the definition of healthy lifestyles, the importance of food labelling in food choices; and knowledge, understanding, liking, and use of food labels.	Subjective understanding: 42.9% participants responded that food labels are easy to understand while 37% indicated the opposite (20% neither agreed nor disagreed). Choice task: 59% of respondents correctly made the healthier choice. Focus Groups: Concerned consumers stated that information on nutrition labels is often unclear.
Nobrega *et al.* (2020)	820 Brazilian adults	Online survey in which participants were allocated to four groups, one per product category (yogurt, juice, bread and crackers), testing two types of claims (present vs. absent) and nutritional warning (present vs. absent). Participants rated perceived healthfulness of the presented products.	Claims had a positive effect on perceived healthiness of products. However, nutritional warnings were found to be more efficient than claims in their ability to significantly influence perceived healthfulness of all four products with unfavourable nutrient profile.

Table 14 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Pettigrew *et al.* (2020)	1 033 adults in Australia	Online survey study to investigate the effect of adding colour and excluding nutrient icons as a way to improve the 'interpretativeness' of the HSR. Participants chose the healthiest breakfast cereal (+ product preference) out of four. Healthiness was indicated by HSR. Between participants, HSR was 1) black & white full, 2) colour full, 3) black & white star rating only, 4) colour star rating only.	HSR variations with colour were better understood than black & white variations. The star only versions performed better than the full versions including nutrient icons. The coloured star-only HSR led to most correct (healthy) choices and was the most preferred.
Taillie *et al.* (2020a)	1 997 participants in Colombia	The online study evaluated reactions and perception to different warning labels (octagon, circle, triangle, control: barcode). Participants viewed these labels on a series of products. They answered questions such as the food nutritional quality, the PME (self-report: perceived health concerns, pleasance, discouraged consumption) and their intention to purchase them.	All labels performed better than the barcode in PME, greater ability to identify foods with high levels of nutrients of concern; and reduced intentions to purchase those products. Results were similar across different levels of education.
Uribe *et al.* (2020)	320 students in Chile	Study assessing the effect of the number of stop signs (warning labels) on a package (none to three) and product type (hedonic: e.g. ketchup vs. utilitarian: e.g. margarine) on healthiness perception and purchase intentions.	Healthiness perceptions decreased with an increase in the number of stop signs on a food package. This effect was regardless of the type of product. The effect of warning labels on healthiness perceptions appeared faster for utilitarian products.
Centurion *et al.* (2019)	100 participants in Uruguay, recruited among students and workers of the University of Psychology, aged between 18 and 56 years(75% female)	Lab experiments assessing the combination of images of fruit (with/without), nutrient claims (with/without) and nutritional warnings (with/without) on attention (eye-tracking) and healthfulness perceptions of cereal bars.	Participants mainly relied on nutritional warnings to make healthfulness judgments. Other features such as nutrient claims or fruit images did not significantly impact

Table 14 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Centurion *et al.* (2019) *(cont.)*			respondents' perceived healthfulness of the products.
Correa *et al.* (2019)	84 mothers in Chile	Nine focus groups were held to explore mothers' response to the 2016 Chilean law of food labelling and advertising. In particular, they assessed perceptions and knowledge about Warning Labels on food packaging.	In general, participants reported that more products bearing more labels were less healthy than those with fewer labels. Some participants (mostly from middle & upper- socioeconomic levels) said they use labels as shortcuts ("I don't read them [..] (very closely) but when I see too many, I don't buy it.").
Gregori *et al.* (2019)	333 Chilean adults, interviewed twice, in 2012 and 2016	Computer-assisted telephone interviews, conducted on the same respondents, in 2012 and 2016, with the aim of studying consumers' attitudes towards and understanding of FOP nutrition label before and after the introduction of the Chilean regulation on food labelling.	Both before and after the introduction of the law, people expressed interest in FOPNL and reported having a good understanding. This was not confirmed when assessed objectively. This suggests that educational interventions should accompany any new FOPNL scheme.
Grummon *et al.* (2019)	1 360 US adults	Online survey to assess the PME of health warnings for SSBs. Respondents were randomly allocated to 4 conditions: a) health effects; b) nutrient disclosure; c) marker word "Warning"; d) shape (octagon vs. rectangle).	The PME was higher for health warnings that included health effects or nutrient disclosure. However, the inclusion of the latter on top of the former did not bring any additional improvement in PME. Health effects, marker word and octagon-shaped symbols also induced more fear and thinking about harms.
Lima *et al.* (2019c)	141 participants in Brazil	Study to investigate the effect of the TL System on food healthfulness perceptions in Brazil. Three types of dairy products were shown with or without the TL system for a well-known or unknown brand.	No effect of the presence of the TL system on perceptions of product healthfulness were reported.

Table 14 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Miller *et al.* (2019)	80 college students (USA)	Tested a nutrition-label e-training on students' ability to understand and interpret nutritional information (nutrition labels, ingredient list). Participants' effort (eye-tracking: number of left-to-right sweeps), their perceptions of empowerment (ability and willingness to use nutrition information) and the usability of the intervention were measured.	Participants' effort significantly decreased with the task while their accuracy and empowerment increased. Specific feedback further reduced participants' effort.
Pongutta *et al.* (2019)	1 364 adults in Thailand	Interviews aimed at assessing consumers' understanding and use of GDA, with respect to GDA with colour, GDA with text (high/low), and GDA with text and colour.	Participants who read any of the three GDA variants were on average three times more likely to make healthier food choices, compared to having read an ordinary GDA label. Participants who recognised the link between diet and non-communicable diseases were 1.2 times more likely to choose healthier food.
Retno (2019)	41 Indonesian female teenagers	Quasi-experimental approach aimed at assessing the FOP TL nutrition label on participants' comprehension level, after an educational media intervention (on how to read and use nutrition labels).	The intervention group (with FOP TL) showed on average higher comprehension scores. Educational material improved the performance of both groups, with the intervention group improving more than the control group.
Siegrist *et al.* (2019)	780 participants in Switzerland	Online study on the use of FOP information to judge healthfulness of breakfast cereal. Participants were either only presented with an image of the package, image + a healthy choice label for healthier product, image + nutrition table on demand, or image + healthy choice label + nutrition table on demand. Participants' task was to choose the healthier product.	There was no difference between showing only the image and showing image + simple healthy choice label (self-designed checkmark). Best choices were made when participants had the image and the healthy choice label and the nutrition table on demand.

Table 14 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Sulong *et al.* (2019)	366 participants, convenience sample of 18-60 year-olds in Malaysia	This was a guided, self-administered survey using a convenience sample. It aimed at establishing consumers' awareness and understanding of the FOP energy icon, launched in Malaysia in 2012.	Results showed that 85% of participants were aware of the FOP energy icon. Out of these, 50% had an 'excellent' understanding of the label, and a further 41% a 'good' understanding. There were some socio-economic differences: those who understood the icon were more likely to be highly educated, young and female. The study concludes that the FOP energy icon is a potential tool, complementary to nutrition information panels.
Vargas-Meza *et al.* (2019b)	120 Mexican adolescents (13-15y), young adults (21-23y), mothers of children (3-12y), fathers of children (3-12y) and older adults (55-70y).	Ten focus groups with 12 participants each, aimed at exploring the awareness, acceptability and subjective understanding, of seven different FOP nutrition labels (HSR, Warning labels, Warning labels in red version, TL, GDA, Healthy Choice, and a (fictitious) 5-colour nutrition label) by low- and middle-income Mexican consumers.	The participants were aware of the GDAs but found it complex and rarely used it. Directive and semi-directive labels (such as warning labels, HSR and MTL) may be more effective in encouraging healthier food choice for low- and middle-income groups. The study reported a low subjective understanding for a fictitious 5-colour nutrition label.
Zlatevska *et al.* (2019)	Study 1: 119 participants Study 2: 500 participants Study 3: 356 participants Study 4: 502 participants Sample drawn from Mturk workers	In 4 online surveys, the authors investigated the effect of combining positive (virtues) and negative (vices) nutritional icons of the Facts-Up-Front label on the interpretation and healthiness evaluation of food items.	The studies suggest when vices and virtues are presented in the same label, healthiness ratings reflect a compensatory process. For example, products with two vices were perceived less healthy than products with the same vices and also two virtues. Products with only two virtues were seen as healthiest (Study 1). Combining positive and negative labels could thus

Table 14 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Zlatevska *et al.* (2019) *(cont.)*			increase healthiness perceptions in contrast to only including vices. Nutritional literacy did not moderate the effect.
Goodman *et al.* (2018)	11 617 adults from Australia, Canada, UK, and US	In an online survey, participants used one of 11 formats for FOP signs on cereal boxes signalling high SFA and sugars to assess the level of sugar and SFA (low/medium/high) of a product: control (no FOP symbol), red circle, red 'stop sign', magnifying glass, magnifying glass + exclamation mark, and 'caution' triangle + exclamation mark, with each of these five conditions accompanied by a 'high in' text descriptor.	The red stop sign, caution triangle with exclamation mark, red circle, or magnifying glass with exclamation mark signs that also included the 'high in' phrase led to more accurate perceptions of high SFA and sugar in the cereals compared to the control group. The red stop sign and caution signs alone were also effective, even without featuring the 'high in' text. The magnifying glass sign on the other hand, did not differ from the control condition. Participants perceived the red stop sign (37.7%) and the triangle + exclamation mark (22.0%) as most suited to confer high contents of fat and sugars.
Mantzari *et al.* (2018)	2 002 parents of 11–16-year-olds living in the UK, with a total household consumption of SSBs of at least 500 ml/week	Online experiment in which participants had to indicate the extent to which they perceived the consumption of SSBs as risky in terms of health. The beverages displayed an image warning or not following a between-subject factorial design: 3 (image-based warning label: no image, picture of rotting teeth, picture of a teaspoon of sugar) × 2 (calorie information label: absent, present)	Compared to the control group, participants who saw an image-based warning label (picture of rotting teeth or picture of a teaspoon of sugar) perceived the consumption of SSBs as significantly riskier for health.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); PME, perceived message effectiveness; SFA, Saturated fat; SSB, Sugar-Sweetened Beverage; TL, Traffic Light(s).

3.4.2.2 Studies comparing consumer understanding of different FOP nutrition labels

Several studies compare the understanding of specific FOPNL schemes directly (Table 15). Due to the use of various methodologies, outcome variables, and different comparisons, summarizing these results is challenging. In the interpretation of the results, we have to take into account that consumer understanding is multi-faceted and can be measured in different ways. Therefore, results may differ according to the experimental task and thus the measured outcome. For example, identifying whether a product has a large amount of a particular nutrient may be easier with warning labels or the MTL which clearly indicate the amount of a specific nutrient (e.g. 'high in', red label), and it may be more difficult with a summary indicator that provides an overall evaluation (e.g. Nutri-Score). On the other hand, providing a summary evaluation (e.g. rank products according to "healthfulness") may be easier with a summary indicator than with a label that provides more details on the nutritional composition of the product. Another important aspect is whether the studies assess consumers' perceptions of nutritional quality between product groups (e.g. yoghurt vs. breakfast cereal) or within product groups (e.g. two types of yoghurt, two types of breakfast cereal). This would have different outcomes depending on whether the label's calculation rules are adjusted by food category or not, whether and which reference quantities are provided (per portion, per 100mg/ml), or whether the scheme is reductive or not. As mentioned earlier, the literature also distinguishes between objective understanding assessed, for example, through healthiness ranking, and subjective understanding, such as participants' rated comprehension or experienced complexity of the label.

Additionally, as some authors note (Hagmann & Siegrist, 2020; Santos *et al.*, 2020), familiarity with a particular label also plays a role in consumer understanding. If consumers are familiar with one particular label, for example because it has already been implemented in their country, they are likely to understand and use this label more accurately than unfamiliar labels. Therefore, studies comparing the understanding of several labels in a particular country have to be interpreted with caution, taking into account consumers' familiarity with a particular label or label features.

Overall, and in line with the previous literature review, the studies listed in Table 15 suggest that **simpler labels may be more easily understood than complex labels** (Deliza *et al.*, 2020; Dubois *et al.*, 2021; Egnell *et al.*, 2019c, 2020a; Hagmann & Siegrist, 2020; Vargas-Meza *et al.*, 2019a), even though some participants report needing further information to select the healthiest product (Santos *et al.*, 2020). In their study, Santos and colleagues observed that this lack of additional information when BOP information is not available can affect the proportion of correctly identified healthy choices (Santos *et al.*, 2020). **Colour-coded schemes, including schemes with a graded indicator, seem easier to understand than monochrome schemes** (Andreeva *et al.*, 2020; Rramani *et al.*, 2020). There is also some evidence that labels that provide a more explicit evaluation ('high in', red colour, grading score) that is easily interpreted, may be more easily understood (Nieto *et al.*, 2019; Sundstrom *et al.*, 2020; Zerbini *et al.*, 2019). In direct comparisons, the Nutri-Score and TL system seem to result in relatively good understanding by consumers (see Table 15).

Table 15 Studies comparing front-of-pack nutrition labelling schemes with regard to subjective and objective consumer understanding

Study (most recent first)	Population	Intervention/Comparator	Outcome
Dubois *et al.* (2021)	1 844 observations (1st wave) and 1 737 observations (2nd wave) in France	Study exploring whether FOPNL improve food purchases in a real-life setting. Products in 60 supermarkets were labelled with either no label (20 supermarkets), SENS label (coloured pyramid with information on how often you should eat the food product), Nutri-Score, Nutri Repère (uncoloured GDA expressed through numbers and bars chart), or Nutricouleur (GDA expressed with numbers and colours). Shoppers filled in a survey before and during the labelling phase to measure attention to and healthfulness perceptions for the different labels.	Most accurate decisions on nutritional quality were made with the help of the Nutri-Score. Accuracy improved when introducing the Nutri-Score or SENS. However, accuracy decreased when introducing Nutri-Couleur and Nutri-Repère.
Medina-Molina & Pérez-González (2021)	301 university students in Spain	Online survey to assess how co-existence with nutrient-specific interpretative labelling impacts the effectiveness of the Nutri-Score to influence purchase intention and healthfulness perception. Two products (one graded B, and one D on Nutri-Score) in the same product category were presented with a) no label, 2) a nutrient- specific interpretative label, 3) Nutri-Score, 4) both nutrient-specific and Nutri-Score.	Purchase intentions and healthfulness perceptions were in line with Nutri-Score suggestion: it was lower when the product was labelled as "D" than when it was labelled "B". The relationship of perceived healthfulness with purchase intention was not moderated by the various formats of interpretative labels.
Vanderlee *et al.* (2021)	1 997 Canadian adults	An online experimental study comparing the impact of three different conditions (HSR, TL and 'high in' Warning Label, with respect to the no label condition) in two sequential tasks (rating healthiness, purchase intentions, and healthiness ranking of products), after a	All three FOPNL systems helped consumers identify healthier and less healthy products compared to the control condition. The TL performed better than all other conditions. The HSR outperformed the TL in task 2. The TL and the HSR also carry a "health halo". The

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Vanderlee *et al.* (2021) *(cont.)*		brief educational session.	authors suggest that the Warning Label was more effective for products that are more "nutritionally ambiguous".
Mabotja *et al.* (2021)	403 South African consumers (only those responsible for household shopping)	Online survey measuring participants' use and understanding of food labels of several FOP systems: Nestlé Know Your Serving; GDA; Teaspoon Nutritional Illustration; Nutritional Information Table; and TL Labelling.	Concerning self-reported ease of understanding of the individual FOP systems, 76% of the participants said that 'Nestlé Know Your Serving' was easy to understand, while the respective percentages were 67% for GDA, 69% for the 'Teaspoon Nutritional Illustration', 68% for the 'Nutritional Information Table', and only 52% for TL labelling.
Mazzù *et al.* (2021)	200 participants in Italy The study is funded by the Italian Federation of Food Industry.	Participants either evaluated products marked with NutrInform Battery or Nutri-Score labels. The food products, with the labels, were shown by the interviewers during a home visit at two points in time: at the start of the trial and then approximately 15 days later. The family member responsible for food purchases rated understanding (Complexity; Comprehensibility/ design; Help to shop) and liking of the NutrInform Battery or Nutri-Score associated to each of the 10 products.	Results suggest that NutrInform Battery performed better than Nutri-Score in terms of subjective understanding and liking at the beginning and at the end of the test period, after four weeks of label utilisation.
Andreeva *et al.* (2020)	1 010 adult Bulgarian consumers	Online survey in which participants had to perform two ranking tasks, in sequence, and then answer whether they recalled having seen a FOP nutrition label. The main outcome was objective understanding of five different FOP nutrition labels (RIs, MTL, Warning label, Nutri-Score, HSR),	Compared to RIs, participants randomized to the Nutri-Score (followed by HSR) showed the largest improvement in product ranking ability across 3 food categories (breakfast cereals, pizzas, and cakes). No improvement was found for MTL and Warning Label compared to RIs.

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Andreeva *et al.* (2020) *(cont.)*		which was assessed by comparing the results of the two ranking tasks.	
Deliza *et al.* (2020)	Study 1: 62 participants; Study 2: 1 932 participants in Brazil	Two studies (one experiment and one online survey) explored the efficacy of the nutrition warning scheme (the Chilean labels), GDA and TL label. Study 1 consisted of a visual search to see how quickly participants identified whether a product had a high nutrient content. Study 2 assessed participants' ability to use the FOP schemes to identify the most healthful product in a set as well as high nutrient content. They also looked at the effect of FOPNL on perceived healthfulness.	Study 1: High nutrient content was quicker detected when products were labels with black octagon or black triangle warning schemes compared to GDA. Study 2: Identification of the most healthful product was more often done correctly when products featured the traffic-light system or warning labels compared to GDA. Perceived healthfulness of products featuring GDA was highest, intermediate for products with TL Label, and lowest for products featuring warning signs.
Egnell *et al.* (2020a)	1 088 participants in Switzerland	Consumer study assessing Swiss' preference and understanding of five FOP nutrition labels (HSR system, MTL, Nutri-Score, RIs and Warning symbol) and their effects on food choices. Participants were asked to make three purchase choices from three products of one category, and asked to rank the products regarding their healthiness.	All FOP nutrition labels improved the product ranking with the Nutri-Score leading to the largest improvement in correct health ranking followed by the MTL, while the comparative performance of the other FOP nutrition labels depended on the product type.
Egnell *et al.* (2020b)	12 391 participants in 12 European countries: Bulgaria, Denmark, France, Germany, Spain, UK, Belgium, Italy, Netherlands, Poland, Portugal, Switzerland)	Online survey in 2018-2019, for three food categories (pizza, cakes, breakfast cereals). Around 1 000 participants per country ranked three products with distinct nutritional quality profiles (lower, intermediate, higher nutritional quality). They did this once without FOP nutrition labels and once	FOP nutrition labels improved nutritional quality of food choices compared to no label. In the aggregated sample (across countries & food categories), Nutri-Score led to the highest improvement in nutritional quality of food choices, followed by MTL. Country analyses only found a positive effect of Nutri-Score in France.

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2020b) *(cont.)*		after being randomly allocated to one of five FOP nutrition labels. The food labels were the (1) HSR system, (2) MTL, (3) Nutri-Score, (4) RIs, and (5) Warning Symbols. Outcome variables were the within-subject change in (i) nutritional quality perception (food choices) and (ii) ability to rank the products by nutritional quality (objective understanding).	All FOP nutrition labels improved the number of correct answers compared to no label (objective understanding). There were large differences between labels: Nutri-Score led to highest percentage of improvements in the answers, followed by the number of correct MTL, HSR, and Warning symbols. Differences between FOP nutrition labels was much smaller for food choices than objective understanding.
Fialon *et al.* (2020)	1 032 participants in Italy	An online survey was conducted to compare food choices and understanding of five FOP nutrition labels: Nutri-Score, HSR, MTL, Warning label and RIs. Participants faced three food categories: pizzas, cakes and breakfast cereals. They first indicated which product they would likely purchase and ranked them according to their nutritional quality without any label. This was then repeated with of the five FOP nutrition labels on the pack.	Food choices did not change on the basis of the presence or absence of a FOP nutrition label. However, the ranking of products according to nutritional quality was influenced by the presence of a label: The Nutri-Score was associated with improvement in participants' ability to correctly rank products compared to the RIs. The effect of HSR was also significant, but smaller. The MTL and warning symbol did not improve ranking compared to RIs.
Franco-Arellano *et al.* (2020)	1 997 participants in Canada	Online survey to study the effect of four FOPNL options (1. control, 2. Warning label, 3. HSR, 4. TL labelling) in combination with nutrition claims on healthfulness perceptions and purchase intentions of more or less healthy beverages. Participants saw four different drinks which varied by healthfulness (two healthier, two less healthy). Within each healthfulness	<u>Healthfulness Perceptions:</u> Healthier drinks with HSR or TL label were correctly perceived as healthier compared to control irrespective of claims. Less healthy drinks displaying any FOPNL were perceived as less healthy compared to the control. Disease reduction claims increased healthfulness perceptions compared to the same drink without a claim. Nutrient

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Franco-Arellano *et al.* (2020) *(cont.)*		category (more/less healthy), they either saw one drink with/without a disease risk reduction claim, and one drink with/without a nutrient content claim.	claims did not have an effect on healthfulness perceptions.
Galan *et al.* (2020)	1 000 participants in Spain	The study assessed objective understanding by consumers of five types of FOP nutrition labels, i.e. HSR, MTL, Nutri-Score, RIs, and Warning symbol. Participants first ranked three sets of label-free products according to their nutritional quality, before ranking the same products again with one of the five types of FOP nutrition labels.	The Nutri-Score led to the best ranking of products in line with nutritional quality, followed by MTL, the Warning symbol, HSR and RIs.
Hagmann & Siegrist (2020)	1 313 consumers in Switzerland (online)	Consumers' ability to evaluate snack food healthiness with one of five FOP nutrition labels. Packages were presented with (1) the Nutrition Facts Table (usually on BOP), (2) the MTL, (3) the Nutri-Score, (4) the Nutri-Score on half of the products, or (5) no nutrition information (control). Participants' task was to select the healthier option in 105 pairwise comparisons of 15 salty snacks.	The Nutri-score led to most accurate healthfulness choices. This effect was reduced when only some products are labelled stressing the importance to have labels on all products. There was no difference between control and nutrition facts table condition in terms of healthy choices, thus confirming that some simpler information is useful. Familiarity with the label influences perceived usefulness and acceptance.
Nieto *et al.* (2020)	78 participants in Mexico	12 focus groups in which participants discussed their perceptions, use and comprehension of nutrition labelling. The specific labels were GDA, Nutrition Facts Table, and nutritional stamps. The latter was on the BOP, not the FOP. Additionally, claims on the FOP were included in the study. In the focus group	Participants did not acknowledge any positive effects from reading the current nutrition labels or reported they did not read them. On the other hand, participants acknowledged the importance of having clear information on foods to make healthy choices. Participants also identified some barriers related to

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Nieto *et al.* (2020) *(cont.)*		studies, participants discussed, in a semi-structured way aspects (mentioned above) related to labelling.	nutrition labels (GDA and Nutrition Facts Table), specifically complex language, the font size, information amount, and lack of trust. All these findings were irrespective of participants' socio-economic background.
Sundstrom *et al.* (2020)	1 026 participants, representative sample of the online adult US population	Survey-based experiment, using three treatment groups with alternative FOPNL of nutritional content to assess their effect on healthfulness perceptions. The treatment groups presented the information with different degrees of salience. Specifically: one label just gave nutrient information/serving, the second added whether the product was "high" or "low" in a specific nutrient, and the third added colours (traffic-light type) to the second label. The outcome measure was participants' assessment of the healthfulness of the food they were shown.	The study reports that most individuals changed their health rating according to the FOP nutrition labels. Results suggest that salience of nutrition information on FOP influences health perceptions only when people have nutrient-specific concerns that motivate them to attend to the provided information. This would suggest that FOP nutrition label formats should provide personally meaningful information. The authors suggest that labels that provide easily interpretable information on whether a particular key nutrient is low or high (e.g. green or red) fulfil this objective.
Santos *et al.* (2020)	357 participants in Portugal	An online questionnaire aimed to a) assess the preferences of consumers for different FOP nutrition labels and b) evaluate the impact of those FOP nutrition labels on the selection of food products according to perceived nutritional quality. Each choice scenario contained one out of four FOPNL systems (TL, %GDA, Nutri-Score or HSR) or a no-nutrition label control. Participants were also asked to select the healthiest food product from a set of three	The TL led to most correct choices of healthy foods, though its positive impact on food choices was not significantly larger than any of the other labels. The option "not able to decide" without additional information was more frequent for Nutri-Score than for any of the other FOP nutrition labels (in the absence of detailed BOP nutrition information). The average time required for giving a correct answer was lower for Nutri-Score than for any of the other FOPNL scheme. The Nutri-Score

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Santos *et al.* (2020) *(cont.)*		alternatives.	was better in terms of reducing differences between socio-demographic groups. The authors acknowledge the role of familiarity since TL and %GDA are known in Portugal.
Vandevijvere *et al.* (2020)	1 007 adult Belgian consumers	Online survey to assess objective understanding and perceptions of five FOP nutrition labels: HSR, MTL, Nutri-Score, GDA, and Warning Labels. Participants were randomized to see products with one of the FOP nutrition labels. They then had to 1) choose between products of the same categories; 2) rank products according to their nutritional qualities; 3) express their perceptions regarding the label to which they were exposed.	Food choices did not differ significantly between the different FOP nutrition labels. However, Nutri-Score performed best for ranking products according to nutritional quality.
Egnell *et al.* (2019c)	1 032 adult Dutch consumers	Online survey to compare HSR, MTL, Nutri-Score, RIs, and Warning Symbols regarding perception and understanding. Participants had to 1) choose between products of the same categories; 2) rank products according to their nutritional qualities; 3) express their perceptions regarding the label to which they were exposed.	No significant differences were observed across FOP nutrition labels in terms of effects on food choices. The MTL took long to understand compared to the Nutri-score and warning symbol. Objective understanding (ability to rank according to nutritional quality of the foods) was highest for the Nutri-Score compared to the RIs.
Egnell *et al.* (2019d)	1 000 German participants	Online survey assessing consumers' objective understanding of five FOP nutrition labels: HSR, MTL, Nutri-Score, RIs, and warning symbol. Participants ranked products according to nutritional quality first without, then with a FOP nutrition label.	Overall, the Nutri-Score led to the greatest increase in correct answers (objective understanding), followed by MTL, warning symbol, HSR, and RIs. There were some differences according to food category.

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Nieto *et al.* (2019)	7 159 adults (3 626 from the US and 3 533 from Mexico) from an online consumer panel	Participants to an online survey were shown five food labelling systems: (1) Nutrition Facts Table, (2) GDA, (3) MTL, (4) HSR, (5) Warning Label, and rated each label on understanding and, for Nutrition Facts Table and GDAs, also frequency of use.	In relation to the Nutrition Facts Table, the Warning Labels was better understood, whereas the MTL and HSR were understood less. Ethnicity did not change this relation. Compared to Latinos, Mexicans were more likely to report they understood the Warning Labels, HSR, and MTL than the Nutrition Facts Table. Compared to Latinos, Whites had a lower probability of reporting to understand the HSR and MTL. Participants used GDAs less often than Nutrition Facts Table (and this was especially the case for US Whites). Authors report some additional findings relating to ethnicity and gender effects.
Vargas-Meza *et al.* (2019a)	2 105 Mexican adults	Participants were randomly assigned to either GDA, MTL or Warning labels condition. They were asked to detect, among 3 products, the one with the lowest nutritional quality.	MTL and Warning Labels increased the likelihood to correctly identify the less healthy choices, and do so in less time. GDA led to the lowest objective understanding among the labels tested.
Zerbini *et al.* (2019)	32 Italian undergraduate students; half with normal weight, half with overweight	fMRI study testing FOP labels. In addition to some well-known FOP, it introduces the "body label", which is a stylised figure of a human body, of regular shape or with overweight. It uses a 2x4x2 factorial design: regular vs. light product; four labels (text, TL, star rating, and body label); and 2 groups of people (with normal weight vs. with overweight). Participants were exposed to the products and asked to (a) observe them and (b) indicate how much of it they would consume.	Based on their finding that the HSR led to strongest activity in the right lateral prefrontal cortex, possibly reflecting attentional load, they suggest that the HSR is less intuitive and more cognitively demanding compared to the other labels. This may be due to the counterintuitive rating: more stars reflecting less calories.

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Acton *et al.* (2018a)	675 respondents aged 16 and over in southwestern Ontario	The study consisted of two phases: 1) a between-group experiment examining the influence of various summary indicator labels (numeric rating, HSR, simplified TL) and 2) a question (administered after the experiment) examining participants' preferences between a summary indicator and a nutrient-specific FOP nutrition label.	None of the labels tested had a significant impact on beverage perceptions for products people already believe are healthy (i.e., unflavoured milk) or unhealthy (i.e., a regular soda). Both the star ratings and the simplified TL label led participants to more accurate perceptions of chocolate milk as a 'moderately healthy' beverage.
Machín *et al.* (2018b)	Overall: 1 228 Uruguayan Facebook users Study 1: 216 Uruguayan Facebook users Study 2: 1 003 Uruguayan Facebook users	Two online experimental studies testing the effect of providing information about low nutrient content using TL system or warnings on perceptions of healthfulness of high-nutrition content (sugar, fat, sodium) food products. Study 1 tested four different FOPNL options: Three TL systems indicating (1) a different number of green nutrients; (2) high content of one nutrient (in red) + the word "High" & low content of one nutrient (green code + the word "Low"); (3) high content of one nutrient (red code + "High") & low content of two nutrients (green code + "Low"); (4) warning symbol highlighting high content of one nutrient. Study 2 tested three FOP nutrition labels included on pictures of food products containing one high nutrient content: TL with high content of one + low content of two nutrients, a simplified version only showing high content of one nutrient, or nutritional warnings highlighting one nutrient.	Study 1: Healthfulness perceptions increased when information about low content of another nutrient (instead of only high nutrient content information) was provided. Healthiness perceptions increased more when information about low content of two nutrients was provided. Nutritional warnings had no differential effect compared to TL system including only information about a high nutrient content. Study 2: Highest healthfulness was perceived for products with a TL system indicating high content of 1 nutrient and low content of 2 nutrients. The simplified version differed from the warning only for yogurt, where the latter decreased perceived healthfulness.

Table 15 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Prevost *et al.* (2018)	50 participants in France	fMRI study to test the neural correlates of evaluating food healthiness according to GDA and the TL labels. GDA and TL labels were simplified in that, per nutrient, GDA was represented by circles with numeric information and TL by colourful circles.	Healthiness evaluations were faster on the basis of TL information than GDA (numeric) information, and if less information had to be combined rather than more. Interestingly, brain regions involved in arithmetic were more active when processing both TL and GDA labels if more than one piece of information was presented. This suggests that integrating several pieces of information requires some complex, likely analytical processing.
Machín *et al.* (2016)	Five focus groups, each consisting of 5-10 mothers of young children who were the beneficiaries of food stamps (n = 42) in Uruguay.	Discussions focused on food choices for their children and the perception of FOPNL systems.	GDA label and the Chilean Warning System were found confusing and participants indicated that information was lacking. They preferred the TL system, which they found easy to understand. Ideally, they would like the TL system combined with a traditional nutritional table.

BOP, Back-Of-Pack; fMRI, Functional Magnetic Resonance Imaging; FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; SENS, Système d'Etiquetage Nutritionnel Simplifié; TL, Traffic Light(s).

3.4.3 Conclusions regarding consumers' understanding of FOP nutrition labels

Based on the literature reviewed up to 2018, the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) highlighted that:

I. Evaluative (interpretative) FOP schemes help consumers gauge the nutritional value of products better than reductive schemes.

II. Short, simple labels achieve the best objective understanding.

III. The majority of laboratory and field studies suggest that evaluative schemes that use colour coding with or without a graded indicator help consumers to identify nutritious products, although there are indications that consumers can get confused when they have to integrate a mix of greens, ambers, and reds on the same label.

IV. The TL scheme and the Nutri-Score generally seem to lead to a high level of understanding and this is probably because the colour coding and grading reduce the complexity of decision-making.

V. Three studies were reported in 2018 on the effect of reference quantities (Gregori *et al.*, 2014; Raats *et al.*, 2015; Vanderlee *et al.*, 2012), and it was concluded that FOP schemes providing nutrition information 'per 100 g' seem to achieve better objective understanding than FOP schemes based on portions. However, the impact of the reference was suggested to depend on the task to be completed.

With the literature reviewed for this update, most conclusions above remain unchallenged. Additional insights can be added to V., i.e. the effect of reference quantities of consumer understanding. The reviewed studies indicate that salient, consistent and simple reference quantities are preferred and that consumers generally understand nutritional information better when it requires less "mental math" to process the information.

3.5 Effects of FOPNL on purchasing

The model by Crockett *et al.* (2018) posits that purchasing changes at the individual level are one of the key mechanisms by which FOPNL could influence diets. The authors posit that labels act on diet at the individual level – through changes in awareness and knowledge that may be affecting purchase – as well as at the industry level, through reformulation. In addition, the impact of FOPNL on food choices is also influenced by the cultural, social, physical and individual contexts in which the purchase takes place.

Scientific studies that test whether FOP nutrition labels have a real-life impact on consumers' choices are somewhat rare, and mainly comprise studies with real incentives conducted on the field or pre-/post- studies of the implementation of a FOP nutrition label regulation. Most studies testing whether FOP nutrition labels have any impact on consumers' food purchasing decisions entail surveys or experiments, looking at the intention to purchase – as opposed to actual purchases - in response to FOP nutrition labels. Studies looking at actual shopping behaviour in real situations are difficult to implement, and therefore rare.

Section 3.5 is divided into three subsections, one giving account of the evidence of FOPNL on purchasing behaviour coming from experimental studies (section 3.5.1), one reviewing non-experimental empirical studies (section 3.5.2), and one on the potential impact of FOPNL on shopping costs (section 3.5.3).[3] Regarding experimental studies on purchasing behaviour, 46 new articles were identified. In addition, 12 new articles presenting non-experimental empirical studies on purchasing behaviour were identified. Finally, four new studies were identified regarding the potential effect of FOP nutrition labels on shopping costs.

3.5.1 Effects of FOPNL on purchasing – experimental studies

The advantage of laboratory experiments is that the artificial environment, the *ad hoc* selection of the products under analysis, the randomisation of subjects, and the matching of experiment conditions/participants characteristics across experiment arms make it possible to control for confounding

[3] In short, a study is said to be empirical when it is based on observations of given phenomenon, in our case consumer behaviour. Such observation may be experimental or not. An experimental study is characterised by the manipulation of an independent variable (e.g., the presence or the absence of a FOP nutritional label) and the observation of the effects of a dependent variable (e.g., the relative healthiness of the product(s) being purchased). We include articles based on non-experimental empirical studies in 3.5.2.

factors that may influence the choice, allowing for establishing effect sizes that are not confounded. The use of a laboratory setting also has the advantage of being easily replicable and highly standardised.

Notwithstanding these positive features, lab studies often examine the intention to purchase rather than actual purchasing behaviour, thus focusing on a hypothetical choice that has limited external validity. For instance, out of the 46 papers included in this section, only three laboratory experiments include incentivised outcome measures that are not hypothetical (Crosetto et al., 2020; Defago et al., 2020; VanEpps et al., 2016). Other aspects limiting the external validity of some lab studies is that they often compare two consecutive purchase decisions, taken within a short time span and that participants are aware that their behaviour is being observed. This can lead them to behave differently than they would in real life (cf. Hawthorne effect).

The tested experimental conditions vary widely in the reviewed set of studies (e.g., with respect to type of label being tested, serving size, type of control treatment, duration, specific contextual setting, country, population cohort, number of groups in the experimental protocol, food item category, type of outcome). The studies also vary in terms of methodology, some adopting a between-subjects design (i.e., each person is only exposed to a single condition, and comparison across subjects are drawn) (Fisher, 2018; Morley et al., 2013) while others follow a within-subjects study design (i.e., where each user is exposed to two or more conditions) (Hartley et al., 2018) or even cross-over designs (Shin et al., 2020). Finally, the papers included in this section focus primarily on purchase behaviour (e.g., food choice, nutrient profile of shopping basket) but we have also included papers assessing the impact on perceived healthfulness - even if this differs from mere purchase - when the choice context replicated a shopping behaviour.

A number of different insights can be drawn from the available experimental evidence (see Table 16). First of all, the overall results seem to show a small positive impact of FOPNL on purchases. Of the 46 papers included, only 4 show either no impact of FOPNL (Finkelstein *et al.*, 2020) or a positive but non-significant trend (Hamlin & McNeill, 2018; Lima *et al.*, 2019a; Velasco Vizcaíno & Velasco, 2019). In the first case, the FOP nutrition label explored was not a commonly used one, but a "Lower Calorie" label (Finkelstein *et al.*, 2020). Interestingly, in the paper by Lima *et al.* (2019a), FOPNL (both Warning Labels and TL) only made a difference in choice when participants had not tasted any products yet (encouraging choice of lower sugar concentration packages); the presence of FOPNL on the previously tasted products was rendered not important. A similar effect was observed in the study by Vizcaino and colleagues (2019), where the presence of FOPNL (TL) on products from familiar brands did not affect purchase. The effect of FOPNL was only observed in the presence of unfamiliar brands. Finally, Hamlin & McNeill (2018) found a weak and borderline significant effect of FOPNL (HSR) on choice in a study replicated in 13 stores in 2 different locations in New Zealand. They also found a weak positive impact on consumer preference, both in terms of higher preference for 5-star rated muesli and of lower preference for 2-star rated ones, compared to no FOPNL.

Following up on the findings reported in section 3.2.2, the experimental evidence mostly suggests that colour-coded FOPNL schemes (e.g. MTL, Nutri-Score, coloured HSR) serve consumers better than monochrome labels in making healthier food purchases (e.g., Muller & Ruffieux, 2020; Pettigrew et al., 2021; Rramani et al., 2020). Similarly, simple FOP nutrition labels – e.g., summary and hybrid labels (e.g., Gustafson & Prate, 2019; Medina-Molina & Pérez-González, 2021)– are more effective than nutrient-specific labels. Some evidence

suggests that "a simple aggregated coloured sign is welcomed for fast, simple and clear choices" (Muller & Ruffieux, 2020, p. 13). Muller & Ruffieux (2020) posit that non-directive FOPNL elicits different processes and behavioural responses compared with directive FOPNL. Non-directive schemes appeal to consumers that do not mind doing some mental math, whereas directive FOP schemes mostly appeal to those consumers who prefer to merely comply or not with the info provided (i.e. presence of an endorsement scheme or the best grade in graded indicators).

Besides objective and label-specific peculiarities, though, the available evidence suggests that there are a number of contextual features that might impact the effectiveness of FOP nutrition labels. Time pressure for example plays a role. An online experiment (Blitstein *et al.*, 2020) showed that when provided with simple FOP nutrition labels (summary star label and nutrient-specific star label), these labels were more effective than colour-coded nutrient-specific FOPNL. However, time pressure decreased healthy choices compared to shopping in the absence of a time limit (with the same, simple FOP nutrition labels), and reduced the healthfulness of the shopping basket to levels achieved with the colour-coded nutrient-specific label (Blitstein *et al.*, 2020). Time pressure did not affect participants exposed to the colour-coded nutrient specific FOP nutrition label.

Consumers' individual characteristics also help explain the impact of FOP nutrition labels on purchases. Although sodium warnings had a significant effect on participants' choices, this impact was moderated by time orientation (lower when participants express a myopic attitude, i.e. when participants show to care less about the future consequences of their current diet) and risk perception (lower when participants think this risk could be compensated) (Rojas-Rivas *et al.*, 2020). There are also differences when it comes to assessing the impact of income and education (Jáuregui et al., 2020; Sánchez-García et al., 2019) with low income and education groups tending to benefit less from all labels tested (i.e., GDA, MTL and Warning Labels). The same applies to health literacy and motivation, and health conditions – a finding aligned with the evidence presented in previous sections – with FOP nutrition labels being more effective for people without obesity, more effective for people featuring greater health motivation, whereas health literacy per se does not influence the successful use of FOPNL (Ares *et al.*, 2018a; Mansfield *et al.*, 2020; Thiene *et al.*, 2018; Vanderlee *et al.*, 2021).

A further interesting insight comes from experimental studies that, despite being web-based, try to approximate a real-life context. Such studies point to other factors limiting any FOPNL effect on purchasing decisions. For example, when consumers' trust in the brand is undermined, FOP nutrition labels no longer exert a positive effect on their preferences (Schneider & Pocheptsova Ghosh, 2020; Velasco Vizcaíno & Velasco, 2019).

In terms of relative effectiveness of different FOP nutrition labels, another large online experimental study (Egnell *et al.*, 2019a) found higher nutritional quality for shopping baskets purchased when being exposed to Nutri-Score compared to the RIs label, but no significant changes of the Nutri-Score group compared to the control group. On the other hand, Poquet *et al.* (2019) showed an increase in the nutritional quality of the snacks chosen when Nutri-Score was used compared to a no-label condition.

Overall, the results show that different FOP nutrition labels have different effects on choice goals. No specific label performed better at increasing the choice of healthy products, though in a few studies there was an observed effect for TL (in 2 out of 8 studies using TL), Nutri-Score (in 2 out of 9 studies) and HSR (in 1 out of 8 studies). In the majority of studies, FOP nutrition labels (i.e. TL/MTL, HSR and Nutri-Score) had a better aggregate effect compared to the control group (i.e. improved overall nutrition quality of food baskets, or a combined effect of increasing the choice for healthy products and decreasing that for the unhealthy ones). Overall, RIs/GDA also work in the same direction (i.e. to increase overall healthiness) when compared to no label condition but to a lesser degree of magnitude. The clearest pattern was observed for the Warning Labels, that - aligned with their intent –decreased the consumption of unhealthy products (in 14 out of the 18 studies that used Warning Labels; the other 4 improved the overall healthiness) (e.g, Ang et al., 2019; de Alcantara et al., 2020; Hamlin & Hamlin, 2020; Machín et al., 2019; Mantzari et al., 2018; Moran & Roberto, 2018).

Regarding the impact on portions, recent experimental evidence has broadened the scope of research and has shown that the impact of FOP nutrition labels on portion selection depends on the taste of the products. Some authors have highlighted how experimental studies conducted without product tasting may over-estimate the influence of FOP nutrition labels on purchasing behaviour (Antúnez *et al.*, 2020; Lima *et al.*, 2019a).

Other studies suggest that the impact on purchasing behaviour is not homogeneous across product types. For example, one study on the Nutri-Score (De Temmerman *et al.*, 2021) shows higher purchase intentions for products with a positive score (A and B) whereas no difference in purchase intentions was observed for products with a negative score (D and E) when the Nutri-score was present. In the same line, Billich *et al.* (2018) showed that in the presence of HSR, a higher percentage of consumers chose SSBs with a better profile (i.e., more stars) compared to a no-label condition. Kunz and colleagues (2020) found a similar pattern for desserts in an experimental study. Namely, participants were more willing to purchase products low in sugar but did not report lower purchase intentions for products high in sugar. On the other hand, another experimental study (Franco-Arellano *et al.*, 2020) focussing on juice-type drinks showed an effect of FOPNL on purchase intentions of less healthy products but not of healthier ones. The intention to buy less healthy drinks was reduced by all FOP symbols compared to the control, and across the various FOPNL systems, HSR resulted in the most negative purchase intentions. In addition, no significant increase in purchase intentions was observed for healthier drinks.

On this aspect, too, we found diverging evidence, with some research instead showing that consumers also use FOPNL to avoid less healthy foods (Crosetto *et al.*, 2020; Vanderlee *et al.*, 2021). This variation in the impact of FOPNL on purchasing due to the nutritional quality of the products or product categories (hedonic vs. healthy/utilitarian products) is further evidenced by two studies (Tórtora *et al.*, 2019; Uribe *et al.*, 2020). In the study by Tórtora *et al.* (2019), a difference was observed across product categories: participants preferred hedonic cookies (i.e. chocolate chip) over those with a healthiness connotation (i.e. granola ones) but preferred the healthier (i.e. whole wheat) crackers over the hedonic choice, i.e. the plain ones. This likely indicates that the type of products (hedonic vs. utilitarian) came before the FOPNL effect on selection. Furthermore, Uribe *et al.* (2020) reported that the effect of the FOPNL (Warning Labels) was immediate and negative on purchase

intention of utilitarian food, but the same was not evident on hedonic products. In fact, hedonic foods only saw an actual decrease in purchase intention when having at least 3 Warning Labels.

When it comes to interpreting the results of an experimental study, one should be cautious as, by design, specific experimental features may contribute to determine the observed evidence. For example, Acton and colleagues (2019) showed that when products were selected to be consumed in one sitting, Nutri-Score performed less well compared to other directive FOP nutrition labels (i.e. a 'High in…' label and MTL), possibly because the study at stake focussed on nutrient-specific outcomes (e.g., reduction of sodium) rather than overall nutritional quality. Moreover, care should be taken when comparing the performance of alternative FOPNL systems, as in countries where labels are already in use, their relative performance with respect to other labels is observed to be larger, i.e. Nutri-Score in France and Belgium, or MTL in the UK (De Temmerman *et al.*, 2021; Talati *et al.*, 2019a). Finally, it is difficult to derive the potential and limits of FOP nutrition labels in influencing purchase decisions from experimental studies, as most participants seem to substitute a product within the same category (Ares et al., 2018b; Finkelstein et al., 2020; Tórtora et al., 2019).

Overall, the majority of the experimental studies reviewed in this update suggests that, FOPNL seems to have a small positive impact on purchase. Colour-coded labels perform relatively better than monochrome labels, and summary or hybrid labels also perform relatively better than nutrient-specific labels. There were observable differences between FOP nutrition labels; most (TL/MTL, HSR and Nutri-Score, and RIs/GDA to a lesser extent) increased overall healthiness of purchases, whereas Warning Labels led to decreased purchase of unhealthy products. Despite the wide range of methodological approaches in experimental studies reviewed, and the differences in the possible exposures and groups evaluated, there is a general trend supporting a small positive impact of FOPNL on purchasing.

Table 16 Experimental studies of the impact of front-of-pack nutrition labelling schemes on food purchases and consumption

Study (most recent first)	Population	Intervention/Comparator	Outcome
De Temmerman *et al.* (2021)	Study 1: 292 Belgian adults Study 2: 415 Belgian adults	Two online studies that investigated the effect of the presence (vs. absence) and the effect of the five categories of the Nutri-Score on perceived healthiness of products as well as purchase intentions. Study 1 followed a 3 (meal Nutri-Score category: A, B, C) x 2 (Nutri-Score presence:	Respondents expressed higher intentions to purchase products with a positive Nutri-Score (A and B) than for products with a negative Nutri-Score (D and E), as well as for healthy products that feature the Nutri-Score rather than those without it. However, average intentions to purchase unhealthy

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
De Temmerman *et al.* (2021) *(cont.)*		present vs. absent) between-subject design. Study 2 followed a 2 (Nutri-Score between participants: present vs. absent) × 2 (brand between participants: manufacturer brand vs. private label) × 5 (Nutri-Score within participants: A, B, C, D, E) mixed design.	products were identical, whether the Nutri-Score was present or not.
Medina-Molina & Pérez-González (2021)	301 university students in Spain	Online survey to assess how the co-existence with nutrient-specific interpretative labelling impacts the effectiveness of the Nutri-Score in influencing purchase intention and healthfulness perception. Two products (one graded B, and one D on the Nutri-Score) in the same product category were presented with a) no label, 2) a nutrient-specific interpretative label, 3) Nutri-Score, 4) both nutrient-specific and Nutri-Score.	When products were classified as B with Nutri-Score and only this FOPNL is present, no differences are found for perceived healthfulness, but only significant differences for purchase intention. However, when both types of labels are displayed in the products with B, significant differences are found for both outcomes. When products were classified as D in Nutri-Score, and only Nutri-Score is on label, significant reductions are found for both healthiness and purchase intention. However, when together with nutrient-specific interpretative labels, differences are not significant. The relationship between perceived healthfulness and purchase intention was not moderated by the various formats of interpretative labels nor by the presence of both types.
Pettigrew *et al.* (2021)	7 545 participants in seven countries (Australia, Canada, China, India, New Zealand, UK, USA)	In an online survey experiment, participants were exposed to several breakfast cereals with four variations of the HSR, resulting from a combination of 2 types of FOP: summary HSR vs. hybrid	The aggregated data showed that the simplified coloured version of the HSR demonstrated the strongest performance relative to the current monochrome hybrid version for both

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Pettigrew *et al.* (2021) *(cont.)*		HSR (summary and nutrient-specific information); and 2 types of colour condition: coloured (red/orange/green) vs. black & white) design. In each trial one product had no rating, one had 1.5 star, one had 3 stars and one had 4.5 stars. Participants indicated purchase intentions and rated the perceived healthfulness of the products.	understanding and purchase intentions across the whole sample. The coloured hybrid version also performed well. Across countries, and compared to the reference condition, there was an improvement in understanding for the majority of the countries, when the products were labelled with at least one of the coloured versions. In contrast, it was the monochrome summary version that performed worse than the reference condition in Canada and coloured hybrid scheme performed worse than the reference condition in China. As for the purchase intention, fewer country-level differences were evident. For the UK all three FOP nutrition labels outperformed the reference condition. For the USA and Australia, only the colour simplified version showed an improvement compared to the reference.
Vanderlee *et al.* (2021)	1 997 Canadian adults	An online experimental study comparing the impact of three different conditions (HSR, TL label and 'high in' warning label, with respect to the no label condition) in two sequential tasks (rating healthiness, purchase intentions, and healthiness ranking of products), after a brief educational session.	All three FOPNL systems helped consumers identify healthier and less healthy products compared to the control condition. Overall, consumers may be more likely to use FOPNL to avoid less healthy foods, rather than to pick healthy items. More specifically, purchase intentions dropped when TL label had at least two red lights or two fewer stars in the HSR.
Antúnez *et al.* (2020)	171 participants recruited in Montevideo	Lab in the field study, examining the effect of sodium warnings, divided in	Although the subjects clearly expressed a preference (58% vs. 42%)

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Antúnez *et al.* (2020) *(cont.)*	(Uruguay).	four tasks: a preference expression over two differently salted bread (one with 1.38% salt, and one with 2%): package observation and rating, tasting and revealed intention to re-purchase the product after tasting.	for the saltier bread (2% instead of 1.38% salt), the presence of sodium warnings encouraged the majority of consumers to select breads with low sodium content.
Blitstein *et al.* (2020)	1 452 parents in the USA, at or below 150% of the poverty level, with at least one child aged 4-12 y.	Online 4x2 experimental design to assess how FOP nutrition labels influence food choices among low-income parents. Participants shopped with either no FOPNL or one of three FOP nutrition labels: summary (star rating), nutrient-specific (TL), hybrid (energy per serving + stars for each nutrient in excess) on the products. They either shopped under time pressure (10 minutes time constraint) or not (no limit). The summary nutrient profile of the shopping basket was assessed using Healthy Purchase Index, based on the FSA score.	All FOP nutrition labels led to healthier shopping baskets compared to the control condition. Simple FOP nutrition labels – the summary and hybrid labels – were more effective than the colour-coded nutrient-specific label. When provided with simple FOP nutrition labels, time pressure decreased healthy choices compared to shopping in the absence of a time limit (with the same, simple FOP nutrition label), and reduced healthfulness of the shopping basket to levels achieved with the nutrient-specific label. Time pressure did not affect parents exposed to colour-coded nutrient-specific FOP nutrition label.
Crosetto *et al.* (2020)	691 participants in France	An incentivised experiment tested the effectiveness of five FOPNL schemes (MTL; RIs; HSR; Nutri-Score, SENS) and control. Participants were told to shop enough to last 2 days and shopped twice. They made their choices without any label first (benchmark), and then continued with one of the five labels.	All five labels improved nutritional quality (measured by FSA score) with the Nutri-Score being the most effective followed by HSR. Total expenditure stayed the same for most label conditions, however it decreased for HSR and MTL. Therefore, HSR and MTL both increased the nutrition quality of the basket and decreased total expenditure on the basket.

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
De Alcantara *et al.* (2020)	1 232 adults (18-65 years old) in Brazil	Online choice experiment in which participants viewed six series of three packages of products and were asked to indicate which one they would buy. Between subjects, the presence of either no further information, health logos, or nutritional warnings on the products were manipulated. They also completed a word association task measuring the potential impact on these different FOP nutrition labels on their cognitive and affective responses towards the word "sugar".	Labels with information about sugar content made consumers more likely to choose the healthier product. Nutritional warnings were more effective compared to health logos. The inclusion of a health logo increased the percentage of participants who chose products with less sugar content in 4 out of 6 categories.The word association task suggested that this pattern may be due to warnings increasing the salience of the negative effects of sugar.
Defago *et al.* (2020) *(cont.)*	100 students aged between 16 and 26, recruited at a University campus in Lima.	Choice experiment (with and without MTL) conducted in a classroom after the administration of a short survey. As a "compensation" for answering the survey, students were given a snack and a beverage. Before starting the experiment, participants were randomly assigned to a control group and or treatment group. The offer consisted of three options of crackers and three of beverages, and participants had to select one of each. Only the treatment group saw the MTL labels on the products.	The presence of the MTL significantly improved the quality of choices for the treatment group: compared to the control group, the probability of choosing healthy products increased. Participants in the treatment arm tended to avoid harmful choices and seek the healthier alternatives. This result was largely driven by female students, and is particularly strong for respondents with above average dietary habits and for respondents with lower nutritional knowledge. Results also differed by the product category. For beverages it was evident that MTL reduced the probability of choosing the least healthy and increased the probability of choosing the healthiest item. For the crackers, no statistically significant results were observed (though the magnitude points in the same direction).

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2020a)	1 088 Swiss adults	Consumer study assessing Swiss consumers' preference and understanding of five FOP nutrition labels: HSR, MTL, Nutri-Score, RIs and Warning symbol, and their effects on food choices. Participants were asked to make three purchase choices from three products of one category and to rank the products regarding their healthiness.	More than half of the participants did not change their purchase decisions after viewing the FOP, but those who did significantly improved their food choices upon viewing the FOP, with the Nutri-Score leading to the greatest improvement, and RIs and the Warning symbol leading to the smallest improvement. All FOP nutrition labels also improved the product ranking, with the Nutri-Score leading to the largest improvement followed by the MTL, while the comparative performance of the other FOP nutrition labels depended on the product type.
Finkelstein *et al.* (2020) *(cont.)*	146 participants in Singapore	Experiment to assess the effect of calorie-labelling within or across categories on food purchases. Using an online supermarket platform, participants either saw either a) no label on products, or b) a "lower calorie" label (a logo designed by the researchers) on the 20% of the products with lowest calories within their categories. Their purchase behaviour was monitored.	Participants bought significantly more labelled products compared to the control condition only in the within-category labelled condition. For beverages only, across-category labels resulted in more purchases of labelled products compared to the control. Neither strategy resulted in reductions in calories purchased, but for beverages. For beverages only, total calories purchased were lower in both labelled conditions compared to the control and more so in the cross-category compared to the within category condition. Dollars spent, calories per dollar spent, total calories consumed and calories per serving were not affected by labels.

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Franco-Arellano *et al.* (2020)	1 997 participants in Canada	Online experimental study to investigate the effect of four FOPNL options (1. control, 2. warning label, 3. HSR, 4. TL labelling) in combination with nutrition claims on healthfulness perceptions and purchase intentions of more or less healthy beverages. Participants saw four different drinks which varied by their relative healthfulness (two healthier, two less healthy). Within each healthfulness category (more/less healthy), participants either saw one drink with/without a disease risk reduction claim, and one drink with/without a nutrient content claim.	The intention to buy less healthy drinks was reduced by all FOP symbols compared to the control, with HSR resulting in the most negative purchase intentions. There was no significant increase in purchase intentions for healthier drinks, though there was a trend. No claim had any effect on purchase intentions.
Hamlin & Hamlin (2020)	240 New Zealand adolescents aged 16-18 years	Discrete choice between-subjects experiment aimed at measuring the impact of FOP nutrition labels on participants' choice of breakfast cereal products. Participants were randomly allocated to 3 conditions: a) an octagon with "STOP High Sugar" (similar to a warning label); b) HSR with 1 star (low nutritional quality); c) no FOP.	The inclusion of the visual clue "STOP: High Sugar" significantly reduced intention to purchase a range of breakfast cereal that carried the label, compared to the control condition. On the other hand, no significant difference was observed between HSR and the control condition.
Jauregui *et al.* (2020)	2 194 middle-income Mexican adults	In an online simulated shopping context, participants were allocated to one of three labelling conditions: GDA, MTL and red Warning Labels. Primary outcomes were the overall nutritional quality, the mean energy and the nutrient content of purchases.	The interpretative labels such as MTL and Warning Labels outperformed GDA in terms of the overall quality of the shopping cart, and also required lower shopping times. Low-income/education groups performed less well in all labelling conditions.
Kunz *et al.* (2020)	173 adults in Austria	This online study used pictures of unknown desserts (i.e., not available in the Austrian market – e.g., puddings, rice puddings, flans, mousses, etc.) These were of	When TL labels were used, participants reported slightly higher purchase intentions for products low in sugar (compared to no TL label), though they did not

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Kunz *et al.* (2020) *(cont.)*		varying sugar levels (low, medium, and high) and included the presence (vs. the absence) of FOP nutrition label (in this case, the TL), to estimate the impact on tastiness expectations (as one potential drive of purchase intentions) and purchase intentions.	elicit reduced purchase intentions for higher sugar products.
Mansfield *et al.* (2020)	625 consumers of varying health literacy levels, in Canada	Consumers completed six shopping tasks while wearing eye-tracking equipment in a retail food lab. Their product selection and response time to make food choices were measured. Participants either saw products with a) no labelling (control) or one of the four 'high in' FOP nutrition labels: (b) magnifying glass, c) exclamation point, d) black 'high in', or e) red 'high in'.	All tested FOP warning labels were equally effective and helped consumers in identifying foods high in "nutrients of concern" more effectively and led to healthier choices than current (no FOP) labelling. The FOP nutrition labels were effective for people of varying health literacy.
McCrickerd *et al.* (2020)	Study 1: 116 participants; Study 2, 48 participants; Study 3, 94 participants in Singapore	Three studies explored whether sensory characteristics influence label-generated biases (halo effect, lower calorie estimations per portion, even for labels that did not refer to the product's calorie content; and larger portion selection, possibly prompted by perceived lower calorie content). In Study 1, five different FOP (health or nutrient related) were tested in two products, soy milk and instant noodles: a) organic, and b) Healthier Choice Symbol – for both. And then c) reduced sugar, d) +probiotics, e) +Neotame – for the soy milk. And c) no monosodium glutamate, d) +omega-3, and e) +BVO for the instant noodles. Participants indicated their	Participants were consistently willing to pay more for products with an added label (compared to no label) in each product category. In addition, participants consistently estimated that products with "healthier choice" and "reduced sugar/ monosodium glutamate" have fewer calories than the control product. The same was seen for "organic" in the instant noodles but not in soymilk. As for portion selection, participants selected larger portions for "healthier choice" and "organic" products. The same was observed for "+probiotics" for soy milk, and "reduced MSG" for instant noodles. The impact of FOP

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
McCrickerd *et al.* (2020) *(cont.)*		willingness to pay for the product, estimated calories, and how much they would consume of the product.	nutrition labels on portion selections depends on the taste of the products. Consumer portion selections made in the absence of product tasting are likely to over-estimate the influence of FOP nutrition labels on these behaviours.
Muller & Ruffieux (2020)	364 participants in France	Framed field experiment using a made-up e-shop offering 273 food products to measure the effect of directiveness, scope and gradation, set of reference, and sign of FOPNL systems (on food purchases. Participants were shown a catalogue of products and had the possibility to access product details as well as to compare a "reference basket" with their selected items. Participants were then randomly allocated to one of seven labelling conditions testing the effect of each characteristic on food purchases. The seven experiment conditions were as follows: 1- Non-Directive: RIs 2- Diet-Directive, within-category: three coloured signs – one per nutrient – comparing the product in the same food category 3- Diet-Directive, across-category: same as above but comparing the nutrient level in relation to all foods 4- Food-Directive, within-category: one coloured sign when food is healthy in relation to the same food category 5- Food-Directive, across category: same as above but	Food-Directive FOP nutrition labels (i.e., grading the whole food, as opposed to each nutrient) had a larger nutritional impact compared to Diet-Directive FOP nutrition labels (appraising the suitability of food as part of a daily diet). That is, when the product was graded as whole, it led to a greater change in purchasing choices than when its nutrients were graded separately. The non-directive reference intake system was better at improving purchase quality compared to the diet directing FOP nutrition labels (the RIs condition ranked 4th among the seven formats tested). Recommended and warning Food-Directive FOP nutrition labels led to greater basket change (and nutrition impact) compared to the reference basket (with an higher average Nutri-Score decrease when compared to conditions 4 and 5), but this meant not only more consumers significantly improving nutrition scores (33.9% vs. 18.1% participants decreasing by over -20%, p = 0.032), but also more consumers worsening the nutrition quality of their

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Muller & Ruffieux (2020) *(cont.)*		comparing to all foods 6- Food Directive, within category: same as condition 4 but including sign when food is not only Recommended for healthy but also Warned for unhealthy 7- Food-Directive, across category: same as condition 5 but including not only Recommended for healthy but Warned for unhealthy	baskets (23.2% vs. 12.6%, though not significant, p=0.65). There was no significant difference as to the impact of the average nutrition score for within vs. between-categories systems, but it generated contrasting behavioural differences (generating substitutions within-categories or across).
Rojas-Rivas *et al.* (2020)	498 Uruguayan adults	Online experimental study aimed at evaluating the impact of sodium warnings (warning labels) on bread choices.	Sodium warnings had a significant effect on participants' choices, with this impact being moderated by time orientation (lower when participants expressed a myopic attitude, i.e. when participants show to care less about the future consequences of their current diet) and risk perception (lower when participants thought this risk could be compensated).
Rramani *et al.* (2020)	50 participants in Germany	Eye-tracking study conducted in a lab in Germany to assess whether TL labels attract more attention than GDA labels. Additionally, they tested whether attention shifts more toward healthy foods as a consequence of TL labels compared to GDA, and more food choices are more influenced by attention to the label in the case of TL labels. Participants chose between a healthy and an unhealthy food product that were either both presented with GDA or with TL labels. In an earlier part, participants indicated self-reported liking, and after the choice task indicated their willingness to pay for each of the 100 products.	Participants showed a greater inclination to choose healthy when presented with TL labels compared to GDA labels. Additionally, the influence on TL labels on healthier food choices are suggested to operate via increasing the effect of attention to the label on choice.

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Schneider & Pocheptsova Ghosh (2020)	1 772 U.S adults Study 1: 161 Study 2: 143 Study 3a: 199 Study 3b: 402 Study 4: 302 Study 5: 160 Study 6: 405	Seven sequential online experimental studies using both between-and within-subjects designs. The study aimed at assessing the impact of a FOP nutrition label (Facts-Up Front that includes calories, grams of SFA, mg of sodium, and grams of sugar) on healthiness perception, preferences, and choice.	Prior beliefs about the perceived healthiness of a product or a brand determine FOP nutrition labels effects on consumer choices, regardless of whether the latter is measured in terms of Willingness-to-Pay, likelihood of purchase or choice. In particular, consumer trust increases when the FOP nutrition label is displayed on brands/ products perceived as healthy (i.e., for which consumers hold a prior belief that a product/brand is health) but not on brands/products perceived as unhealthy.
Shin *et al.* (2020)	125 adults residents of Singapore aged 21 and over, and primary grocery shopper for their households	Experiment to test the effect of DFLF compared to no label, allowing for consumers to choose from and toggle between any of seven FOP nutrition labels at the click of a button in an online grocery store website. The seven FOP nutrition labels included: a) Nutri-Score which was the default and also used to evaluate the effects of this experiment, b) calorie information as physical activity equivalents; c) calories per serving and percentage of DRI; d) sugar content per serving and %DRI; e) sodium content per serving and %DRI; f) SFA content per serving and %DRI; and g) total fat content per serving and %DRI. The DFLF also provided a live visual indicator of the healthiness of the shopper's basket. For each product a participant chose to buy, the healthiness of the product was evaluated by all seven	The DFLF improved overall nutritional quality (assessed by the average Nutri-Score) by 12.6% (on a range 1 to 5, the mean weighted Nutri-Score was 0.41 higher in the treatment, with respect to the control) and reduced the amount of sugar participants purchased.

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Shin *et al.* (2020) *(cont.)*		different food labels with the MTL colours.	
Uribe *et al.* (2020)	320 students in Chile	Study assessing the effect of the number of warning labels on a package (none to three) and product type (hedonic: e.g., ketchup vs. utilitarian: e.g., margarine) on healthiness perception and purchase intentions.	An increased number of warning labels decreased purchase intentions. That effect was evident for utilitarian foods with one or two warning labels, but not for the hedonic products. However, with three warning labels, the difference disappeared, and the effect was clear in both groups.
Acton *et al.* (2019)	3 584 Canadians aged 13 and older, recruited in shopping centres located in 3 Canadian cities	The subjects participated in an incentivised experimental marketplace study using a 5 (FOP nutrition label condition: no label; 'high in' nutrient symbol; MTL; HSR; Nutri-Score) x 8 (tax condition) between-within group experiment. Participants saw images of 20 beverages and 20 snack foods available for purchase.	Compared to the control (no label) condition, only the 'high in' nutrient symbol significantly reduced the amount of sugar, calories and fat of the purchased beverages. For the solid food purchases and when compared to no label, 'high in' and MTL had a significant reduction of sodium and calories, whereas the HSR only in calories. Similarly, those assigned for the MTL compared to the Nutri-Score purchased less sodium and fewer calories. Other testing conditions did not reach statistical significance.
Ang *et al.* (2019)	512 participants in Singapore	RCT to test the effectiveness of two FOP warning labels in reducing purchases of products that are high in sugar. Participants shopped for products in an online grocery store, which showed either 1) no FOP nutrition label, 2) a graphical high-in-sugar labels (stop sign) or 3) a text-based warning label. Purchases were hypothetical.	The text warning message reduced would-be purchases of products high in sugar by about 4%. The graphical label resulted in a non-significant decrease in unhealthy purchases.

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2019a)	1 866 French students (aged 18-25)	A 3-arm RCT (in an experimental online supermarket with a large diversity of food products, 751 food items over 20 categories) to compare the effects of 3 different labelling practices (Nutri-Score, RIs, no label) on the overall nutritional quality of students' purchases.	The HCSP score was lower (corresponding to higher nutritional quality) in the Nutri-Score group than in the RIs group (mean difference = –0.67; P=.002), but the scores of the Nutri-Score group did not differ significantly from the no-label groups (–0.43; P =.07), nor did the RIs group (0.23; P = 0.5). The Nutri-Score group's shopping cart contained significantly higher amounts of fruit and vegetables than in the other two groups, and had a lower content of fat and SFA.
Finkelstein *et al.* (2019)	147 participants in Singapore	Online study to assess whether MTL and Nutri-Score (both not introduced in Singapore at the time of the study) affect diet quality of purchases compared to BOP nutrition information. Participants shopped online three times over the course of the study. Each shopping trip was preceded by a short video explaining both labels. The AHEI was calculated and the average Nutri-Score of the purchases.	Both labels (MTL and Nutri-Score) resulted in improved AHEI scores and average Nutri-Score compared to the BOP control condition. Both labels were effective in improving AHEI scores. Nutri-Score performed better than MTL when looking at average Nutri-Score, with significant improvements. Overall, MTL reduced purchased calories, fat and protein (and sugar, but just in beverages) compared to the control condition. For Nutri-Score the reduction was seen in SFA (significant in solid foods).
Gustafson & Prate (2019)	115 supermarket shoppers on a rural American Indian reservation (data collected in 2015 in Rosebud Indian Reservation)	Choice experiment to test generic and tailored healthy food FOP nutrition labels for a high-risk, rural, minority population. The study tested the effect of: a) a tailored label (developed by the researchers together with the community members - an	The generic label (smiley face) was effective in increasing the probability of choosing the healthier product. The tailored label was also effective for selecting the healthy product, but also decreased the likelihood of choosing

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Gustafson & Prate (2019) *(cont.)*		image of a bison with a "social" message ("produced by the community")); b) a control label – just the image of the bison (a symbol for health and strength in the community); and c) a generic label (a smiley face) on food choice (breakfast cereals) compared with d) no label.	the unhealthy item. The presence of labels in a choice set generally decreased the willingness to pay for the unhealthy items, but only the tailored label reached significance. The tailored label also increased willingness to pay for the healthier product.
Kinard (2019)	313 participants in the USA	Experimental study to assess the effect of FOPNL (one displaying the calories, g of SFA, ml of sodium, g of sugar) on consumer impressions and purchase intentions of an unhealthy snack (vanilla ice cream) using a 2 (manipulated message type: motivational "treat yourself" vs. informational "made with fresh milk & cream") × 2 (nutritional information: present vs. absent) between-subjects design. Purchase intentions, label and product evaluations were assessed.	Nutritional information on the front of pack moderated the effect of the motivational ("treat yourself") message in that positive effects of the messages on product evaluations were reduced by nutritional FOP information. Neither message type nor presence of FOPNL impacted label evaluations separately. Both product and label evaluations significantly and positively influenced purchase intentions.
Lima *et al.* (2019a)	800 participants (400 6–12-year-old children, 400 adults) in Brazil	The effect of two FOPNL designs (TL System, nutritional warnings) on product choices (drinks with low, medium, or high sugar levels) were assessed under three different conditions (within-subject): (a) blind-tasting the drink without any nutrition information, (b) looking at the package without tasting, and (c) both tasting and looking at the package.	When adults and children had to decide between packages featuring FOPNL schemes that highlighted high sugar content, they tended to select the product version with the largest sugar reduction in both product categories. Nutritional warnings were more effective than TL in this reduction for one beverage category (grape nectars), in adults. The presence of a FOPNL did not modify participants' choices when they had tasted the product. No significant differences between TL and Nutritional warnings, except for grape nectars for adult

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Lima *et al.* (2019a) *(cont.)*			consumers. Both TL and Nutritional warnings encouraged adults and children to select the package of the product with the lowest sugar concentration.
Machín *et al.* (2019)	199 participants of a convenience sample in Uruguay	Experiment on the influence of nutritional warning labels (present/absent) on consumers' choice of a snack. Additionally, the authors measured attention to warning labels with mobile eye-tracking.	The presence of nutritional warning labels decreased the number of participants who chose a product with excessive contents of at least one nutrient from 85% (control group) to 62%. The presence of warning labels – compared to a situation where they were not displayed - resulted in a relative reduction of 11.7% calories, 42.9% added sugars, 42.6% SFA and 50.2% in sodium content of the chosen products.
Poquet *et al.* (2019)	95 French mothers and children aged 7-11	Laboratory experiment in which participants (both mothers and children) were asked to choose a snack (two food items and a beverage), in two rounds (first without Nutri-Score and then with it).	The Nutri-Score led to a significant improvement of the nutritional quality of the selected snacks (for themselves, and for the other dyad member). However, it also brought about a reduction in liking for the choice made (hedonic cost).
Sánchez-García *et al.* (2019)	330 women in Ecuador (150 in median-high income; 180 in low-income)	Two focus groups and a quasi-experimental approach with a 3x2 design (with manipulation of two variables, TL (green, yellow, red) and income (high and low), to analyse the impact of TL on negative emotions.	TL colours significantly influence participants' levels of negative emotions (fear and guilt), as well as their intention to purchase. The influence of TL on consumers' purchase intention is asymmetrical; being stronger for red. Purchase intention is high for green (low fat and low sugar products), and it remains positive for yellow, dropping slightly. The dramatic reduction comes

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Sánchez-García *et al.* (2019) *(cont.)*			when red predominates. Income plays a moderating role: high-income groups are more responsive to green and yellow (i.e., relationship is linear between TL and emotions and purchase intention), and low-income ones to red (i.e., dramatic shift when red is present, whereas yellow remains similar to green, only slightly decreased). Therefore, the asymmetric effect seems to only occur for low-income people.
Talati *et al.* (2019a)	11 100 respondents from 12 countries (Argentina, Australia, Bulgaria, Canada, Denmark, France, Germany, Mexico, Singapore, Spain, the United Kingdom, and the United States)	Study to assess which of five FOP nutrition labels was most effective at guiding healthier food choices. Respondents saw (in a survey) three categories of food (pizza, cake, cereal) and three products with different levels of healthiness for each category. First, participants selected the product they would be most likely to purchase. Then, the same choice sets were presented with one of five randomly allocated FOP nutrition labels on the package (HSR, MTL, Nutri-Score, RIs, or Warning labels).	Improvements in the healthiness of products chosen occurred only for 12% of choice pairs and a deterioration occurred for 6%. The most effective labels were the Nutri-Score and the MTL, then the Warning Label, the HSR, and finally RIs. Results are significant only at aggregate level, not by country. Additionally, in countries where labels were already in use, their difference with other labels was greater (i.e. Nutri-Score in France, MTL in UK).
Tórtora *et al.* (2019)	124 participants in Uruguay	Choice-conjoint and eye-tracking study in which FOP nutrition information (nutritional warnings vs. Facts-Up-Front panel), nutrient claim (present vs. absent) and type of product (conveying health vs. hedonic associations) were manipulated. Included were 16 sets of pairs of labels, 8 pairs corresponding to labels of cookies and the other 8 to labels of crackers.	The choice of labels of cookies and crackers were significantly influenced by the three variables; type, FOP, and nutrient claim. Choice data showed that nutritional warnings discouraged the choice (compared to the Facts-Up-Front option) of a product. Nutritional claims, on the other hand, encouraged choice. There was a difference

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Tórtora *et al.* (2019) *(cont.)*			across categories; participants preferred the hedonic cookies (vs. those with health-associations), and the crackers with health-associations (vs. the hedonic choice). This highlighted that the effect of the type of products came before FOPNL effect on selection.
Velasco Vizcaino & Velasco (2019)	Study 1: 133 participants in Ecuador (experimental data) Study 2: 837 participants in Chile, online experiment Study 3: 181 participants in Ecuador, online study Study 4: 201 participants of Prolific, an online consumer panel, in the UK	The study relied on four independent but related experimental studies. They were designed sequentially, building on results from the previous one. At their most basic, the studies looked at whether the presence (vs. absence) of TL labels influenced consumer purchase intention of products. Studies 2-4 also manipulated brand familiarity, adding another dimension to the studies (i.e. familiar vs. non-familiar brand).	Main result, replicated in the studies that included the familiar vs. unfamiliar manipulation: when the brand was unfamiliar, TL labels led to less purchase intentions but when the brand was familiar, there was no effect of TL label (i.e., there is an interaction effect between FOPNL and brand familiarity). The study posits that when consumers evaluated a familiar brand, trust in that brand made them have positive evaluations of the product, even if there were warning signs in the form of TL label. On the other hand, when they evaluated an unfamiliar brand - and give less attention to the evaluation process - where TL labels were present, the food choice became less attractive. Their distrust made them look for additional cues.
Ares *et al.* (2018a)	395 consumers in Uruguay	Using a repeated purchase simulation, it was assessed whether and to what extent warning labels can influence food purchases. Participants were approached in a supermarket and completed two choice tasks with eight product categories. The eight categories of processed and	FOP warning labels resulted in modified choices in about half of the participants. Most often, participants substituted a product within the same category. If all products in the category included at least one warning, the most common effect was abandonment of

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2018a) *(cont.)*		ultra-processed products included were: canned green peas, cookies, salty crakers, chicken, nuggets, organge juice, toast bread, soda (cola) and strawberry yogurt.	the product. Generally stronger reactions to warnings came from consumers with greater health motivation.
Billich *et al.* (2018)	994 young adults in Australia (18-35 years old)	Study to investigate whether FOPNL with a graphic warning, text warning, sugar information (# of teaspoons) or HSR influenced choices of SSBs. Participants were divided into: Group A: no labels; Group B: graphic warning label – picture of decayed teeth + warning text; Group C: warning text (same message as above but no picture); Group D: sugar information label (with content); and Group E: HSR	The selection of an SSB was significantly reduced with all experiments; by graphic warnings, text warnings, sugar information and HSR labels compared to when participants were not exposed to a label. The biggest effect was found for graphic warning labels.
Fisher (2018)	87 students in the USA	Participants fasted for 4 hours prior to the study. They received 4 tasks with regard to 50 snacks (liking rating, bidding task (willingness-to-pay), subjective health rating, taste beliefs). After the liking task, participants either saw each snack with or without a nutrition label (displaying total calories, fat, SFA, sugar, sodium + daily recommended amount).	The nutrition label significantly lowered hungry participants' bids to foods by an average of 0.25 $. This effect only remained significant for high calorie foods. When calories were unknown to subjects, they tended to value the higher calorie options more highly.
Hamlin & McNeill (2018)	2 600 "New World" adult shoppers in New Zealand	2x2 factorial experimental design with 2 product treatment levels (on a cold ready to eat muesli): a) one product with high and one product with low nutritional values (5 and 2 stars respectively); b) two HSR FOP treatment levels (HSR reflecting the nutritional value of the item; and no HSR) on consumer choice. This format was replicated in 13 stores in 2 different locations.	A weak and general positive impact of both labels on consumer preference is observed, with no statistical significance. In addition, a tendency for, on average, an increased choice for those with the 5 stars and decreased for those with 2 stars compared to control – though not significant. There was no consistent effect of FOPNL in the replications.

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Hartley *et al.* (2018)	153 students in Australia	Lab study testing the effect of different PACE labels on consumption. Over two sessions in two consecutive weeks, participants rated their liking, familiarity, and prospective consumption of 20 different label/snack combination. Actual consumption was measured. Four labels were presented; no label, a fake label, PACE walking minutes, and PACE x2.	When the PACE label was present on familiar snack foods, their consumption decreased by 9.9% (in grams) and prospective consumption by 9.1% than when such label was not present. Such pattern was not seen in unfamiliar snacks.
Mantzari *et al.* (2018)	2 002 parents of 11–16-year-olds living in the UK, with a total household consumption of SSBs of at least 500 ml each week.	Online experiment in which participants had to select one drink from a virtual vending machine for their child. The SSB displayed an image warning or not following a between-subject factorial design: 3 (a) disease image-based warning label (rotting teeth), b) no image, c) picture of a teaspoon of sugar – sugar content) × 2 (calorie information label: absent, present). Participants were randomized into one of the six groups.	Compared to the control group (no image label, and no calorie information), the use of all image-based warning labels decreased the odds of selecting an SSB. No difference was observed when comparing just calorie information with the control group. The rotting teeth image label was superior at decreasing the odds of SSB selection compared to the sugar content image label.
Moran & Roberto (2018)	2 381 parents in the USA	Parents saw beverages without label, a calorie label, or a warning label. They then rated the caloric value, sugar content, health consequences (several items), and purchase intentions of different beverages for their child, and selected a beverage for their child in a choice task. Data were collected in 2015.	Warning labels significantly increased parents' risk perceptions for all beverages (except soda) compared to no label. Warning labels reduced the likelihood of choosing fruit drinks for the child. This effect was mediated by changes in health beliefs and risk perceptions. Calorie labels were less influential.
Thiene *et al.* (2018)	797 participants in Northern Ireland	Discrete Choice Experiment to test the influence of FOPNL formats on consumers' stated food choices. Total fat, SFA, salt, and sugar were the nutritional attributes used and presented in different	MTL and GDA induce more propensity towards healthier food baskets in respondents with self-reported obesity, compared to the baseline text only or integrated (combined) FOP

Table 16 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Thiene *et al.* (2018) *(cont.)*		quantities (levels). Four treatments of FOP nutrition label/text: 1) Baseline text: e.g. "saturated: high – sugar: low"; 2) Test + MTL for each nutrient, 3) Baseline text + GDS, or 4) Combination of TL colours and GDA percentages.	nutrition label format. The GDA label had the strongest effect on respondents with no obesity, and a similarly strong effect as the MTL for respondents with obesity.
VanEpps *et al.* (2016)	249 employees at a large health care company in the USA	Field experiment in which participants choose real food items from a lunch ordering website (once or several times), which they paid for and received. They assessed the total number of calories of ordered food after participants either received a) no nutritional information, b) number of calories only, c) TL calorie label, or d) a combination of number of calories and TL calorie label for each dish. Numeracy skills and BMI were taken into account.	Compared with the control condition, participants ordered fewer total calories when exposed to numeric calorie labels or to TL labels. The combined presence of numeric and TL label information reduced calories ordered compared with the control condition. However, there was no additional benefit of the second piece of information (adding TL or numeric calorie information).
Morley *et al.* (2013)	1 295 Victorian (Australia) adults aged 18-49	The study used a between-subjects experimental design to test five menu labelling conditions (no labelling, kilojoules, kilojoules and Daily Intake, kilojoules and TL, kilojoules and TL and Daily Intake).	The results indicate that the provision of kilojoule information, with and without TL labels, is associated with lower energy content of selected meals compared with no nutrition information.

AHEI, Alternate Healthy Eating Index; BOP, Back-Of-Pack; DFLF, dynamic label with real-time feedback; DRI, Daily Recommended Intake; FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; FSA, Food Standards Agency; GDA, Guideline Daily Amount(s); HCSP, Haut Conseil de la santé publique; HSR, Health Star Rating; MTL, Multiple Traffic Light(s); PACE, Physical Activity Calorie Equivalent; RCT, Randomised, Controlled Trial; RIs, Reference Intakes; SENS, Système d'Etiquetage Nutritionnel Simplifié; SFA, Saturated fat; SSB, Sugar-Sweetened Beverage; TL, Traffic Light(s).

3.5.2 Effects of FOPNL on purchasing – non-experimental empirical studies

This section gives account of studies conducted on purchasing in real shopping situations as well as studies reporting non-experimental data shedding light on purchasing behaviour.

As highlighted above, studies carried out in real shopping situations are more realistic, and potentially include a larger variety of products, thus presenting higher generalisability. However, the results may be affected by

confounding factors that are difficult to isolate – such as brands, habits, self-selection, price, and seasonality – or by design or methodological peculiarities to be taken into account when interpreting the findings.

For example, in a recent study (Ares *et al.*, 2021), the authors tested the impact of newly implemented nutritional warnings in Uruguay, by conducting a before-and-after study, and focussing on awareness, understanding, but also *self-reported* use. The study found that 58% of participants *stated* that they modified their purchase decisions after noticing the warnings on the products.

Self-reported evidence was also analysed in a study conducted in France, between 2018 and 2019 (Sarda *et al.*, 2020); in this study, almost 43% of the participants (especially among younger cohorts and frequent labelling readers) reported that they have modified their purchasing behaviour after the introduction of the Nutri-Score. Another study relying on self-reported behaviour was by Adasme-Berrios *et al.* (2020). However, these figures are likely to overestimate the real impact as we may give *socially desirable answers* when responding to surveys, and have the tendency to portray ourselves as the person the researcher would like to see, or as the person we would like to be (idealised-personal bias; Isham *et al.*, 2002). Therefore, direct observation is to be preferred. We found 8 studies using direct observation and real life data (Table 17). Of these, 5 studies find a positive impact of FOPNL on purchasing, 1 found no association, and 2 found a positive trend. This being said, even in studies based on direct observations, we may still find differences due to a number of factors (e.g., duration of the study, time span between first and last purchase, presence of the label on all products or on a subset of them, people's awareness of being studied). Dubois *et al.* (2021) estimated that the effect size of FOP nutrition labels on the nutrient profiling score of the shopping basket in real-life grocery shopping settings (natural experiment) was on average 17 times smaller than what was estimated in a comparable laboratory study by Crosetto *et al.* (2020) where data were also collected through an incentive-compatible methodology (framed natural experiment). However, despite the many similarities between these two studies, they didn't exactly replicate the same approach. For example, Dubois *et al.* (2021) study was limited to only 4 food categories (fresh prepared foods, pastries, bread and canned prepared meals), while Crosetto *et al.* (2020) included the full food basket, which may help explain the difference in magnitude.

Other limitations are mentioned regarding the findings of another large study (Taillie *et al.*, 2020c), adopting an observational approach. The authors tested the impact of a new Chilean Law of Food Labelling and Advertising on the purchase of SSBs, with respect to a counterfactual (i.e., the estimation of what would have been observed in post-regulation, based on pre-regulation trends). The observational nature of the study entailed researchers visiting the households over a two-year period, before and after the law was implemented. The study found that, after the law was implemented, household purchases of 'high-in' (as opposed to 'low-in') beverages decreased by almost 24%. One limitation, also mentioned in the study, is that any effect found in the study cannot be assigned to changes in FOP nutrition labels only, as the law also included other interventions (e.g., awareness campaigns, school sales bans, etc.). Therefore, the authors acknowledge that the overall finding of a reduction in SSBs by 23.7% cannot be attributed solely to the FOP nutrition label, as they were unable to disentangle the respective effect of each policy measure.

Regarding the impact of FOP nutrition labels on purchased nutrients of concerns, there is evidence coming from interrupted time series analysis (a quasi-experimental study based on over 20 000 UK households) suggesting that households responded to the introduction of labelling by reducing the total monthly calories, SFA, sugars, and sodium of store-brand labelled foods by 9–14% on average, relative to the mean (Fichera & von Hinke, 2020).

As was the case for the studies reviewed in the previous section, the impact of the FOPNL on purchasing behaviour is measured with respect to the healthfulness of specific food items chosen, or, in fewer studies of a larger food basket (Dubois *et al.*, 2021; Harrington *et al.*, 2019). Dubois *et al.* (2021) found that both Nutri-Score and Nutri-Couleurs led to statistically significant increases in purchases of high nutritional quality products . These results were mostly driven by the food category with the widest Food Standards Agency (FSA) scores across products. This gives an indication of another difficulty in these studies, when looking at food categories with a small variation of FSA scores across products, one cannot expect a wide variation of the impact of using FOPNL on food baskets measured by the same FSA scores.

The limited evidence on actual shopping behaviour from real-life supermarket studies and sales data analyses suggests that the impact of FOPNL on 'on-the-spot' purchasing seems to be smaller in magnitude compared with what is observed in experimental studies. As also described in the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a), a possible reason is that real-time purchasing decisions are influenced by a multitude of other factors (price, taste, habit, brand familiarity, FOPNL familiarity, time pressure, cognitive depletion, etc.) which may be difficult to isolate, making evidence on actual shopping behaviour difficult to obtain.

In one large real-life study, with four different types of labels affixed to food products in four food categories, Dubois and colleagues (2021) found that the Nutri-Score outperformed other FOP schemes and increased the purchases of healthier food items in all four categories (i.e., those in the top tercile, in Dubois' categorisation of food products) by 14%, but had no significant impact on the purchase of foods with medium, low or unlabelled nutritional quality.

One explanation of finding more limited effects on actual food choices is that food selection is driven by expected tastiness and that higher tastiness is negatively correlated with healthfulness for many consumers (Koenigstorfer *et al.*, 2014; Smed *et al.*, 2019), although not all studies support this conclusion (Wang *et al.*, 2016). Another possible explanation for the limited impact found of FOP nutrition labels on 'on-the-spot' purchasing, as mentioned above, is that purchases are influenced by a multitude of other factors (e.g., brand, price, taste, habit, discounts, cognitive depletion) which may be difficult to isolate. Logically FOP nutrition labels play a larger role in new rather than in routine purchases (Bartels et al., 2018).

In two recent real-life studies (Harrington *et al.*, 2019; Sandoval *et al.*, 2019), the authors observed no difference in the healthiness of purchased food items between participants in the intervention group and in the control group, for ready-made meals and pizzas, in the first study, and high-sugar carbonated soft drinks in the second study. In the case of Harrington *et al.* (2019), both intervention and control groups were exposed to the FOPNL (TL), but only differed in behavioural interventions designed to emphasize the effect of FOPNL. The null result might signal that further actions at the individual level might not provide additional benefit on

top of the one that FOPNL provides. On the other hand, while Sandoval *et al.* (2019) found no significant effect on the overall purchases of high-sugar carbonated soft drinks, there was a downward trend for the most recognized brand and the highest consumed in Ecuador. When comparing two groups (one self-reporting use of food labels, and one not using it), Ronnow (2020) did observe that FOPNL labels (the Keyhole and the Whole Grain label) are associated with an increased overall dietary quality (reduced intake of sugar and increased intake of fibre, though also an increase in fat), although the effect is small, and only marginally significant. The fact that these are endorsement logos might have to do with the fact that the results are small, as these logos only classify products as "best in the category" (especially the Keyhole), and therefore do not allow for any substitution behaviour or avoidance of unhealthy products. In fact, observing only significant effects on reduced sugar intake and increased of fibre show that the Whole Grain label might work well for the specific nutrients directly associated with it.

In another study by Smed *et al.* (2019) investigating an endorsement logo (the Dutch Healthy Choice label), the introduction of the label led to the overall increase purchase of products carrying the label (especially dairy products and sauces category). However the effect was minimal for fats and oils and for breakfast cereals. The authors suggest that food categories where the label does not make a difference is because they don't have much variation between healthy and non-healthy, or because the whole category is perceived as healthy by participants (such as breakfast cereals). Breakfast cereals being one of the most investigated categories due to simplicity, it could be that since it is perceived as healthy overall, the endorsement logos might not be enough to dissuade people from buying less healthy options. This might also explain other null results when investigating this food category. In fact, Zhu *et al.* (2019) found a positive impact of voluntary FOPNL in this category, with a more robust analysis. The study also found a strong negative spillover effect on non-participating products, highlight the potential asymmetric impact of voluntary FOPNL labels on purchases, as the presence of voluntary FOPNL labels in a subset of brands of a given category of products may encourage purchase of those brands and have a negative spillover effect on non-labelled but equally healthy products With this, the authors highlight another limitation of observational studies; ignoring labelling information spillovers in empirical analysis could lead to an under-estimation of consumer valuation of FOPNL label impacts on products carrying FOPNL, and an over-valuation of those products who don't.

The 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) gave account of several other factors that help explain the limited impact of FOPNL on actual purchasing behaviour. This includes people's dietary goals (Bialkova *et al.*, 2016; Machin *et al.*, 2017; Machín *et al.*, 2018c; van Herpen & van Trijp, 2011) or people's sensitiveness to health issues (Sonnenberg *et al.*, 2013; Thorndike *et al.*, 2014), concluding that FOPNL labels are effective in supporting consumers that are already health-conscious. The report also referred to the type of FOPNL scheme which may influence the effect on purchasing behaviour depending on the type of consumer. Evaluative and reductive labels may indeed require more or less effort or complex processing, with evaluative labels being easier to process and reductive labels more complex. The report also found that for optimal effectiveness, FOP nutrition labels should be combined with appropriate education and promotion campaigns (e.g., Graham *et al.*, 2017). Also, the type of food category plays a role, with a larger effect on healthier product categories measured by their average nutritional value score (Ni Mhurchu *et al.*,

2018; Nikolova & Inman, 2015). The evidence reviewed in this addendum confirms previous findings, in this respect.

The reviewed evidence from empirical studies expands the findings presented in the 2020 JRC report. The more recent studies on the effect of FOPNL on purchases show that a) the use of evaluative FOP schemes or warning labels has mostly promising results, albeit of weak or moderate effect, b) other factors such as age, sex, consumer's health-consciousness, prices, etc., may moderate this effect, and c) the effect varies depending on the healthfulness of the products bearing the scheme. However, a pattern seems to emerge when it comes to the impact of FOPNL on purchasing behaviour. Five of the 8 observational studies included show a positive impact of FOPNL on purchasing behaviour. This points in the same direction as the previous section. It is not yet possible to conclude with certainty that FOP nutrition labels have either a consistent or a sizeable impact on purchasing behaviour, but there seems to be a consistent pattern in different methodologies confirming the positive direction of the effect. In addition, no specific FOPNL scheme seems to *systematically* outperform all other schemes, but this was hard to evaluate in the few studies included.

Table 17 Non-experimental empirical studies of the impact of front-of-pack nutrition labelling schemes on actual food purchases based on real-life choice contexts

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2021)	Study 1: 855 participants; Study 2: 917 participants in Uruguay	Two online surveys were conducted before (May-June 2019) and during the first month (March 2020) of the implementation of nutritional warnings in Uruguay to assess awareness, self-reported use (for making purchase decisions) and understanding of nutrition information. Participants in Study 1 served as control and evaluated packages without warnings (baseline condition), and those in Study 2 evaluated the same packages but with warnings. Participants had to indicate which was the most healthful product from three series of three products included in the following categories: cookies, juice and yogurt.	As to purchases, 58% of participants who saw the warnings (67% of the total) stated that they modified their purchase decision after noticing the warnings on the product. 23% of the participants reported purchasing a similar product without warnings, whereas 17 % reported purchasing a similar product with fewer warnings (substitution in both cases). However, a category abandonment effect was also observed as 18% of the participants reported not having purchased any similar product.

Table 17 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2021) *(cont.)*		Participants were asked if they remembered seeing any warnings on the products they intended to buy, and if so they were asked to indicate what they had done (purchased it anyway, purchased a similar product with fewer excess signs, purchased a similar product with no excess signs, or didn't purchase the product at all).	
Dubois *et al.* (2021)	A-Experiment: From 26th of September to 4th of December 2016 40 randomly selected supermarkets (10 per labelling system)20 randomly chosen control supermarkets Data set: 1 668 301 purchases, 3586 products, and n = 171 827 consumers B-Shopper survey: 1 844 observations (1st wave – September, before the start of the experiment) and 1 737 observations (2nd wave– late November), in France	Study exploring whether FOP nutrition labels improve food purchases in a real-life setting. The nutritional quality of 1 668 301 purchases was analysed. Products in four food categories (fresh prepared foods, pastries, bread and canned prepared meals) in 60 supermarkets were labelled with either no label (20 supermarkets), SENS nutrition label (coloured pyramid with information on how often you should eat the food product), Nutri-Score, Nutri Repère (uncoloured GDA expressed through numbers and bars chart), or Nutricouleur (GDA expressed with numbers and colours). Retailers provided purchase data from loyalty card holders for two time periods.	The purchase of products with high nutritional quality was significantly increased by Nutri-Score and (to a lesser degree) Nutri-Couleurs – 14.4% and 8% respectively. The overall results are mostly driven by the prepared foods category, which is the category with the widest FSA scores across products. Additionally, Nut ri-score was the only label that was found to always have a positive impact on the purchase of the highest nutrition quality products. Looking at nutritional basket for the overall nutrition quality, coefficients of the four labels were all in the expected (negative) direction, but all are statistically insignificant, except for Nutri-Score with an average FSA score reduction of 0.142 ($p<0.10$).
Adasme-Berríos *et al.* (2020)	807 respondents in Chile, responsible for buying food in their home	A questionnaire was used to assess how risk perceptions are related to the avoidance of purchasing food with warning labels. Socio-economic groups were taken into account.	Perceived risks (related to performance, financial, physical and psychological) predict intentions not to buy processed foods with nutritional warning labels. Specific features (i.e., frequently consuming processed foods, being male,

Table 17 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Adasme-Berríos *et al.* (2020) *(cont.)*			and belonging to a lower-income socio-economic group) are associated with lower use of nutritional warning labels.
Fichera & von Hinke (2020)	A non-representative sample of 20 707 UK households	A longitudinal quasi-experimental study between 2005 and 2008 (before and after the introduction of FOPNL (TL system, GDA and a hybrid version using elements of both) in the four supermarket chains covered), using Kantar Worldpanel data.	Households responded to the introduction of labelling by reducing the total monthly calories, SFA, sugars, and sodium of store-brand labelled foods by 9–14% on average, relative to the mean. This resulted in an overall improvement of the nutritional composition of the households' grocery basket. This result is found to hold in particular for lower socio-economic groups, as opposed to higher social classes.
Ronnow (2020)	2 500 Danish households during the 2009-2016 period	Desk analysis on GfK (Panel Services Scandinavia) home-scan panel data – consisting of grocery shopping data (down to the brand level, connected with nutritional information per 100g via the EAN) (and two additional and identical questionnaires (in 2013 and 2016, detailing about health habits, attitudes and behaviour) with difference-in-difference methods. Total consumption of each nutrient results from multiplying the nutrient content by the volume of the purchased products. The HEI was calculated on the basis of that information, to measure nutrition quality.	The use of FOPNL (Keyhole and the Whole Grain label) improved the overall dietary quality of purchases measured by the HEI. This was mostly driven by decreased intake of sugar and increased intake of fibre, and a non-significant slight increase in fat, although the magnitude of the overall effect was small and marginally significant.
Sarda *et al.* (2020)	4 006 French adults – independent samples -across three waves (1st wave: Apr 2018, before the implementation of a national awareness	An online survey over three successive waves, with questions regarding awareness of the Nutri-Score, support of the measure, and self-reported change of behaviour following the	42.9% of participants (among those who reported familiarity with the Nutri-Score) also reported that they changed at least one of five behaviours. Change in behaviour entailed: 1) choice of a product with better score

Table 17 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Sarda *et al.* (2020) *(cont.)*	campaign, n = 1 005;2nd wave in May/June 2018, after the broadcast of the national campaign, n = 2 000; and final and 3rd wave in May 2019, 1 year after first questionnaire, n = 1 001)	implementation of the Nutri-Score.	in the same shelf; 2), choice of a brand with better scores for the same food product; 3) change towards healthier eating habits through time; 4) reduced purchase of products with no logo or, 5) lower scores; thanks to the Nutri-Score
Taillie *et al.* (2020c)	2 383 participants in Chile, representative of the urban population	This observational study evaluates the impact of the Chilean Law of Food Labelling and Advertising on the purchase of SSBs. Researchers visited households (to collect data on household beverage purchases for the Kantar World Panel Chile), over a two-year period and registered their consumption of SSBs (before and after law implementation). The main outcome measures were: per capita daily volume, calories and sugars purchased from beverages. The law introduced a policy package that included FOP nutrition labels ('high in' warning labels), child-directed marketing restrictions and restrictions on sales in schools. The counterfactual used was the pre-regulation trends predicted into the post-regulation period.	The study found that, after the law was implemented, household purchases of 'high-in' beverages decreased by almost 24% (circa 23 mL/capita/day). This is a larger effect than other standalone policies in Latin America, like taxes. In terms of socio-economic effects, households with a higher degree of education had larger reductions in "high-in" beverages than households with less education (middle-educated households had the lowest reduction).
Harrington *et al.* (2019)	493 participants in the UK provided purchase data (through loyalty card data), 208 of them completed all questionnaires	The study aimed to test a 6-week online intervention on the healthiness of ready meals and pizzas purchased in supermarkets. In the intervention, participants could receive personalized feedback regarding the healthiness of previous purchases, set healthiness	No difference was observed in the healthiness of purchased ready meals between participants in the intervention group and the control group (both exposed to TL label). This was the case during and after the intervention.

Table 17 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Harrington *et al.* (2019) *(cont.)*		goals for future purchases and evaluate the healthiness of purchases using TL labels. Control participants received general information about TL labels. Therefore, both groups were exposed to TL labels. Purchases were analysed for 6 months before, during, and 12 weeks after the intervention period.	
Sandoval *et al.* (2019)	Carbonated soft drinks purchase data from a panel of 1 646 households in Ecuador, during 36 months	Study using data from the Kantar World Panel Company to compare the demand (total quantities and price elasticities) for high sugar vs. low sugar carbonated soft drinks, before and after the introduction of a mandatory TL FOPNL system. This took place in Ecuadorian households between 2013 (20 months before) and December 2015 (16 months after the deadline for compliance with the TL labels). TL denotes content of only 3 nutrients (and not 5 like in most other places where implemented): fat, sugar and salt.	Results show that the introduction of the TL labelling had no significant effect on the purchases of high-sugar carbonated soft drinks (though there was a trend downwards especially of a widely known carbonated soft drink brand - the highest consumed in Ecuador), nor on price elasticities.
Smed *et al.* (2019)	Between 831 – 7 216 Dutch households of a consumer panel (data are from 2005-2008)	Analysis of households' share (provided by GfK Consumer Scan Panel) of products eligible for the Healthy Choice label (certifying whether a specific product is a healthy choice within its product category) as a function of changes in the market share of products with the label.	The introduction of the label led to the overall increase purchase of products that carry the Choices label. For dairy products and for the sauces category, the effect is significantly positive and of a considerable size. However, minimal or no effect was found in fats and oil categories, as well as for cereals.

Table 17 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Zhu *et al.* (2019)	Market study of purchases, media exposure and packaging in the US ready-to-eat cereal market, leading to a total of 14 550 observations from 30 cereal brands, observed over 485 market areas, in two-week period combinations.	Market analysis of the impact of FOP nutrition labels on the ready-to-eat cereal market in the US. They looked at cereals that have implemented voluntary FOPNL and those that have not, and measured the impact, of any, on actual consumer choices. They looked for a participating effect (i.e., the effect on purchases of those brands participating in voluntary FOPNL) and spillover effect (i.e., the effect on those brands that did not participate in it).	Results showed that voluntary FOPNL had a positive effect, i.e. more purchases, on participating RTEC products. Interestingly, VNL also had a negative spillover effect, meaning that non-participating ready-to-eat cereal products were purchased less. As a result of the voluntary FOPNL, consumers purchased relatively healthier ready-to-eat cereal alternatives from both participating and non-participating manufacturers. These effects were stronger for healthier products, and weak or insignificant for unhealthier ones. The study found that voluntary FOP nutrition labels had a weak impact on consumers who were buying unhealthier products (i.e., labels tend to influence consumers who buy healthy products in the first place). Despite this, an implication of the findings is that avoiding these externalities can act as an incentive for firms to participate in voluntary FOPNL.
Bartels *et al.* (2018)	60 grocery shoppers (convenience sample) in the USA	Product choices (within three target product categories; ready-to-eat cereal, snacks, and soup) were assessed in combination with visual data from a mobile eye-tracking device in a real shopping environment. Each participant shopped in two aisles; a first one as a practice session, and a second with one of the three randomly selected categories.	Eye-tracking data revealed that 1/3 of participants viewed nutrition information at least once. 42% of participants viewed 1 or more of the provided nutrition information elements (Nutrition Facts label, claims, Facts-Up-Front, and nutrition signage) immediately before selecting product for purchase. This included 10% of participants who viewed the Facts-Up-Front label before purchase. 42% of participants reported that they find FOP nutrition information “extremely” or

Table 17 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Bartels *et al.* (2018) *(cont.)*		Among the various visual stimuli the FOP information included the Facts-Up-Front icon.	"very" important. 62% of participants indicated that the importance of FOP information was different depending on whether they were buying a new or routine product.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; FSA, Food Standards Agency; GDA, Guideline Daily Amount(s); HEI, Healthy Eating Index; SFA, Saturated fat;; TL, Traffic Light(s).

3.5.3 Effects of FOPNL on shopping costs

In the sections above (section 3.3, on preferences, but also in 3.5.1, about experimental evidence on purchasing behaviour) it was noted that consumers tend to be more willing to pay for healthier products (Balcombe *et al.*, 2010; Gustafson & Prate, 2019; Talati *et al.*, 2017).

A study by Crosetto *et al.* (2020) estimated that the nutritional improvements due to FOPNL may come at an economic cost, as the average cost of a 2 000-kcal diet increases when shopping for labelled products. However, the data showed that labels do not have the regressive effects of other policies, such as taxes and subsidies (Muller *et al.*, 2017). Lower-income subjects were less affected in terms of cost of nutritional adjustment than medium and high-income subjects were, especially for the Nutri-Score and HSR. Crosetto *et al.* (2020) concluded that nutritional gains were not correlated with higher expenditure. In another study, de Abreu and colleagues (2019) found that the HSR of products was not related to the price of the product. Additionally, products with HSR were similarly priced than products not displaying it.

Though there is evidence dismissing the existence of any correlation between FOP nutrition labels and consumers' expenditure (Crosetto *et al.*, 2020; Finkelstein *et al.*, 2020), all other things being equal, one study presents somewhat diverging findings. Some authors found that adding the Nutri-Score label to food sold in a Colombian cafeteria made people spend more money overall, and more on healthier items specifically (Mora-García *et al.*, 2019).

In the EU, the vast majority of pre-packed foods are required to display a nutrition declaration in order to allow consumers to make informed and health-conscious choices (Regulation (EU) No 1169/2011 (European Union, 2011) on the provision of food information to consumers). This mandatory nutrition declaration is often provided on the BOP. As a minimum, it must include the energy value as well as the amounts of total fat, SFA, carbohydrate, sugars, protein and salt, expressed per 100 g or per 100 ml (and optionally per portion).

Table 18 Studies assessing the impact of front-of-pack nutrition labelling schemes on shopping costs

Study (most recent first)	Population	Intervention/Comparator	Outcome
Finkelstein *et al.* (2020)	146 participants in Singapore	Experiment to assess the effect of calorie-labelling within or across categories on food purchases. Using an online supermarket platform, participants either saw no label on products, saw a "lower calories" label on the 20% of the products with lowest calories within their categories, or a lower calories label on the lowest 20% of all products. Their purchase behaviour was monitored.	Participants bought more labelled products compared to the control condition only in the within-category labelled condition. For beverages only, across-category labels resulted in more purchases of labelled products compared to the control. Additionally, for beverages only, total calories purchased were lower in both labelled conditions compared to the control and more so in the cross-category compared to the within category condition. Dollars spent, calories per dollar spent, total calories consumed and calories per serving were not affected by labels.
Crosetto *et al.* (2020)	691 participants in France	An incentivised experiment tested the effectiveness of five FOPNL schemes (MTL; RIs; HSR; Nutri-Score, SENS) and control. Participants were told to shop enough to last two days and shopped twice. They made their choices without any label first (benchmark), and then continued with one of the five labels.	All labels improved nutritional quality with the Nutri-Score being the most effective, followed by HSR. Nutritional gains were not correlated with higher expenditure. The authors state this would mean that the FOPNL induced people to make nutritionally improved choices, without making them spend more money.
de Abreu *et al.* (2019)	1 578 participants in Australia between June 2014 and September 2016	Participants shopped at supermarkets at least once a week over a 5-week period. Using shopping receipts, the study investigates whether (i) healthier products, as indicated by HSR are more expensive than less healthy alternatives and (ii) products displaying the HSR are more expensive than similar products that do not. The study includes three	The HSR of products was not consistently related to price. For juice and cereal-based bars, some small positive associations were observed. However, products with HSR were not more expensive than similar products that did not display the HSR.

Table 18 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
de Abreu *et al.* (2019) *(cont.)*		categories (breakfast cereals, cereal-based bars and fruit juices). The study looks at correlations between HSR and price [per energy ($/100 kJ) and per unit ($/100 g)] for products of similar sizes.	
Mora-García *et al.* (2019)	385 participants in Colombia	To test whether providing individuals with information regarding the Nutri-Score (with coloured numbers) influenced purchasing decision, they approached people in a cafeteria and either provided them with information on Nutri-Score or not. Products in the cafeteria bore the Nutri-Score FOP nutrition label. Participants' receipts were inspected to see how this affected purchases.	Randomly providing information on Nutri-Score increased total expenditure by $0.18. Additional spending on healthier items was 21% or $0.26 higher, with no change for less healthy items. Expenditure estimates were higher among customers who were aware of the system's existence. Customers in the study were also 10% more likely to buy a healthier item than control customers.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; SENS, Système d'Etiquetage Nutritionnel Simplifié.

3.5.4 Conclusions regarding the effects of FOPNL on purchases

Based on the literature reviewed up to 2018, the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) highlighted that:

I. Experimental studies looking at the intention to purchase show that FOPNL, especially colour-coded labels, can improve the nutritional quality of food choices and shopping baskets.

II. The limited evidence on actual shopping behaviour suggests a small effect of FOPNL on 'on-the-spot' purchasing. A possible reason is that real-time purchasing decisions are influenced by a multitude of other factors (price, taste, habit, cognitive depletion, etc.) which may be difficult to isolate, making evidence on actual shopping behaviour difficult to obtain.

III. Some real-life studies confirm that evaluative FOP schemes can improve the nutritional quality of people's actual food choices; evaluative FOP schemes with colour coding and/or with colour coding in combination with a grading indicator appear most promising.

IV. FOP nutrition labels are effective in supporting health-conscious consumers.

V. For optimal effectiveness, FOP nutrition labels should be combined with appropriate education and promotion campaigns.

VI. The type of FOPNL scheme may influence the effect on purchasing behaviour depending on the type of consumer. Evaluative labels may require less complex processing than reductive labels.

The current report, on the basis of the recently added literature reviewed, provides updates to Conclusion I by adding evidence on the way different FOP schemes are more effective in different outcomes. Some FOP schemes (Warning Labels) seem to decrease unhealthy choice to a stronger degree, whereas others (TL/MTL, HSR and Nutri-Score, and to a lesser extent RIs/GDA) seem to work better at improving overall healthiness of choices - combining both increase of the healthy and decrease of the unhealthy products- and not effecting changes specifically on the purchases of either healthy products or unhealthy ones only (see 3.5.1 and Table 16 for more details on all 43 studies reviewed regarding this aspect). Some real-life studies confirm the findings of experimental studies as regards impact of FOPNL on purchasing behaviour. It has to be noted, though, that some of these real-life studies focus only on specific categories of products (e.g., SSBs, ready-to-eat cereals), or on specific categories of consumers or facilities, which makes it difficult to generalise on the impact of FOP nutrition labels across the board. For example, real-life evidence for four food categories (Dubois *et al.*, 2021) suggests that Nutri-Score encourages the purchase of the healthiest categories; in addition, the effects on purchases were ordered appropriately with an increase of the higher nutritional quality products, a decrease of the medium-quality ones and an even bigger decrease of the low-quality ones.

Strengthening Conclusion II, in this update we cover a larger number of empirical studies, in real shopping contexts. The effect of FOP nutrition labels on improving the nutritional quality of the shopping basket in real-life contexts was substantially lower than what was found in laboratory settings (Dubois *et al.*, 2021). Time pressure can influence how consumers interact with different types of label information: a study by Blitstein *et al.* (2020) concludes that simple FOP nutrition labels are more effective than FOP nutrition labels that present an array of nutrient information. However, time pressure decreased healthy choices made with the simple FOP nutrition labels compared to shopping in the absence of a timeline and reduced healthfulness of the shopping basket to levels achieved with colour-coded nutrient-specific labels. Finally, Velasco Vizcaino & Velasco (2019) also point to the fact that FOP nutrition labels, i.e., the TL labelling in the study at stake, seemed to exert an asymmetric impact, depending on whether they accompanied products with a brand familiar or unfamiliar to consumers (see 3.5.3).

Adding to Conclusion IV, a difference of FOPNL impact on purchasing was also observed depending on whether the food category was considered healthy or hedonic (Tórtora *et al.*, 2019; Uribe *et al.*, 2020); effects of FOPNL were more pronounced in the case of healthy/utilitarian foods but were more difficult to achieve for hedonic foods.

Conclusion V is further strengthened with additional research (De Temmerman *et al.*, 2021; Talati *et al.*, 2019a) showing that familiarity with the FOPNL scheme, especially when already in use in the country evaluated, seems to influence the impact of FOPNL on purchasing.

The overall findings on the impact of FOPNL schemes on actual purchasing behaviour indicate that there may be an overall positive effect of FOPNL on intention to purchase, somewhat confirmed in observational studies,

despite methodological differences and some varying results. As it is always the case, many aspects remain unanswered or not fully understood. Further research is needed to systematically identify the real-life conditions under which FOP nutrition labels may affect consumers' behaviour towards making overall healthier food choices.

3.6 Attention, preferences, understanding of FOPNL and effect on purchasing behaviour in different population groups

The studies reported in the previous sections provide information on the average consumer. However, there are various types of consumers, differing by level of education, health-consciousness, wealth, age, gender, and other characteristics. This means that different labelling schemes may be more accessible for some consumers than others and consequently the same intervention is likely not to generate the same impact across different categories of consumers.

Several recent studies have provided evidence on the effects of displaying FOPNL, using population subgroups according to specific sociodemographic characteristics. The classification used in the papers includes diverse variables such as age group, education level, income, health literacy, and ethnicity.

3.6.1 FOP nutrition label effectiveness in children and adolescents

We identified four recent studies specifically examining the effect of FOPNL on children and adolescents.

Two studies used an experimental design in order to explore whether the presence of FOPNL had an effect on the choices of children and adolescents (Becker *et al.*, 2019; Poquet *et al.*, 2019). It has been shown that the presence of colour-coded FOPNL improved the speed and the accuracy in identifying healthier products (Becker *et al.*, 2019). Moreover, the presence of the Nutri-Score resulted in the selection of snacks of better nutritional quality compared to a no label condition (Poquet *et al.*, 2019).

In a study evaluating the effectiveness of FOPNL with or without the presence of health and nutrient claims in children and adults, it has been shown that participants were more likely to make the healthier choice when FOPNL were present without claims (Talati *et al.*, 2018). Finally Lima *et al.* (2019b) assessed the emotional response of children when they eat a product featuring GDA label, TL or nutritional warning; children selected emojis associated with positive emotions less frequently when evaluating packages with the (semi-)directive schemes than those with the GDA.

In conclusion, the presence of FOP nutrition labels, especially directive and semi-directive labels can result in healthier choices for children and adolescents.

Table 19 Studies of children's and adolescents responses to front-of-pack nutrition labelling schemes

Study (most recent first)	Population	Intervention/Comparator	Outcome
Becker *et al.* (2019)	80 children (6-10 years of age) in the USA	Experimental study to assess whether children can understand FOP nutrition labels. Children played a video game called "Munchy Monster", where they were asked to feed healthy foods to the monster. The foods had FOPNL either with or without colour coding and with or without a facial icon, thus a 2 (colour/ no colour) x 2 (icon / no icon) design. The experiment was done on two groups of children: one received no instructions other than to feed the monster the healthiest option, the other was told that a part of the package (i.e., the FOPNL) could help them decide which option was the healthiest.	Colour coding and facial icons – especially when combined – significantly improved accuracy and speed. Moreover, minimal instruction improved accuracy and speed even more. The authors take this as evidence that FOPNL that leverages visual indicators can help children make the right choices, which would be strengthened with some training to children.
Lima *et al.* (2019b)	492 children (6-12 years old) in Brazil	Between subjects design with 3 groups: one for each FOPNL scheme (GDA, TL and Nutritional Warnings). Children were presented with a series of food products images and asked to select all the emojis that described how they would feel eating the product (16 emojis).	Emojis associated with positive emotions were less frequently selected when children evaluated packages with (semi-) directive schemes than those with the GDA system. Age and type of school moderated the effect of FOPNL on emotional associations. Children from public schools tended to have more positive reactions regardless of the FOPNL scheme. The effect of directive and semi-directive FOPNL schemes, particularly nutritional warnings, tended to be higher for children from public schools.
Poquet *et al.* (2019)	95 French mothers and children aged 7-11 years	Laboratory experiment in which participants (both mothers and children) were	The Nutri-Score led to a significant improvement of the nutritional quality

Table 19 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Poquet *et al.* (2019) *(cont.)*		asked to choose a snack (2 food items and a beverage), in two rounds (first without Nutri-Score and then with it).	of the selected snacks (for themselves, and for the other dyad member), however it also brought about a reduction in liking for the choice made (hedonic cost).
Talati *et al.* (2018)	2 069 adults and children in Australia	Discrete choice experiment to assess the effectiveness of FOPNL in improving healthfulness of food choices when combined with nutrient or health claims on-pack. Respondents saw 8 choice sets, each containing four product alternatives of the same product category (cookies, cornflakes, pizza or yoghurt). They saw the same FOP nutrition label (Daily Intake Guide, MTL, HSR) across sets.	Participants were more likely to avoid unhealthy products and choose healthy products when FOPNL were presented on the package without claims. Adding nutrient or health claims to the package increased the likelihood of choosing less healthy products across all FOPNL conditions, suggesting that claims can counteract the potential for FOPNL to facilitate identification of less healthy products. There were no significant differences between age groups (aged 10–17, 18–46, or ≥46 y) in their choice of mock packs on the basis of healthfulness × FOP nutrition label × health claim combinations.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); TL, Traffic Light(s).

3.6.2 Effect of FOPNL on preferences and understanding across socio-economic groups

Results show different trends in the overall knowledge and interest in using of FOPNL schemes among consumers from different socio-economic groups. While some studies found a higher interest in FOPNL information in lower socio-economic groups (Dana *et al.*, 2019; Farrell *et al.*, 2019), or a neutral effect of the socio-economic status in their support to the policy (Ares *et al.*, 2018b), most of the papers highlighted that the knowledge and interest in using FOPNL decreased in lower socio-economic population groups (Bryla, 2020; Correa *et al.*, 2019; de Morais Sato *et al.*, 2019; Patiño *et al.*, 2019; Sarda *et al.*, 2020). A study by Vargas-Meza *et al.* (2019a) reports that directive FOP nutrition labels such as warning labels and semi-directive labels, such as HSR and MTL, seem to be especially preferred by consumers of low and middle income.

The fact that lower socio-economic groups were less interested in using FOPNL schemes could be explained by the lower level of understanding in these most vulnerable populations. Especially those with poor education and low health literacy were less able to interpret the information provided by the FOPNL schemes, as shown in ranking tasks (Goodman *et al.*, 2018; Graça *et al.*, 2019). However, other studies found that the ability to rank products according to their healthiness in the presence of various FOP nutrition labels did not vary across socio-economic groups (Acton *et al.*, 2018a; Egnell *et al.*, 2018b, 2020a). Actually, the understanding of FOPNL by consumers of different socio-economic groups varied according to the type of scheme displayed. Directive and semi-directive labels were often interpreted more easily by respondents from low socio-economic groups (Ares *et al.*, 2018b; Egnell *et al.*, 2020b; Gomes *et al.*, 2020; Graça *et al.*, 2019; Mansfield *et al.*, 2020; Patiño *et al.*, 2019; Santos *et al.*, 2020); non-directive labels were easier to process by those in higher socio-economic groups compared with those in lower socio-economic groups (Graça *et al.*, 2019; Patiño *et al.*, 2019; Sulong *et al.*, 2019). Some studies report that Nutri-Score has a similar performance across different socio-economic groups (Egnell *et al.*, 2018a; Graça *et al.*, 2019; Santos *et al.*, 2020).

Table 20 Studies of the impact of front-of-pack nutrition labelling schemes on understanding across different socio-economic groups

Study (most recent first)	Population	Intervention/Comparator	Outcome
Adasme-Berríos *et al.* (2020)	807 respondents in Chile, responsible for buying food in their home	A questionnaire was used to assess how risk perceptions are related to the avoidance of purchasing food with warning labels. Socio-economic groups are taken into account.	Perceived risks predict intentions not to buy processed foods with nutritional warning labels. Frequently consuming processed foods, being male and belonging to a lower-income socio-economic group are associated with lower use of nutritional warning labels.
Egnell *et al.* (2020a)	1088 Swiss consumers	Ranking task of mock products (pizzas, cakes, and breakfast cereals) according to their nutritional quality, before and after the display of FOPNL (MTL, Nutri-Score, HSR, Warning label, or RIs as a reference).	Compared to the no label condition, all FOPNL schemes improved the percentage of correct answers. For all three food categories, the Nutri-Score produced the largest improvement in correct answers in the ranking tasks, followed by the MTL. No interaction was found between FOPNL and

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2020a) *(cont.)*			socio-economic characteristics (educational level, level of income).
Gomes *et al.* (2020)	1127 Portuguese shoppers	Focus groups and questionnaire about use and liking of food labels	To the survey asking "If you consider that nutritional information displayed in food labelling is confusing and difficult to understand, what you would change?", one of the answers, mainly from people with low literacy level, was: "the use of coloured symbols like TL would be helpful and more easily understood by consumers".
Hutton & Gresse (2020)	359 South African adult shoppers	People were interviewed at the exit of randomly selected retailers outlets (questionnaire adapted from the one used in NutriNet-Santé study) about Nutri-Score, Warning labels, MTL, and Health Endorsement Logo.	RIs were chosen as the most difficult label to understand across all education levels. Participants with some form of primary school education perceived the Nutri-Score as being more difficult to understand (31.8%) when compared to participants with higher levels of education.
Sarda *et al.* (2020)	National and representative sample (n = 4 006) of the French population aged 15 years and above	3 waves of survey, at different dates, before and after a national campaign started for Nutri-Score implementation. Participants were asked about: awareness of the logo, impact of the logo on their purchasing behaviour.	The odds of knowing the Nutri-Score significantly decreased when people belonged to a lower socio-economic group (i.e., lower income, education level, socio-occupational category). However, awareness of the logo did not vary according to household income, and level of diploma. Regarding the implementation of Nutri-Score, participants were more likely to be in favour if they had a household income above 1 500€.

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Nieto *et al.* (2020)	78 Mexican adults	12 focus groups discussing use and understanding of nutrition labels among different socio-economic categories. Each focus group included 8 to 10 participants of similar characteristics (age, education, and socio-economic status). The FOPNL assessed were the GDA, and a directive nutritional stamp.	Regardless of socioeconomic level, participants made clear they did not understand the current labelling (GDA, nutrition information table); they found it useless to read. GDAs were not used nor comprehended as intended across all socioeconomic groups. Regarding the Nutritional Stamp, participants among the different socioeconomic groups did not agree about a meaning.
Blitstein *et al.* (2020)	1 452 parents in the USA, at or below 150% of the poverty level, with at least one child aged 4-12 y.	Online 4x2 experimental design to assess how FOP nutrition labels influence food choices among low-income parents. Participants shopped with either no FOPNL or one of 3 FOP nutrition labels: summary (star rating), nutrient-specific (TL), hybrid (energy per serving + stars for each nutrient in excess) on the products. They either shopped under time pressure (10 minutes time constraint) or not (no limit). The summary nutrient profile of the shopping basket was assessed using Healthy Purchase Index, based on FSA score.	All FOPNL led to healthier shopping baskets compared to the control condition. Simple FOP nutrition labels – the summary and hybrid labels – were more effective than nutrient-specific labels. When provided with simple FOPNL, time pressure decreased healthy choices compared to shopping in the absence of a time limit (with the same, simple FOPNL), and reduced healthfulness of the shopping basket to levels achieved with nutrient-specific labels. No effect of time pressure was found for nutrient specific FOPNL.
Bryla (2020)	1 051 subjects representative of the Polish population	Questionnaire investigating FOPNL reading when shopping at store and when at home after purchase	Respondents who had tertiary education read food labels in shops more often than the other education groups. FOPNL reading at shop was highest among respondents living in households with middle

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Bryla (2020) *(cont.)*			income and the highest income. In retrograde step regression models, FOPNL shop increased with being a white-collar worker.
Santos *et al.* (2020)	357 participants in Portugal	Questionnaire in which participants were asked to indicate which of the four FOP nutrition labels fit better with 12 evaluative statements. Also five online choice tasks experiments with five FOPNL systems conditions (TL, %GDA, Nutri-Score or HSR, no-label control). Participants were asked to select the healthiest food product from a set of three alternatives.	Over 60.9% of participants with more than 9 years of school made the correct choice using any of the FOPNL schemes, whereas correct choices among the less educated subjects (when a FOPNL system was presented) ranged between 63.5% using Nutri-Score and 68.0% using HSR (TL: 66.3%, %GDA: 65.2%). Significant differences between level of education groups were only detected for TL. Using the PROGRESS-Plus to account for the risk of inequities, the Nutri-Score seemed to be the best option (no significant differences found between any of the considered subgroups).
Mansfield *et al.* (2020)	625 Canadian consumers	Participants completed purchasing tasks for their household, for someone with dietary restrictions, and to find a product with a nutrient in excess. Five arms of labelling used: current labelling, i.e., no FOPNL (control), and four different variations of the 'high-in' FOP nutrition label.	Overall, for all five tasks, both marginal and adequate health literacy participants were significantly more successful with FOPNL than with current labelling. All FOP nutrition labels were equally effective.
Correa *et al.* (2019)	84 Chilean mothers of children aged 2-14 years	Nine focus groups with 3x3 stratification according to socio-economic status (lower, middle, upper, depending on family income, possession of material goods, type of	Mothers, particularly from middle and upper-socioeconomic groups, asserted that they pay very close attention to FOPNL to decide what to buy. Low- socioeconomic

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Correa *et al.* (2019) *(cont.)*		school attended by their children and district of residence). Knowledge of Nutritional Warnings and perceptions and behaviours associated with the new regulation of mandatory FOPNL were assessed.	groups reported that special events at school no longer include unhealthy food since the law is in place. However, in these groups, there were high levels of uneasiness about the changes in the school environment due to the implementation of the mandatory FOPNL. Children in all socioeconomic groups, and especially in the middle- and lower- ones, were more committed to using the logos to make food choices.
Dana *et al.* (2019)	1 558 Australian adults	Subjects completed a survey in which they rated their perceived importance of the provision of energy and nutrient information on the front of food packs.	Respondents who exhibited neutral and low levels of interest in FOP nutrition information were characterised by higher socioeconomic level.
Sánchez-García *et al.* (2019)	330 women in Ecuador	Two focus groups and a quasi-experimental approach with a 3x2 design (with manipulation of two variables, TL FOPNL (green, yellow, red) and income (high and low), to analyse the impact of TL FOPNL on negative emotions.	TL colours significantly influence participants' levels of negative emotions (fear and guilt), as well as their intention to purchase. Income plays a moderating role: high-income groups are more sensitive to green and yellow, and low-income ones to red.
De Morais Sato *et al.* (2019)	96 Brazilian shoppers (20-50 y, 50% males)	Focus groups about opinions about labels and barriers to use, and about Nutritional Warnings and how they affect participant's use of labels. Groups were stratified by gender (f/m) and socioeconomic level (low/high).	Overall lower interest in nutrition information among the participants with low socioeconomic level, for whom the main barrier for label use were the technical terms. They said more frequently that they would choose another product or keep eating the food with a Nutritional Warning than the ones with high socioeconomic level.

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
De Morais Sato *et al.* (2019) *(cont.)*			More people with high socioeconomic level declared using the information to compare products, and they more frequently mentioned the need for a new label and said they would reduce the amount of a food with Warning label. They also saw the Warning labels as an educational tool for their children.
Aliaga-Ortega *et al.* (2019)	200 Chilean adults	Questionnaire evaluating participants' familiarity with Nutritional Warnings and its effect on their choice of processed foods, using the Theory of Planned Behaviour components	The analyses provided no evidence that socio-demographic factors could explain the behaviour of consumers regarding processed foods with Nutritional Warnings.
Farrell *et al.* (2019)	Sample of the cross-sectional South Australian Health Omnibus Survey, representative of people aged 15 and over (n = 2 732, 49.2% males)	Interviews investigating the level -and reasons- of support of the regulation mandating the provision of nutrition information on FOPNL, using a five-point Likert scale.	Those in the most disadvantaged socio-economic group were more likely than those in any other group to report wanting to use nutrition labels themselves. They were only slightly more likely to support mandatory nutrition labelling for the benefit of others rather than for personal use, in contrast to more advantaged groups, and they were more likely to report wanting to use the information themselves.
Sulong *et al.* (2019)	366 Malaysian citizens	Self-administered questionnaire about awareness and understanding of the energy icon	The level of education was significantly associated with the understanding of FOPNL (energy) icon: those who understood the icon were in the categories of high education.

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Vargas-Meza *et al.* (2019a)	2 105 Mexican adults	Participants were randomly assigned to either GDA, MTL or Warning labels condition. They were asked to detect, among three products, the one with the lowest nutritional quality.	No differences in label understanding were found across socio-demographic characteristics. Overall, both the MTL and the Warning Labels were more accepted and better understood than the GDA, and allowed low- and middle income consumers to make nutrition-quality related decisions quicker.
Vargas-Meza *et al.* (2019b)	120 participants in Mexico: adolescents (13-15y), young adults (21-23y), mothers of children (3-12y), fathers of children (3-12y) and older adults (55-70y)	Ten focus groups (five of low- and five of medium-socioeconomic level) with 12 participants each, aimed at exploring the 1) awareness and use of the GDA, 2) acceptability, and 3) subjective understanding of labels, of seven different FOP nutrition labels: GDA, MTL, Chilean Warning.labels, Warning labels in Red, 5-Color Nutrition Label, HSR, and Healthy Choice label) by low- and middle-income Mexican consumers	The participants were aware of the GDAs but found it complex and rarely used it. Older adults also tended to report using GDA more frequently for health reasons. Directive and semi-directive labels (such as warning labels, HSR and MTL) may be more effective in encouraging healthier food choice for low- and middle-income groups than non-directive FOP nutrition labels such as the GDA. The study reported a low subjective understanding for a (non-existing) 5-colour nutrition label.
Teran *et al.* (2019)	73 adult shoppers in Ecuador	Survey at two different urban supermarkets allowed to obtain subjective data about TL use (which was compared with purchases). One supermarket was in a high socio-economic area, the other in a low socio-economic area.	A significant association was found between knowledge of the TL and educational level. No association was found between socio-economic status (supermarket), gender or age when compared with the knowledge and use of the TL. However, highest level of education related to a positive knowledge of the TL.

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Nieto *et al.* (2019)	Participants from the survey: US and Mexico administrations of the 2017 international Food Policy Study	Participants were asked how easy or difficult the information from labels (GDA, MTL, HSR, Warning Labels and non-FOP Nutrition Facts Table), was to understand, and how often they used that type of label when choosing food to purchase.	Latinos reported a higher use of labels. Latinos with higher education levels had higher odds of understanding food labels. Whites reported the highest level of understanding for Warning Labels, and reported lowest understanding of HSR and MTL. Latinos and Mexicans also reported higher understanding for Warning Labels. Compared to Latinos, Mexicans were more likely to report understanding the Warning Labels, HSR and MTL than Nutrition Facts Table. Compared to Latinos, Whites had lower odds for understanding the HSR and MTL.
Graça *et al.* (2019)	469 Portuguese adults	Focus group with citizens and experts, and interviews on perceptions about food labelling. Choice task to select the healthiest food package from a set of 3 alternatives with either 1 of the 4 FOPNL schemes assessed (MTL, HSR, GDA, Nutri-Score) or control (no FOP scheme) condition.	Citizens and experts perceived the GDA as poorly beneficial for people with general or low health literacy. They found that the TL, Nutri-Score and HSR could be helpful for people with low literacy skills since they allow an easy understanding. Participants with >9 years of school had the highest percentage of healthiest choice with TL as FOPNL (89.5%). Nutri-Score was the only FOPNL without differences within subgroup analysis. However, food insecurity and understanding of nutritional information were not associated with probability to select the

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Graça *et al.* (2019) *(cont.)*			correct answer. Finally, when considering only people with 9 years of education or less, the magnitude of the association between correct answers and the presentation of each of four systems was higher with HSR.
Patiño *et al.* (2019)	966 parents of elementary school children in four Latin-American Countries (Argentina, Chile, Costa Rica and Mexico)	27-item questionnaire designed to collect self-reported evidence on usage, perceptions and preferences regarding FOPNL (GDA, TL and warning labels, in terms of legibility, clarity and nutrition).	While the TL format was preferred across all countries, the GDA format was preferred by the better educated, and warning labels were preferred by parents with low educational levels and/or with overweight.
Acton *et al.* (2018a)	675 Canadian White, Non-white and Indigenous subjects	Randomised controlled experiment to assess perceived healthfulness of a range of beverages displaying no label, a simplified coloured version of the TL, HSR or a numeric rating (0-100).	No evidence for moderating effects of socio-demographic variables, suggesting that consumers across ethnicities were equally able to interpret the labels tested.
Goodman *et al.* (2018)	11 617 UK, USA, Mexican and Canadian adults	Between groups experimental task. Cereal boxes displayed FOP 'High in' labels for sugar and SFA with five experimental conditions to which participants were randomised: control (no FOPNL); red circle; red stop sign; magnifying glass; magnifying glass + exclamation mark; and 'caution' triangle + exclamation mark. All FOPNL symbols were also displayed with added 'high in' text, for a total of 11 experimental conditions.	Those with a high level of education were significantly more likely to respond correctly compared to those with a low level (Odds for SFA: low education level: reference; middle: 1.00 (0.86, 1.16); High: 1.30 (1.13, 1.48).
Egnell *et al.* (2018b)	Sample of the NutriNet-Santé French cohort (n = 3 751)	Participants were asked to rank food according to the nutritional quality of food products (according to a FOPNL or a no-label control	The objective understanding of each FOPNL label format was higher among participants with higher

Table 20 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2018b) *(cont.)*		condition) to evaluate their objective understanding of the MTL, Nutri-Score, SENS logo and Modified RIs.	educational level (greater odds of correct product ranking in multivariate model). However, the odds of correctly ranking products did not vary according to household income. The Nutri-Score performed best across all sub-groups, followed by SENS, MTL and Modified RIs.
Ares *et al.* (2018b)	Sample of 1 416 Facebook users participating in a survey, representative of the different socio-economic groups in the Uruguayan population	Online survey exploring citizens' perception and expected reaction to Nutritional Warnings, as well as their support for the label implementation policy. Respondents were also asked what they would do if they saw one of the products they usually buy in the supermarket, but containing Nutritional Warnings.	The Warnings were perceived as more helpful for consumers from low socio-economic status and they considered that the policy would help them improve the quality of their diet more than the medium and high socio-economic groups. However, the socio-economic status did not significantly influence participants' support of the policy, nor their disposition to take nutritional warnings into account when choosing foods and the quality of their diet.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; SFA, Saturated fat; TL, Traffic Light(s).

3.6.3 Effect of FOPNL on choices and purchasing across socio-economic groups

Regarding the impact across socio-economic groups, most of the studies assess the association between the socio-economic category and consumption behaviour in the presence of FOP nutrition labels using choice-task experiments in mock shopping conditions and surveys to capture purchasing intentions. Most of the studies found no difference across socio-economic categories (Adasme-Berríos *et al.*, 2020; Cooper *et al.*, 2020; Mantzari *et al.*, 2020; Poquet *et al.*, 2019). However, some experiments have shown that FOPNL schemes

were more efficient at decreasing the purchase intentions of unhealthy products in people with higher income (Sánchez-García *et al.*, 2019) or education (Anderson & O'Connor, 2019). In addition, in some studies the observed nutritional quality of the shopping cart was found to be lower among those with low income, lower educational levels and lower levels of nutrition knowledge (Jáuregui *et al.*, 2020; Taillie *et al.*, 2020c).

Other studies have shown that FOPNL could be more effective in positively impacting food choices in lower socio-demographic groups than in higher ones (Basto-Abreu *et al.*, 2020; Fichera & von Hinke, 2020; Sarda *et al.*, 2020).

Table 21 Studies assessing the impact of front-of-pack nutrition labelling on food choices and purchasing behaviour across different socio-economic groups

Study (most recent first)	Population	Intervention/Comparator	Outcome
Adasme-Berríos *et al.* (2020)	807 Chilean adults	Questionnaire on purchase of processed foods, and the perceived risk of purchasing processed foods with Nutritional Warning labels (using a scale about intention to avoid buying processed foods with nutritional warnings).	Intention to avoid buying processed food with Nutritional Warning labels was lower for the low socioeconomic group (multiple regression model coefficient of low socioeconomic level vs. middle: -0.372).
Jáuregui *et al.* (2020)	2 194 Mexican adults	Purchasing task on a web-based virtual supermarket with different FOPNL conditions: GDA, MTL, or Chilean warning labels in red.	The nutritional quality of the shopping cart tended to be lower among those with the lowest household income and education level. These effects were similar across all FOP nutrition labels. Interaction terms between label group and demographic indicators (i.e., household monthly income, education level) were non-significant.
Taillie *et al.* (2020c)	2 383 adults in Chile, representative of the urban population	This observational study evaluates the impact of the Chilean Law of Food Labelling and Advertising on the purchase of SSBs. The law introduced a policy package that included FOPNL, child-directed marketing restrictions and restrictions on sales in schools of unhealthy foods and beverages).	The study found that, after the law was implemented, household purchases of 'high-in' beverages decreased by almost 24%. This is a larger effect than other standalone policies in Latin America, like taxes. In terms of socio-economic effects, households with a higher degree of education had larger reductions in

Table 21 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Taillie *et al.* (2020c) *(cont.)*		Researchers visited the sampled households over a two-year period and registered their SSB consumption before and after the law was implemented, collecting information on: per capita daily volume, calories and sugars purchased from beverages (in turn divided into 'high-in', normally referring to the amount of sugar; 'low-in'; and total beverages). They compared these post-regulation purchases with a counterfactual, based on an estimate of what the consumption would have been by pre-regulation consumption trends.	"high-in" beverages than households with less education.
Egnell *et al.* (2020a)	1 098 Swiss adult consumers	Purchasing choice task to analyse nutritional quality of selected before and after the display of FOPNL (MTL, Nutri-Score, HSR, Warning labels, or RIs as a reference).	Nutri-Score demonstrated the greatest improvement in food choices, while RIs and Warning Labels the smallest. Significant interaction with income. While all labels tended to have a greater effect than the RIs among those on medium incomes, the MTL and the Warning Labels were significantly less effective than the RIs among individuals on low incomes.
Fichera & von Hinke (2020)	Household grocery purchase data collected from 9 UK retailers	Investigation of nutritional quality of purchases after the implementation of the TL system, and a hybrid system (including elements of TL and GDA).	Both low and high social class households reduced the quantity purchased of store-brand labelled foods after the introduction of FOPNL; this reduction was larger for the lower compared to higher social classes. Results suggested that the reduction in the quantity and the improvement in the quality of labelled store-brand foods is larger for lower social class households.

Table 21 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Blitstein *et al.* (2020)	1 452 parents in the USA, at or below 150% of the poverty level, with at least one child aged 4-12 y.	4 by 2 experimental design. 4 FOPNL conditions on a web-based virtual supermarket: summary (star rating), nutrient-specific (TL), hybrid (energy per serving + stars for each nutrient in excess), and a no-FOPNL. 2 time constraints: 10 minutes or no limit. Basket measured with Healthy Purchase Index.	All FOPNL groups obtained significantly higher Healthy Purchase Index scores than the no-FOPNL control group: the Healthy Purchase Index hybrid label group had the highest mean Healthy Purchase Index score, followed by those in the summary label group (36.1 points), parents in the nutrient specific group, and parents in the control group. Simple FOP nutrition labels without nutrient information provides greater utility for selecting healthier products. Time pressure reduced the Healthy Purchase Index of the basket in directive and hybrid label groups.
Cooper *et al.* (2020)	1 024 Australian adults	Online survey assessing consumer valuation of the HSR and using a willingness-to-pay scenario.	Socio-demographic variables including education, income level and food security status were not significantly associated with consumers' willingness-to-pay for the HSR.
Basto-Abreu *et al.* (2020)	6 049 Mexican adults	Modelling to predict the obesity reduction after implementing Warning Labels using dietary intake data from the Mexican 2016 ENSANUT study.	Assuming a reduction of purchased calories by 10.5% in beverages and by 3.0% in snacks, due to the implementation of Warning Labels, middle and high socioeconomic groups (−15.1% and 15.5%) were expected to present larger obesity reductions in comparison with low socioeconomic group (−12.6%).

Table 21 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Sarda *et al.* (2020)	National and representative sample of the French population aged 15 years and above	3 waves of survey, at different dates, before and after national campaign started for Nutri-Score implementation. Participants were asked about: awareness of the logo, impact of the logo on their purchasing behaviour.	The impact on purchasing behaviours was positively associated with intermediate income. Participants with a higher educational level were less likely to change their purchasing behaviour after implementation.
Mantzari *et al.* (2020)	401 residents in England	Randomised controlled study in which participants were presented with 6 bottles (four SSBs and two non-SSB) and asked to choose one for immediate consumption. They could also not choose any. Three conditions: pictorial health warning label on SSBs only; calorie information label on all drinks; control with no additional label.	Socio-economic position had a significant impact on SSB selection, with those of lower socioeconomic level being more likely to select an SSB compared to those of higher socioeconomic level. Participants from the lower socioeconomic group were more likely to select an SSB compared to those of higher socioeconomic group, but socioeconomic level did not moderate the impact of labels on drink selection. The FOPNL did not differentially affect SSB selection in those in lower or higher socioeconomic groups (no significant interaction effect).
Anderson & O'Connor (2019)	249 participants aged 17-83 years in Australia	Participants' willingness to purchase products was assessed through a survey-based cross-sectional design. Three different comparative contexts (no label vs. no label, HSR vs. no label, and HSR vs. HSR) on mock cereal products with an HSR score of 2 or 5 stars.	No significant bivariate correlations between income and willingness to buy the HSR2 or the HSR5 product. Education was significantly negatively correlated with willingness to purchase the HSR 2 product. Age and education were significantly negatively correlated with willingness to purchase the HSR5 product. No observed effects in multiple regression models.

Table 21 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Acton *et al.* (2019)	3 584 Canadians aged 13 and older, recruited in shopping centres located in 3 Canadian cities	Participants were presented with images of 20 beverages and 20 snack foods available for purchase to exam the impact of different sugar taxes and FOP. Participants were randomised to one of five label conditions (no label; 'high in' nutrient symbol; MTL; HSR; Nutri-Score) x 8 tax conditions. Participants received one of the products they chose and any change from their compensation.	There were no significant two-way interactions between tax and labelling condition for any of the four outcomes in the beverage tasks. The effectiveness of the different FOP labels was the same across ethnicities, education status. Income adequacy, health literacy, and BMI. Only the 'high in' nutrient symbol affected the amount of sugar, calories and fat of the purchased beverages significantly. The MTL and the 'high in' symbol reduced the number of calories and sodium of the purchased foods; the HSR only reduced calories. Nutri-Score had no effect on the amount of calories or nutrients from neither foods nor beverages.
Poquet *et al.* (2019)	95 mother-child dyads in France	Participants were asked to select items (one beverage and two food items) for a snack for themselves and then for the other dyad member among products without label; then the same task among products with Nutri-Score label.	There was no significant effect of the mother's education level on nutritional quality of chosen snacks.
Gustafson & Prate (2019)	115 subjects from the rural American Indian reservation of Rosebud	Assessment of willingness-to-pay for two breakfast cereal products through a choice tasks experiment. Three FOP nutrition label conditions: control label (bison drawing), generic label (smiley face) or tailored label (bison drawing + text for the Rosebud community). Participants could select the healthier item, the less healthy item, or indicate that they would	Both the tailored and generic labels increased the probability that participants chose the healthy item. The presence of labels in a choice set generally decreased willingness to pay for the unhealthy items. The presence of the tailored image in the choice set also decreased the likelihood that participants chose the

Table 21 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Gustafson & Prate (2019) *(cont.)*		purchase neither product (varying prices were also displayed).	unhealthy item, but neither the generic label nor the control label in the choice set significantly impacted the probability that the unhealthy item was chosen. The tailored and generic labels both increased willingness to pay for the healthy food item relative a choice set in which no label is present.
Sánchez-García *et al.* (2019)	330 Ecuadorian women aged between 18 and 65 years	Questionnaire in which participants had to imagine there were shopping for dairy products at the supermarket. Emotions captured via a seven point Likert scale and purchase intention was measure via a seven-point scale. Different TL colours were used.	Income had a moderating effect on the influence of TL colours on consumers' fear and guilt and purchase intentions. The effect of colour in purchase intention was more intense in high-income people. Overall, the emotions and purchase intention were linear in the high-income group between green-yellow-red, but in the low-income group there was almost no change between green and yellow, they reacted mostly to the red colour.
Thiene *et al.* (2018)	797 participants in Northern Ireland	Discrete Choice Experiment to test the influence of FOPNL formats on consumer's stated food choices. Total fat, SFA, salt, and sugar were the nutritional attributes used and presented in different quantities (levels). Four treatments of FOP nutrition label/text: 1) Baseline text: e.g., "saturated: high– sugar: low", 2) Test + MTL for each nutrient, 3) Baseline text + GDA, or 4) Combination of TL colours and GDA percentages.	MTL and GDA induced more propensity towards healthier food baskets in self-reported respondents with obesity, compared to the baseline text only or integrated (combined) FOP nutrition label format. The GDA label had the strongest effect on respondents with no obesity, and a similarly strong effect as the MTL for respondents with obesity.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; TL, Traffic Light(s).

3.6.4 Conclusions regarding differences in the attention to, preferences for, and understanding of FOPNL across different population groups, and effect of FOPNL on their purchasing behaviours

Based on the literature reviewed up to 2018, the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) highlighted that:

I. There is consistent evidence showing that label use is associated with certain consumer characteristics: women are more likely to read nutrition labels compared to men; higher income and higher education level are positively associated with understanding and use of nutritional information; and better nutrition knowledge and understanding of diet-disease relationships as well as general interest in healthier eating habits are positively related with label use. There is no clear evidence about the association of age and nutrition label use.

II. Generally, older adults and those with lower income and/or education and nutritional knowledge struggle the most to interpret FOP nutrition labels correctly.

III. Poorly educated consumers seem to favour simpler, evaluative FOP nutrition labels.

IV. Evidence suggests that the traffic-lights and Nutri-Score schemes are particularly effective among consumers of lower socio-economic status in helping them identify the healthier option.

On the basis of the literature reviewed for this report, the following conclusion can be added:

V. Presence of FOP nutrition labels, especially directive and semi-directive labels can result in healthier choices for children and adolescents.

In general, the rest of the conclusions drawn in the previous report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) remain unchallenged. The evidence shows that the understanding of FOPNL by consumers of different socio-economic groups varies according to the type of scheme displayed. Evaluative FOP nutrition labels seem to be preferred by consumers with lower income. Overall, results highlight the importance of choosing and implementing the appropriate scheme that could impact people's choices favourably, especially those of vulnerable populations.

3.7 Effects of the implementation of different labelling aspects on consumer understanding, preferences, and impact on consumer behaviour

In addition to the topics discussed in the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a), several other aspects of FOPNL may have implications for consumer understanding, preferences, and behaviour. Under 3.4.1.1, we discussed implications of using different reference quantities for consumer understanding, this will be extended in 3.7.1 with implication of different reference quantities for consumer preferences and behaviour. 3.7.2 will discuss the effect of voluntary and mandatory implementation of FOPNL schemes on consumer understanding and behaviour. In 3.7.3, we highlight studies looking at consumers' behaviour and understanding of FOPNL schemes for highly processed foods, and in 3.7.4 the effect of combining different FOPNL schemes as well as combining FOPNL schemes with claims for consumer understanding and behaviour.

3.7.1 Implications of using different reference quantities for consumer preferences and behaviour

In 3.4.1.1, we discussed the implications of using different reference quantities for consumer understanding, and concluded that **nutritional information seems to be better understood when it requires less "mental math".** This section presents the available evidence on the impact of different reference quantities on consumers' behaviour.

The literature listed in Table 22 underlines the implications of granularity of reference quantities on consumer preferences as well as consumer behaviour, especially regarding (intended) consumption. An early study collecting focus group data suggested that consumers' preference for reference quantities depended on the purpose of this information: calories per portion was seen as useful to assess calories of what one was actually buying or consuming, while calories per 100 g was seen as an instrument for comparison. In general, consumers indicated to prefer simple FOP nutrition information that is supported by details on the BOP (van Kleef *et al.*, 2008). As mentioned in 3.4.1.1, if smaller serving sizes are presented on packages than those usually consumed in one sitting, consumers tend to underestimate the energy and nutrient content of the particular food. Consequently, Tangari and colleagues (2019) reported that consumers ate more of an unhealthy snack than they would have if there was no label. This effect was most pronounced for consumers who managed their weight more actively.

Not only expectations, also the description of serving sizes seems to have an impact on consumers' perception and consumption behaviour. A study by Lewis and Earl (2018) suggests that finer grained descriptions of serving sizes (e.g. 15 gummy candies) are perceived as bigger than gross-grained labels ('one serving'), and that this finer grained description makes it easier for consumers to regulate their intake if they wish. This may also speak to the clarity aspect, since a description of the serving size (15 gummy candies) is less ambiguous than indicating nutritional quality "per portion".

Overall, the studies listed in Table 22 suggest that consumer preferences regarding reference quantities differ and that reference quantities can influence behaviour.

Table 22 Studies of the impact of specific reference quantities used in front-of-pack nutrition labelling schemes on consumer preferences and behaviour

Study (most recent first)	Population	Intervention/Comparator	Outcome
Tangari *et al.* (2019)	Study 1: 140 students in the USA Study 2: 403 participants (online) Study 3: 106 students in the USA Study 4: 76 students in the USA	Five studies assessed how calories- per- serving information on labels influences snack consumption. Expectations regarding the calories per serving were manipulated across studies to confirm or disconfirm expectations.	If calorie expectations are higher than provided on the label, calories-per-serving information can increase consumption of unhealthy, but not healthy snacks. Lower calories-per-serving backfired in that people ate more than

Table 22 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Tangari *et al.* (2019) *(cont.)*	Study 5: 115 students in the USA	Intentions to eat the snack (quantity) was assessed in Study 2. Consumption was assessed in studies 1, 3, 4, and 5.	they would have if there was no label in the case of unhealthy snacks. The negative influence on consumption (calorie disconfirmation effect) is most pronounced for individuals who manage their weight more actively.
Hartley *et al.* (2018)	153 students in Australia	Lab study testing the effect of different PACE on consumption. Over two sessions in two consecutive weeks, participants rated their liking, familiarity, and prospective consumption of 20 different label/snack combination. Actual consumption was measured.	When the PACE label was present on familiar snack foods, participants sampled 9·9% less than when such label was not present. Such pattern was not seen in unfamiliar snacks. In sum, results suggest that the PACE label may decrease familiar snack food consumption, at least in young, health-minded participants.
Jahn *et al.* (2018)	698 students in Germany	Choice-based conjoint study to assess whether CARPs, which highlight within-category differences by disclosing the average amount of sugar for a given product category, affect sugar consumption. The experimental design was 2 (CARP: high (37g) vs. low (10g)) x 2 (Source credibility: consumer protection foundations vs. the Bild German tabloid).	Provision of a high CARP increased sugar utility, compared to provision of a low CARP. Consumers chose less sugar in products when provided with a low CARP. Source credibility affected the effect of CARP on participants' choices, as more credible sources made the effect of CARPs stronger only when they were high.
Lewis & Earl (2018)	Six studies in total: 3 field studies (US, Michigan. n = 80; n = 79; n = 79), 3 online experimental surveys, 1 lab study (n = 200, n = 160, n = 300, n = 323)	Six studies were conducted to investigate the effect of granularity of labels describing portion sizes on food consumption and consumption intentions.	Across several studies, they find that finer grained descriptions of serving sizes (e.g. 15 gummy candies) are perceived as bigger, and make it easier for consumers to regulate their intake when they have a weight-loss goal than gross-grained labels such as "one serving".

Table 22 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
van Kleef *et al.* (2008)	12 groups of 8-10 participants each, in Germany, the Netherlands, France, and the UK. Groups were divided by age and family circumstance: 18–24 years old, families (25–55 years old with children in the age group 4–18 years old), and empty nesters (over 55 years old).	Focus group discussions on the appeal and information value of eight variants of FOP calorie flags.	Participants preferred simple FOP nutrition information that is supported by details on the BOP. Calories per portion was seen as useful to assess calories of what one was actually buying or consuming, while calories per 100 g was seen as an instrument for comparison. Consumers found serving calorie label as the most preferable as long as the serving represents a realistic and easy-to-understand consumption unit. Otherwise, they would rather have the energy expressed per 100 g. Finally, although participants seem to be familiar with the notion of calories, they do not seem to fully understand how to apply it. Many participants were sceptical or negative about the labels referring to exercise.

BOP, Back-Of-Pack; CARP, category average reference point; FOP, Front-Of-Pack; PACE, Physical Activity Calorie Equivalent.

3.7.2 Effects of voluntary and mandatory implementation of FOPNL schemes on consumer understanding and behaviour

A voluntary compared to a mandatory implementation of FOPNL may have significant implications for the consumer by influencing their familiarity with the label, their understanding of the label, and their behaviour. However, only a handful of studies have investigated this directly (Table 23).

One study has found that consumers' willingness to pay for products that bear a red nutrition label (i.e. indicating less healthy nutritional composition) was considerably lower (Marette *et al.*, 2019). As a consequence, FOP nutrition labels may appear disproportionately more often on healthier products as has been the case after the voluntary implementation of the HSR (Talati *et al.*, 2019b). Some authors have thus argued for mandatory labelling (Marette *et al.*, 2019; Talati *et al.*, 2019b). Consumers also seem to support a mandatory implementation of nutrition labelling (Talati *et al.*, 2019b) . More specifically, a third of participants

in Talati and colleagues' (2019b) study indicated that they 'strongly agreed' that the FOP nutrition label they were exposed to should be compulsory on packs.

A small number of studies has looked into the effect of having a nutrition label on some, but not all products on consumer understanding. Zhu *et al.* (2019) showed that voluntary FOPNL led to more purchases of participating products and as a spillover effect also led to fewer purchases of non-participating products. In addition, consumers purchased relatively healthier alternatives from both participating and non-participating manufacturers. Hagmann & Siegrist (2020) asked consumers to evaluate the healthiness of snack foods. For one group of consumers, the Nutri-Score was only presented on some of the products. They found that consumers' ratings of the healthiness of the foods was less accurate when only some products were labelled. Similar results were also found in a choice study by Anderson & O'Connor (2019) which displayed the HSR. This provides preliminary support to the idea that FOP nutrition labels should be mandatory to benefit consumer understanding, while also being in line with consumer support for mandatory implementation (Talati *et al.*, 2019b).

Table 23 Studies on the impact of voluntary vs. mandatory FOPNL

Study (most recent first)	Population	Intervention/Comparator	Outcome
Hagmann & Siegrist (2020)	1 313 consumers in Switzerland (online)	Consumers' ability to evaluate snack food healthiness with one of five FOP nutrition labels. Packages were presented with (1) the nutrition facts table (usually on BOP), (2) the MTL, (3) the Nutri-Score, (4) the Nutri-Score on half of the products, or (5) no nutrition information (control). Participants had to select the healthier option for 15 salty snacks in 105 pairwise comparisons.	The positive effect of the Nutri-Score on more accurate healthfulness choices was reduced when only some products were labelled. This suggests that it is important to have labels on all products.
Zhu *et al.* (2019)	Market study of purchases, media exposure and packaging in the US ready-to-eat cereal market, leading to a total of 14 550 observations from 30 cereal brands, observed over 485 market areas, in two-week period combinations.	Market analysis of the impact of FOP nutrition labels on the ready-to-eat cereal market in the US. They looked at cereals that have implemented voluntary FOPNL and those that have not, and measured the impact, of any, on actual consumer choices. They looked for a participating effect (i.e., the effect on purchases of those brands participating in voluntary FOPNL) and spillover effect (i.e., the	Results showed that voluntary FOPNL had a positive effect, i.e. more purchases, on participating ready-to-eat cereal products. Interestingly, voluntary FOPNL also had a negative spillover effect, meaning that non-participating ready-to-eat cereal products were purchased less. As a result of the voluntary FOPNL, consumers purchased relatively healthier ready-to-eat cereal alternatives from both participating and non-

Table 23 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Zhu *et al.* (2019) *(cont.)*		effect on those brands that did not participate in it).	participating manufacturers. These effects were stronger for healthier products, and weak or insignificant for unhealthier ones.
Anderson & O'Connor (2019)	253 participants recruited via Facebook in Queensland (Australia)	A survey-based cross sectional design to investigate the influence of the HSR on 1) participants' forced-choice responses in two-product comparisons and 2) participants' overall willingness to purchase each cereal product.	Consumers' ability to select healthier products was heightened when both products displayed a HSR (i.e. mandatory labelling), regardless of BOP viewing.
Marette *et al.* (2019)	86 French people from a region around Paris	Investigated the effect of colour-coded TL on willingness-to-pay for breakfast cereals. These breakfast cereals covered a diversity of rankings of the Nutri-Score system – six of these (labelled with A (green), C (yellow), or E (red), from a national or private brand, respectively) were included. Participants indicated the maximum price they were willing to pay for a product. They did so first for each product without nutrition information. Then, they did so for each product including information on each product's Nutri-Score. Afterwards, additional information on the TL system was provided, explaining its construction or highlighting nutrition and health. Willingness-to-pay was elicited again.	The negative impact of the red colour on willingness-to-pay dominated other effects. Based on this, the authors suggest that voluntary labels would be insufficient since companies would not voluntarily put red labels on their products. They suggest that mandatory TL labels with or without additional explanations would be most useful. Their calculations suggest that a combination of mandatory FOPNL, a standard banning low-ranking products, a tax on medium-ranking products, and a subsidy for high-ranking products would have the highest positive welfare effect.
Talati *et al.* (2019b)	12 015 participants in 12 countries (Argentina, Australia, Bulgaria, Canada, Denmark, France, Germany, Mexico, Singapore, Spain, the UK, USA)	Respondents were asked to provide their perceptions of five different FOP nutrition label schemes: HSR, MTL, Nutri-Score, RIs and warning label) in an online survey. "Perception" was a 9-item scale that included items measuring	Respondents indicated a strong preference for mandatory FOPNL regardless of label condition: 1/3 of participants selected that they 'strongly agreed' that the FOP nutrition label they were exposed to should be compulsory on-pack. The MTL

Table 23 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Talati *et al.* (2019b) *(cont.)*		liking, trust, comprehensibility, salience and desire for the label to be mandatory.	label was evaluated most favourably in this study. There were no substantial differences between countries regarding label preference.

BOP, Back-Of-Pack; FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; TL, Traffic Light(s).

3.7.3 Consumers' behaviour and understanding of FOPNL schemes for highly processed foods

Due to health risks associated with a high consumption of ultra-processed foods (Blanco-Rojo *et al.*, 2019; Fiolet *et al.*, 2018; Monteiro *et al.*, 2019; Schnabel *et al.*, 2019), there has been interest into whether FOP nutrition labels support consumers in distinguishing between single-ingredient or less processed, and ultra-processed foods. Ultra-processed foods are "made from processed substances extracted or refined from whole foods; most are shelf-stable, ready-to-eat, high in energy density, high in other nutrients of concern (e.g., free sugars, sodium), and low in beneficial nutrients (e.g., fibre)" (Taillie *et al.*, 2020b). Some associations and groups concerned with food and diets have suggested that FOP nutrition labels should take the level of processing of foods into account (e.g., Spanish Federation of Nutrition, Food and Diet Associations (www.fesnad.org).

Only a handful of studies have looked at how consumers interpret FOP nutrition labels on highly processed foods, none of which compared the interpretation of different FOP nutrition labels for highly processed compared to single-ingredient foods (Table 24). Devia and colleagues (2021) investigated the effect of combining marketing claims with nutritional warnings on highly processed foods. Adasme-Berríos and colleagues (2020) aimed to identify specific risk perception dimensions and socio-demographic variables that relate to avoiding processed foods marked by warning labels. Lemos and colleagues (2020) assessed affective reactions to images of ultra-processed foods that were preceded by green, amber, or red codes.

Due to the limited research in this area and the various foci of the studies listed, no robust conclusions can be drawn regarding the effect of FOP schemes on consumer understanding of highly processed compared to single-ingredient products.

Table 24 Studies of consumer understanding of front-of-pack nutrition labelling schemes for highly processed foods

Study (most recent first)	Population	Intervention/Comparator	Outcome
Devia *et al.* (2021)	790 participants in Uruguay	An online experiment assessed the combination of nutritional marketing claims (e.g. references to being 'home made' and images of healthy raw ingredients or a wooden table) on the front of pack of ultra-processed foods with nutritional warnings (black hexagons) on consumers' purchasing intention and perceived healthfulness.	References to home-made and images of natural foods had a positive effect on purchase intention and increased healthfulness perception. Warning labels were associated with products being perceived as less healthful and decreased purchasing intentions in most product categories. Interestingly, images of healthy foods decreased the effect of nutritional warnings.
Adasme-Berríos *et al.* (2020)	807 respondents in Chile, responsible for buying food in their home	A questionnaire was used to assess how risk perceptions are related to the avoidance of purchasing food with warning labels. Socioeconomic groups were taken into account.	Perceived risks predicted intentions not to buy processed foods with nutritional warning labels. Frequently consuming processed foods, being male and belonging to a lower-income group were associated with lower use of nutritional warning labels.
Lemos *et al.* (2020)	Study 1: 78 students in Brazil Study 2: 31 students in Brazil	Two experiments testing participants' emotional reactions to TL-coloured scheme with self-report (Study 1) and using electroencephalography (Study 2). Participants' hedonic and arousal reactions to 45 ultra-processed sweet and salty products were tested when preceded by either green, amber or red coloured circles. Study 1 used SAM (a nonverbal pictorial assessment method measuring affective reactions to stimuli), and Study 2 assessed Early Posterior Negativity.	Participants' affective reactions were more positive when they saw sweet products preceded by a red circle compared to a green or amber circle. For salty products, pictures were more arousing when preceded by green than an amber or red circle. Participants rated food healthiness correctly (less healthy when preceded by red compared to green colour). Study 2 reported a reduced Early Posterior Negativity (hypothesized to be a response to more arousing and hedonic stimuli) for the sweet products relative to salty when primed with the red circle. When primed with a green circle, the difference between sweet and salty products disappeared.

TL, Traffic Light(s).

3.7.4 Combining different FOPNL schemes and combining FOPNL schemes with claims

3.7.4.1 Combining different FOPNL schemes

All FOPNL schemes have advantages and disadvantages (e.g. very simplified, relatively complex, too little/too much information) and thus may facilitate consumers' choices in some aspect but not another (e.g choosing the healthier product overall vs. choosing the product that has least sodium). To address such issues, some have suggested that schemes combining both directive and non-directive elements can be an effective format (Hodgkins *et al.*, 2021). Consumers who have less time, motivation, and cognitive resources to process detailed information may benefit more from a simpler, evaluative FOP nutrition label, whereas consumers who are motivated, and have sufficient time and cognitive resources may additionally want to receive further information through a more detailed FOP nutrition label. However, combining FOPNL schemes should not lead to consumer confusion and should ensure that the labels do not provide seemingly contradictory information, which may increase consumers' uncertainty. In line with this argument, a criticism regarding non-summary (nutrient-specific) labels has been that these labels present a detailed evaluation of several different components, on the basis of which consumers can find it difficult to derive a summary evaluation of the healthfulness of a food product (Machín *et al.*, 2018b; Zlatevska *et al.*, 2019). This is especially the case when low and high nutrient contents are simultaneously present (Machín *et al.*, 2018b).

On the basis of the current literature search, we have found few studies that relate to the combination of FOPNL schemes more specifically (Table 25), some of which tested hybrid labels that combined aspects of different labels or added new aspects (e.g. Hoefkens *et al.*, 2012). The limited number of studies do not allow to draw robust conclusions on the effect of combining summary labels with more detailed labels as of yet. There is some indication that combinations of summary and nutrient-specific information perform relatively well in these studies regarding consumer preferences (Hoefkens *et al.*, 2012), purchase intentions and perceived healthiness (Medina-Molina & Pérez-González, 2021; Pettigrew *et al.*, 2021), or healthiness of the shopping basket (Blitstein *et al.*, 2020). However, even though too early to draw conclusions, it seems that combined labels do not perform as well as well-performing individual labels. In a study by Pettigrew *et al.* (2021), a label combining a coloured summary indicator with non-coloured (but with the words 'low'/'high') nutrient-specific information performed well, although not as well as the (non-combined) label with just the coloured summary indicator. Medina- Molina & Pérez-González (2021) showed that when both Nutri-Score and a nutrient-specific interpretative label were present, significant differences in terms of perceived healthfulness and purchase intentions were observed for products displaying a B for Nutri-Score; these differences were non-significant for products displaying a D in Nutri-Score. Another study investigating preferences regarding more detailed (i.e., GDA, HSR with verbal descriptors) or less detailed (GDA energy-only, HSR without descriptors) FOP nutrition labels found similar results (Hoefkens *et al.*, 2012). Participants preferred a non-combined label, in this case the familiar, detailed GDA format. If one was to opt for combining labels, the most preferred combination was the one showing basic (energy-only) GDA with detailed star-rating providing verbal descriptors. Blitstein and colleagues (2020) tested the effect of three different FOP labels (summary: star rating, nutrient-specific: TL, hybrid: energy per serving + stars for each nutrient in excess) or no FOPNL in a virtual supermarket, where the hybrid FOP label can be seen as a combined label. In this study, the hybrid label led to healthiest shopping basket (assessed by the Healthy Purchase Index).

Table 25 Effect of the combination of different types of front-of-pack nutrition labelling on the package

Study (most recent first)	Population	Intervention/Comparator	Outcome
Blitstein *et al.* (2020)	1 452 parents in the USA, at or below 150% of the poverty level, with at least one child aged 4-12 years.	Online 4x2 experimental design to assess how FOP nutrition labels influence food choices among low-income parents. Participants shopped with either no FOPNL or one of three FOP nutrition labels: summary (star rating), nutrient-specific (TL), hybrid (energy per serving + stars for each nutrient in excess) on the products. They either shopped under time pressure (10 minutes time constraint) or not (no limit). The summary nutrient profile of the shopping basket was assessed using Healthy Purchase Index, based on FSA score.	All FOPNL groups obtained significantly higher Healthy Purchase Index scores than the no-FOPNL control group: the hybrid label group had the highest mean Healthy Purchase Index score, followed by those in the summary label group (36.1 points), parents in the nutrient specific group, and parents in the control group. Simple FOP nutrition labels without nutrient information provides greater utility for selecting healthier products. Time pressure reduced the Healthy Purchase Index of the basket in directive and hybrid label groups.
Pettigrew *et al.* (2021)	7 545 participations in seven countries (Australia, Canada, China, India, New Zealand, UK, USA)	In an online survey experiment, participants were exposed to several breakfast cereals with four variations of the HSR, resulting from a combination of 2 types of FOP nutrition labels: summary HSR vs. hybrid HSR (summary and nutrient-specific information); and 2 types of colour condition: coloured (red/orange/green) vs. black & white) design. In each trial one product had no rating, one had 1.5 star, one had 3 stars and one had 4.5 stars. Participants indicated purchase intentions and rated the perceived healthfulness of the products.	Across countries, purchase intentions and healthiness ratings were higher when the products were labelled with the coloured, summary HSR and the hybrid-coloured FOP. The summary coloured version showed the strongest performance. There were noticeable country differences suggesting that effectiveness can vary by country context.
Medina-Molina & Pérez-González (2021)	301 university students in Spain	Online survey to assess how the co-existence with nutrient-specific interpretative labelling impacts the effectiveness of the Nutri-Score in	When products were classified as B with Nutri-Score and only this FOPNL was present, no differences are found for perceived healthfulness, but only

Table 25 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Medina-Molina & Pérez-González (2021) *(cont.)*		influencing purchase intention and healthfulness perception. Two products (one graded B, and one D on the Nutri-Score) in the same product category were presented with a) no label, 2) a nutrient-specific interpretative label, 3) Nutri-Score, 4) both nutrient-specific and Nutri-Score.	significant differences for purchase intention. However, when both types of labels were displayed in the products with B, significant differences are found for both outcomes. When products were classified as D in Nutri-Score, and only Nutri-Score was on label, significant reductions were found for both healthiness and purchase intention. However, when together with nutrient-specific interpretative labels, differences were not significant. The relationship between perceived healthfulness and purchase intention was not moderated by the various formats of interpretative labels nor by the presence of both types.
Crosetto *et al.* (2016)	Study 1: 86 subjects (47 students and 39 participants from the general public) in Grenoble, France. Study 2: 174 participants from the general public in Grenoble, France.	Lab-based menu-building task in which participants were asked to create a healthy menu. Participants were either shown 1) TL label, 2) GDA label, or 3) combination of TL and GDA label. The complexity of the task was varied in that participants had to satisfy 1, 4, or 7 nutritional criteria in their menu creation without (Study 1) and with (Study 2) a time constraint.	Study 1: Without any time pressure and the possibility to make written calculations, people are better able to create healthy menus with GDA than with TL or with a combination of TL and GDA. Study 2: In the presence of time constraints, the three labels (GDA, TL, GDA + TL) performed similarly. This effect was found controlling for individuals' food preferences and their performance in the mathematical and preference-based tasks.
Hoefkens *et al.* (2012)	1 735 University canteen users in Ghent, Belgium	Online choice experiment aimed at studying individual preferences (and the factors explaining them) for alternative nutrition labels on canteen	This non-incentivised choice experiment explored preferences for information (as opposed to product, as usual) attributes. Participants were ready to

Table 25 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Hoefkens *et al.* (2012) *(cont.)*		meals, not products. A typical dish was presented with either one of two versions of GDA (energy-only or detailed with percentages) or with either one of two versions of star rating (with or without verbal descriptor).	pay a 43% price premium to have detailed GDA label, and significantly less to have energy-only GDA information or star rating. Regarding the combination of labels, participants showed a negative preference towards a combination of two simple label formats, and of twodetailed formats. These signal both information insufficiency and information overload. The combination of basic GDA information with detailed star-rating information was the most preferred.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; FSA, Food Standards Agency; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; TL, Traffic Light(s).

3.7.4.2 Combining FOPNL schemes with claims

Some more research has been conducted on the question of combining FOP nutrition labels with nutrition claims, health claims, or marketing pictures that imply healthy or natural food on consumer understanding and interpretation of FOP nutrition labels (Table 26). Most of the reported studies explored how the presence of claims and warning labels influence consumers (Acton & Hammond, 2018b; Centurión *et al.*, 2019; Devia *et al.*, 2021; Mantzari *et al.*, 2018; Nobrega *et al.*, 2020).

For example, Acton and Hammond (2018b) tested whether participants correctly interpreted a product as 'high in' a particular nutrient (e.g. high in sodium) when a claim was either related to the same nutrient (e.g. "reduced sodium") or unrelated ("reduced fat"). Interpretations of FOP 'high in' warnings were influenced by the same nutrient claims, but not by other nutrient claims. They concluded that voluntary claims may thus undermine the efficacy of mandatory FOP nutrition labels for the same nutrient and the authors suggest that countries adopting nutrient-specific FOP warnings, should consider relevant regulations.

A few studies have looked at combining claims with other FOP nutrition labels such as the HSR or TL labels. Franco-Arellano *et al.* (2020) reported that healthier drinks with HSR or TL label were correctly perceived as healthier compared to drinks without a label irrespective of claims. However, they also report a difference by type of claim: Whereas disease reduction claims increased healthfulness perceptions compared to the same drink without a claim, nutrient claims did not have an effect on healthfulness perceptions. Comparing the effectiveness of Daily Intake Guide/GDA, MTL, and HSR in improving healthfulness of food choices when combined with nutrient or health claims, Talati and colleagues (2018) observed that adding nutrient or health claims to the package increased the likelihood of choosing less healthy products across all FOPNL conditions.

Their results suggest that claims can counteract the potential for FOP nutrition labels to facilitate identification of less healthy products. Medina-Molina and Pérez-González (2021) observed that the presence of a nutrient-specific claim (e.g., 'low fat') reinforces a positive Nutri-Score evaluation on perceived healthiness and purchase intention. However, the effect of a negative Nutri-Score evaluation on perceived healthiness and purchase intention is cancelled by the presence of a nutrient-specific summary indicator. None of the listed studies examined a potential interference of claims with endorsement logos like the Keyhole or Choices Logo or any other FOP nutrition labels not mentioned above.

Overall, while the evidence on the effect of adding voluntary claims to FOP nutrition labels on food products is mixed, there seems to be a tendency that voluntary claims and marketing images can interfere with the efficacy of FOP nutrition labels (e.g. Acton & Hammond, 2018b; Talati *et al.*, 2018). Studies testing the combination of claims with some of the existing FOP schemes (e.g. endorsement logos) are not available.

Table 26 Effect of combination of front-of-pack nutrition labelling schemes with voluntary (e.g. nutrition, health) claims.

Study (most recent first)	Population	Intervention/Comparator	Outcome
Devia *et al.* (2021)	790 participants in Uruguay	An online experiment assessed the combination of nutritional marketing claims (e.g. references to being 'home made' and images of healthy raw ingredients or a wooden table) on the front of pack of ultra-processed foods with nutritional warnings (black hexagons) on consumers' purchasing intention and perceived healthfulness.	References to home-made and images of natural foods had a positive effect on purchase intention and increased healthfulness perception. Warning labels were associated with products being perceived as less healthful and decreased purchasing intentions in most product categories. Images of healthy foods decreased the effect of nutritional warnings.
Franco-Arellano *et al.* (2020)	1 997 participants in Canada	Online survey to study the effect of four FOPNL options (1.control, 2. warning label, 3. HSR, 4. TL labelling) in combination with nutrition claims on healthfulness perceptions and purchase intentions of more or less healthy beverages. Participants saw four different drinks which varied by healthfulness (two healthier, two less healthy). Within each healthfulness category (more/less healthy),	<u>Healthfulness Perceptions:</u> Healthier drinks with HSR or TL label were correctly perceived as healthier compared to control irrespective of claims. Less healthy drinks displaying any FOPNL were perceived as less healthy compared to the control. Disease reduction claims increased healthfulness perceptions compared to the same drink without a claim. Nutrient claims did not have an

Table 26 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Franco-Arellano *et al.* (2020) *(cont.)*		they either saw one drink with/without a disease risk reduction claim, and one drink with/without a nutrient content claim.	effect on healthfulness perceptions. Purchase intentions: No claim had any effect on purchase intentions.
Medina-Molina & Pérez-González (2021)	301 students in Spain	Online survey to assess the effectiveness of the Nutri-Score in influencing purchase intention and healthfulness perception. Two products (one A, one D in Nutri-Score) presented with a) no label, 2) nutrient- specific interpretative label (claim), 3) Nutri-Score, 4) both nutrient-specific and Nutri-Score.	Purchase intentions and healthfulness perceptions were in line with Nutri-Score suggestion: it was lower when the product was labelled as "D" than when it was labelled "B". The presence of a nutrient-specific label (e.g., "low fat") reinforces a positive Nutri-Score evaluation on perceived healthiness and purchase intention. However, the effect of a negative Nutri-Score evaluation on perceived healthiness and purchase intention is cancelled by the presence of a nutrient-specific summary indicator.
Nobrega *et al.* (2020)	820 Brazilian adults	Participants were allocated to four groups in an online survey, one per product category (yogurt, juice, bread and crackers), testing two types of claims (present vs. absent) and nutritional warning (present vs. absent). Participants rated perceived healthfulness of the presented products.	Claims had a positive effect on perceived product healthiness. Nutritional warnings were more efficient than claims in their ability to significantly influence perceived healthfulness of all four products with unfavourable nutrient profile.
Centurion *et al.* (2019)	100 participants in Uruguay, recruited among students and workers of the University of Psychology, aged between 18 and 56 (75% female)	Lab experiments assessing the combination of images of fruit (with/without), nutrient claims (with/without) and nutritional warnings (with/without) on attention (eye-tracking) and healthfulness perceptions of cereal bars.	Including a nutrient claim or fruit image did not reduce the number of consumers who attended to the warning labels. Time to first fixation: Overall, participants first fixated on the fruit image, followed by the nutrient claim and nutritional warnings, before fixating on the GDA system. Fixation count: The GDA

Table 26 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Centurion *et al.* (2019) *(cont.)*			system was fixated most often, followed by nutritional warnings. Fruit image and nutrient claim received the least fixations. Participants mainly relied on nutritional warnings to make healthfulness judgments. Other features such as nutrient claims or fruit images did not impact respondents' perceived product healthfulness.
Kinard (2019)	313 participants in the USA	Experimental study to assess the effect of FOPNL on consumer impressions and purchase intentions of unhealthy snacks using a 2 (manipulated message type: motivational vs. informational) × 2 (nutritional information: present vs. absent) between-subjects design. Purchase intentions, label and product evaluations were assessed.	Nutritional information on the FOP moderated the effect of the motivational ("treat yourself") message in that positive effects of the messages on product evaluations were reduced by nutritional FOP information. Product and label evaluations influence purchase intentions positively.
Acton & Hammond (2018b)	1 000 participants in Canada	Two between- group experimental tasks assessing the combination of FOP 'high in' warnings with claims for the same or a different nutrient on consumers' ability to correctly interpret the FOP label. In the first task, respondents viewed food products labelled as 'high in sodium', with a 'reduced sodium' claim positioned next to the warning, away from the warning, or absent. In the second task, participants viewed a food product labelled as 'high in sugar', with a 'reduced fat' claim positioned next to the warning, away from the warning, or absent. Participants then identified whether the products contained high levels of the indicated nutrients.	Participants were more likely to correctly interpret a product as high in sodium when they did not see a "reduced sodium" nutritional claim. Interpretations of FOP "high-in" warnings were not influenced by other nutrient claims. Voluntary claims may thus undermine the efficacy of mandatory FOP nutrition labels for the same nutrient and the authors suggest that countries adopting nutrient-specific FOP warnings, should consider relevant regulations.

Table 26 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Mantzari *et al.* (2018)	2 002 parents of 11–16-year-olds living in the UK, with a total household consumption of SSBs of at least 500 ml each week.	Online experiment in which participants had to select one drink from a virtual vending machine for their child. The SSBs displayed an image warning or not following a between-subject factorial design: 3 (image-based warning label: no image, picture of rotting teeth, picture of a teaspoon of sugar) × 2 (calorie information label: absent, present).	Adding a calorie information label to the rotting teeth image label did not have an additive effect on the proportion of participants choosing a SSB from the vending machine. Adding a calorie information label to the sugar content image label was not more effective than the sugar content label alone, but was more effective than using calorie information label alone.
Talati *et al.* (2018)	2 069 adults and children in Australia	Discrete choice experiment to assess the effectiveness of FOP nutrition labels in improving healthfulness of food choices when combined with nutrient or health claims on-pack. Respondents saw eight choice sets, each containing four product alternatives of the same product category (cookies, cornflakes, pizza or yoghurt). They saw the same FOP nutrition label (Daily Intake Guide, MTL, HSR) across sets.	Participants were more likely to avoid unhealthy products and choose healthy products when FOP nutrition labels were presented on the package without claims. Adding nutrient or health claims to the package increased the likelihood of choosing less healthy products across all FOPNL conditions, suggesting that claims can counteract the potential for FOP nutrition labels to facilitate identification of less healthy products.
Talati *et al.* (2016)	50 adults and 35 children aged 10-17 years in Australia, divided into ten groups.	Focus group discussions in which participants were shown the three FOPNL schemes: Daily Intake Guide, MTL, and HSR. Food packages featured different combinations of FOP nutrition labels and health claims. The relationship between the FOP nutrition labels and health claims was designed to be somewhat contradictory in that the health claims promoted a positive aspect of the food while the FOP nutrition labels provided a negative overall picture of the food.	FOP nutrition labels were the preferred source of information, especially if the information in the health claim and the FOP nutrition label conflicted. Trust in FOP nutrition labels was greater than for health claims, due to the perception that FOP nutrition labels have a stronger factual basis and are supervised by regulation. Health claims are seen mainly as marketing messages. Participants reported that

Table 26 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Talati *et al.* (2016) *(cont.)*			they use health claims only if they are trusted, relevant and informative. FOP nutrition labels are used when they are trusted and easy to understand. Evaluative FOP nutrition labels seemed to reduce any positivity bias created by health claims on unhealthy foods.

FOP, Front-Of-Pack; GDA, Guideline Daily Amount(s); HSR, Health Star Rating; MTL, Multiple Traffic Light(s); TL, Traffic Light(s).

3.7.5 Conclusions regarding effects of the implementation of different labelling aspects on consumer understanding, preferences and impact on consumer behaviour

On the basis of the reviewed articles for this update, we can draw the following conclusions regarding effects of the implementation of different labelling aspects on consumer understanding, preferences, and impact on consumer behaviour.

I. The use of different reference quantities can influence behaviour; clarity, granularity, and consumers' expectations about nutritional value play a role and can influence (intended) consumption. This underlines the conclusion drawn in 3.4.1.1 that **salient, consistent and simple** reference quantities are preferred and that consumers generally understand nutritional information better when it requires less "mental math" to process the information**.**

II. Regarding **voluntary or mandatory labelling**, the limited evidence suggests that mandatory labelling may be beneficial for consumers' understanding of labels, and that consumers prefer a mandatory implementation.

III. Due to the very limited number of studies that address various aspects, no robust conclusions can be drawn regarding the effect of FOP schemes on consumer understanding of and behaviour regarding highly processed compared to single-ingredient products.

IV. The limited number of studies currently available do not allow to draw robust conclusions on **the effect of combining summary labels with more detailed labels**. There is some preliminary indication that combinations of summary and nutrient-specific information seem to perform relatively well in some studies regarding consumer preferences, purchase intentions, perceived healthiness, or healthiness of the shopping basket. However, even though too early to draw conclusions, it seems that combined labels do not perform as well as well-performing individual labels.

V. While the evidence on the effect of **adding voluntary claims to FOP nutrition labels on food products is mixed**, there seems to be a tendency that voluntary claims and marketing images can interfere with the efficacy of FOP nutrition labels.

3.8 Effects of FOPNL on diet and health

There is only limited literature on the effect of FOPNL on diet and health due to the difficulty in measuring consumers' diet over long periods of time and to integrate this with information on FOP label-driven food purchases as well as assess the eventual effect of FOP nutrition labels on health against the counterfactual of no FOP nutrition label exposure. In order to evaluate the effectiveness of FOPNL on diet and health, it is crucial that these FOPNL schemes or the underlying nutrient profiles correctly classify foods. Although not the focus of the current systematic review, we have identified, among the retrieved papers, those that examined the agreement of different FOPNL schemes with other appropriate measures of healthfulness of the food products (Table 27) or national dietary guidelines (Table 28).

Many of the studies used compliance to Nutrient Profile Models or relevant Nutrient Profiling criteria as a healthfulness measure. Agreement was dependent on the FOP scheme used and the food group assessed (Contreras-Manzano *et al.*, 2018; Kupirovic *et al.*, 2020). For example, Contreras *et al.* (2018) found no differences in the proportion of foods classified as compliant between the PAHO model and the 5-star criteria of the HSR; other nutrient profile schemes such as Ecuador's MTL, the Mexican Nutritional Seal and the Chilean Warning Octagons classified ~2-8 times more products as eligible compared to PAHO. Kupirovic *et al.* (2020) examined the agreement of Nutri-Score against three nutrient profile models (Ofcom, WHO Europe, and Food Standards Australia New Zealand- FSANZ) and showed that agreement varied from near perfect (e.g. with Ofcom for breakfast cereals, cheese and pasta; with FSANZ for pasta; with WHO Europe Nutrient Profile Model for cooking oils) to none-to-slight (e.g. with WHO Europe Nutrient Profile Model for yoghurt products) (see Table 27 for more details). Kupirovic *et al.* (2020) further assessed agreement of the NutriScore with health symbols and found that 5% and 0.9% of all sampled foods would be at same time eligible to carry Protective Food symbol or a Finnish Heart Symbol, respectively, but were labelled as non-green by the Nutri-Score. Similarly, Dunford *et al.* (2018) found divergence in HSR ratings and eligibility to display a health claim using the Nutrient Profiling Scoring Criterion (NPSC) in certain food groups; using a HSR cut-off of 3.5 stars ensured the highest agreement between the HSR and products' eligibility to display a health claim.

Other studies evaluated FOP schemes against the NOVA classification for ultra-processing (i.e. products formulated mostly or entirely from substances extracted from foods or derived from food constituents, which are made possible by the use of many types of additives) and showed that products across different processing classes had relatively high median HSRs and the majority of ultra-processed foods received ≥ 2.5 stars (Dickie *et al.*, 2018, 2020) or >3.5 stars (Pulker *et al.*, 2020).

When using wholegrain content as a healthfulness measure, Curtain & Grafenauer (2019) showed that although significant differences were observed between wholegrain bread and breakfast cereal over refined grain varieties, the mean difference in stars was low (0.4 for bread and 0.7 for breakfast cereal). Dunford *et*

al. (2019) showed that mean HSR could discriminate well food groups that are typically considered healthy (such as fruit, vegetables, nuts and legumes) and products high in sugar (confectionary, sugars, honey and related products); however sodium content of foods was not consistently related to HSR ranking. Ranges of HSR ratings were found to overlap between healthy or less healthy products (Morrison *et al.*, 2019).

Overall, FOPNL's ability to classify products in relation to their healthfulness is at times low depending on the food category assessed; this highlights the need of further refinement of FOP schemes to capture different healthfulness aspects more accurately.

Table 27 Studies of different front-of-pack nutrition labelling schemes in relation to the healthfulness of the food supply

Study (most recent first)	Population	Intervention/Comparator	Outcome
Pulker *et al.* (2020)	291 products in Australia	This study aimed to assess the nutritional quality of Australian SOBCCF (supermarket own brands chilled convenience foods), by addressing the following research questions: (1) What proportion of Australian SOBCCF are classified as healthy or unhealthy using contemporary nutrition recommendations and assessment criteria, including the Australian Guide to Healthy Eating, NOVA and HSR score? (2) Does classification of nutritional quality of SOBCCF differ between the three measures? (3) Does the nutritional quality of SOBCCF differ between supermarkets? Nutritional quality was assessed using the principles of the Australian Guide to Healthy Eating, NOVA classification of level of food processing and HSR scores.	There was moderate agreement between the Australian Guide to Healthy Eating and the HSR (3.5 stars cut-off); and fair agreement between AGTHE and the HSR (2.5 stars cut-off); and poor agreement between NOVA and the HSR (3.5 stars cut-off). 41.8 % of SOBCCF were classified as unhealthy by the Australian Guide to Healthy Eating but as healthy using the HSR (3.5 stars cut-off). 64.6 % of SOBCCF were classified as ultra-processed (unhealthy) by NOVA but classified as healthy by the HSR (3.5 stars cut-off).
Dickie *et al.* (2020)	4 251 new food and beverage products carrying a HSR label in Australia	Products (excl. 'baby foods' and 'alcoholic drinks') bearing the HSR were extracted from the Mintel Global New Product Database between the 27th	The median star rating for minimally processed, processed, non-ultra processed combined, and ultra-processed food products was 4.5, 4.4, and

Table 27 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Dickie *et al.* (2020) *(cont.)*		of June 2014 and 30th of June 2019. They were classified into one of four NOVA categories, and either as an Australian Dietary Guidelines 'five food group' food or discretionary food.	3.5, respectively. The median HSR for each category of NOVA was ≥2.5 (healthy pass). There were significant differences between the median HSR of the ultra-processed category (median 3.5) and that of minimally processed (median 4.5), processed (median 4) and non-ultra processed groups combined (median 4). For ultra-processed foods, 73.0% scored an HSR ≥ 2.5, and 55.3% scored an HSR ≥ 3.5, compared to 91.0% and 83.1% for non-ultra-processed foods combined.
Kupirovic *et al.* (2020)	1 370 products from five food categories (Cereal and cereal products, dairy, edible oils and emulsions in Slovenia	The goal of the study was to evaluate the alignment of different FOPNL schemes. A variety of existing FOPNL schemes was evaluated: three interpretive nutrition rating systems (Nutri-Score, HSR, TL system), four health symbols (Protective Food symbol, Choices, Finnish heart, and Keyhole symbol), and also three nutrient profile models developed for other purposes: Ofcom, WHO Europe and FSANZ. For each FOPNL scheme, the proportion of "healthier" products was calculated. The following criteria were used for the different nutrient profiling systems: Keyhole, Protective Food symbol, Dutch Choices symbol, Finnish Heart Symbol: permitted to carry health symbol; Ofcom, WHO Europe: permitted for marketing to children; FSANZ: permitted to carry	The agreement was near perfect between Nutri-Score and the Choices symbol, Finnish heart, Keyhole for cooking oils, and HSR for pasta. A none-to-slight agreement was seen in cooking oils between Nutri-Score and TL. A none-to-slight agreement in yoghurt products between Nutri-Score and Choices symbol, Finnish heart, and Keyhole, and in pasta between Nutri-Score, and Finnish heart and Keyhole. The agreement between Nutri-Score and Ofcom was near perfect for breakfast cereals, cheese and pasta; between Nutri-Score and FSANZ for pasta; between Nutri-Score and WHO Europe for cooking oils. A none-to-slight agreement in yoghurt products between Nutri-Score and WHO Europe. The agreement between the Protective Food symbol and the traffic light system is near perfect for breakfast cereals, cheese and pasta, moderate for the yogurt

Table 27 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Kupirovic *et al.* (2020) *(cont.)*		health claims; Nutri-Score: rated as dark green A or light green B; HSR: scored 3.5 or more; TL system: no red lights.	products, and none for cooking oils. Agreement between the Protective Food symbol and Nutri-Score is substantial in all categories, except the yogurt products,where it is moderate. 5% of all sampled foods would be at same time eligible to carry Protective Food symbol, but labelled as non-green by Nutri-Score. Such a scenario would occur in 0.9% of sampled foods for the Finnish Heart symbol.
Morrison *et al.* (2019)	252 and 156 children's packaged food products collected in 2016 and 2013, respectively, in Australia	The study aims to examine whether the nutritional quality of children's packaged food products available in Australian supermarkets has improved between 2013 and 2016, and whether any change could be detected in product reformulation after the introduction of the HSR labelling scheme. Two methods to assess nutritional quality: a) the NPSC that applies the same criteria used by FSANZ to allow use of health claim (products with score <4 deemed healthy), and b) core food method that considers top 3 ingredients on the package list (major ingredients) and classifies products as 'less healthy' if one of them provides added sugar, SFA or sodium.	'Healthy' foods had a significantly higher mean HSR compared to 'less healthy' foods using the NPSC method, but no difference using the core food group method. The range of ratings appeared to overlap for 'healthy' and 'less healthy' products, with ratings ranging from 1.0 to 5.0 stars and 1.0 to 4.0 stars, respectively.
Curtain & Grafenauer (2019)	441 products from 6 grain –related sub-categories in Australia	This study aimed to determine how effectively HSR differentiates wholegrain and refined grain foods. Products were sampled from the following groups: bread, rice, pasta, noodles, flour, and breakfast cereals.	There was a significant difference in HSR between wholegrain bread and breakfast cereal over refined grain varieties, yet the mean difference in stars depicted on the pack was only 0.4 for bread and 0.7 for breakfast cereal. There was no

Table 27 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Curtain & Grafenauer (2019) *(cont.)*			difference for rice or flour. Median HSR also poorly differentiated wholegrain. More wholegrain foods scored 4–5 stars compared to refined grain ones, yet there was notable overlap between 3.5–5 stars.
Dunford *et al.* (2019)	394 815 products in 12 countries (Australia, Canada, Chile, China, India, Hong Kong, Mexico, New Zealand, Slovenia, South Africa, the UK, and USA)	The healthiness of packaged foods and beverages was compared using the HSR. Data included in the analysis were collected between 2013 and 2018. Each product was assigned to a food or beverage category and mean HSR was calculated overall by category and by country. Median energy density (kJ/100 g), SFA (g/100 g), total sugars (g/100 g) and sodium (mg/100 g) contents were calculated. Countries were ranked by mean HSR and median nutrient levels.	Food groups considered as healthy such as fruit, vegetables, nuts and legumes, and eggs had the highest mean HSR (3.63 and 3.76 respectively), followed by seafood (3.50). Confectionery had the lowest HSR of all categories examined (1.23) followed by sugars, honey and related products (1.39). Countries with higher overall HSR tended to also rank better with respect to nutrient content of their foods and beverages. However, sodium content of foods was not consistently related to HSR ranking. For example, Canadian and USA products with high HSR scores (i.e. top tertile for mean HSR) also had high sodium content (i.e. top tertile for median sodium content).
Contreras-Manzano *et al.* (2018)	2 544 products were sampled from 5 food and beverage categories in Mexico	The products were classified as compliant and non-compliant according to seven nutrient profiling systems: the PAHO model, which served as the reference nutrient profile; the NPSC; the Mexican Committee of Nutrition Experts; the HSR; the Mexican Nutritional Seal; the Chilean Warning Octagons 2016, 2018 and 2019 criteria; and Ecuador's MTL.	No differences in the proportion of foods classified as compliant were observed between the PAHO model (2.3%) and the 5-star criteria of the HSR (2.9%). Higher proportion of foods compared to PAHO were classified as compliant by Ecuador's MTL (<5.4%), the Mexican Nutritional Seal (18.9%), and the 2016 criteria of the Chilean Warning Octagon (17.2%).

Table 27 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Contreras-Manzano *et al.* (2018) *(cont.)*		The following five food and beverage categories were selected: non-dairy beverages; breakfast cereals; dairy products; ready-made foods; and salty snacks.	When examined by food category, HSR classified a higher proportion of ready-to-eat cereals, and salty snacks; and Ecuador's MTL classified a higher proportion of beverages as compliant compared to the PAHO Model.
Dickie *et al.* (2018)	1 269 new food and beverage products carrying a HSR label in Australia	The Mintel Global New Products Database was searched for every new food product displaying a HSR entering the Australian marketplace from 27 June 2014 (HSR system endorsement) until 30 June 2017. Products were categorised by the four NOVA food processing categories: unprocessed and minimally processed, processed culinary ingredients, processed, and ultra-processed, and the distribution of the star ratings within each category was compared and analysed.	Products classified as unprocessed and minimally processed, processed and ultra-processed, all had high median HSRs (4.5, 4 and 3.5, respectively), with statistically significant differences detected between all categories. A relatively lower median HSR of 1 was observed for processed culinary ingredients products. The majority of unprocessed and minimally processed (98.1%), processed (89.8%) and ultra- processed products (76.9%) displayed an HSR ≥ 2.5 stars. The majority of processed culinary ingredients products scored an HSR ≤ 2 stars (89.5%).
Dunford *et al.* (2018)	41 297 packaged food products in Australia	The objective of this study was to examine the agreement between the HSR and NPSC that determines eligibility to display a health claim. Data was obtained by four major Australian supermarkets and supplemented by data provided direct by manufacturers and crowdsourced through the FoodSwitch smartphone application.	The highest agreement between the HSR scoring algorithm and the NPSC threshold to determine eligibility to display a health claim was at the HSR cut-off of 3.5 stars. Overall, 97.3% of products with star ratings of 3.5 or higher were also eligible to display a health claim, and 94.3% of products with star ratings less than 3.5 were ineligible to display a health claim.

Table 27 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Dunford *et al.* (2018) *(cont.)*			Divergence was apparent in certain food categories: • In 'edible oils', 45% products had HSR >3.5, but 64% were eligible to display a claim. • 'Yoghurts and yoghurt drinks', 'soft drinks', and 'packaged fruit' had large absolute numbers of products with HSR <3.5 but eligible to display a claim • 'Milk', 'processed meat', and 'nuts and seeds' had large absolute numbers of products with HSR≥3.5, but ineligible to display a claim.

FOPNL, Front-of-pack nutrition labelling; FSANZ, Food Standards Australia New Zealand; HSR, Health Star Rating; MTL, Multiple Traffic Light(s); NPSC, Nutrient Profilling Scoring Criterion; Ofcom, UK Office of Communications; PAHO, Pan American Health Organization; SFA, Saturated fat; TL, Traffic Light(s); WHO, World Health Organization.

The few relevant identified studies presented in Table 28 showed a reasonable agreement between FOP scheme ratings and dietary recommendations. The available studies addressed HSR and the Nutri-Score. Fruit and vegetables, a food category promoted across different national guidelines, received higher star ratings and were mainly classified in the dark green (A) or green (B) Nutri-Score categories. Sugary snacks, sugar products or animal fat products that are generally discouraged by national recommendations, were mainly classified as orange (D) or dark orange (E) (de Edelenyi *et al.*, 2019; Dréano-Trecant *et al.*, 2020). On the other hand, in the study by Dickie *et al.* (2020), 52.8% of all discretionary foods scored ≥2.5 stars, with snacks having the largest proportion of discretionary products scoring ≥2.5 stars, at 35%.

Table 28 Agreement between front-of-pack nutrition labelling scheme ratings and dietary recommendations

Study (most recent first)	Population	Intervention/Comparator	Outcome
Dickie *et al.* (2020)	4 251 new food and beverage products carrying a HSR label in Australia	Products (excl. 'baby foods' and 'alcoholic drinks') bearing the HSR were extracted from the Mintel Global New Product Database between	The median HSR rating for FFG foods was 4 stars, significantly higher than the median for discretionary foods at 2.5 stars. Fruit and

Table 28 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Dickie *et al.* (2020) *(cont.)*		the 27th of June 2014 and 30th of June 2019. They were classified into one of four NOVA categories, and either as an Australian Dietary Guidelines 'five food group' food or discretionary food.	vegetables had the highest median HSR of all food groups, both at 4.5 stars. The distribution of star ratings for 'five food group' foods was strongly skewed towards higher star ratings, and the majority scored ≥2.5 stars (95.5%). The star ratings for discretionary foods were evenly distributed along the 10-point scale, and 52.8% scored ≥2.5 stars. Of the Mintel categories, Snacks had the largest proportion of discretionary products scoring ≥2.5 stars, at 35%.
Dréano-Trécant *et al.* (2020)	11 347 foods and beverages from eight European countries (Finland, France, Norway, Poland, Portugal, Slovakia, Sweden, and Switzerland)	The European Food Information Resource (EUROFIR) nutritional composition databases from eight European countries were used. The distribution of foods across the Nutri-Score classes within food groups was assessed, as well as the discriminating performance of the label, and the adequacy of nutritional recommendations.	The Nutri-Score demonstrated high discriminating ability for all food groups, with similar trends in the eight countries, and consistency with nutritional recommendations. For instance, fruit and vegetable products were mainly classified in the two healthiest Nutri-Score categories, while sugar and animal fat products were mainly classified in the two less healthy categories of the Nutri-Score. Within food categories, the Nutri-Score seemed to discriminate between refined and whole products. Indeed, for example, wholegrain breads were better classified than white breads.
de Edelenyi *et al.* (2019)	8 587 foods and beverages in Germany	Food composition data concerning German foods was retrieved from the Open Food Facts project database. Foods were categorized using a consumer's point of view, grouping foods with similar use and with distinct	A total of 79.7% of products from "fruits and vegetables", 69.3% of products from "Cereals and potatoes" were classified as dark green (A) or green (B), while 93.4% of products from "Sugary snacks" were classified as

Table 28 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
de Edelenyi *et al.* (2019) *(cont.)*		nutritional characteristics. Main food groups included 'Products containing mainly fruits and vegetables', 'Cereals and potatoes', 'Meat, Fish and Eggs', 'Milk and dairy products', 'Fats and sauces', 'Composite foods', 'Sugary snacks', 'Salty snacks' and 'Beverages'.	orange (D) or dark orange (E). Among beverages, while a majority of fruit juices were classified as C (70.1%), soft drinks were classified as E.

HSR, Health Star Rating.

3.8.1 Associations between diet quality and health

Since the publication of the previous report, one study (Egnell *et al.*, 2021) examined the association of diet quality based on the UK FSA Nutrient Profiling System and disease risk and found that better diet quality was associated with lower risk for overweight but not obesity.

Table 29 Studies using the Diet Index based on the UK Food Standards Agency (FSA) Nutrient Profiling System to examine associations between diet quality and disease risk.

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2021)	Subset of 71 403 adults from the NutriNet-Santé cohort in France	The study aimed to investigate the associations of the original UK FSA-dietary index and three variants, i.e., the FSANZ one (NPSC), the HSR, and the French one (HCSP), with weight status.	The Hazard Ratio for overweight in participants with lowest diet quality compared to those with highest diet quality was 1.27 for the HCSP-Dietary Index; 1.18 for the original FSA-Dietary Index; 1.14 for the NPSC-Dietary Index; and 1.12 for the HSR-Dietary Index. No association was found between any of the four dietary indexes and the risk of obesity. When models were adjusted for the proportion of ultra-processed food intake in diet, only the association between the HCSP-Dietary Index and risk for overweight remained significant (Hazard Ratio, T3 vs. T1 = 1.16)

FSA, Food Standards Agency; FSANZ, Food Standards Australia New Zealand; HCSP, Haut Conseil de la santé publique; HSR, Health Star Rating; NPSC, Nutrient Profilling Scoring Criterion.

3.8.2 Effect of FOP nutrition labels on diet and health – food perception experiments

FOPNL can affect consumers' perception of the tastiness of foods, which in turn may influence purchasing and consumption decisions. The few studies retrieved since the previous report (Table 30), suggest that FOP nutrition labels have the potential to guide consumers towards healthier products, but socio-cultural context (for example trying to make socially desirable choices) is important in achieving the desired impact.

Table 30 Studies highlighting the impact of front-of-pack nutrition labelling on consumers' tastiness evaluations of foods.

Study (most recent first)	Population	Intervention/Comparator	Outcome
Ares *et al.* (2020)	163 adults in Uruguay	The aim of the present work was to explore the effect of the inclusion of nutritional warnings on consumer associations with labels of ultra-processed products. The study was conducted at two time points, before (T1) and after (T2) the compulsory implementation of nutritional warnings in the Uruguayan marketplace. Participants evaluated three labels of ultra-processed products (i.e. crackers, soup, yogurt) using a word association task. At T1, the labels were presented without warnings; at T2, the labels were presented with nutritional warnings (for excessive sodium in crackers and soup; for SFA in crackers; and for sugars in yoghurts), designed as black octagons with the expression "Excess" followed by the corresponding nutrient, according to the Uruguayan regulation.	For both soup and yoghurt, the percentage of people that used the word 'tasty' to describe the product at T1 was significantly higher that at T2. For crackers, no difference was observed between T1 and T2 for 'sweet/salty'; 'too salty/sweet'; 'liking'; and 'disliking'. For soup, between T1 and T2, mentions for 'sweet/salty' increased, and no difference was observed for 'too salty/sweet', 'liking' and 'disliking'. For yoghurt, between T1 and T2, mentions for 'sweet/salty' and 'too sweet/salty' increased while no difference was observed in 'liking' and 'disliking'.
Kunz *et al.* (2020)	173 adults in Austria	A stimulus pool was created with dessert products varying in the displayed amount of sugar (low, medium, high). A nutrition label was added to each picture, displaying the amount of sugar per 100 g of each dessert. Participants	The presence of TL labels did not influence the strength of the explicit belief that unhealthy food tastes better than healthy food. Contrary to the expectations, expected tastiness of low sugar products did not

Table 30 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Kunz *et al.* (2020) *(cont.)*		were randomly assigned to one of two label conditions: a) neutral white label, and b) coloured according to the TL coding system (green, amber and red) by the UK FSA. Each participant saw 20 pictures, drawn randomly from this stimulus pool. Expectations of products' healthiness and tastiness, as well as purchase intentions were assessed.	decrease when TL labels were present. In fact, participants expected products with a low sugar level to be slightly tastier compared to the products with a high level of sugar.

FSA, Food Standards Agency; SFA, Saturated fat; TL, Traffic Light(s).

3.8.3 Effects of FOP nutrition labels on diet and health – food selection in online choice tasks

The majority of the studies found in the literature use online experimental conditions in order to explore the effect of the presence of FOP nutrition labels on the nutritional quality of consumers' food and beverage choices and nutrient intakes (Table 31).

Nutritional quality of products was evaluated using energy density, as well as the products' content in nutrients of public health interest (protein, fibre, sugar, sodium, SFA). Overall, the presence of FOPNL schemes is associated with higher nutritional quality of consumer choices.

Five studies evaluated the effect of the presence of FOPNL on the nutritional quality of the specific products selected (Acton *et al.*, 2019; Acton & Hammond, 2020; Billich *et al.*, 2018; de Alcantara *et al.*, 2020; Goodman *et al.*, 2018; Talati *et al.*, 2019b). Billich *et al.* (2018) and de Alcantara *et al.* (2020) show that the presence of FOPNL is associated with decreased selection of energy dense snacks, and sugar sweetened beverages compared with no-label conditions. The presence of Nutri-Score and MTL schemes has been shown to help towards healthier food choices (Talati *et al.*, 2019b), while MTL have also been shown to assist consumers in choosing snacks with higher fibre content.

Another set of studies evaluated the impact of FOPNL on the nutritional quality of total shopping baskets. Participants had to simulate their grocery shopping in an online supermarket environment (Egnell *et al.*, 2019a; Finkelstein *et al.*, 2019; Machín *et al.*, 2018a, 2018c; Shin *et al.*, 2020). Two studies reported no statistically significant difference of the dietary quality of the total shopping basket among the FOPNL and the control groups (Finkelstein *et al.*, 2020; Machín *et al.*, 2018a). However, most of the studies showed that the dietary quality of the shopping cart was improved in the FOPNL conditions compared to the control condition (Egnell *et al.*, 2019a; Finkelstein *et al.*, 2020; Machín *et al.*, 2018a; Shin *et al.*, 2020).

Overall, the presence of evaluative FOPNL schemes (e.g. colour-coded schemes, positive logos) is associated with positive changes in the nutritional content of the foods and beverages that consumers select.

Table 31 Studies assessing the impact of front-of-pack nutrition labelling schemes on food selection in online choice tasks

Study (most recent first)	Population	Intervention/Comparator	Outcome
Acton & Hammond (2020)	3 584 Canadians aged 13 and older, recruited in shopping centres located in 3 Canadian cities	Participants were randomly assigned to one FOPNL condition (MTL, Nutri-Score, 'High in' warning label, HSR or control group) and then had to complete three consecutive purchasing tasks. For each of the tasks participants were given money (budget 5$ per item) and shown a print-out looking like a store shelf, and had to decide on an iPad which product they wanted to buy out of 20 snack products.	There were no differences in the protein and calcium density of snacks purchased among the 5 FOPNL conditions. Participants using MTL and HSR purchased products with higher fibre density compared to control. Participants using MTL purchased snacks with greater fibre density compared to the ones who used the 'High in' label or the nutrition grade labels.
de Alcantara *et al.* (2020)	1 232 participants 18-65 years old	Participants were randomly assigned in three groups: i. without information about sugar content, ii. Health logo and iii. Nutritional warning. They were asked to imagine that they were at the supermarket and to complete six-choice task, one for each of the selected product categories. For each of the product categories participants were presented with the three packages and were asked to indicate the one they would buy; they were required to choose only one of the products.	Labels with information about sugar content made consumers more likely to choose the healthier product. Nutritional warnings were more effective compared to health logos. The word association task suggested that this pattern may be due to warnings increasing the salience of the negative effects of sugar.
Finkelstein *et al.* (2020)	146 participants over 21 years of age in Singapore, that were the primary grocery shopper for their household	An online grocery store was developed that contained products across major food and beverage categories. A simple 'low calorie' logo was designed. The study was divided in three arms: Arm 1 was the control condition were the logo was not displayed. Arm 2	For total shopping baskets there was no statistically significant difference in calories purchased per dollar spent, total calories purchased, total spending and calories per serving across the three conditions. Relative to control

Table 31 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Finkelstein *et al.* (2020) *(cont.)*		displayed the logo in 20% of products that were lowest in calories per serving within each product category. Arm 3 displayed the label on the 20% of all products that were lowest in calories per serving. Using a crossover design all participants were exposed to all three conditions. Participants were asked to shop once a week for a total of three weeks.	condition there was a 3% increase in labelled products purchase in Arm 2 condition. For beverages, there was a significant calorie reduction in the both intervention arms.
Shin *et al.* (2020)	125 adults residents of Singapore aged 21 and over, and primary grocery shopper for their households	Experiment to test the effect of DFLF; compared to no label, allowing for consumers to choose from and toggle between any of seven FOP nutrition labels at the click of a button in an online grocery store website. The seven FOP nutrition labels included: a) Nutri-Score which was the default and also used to evaluate the effects of this experiment, b) calorie information as physical activity equivalents; c) calories; d) sugar content; e) sodium content; f) SFA content; and g) total fat content. Labels c-e were expressed per serving and percentage of Daily Recommended Intake. The DFLF also provided a live visual indicator of the healthiness of the shopper's basket. For each product a participant chose to buy, the healthiness of the product was evaluated by all seven different food labels with the MTL colours.	DFLF features improved nutritional quality (average Nutri-Score increased by 0.41 (12.6%) to 3.67 in the DFLF arm compared to control) The distribution of purchased products by Nutri-Score was: • Green (A or B): 56% control vs. 66% for DFLF • Yellow (C): 17% control vs. 16% for DFLF • (Dark) Orange (D or E): 27% control vs. 18% for DFLF DFLF significantly decreased the amount of sugar per serving by 0.85 g. No significant effect was found for other nutrients.

Table 31 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Acton *et al.* (2019)	3 584 Canadian participants aged ≥13 years	Participants were randomly assigned to FOPNL condition (MTL, Nutri-Score, 'High in' warning, HSR, or control group) and had to complete eight purchasing tasks. Each participant was given money and shown a printout looking like a store shelf and had to decide on an iPad which product they want to buy. In the first 5 tasks, they had to choose between 20 beverages and in the three last tasks between 20 snacks.	Participants in MTL and "High-in" groups purchased less sodium and calories in comparison to control condition. Participants in MTL group purchased less sodium and calories than colour-graded group. Participants who viewed the HSR purchased less calories than control condition. No significant differences between the FOPNL conditions in the amount of sugars and SFA. Participants in the 'high in' condition purchased beverages with 11% less sugars, 18% less SFA, and 12% fewer calories compared to the control condition.
Egnell *et al.* (2019a)	1 866 participants 18-25 years old who were studying in France and doing grocery shopping.	An experimental online supermarket that included 751 food items divided in 20 categories was created. For each food item, at least two different versions were proposed including a national brand and a retailer's brand. Participants were asked to simulate their food purchases as if they were in their usual supermarket; no payment was required. According to the trial arm, the items had a Nutri-Score label, a RIs label or no label. Raw products had no labels, as these items are not subject to European mandatory nutrition labelling.	The nutritional quality was higher in the Nutri-Score group than in the RIs group. Lower shopping cart content of calories and SFA and a higher content of fruits and vegetables in the Nutri-Score group than in the other 2 groups. Lower content of sodium and protein and a higher content of sugars in the Nutri-Score group than in the no-label group, as well as lower content of fibre than in the RIs group. There were no significant difference between the RIs and no-label groups with respect to calories, SFA, sodium, fibre, or fruits and

Table 31 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2019a) *(cont.)*			vegetables. There were significantly higher levels of sugars, and lower levels of protein in the RIs group than in the no-label group. In the two arms in which labels appeared on prepackaged foods, and in particular in the Nutri-Score group, substitutions between food groups were observed, with more raw products (mainly fruits and vegetables). The Nutri-Score appears to be more effective than the RIs label in encouraging students to make food purchases of higher nutritional quality.
Finkelstein *et al.* (2019)	147 Singapore adults	An online experimental grocery store was developed and contained over 4 000 products commonly purchased in local supermarkets. Participants logged on the supermarket website once a week and were asked to purchase their weekly groceries. Each participant shopped a total of three times during the study, including one shop in each of the three shopping conditions. The intervention was divided in 3 arms: Arm 1 was a control condition that mirrors a traditional web-grocery with BOP nutrition information panels but with no FOP nutrition labels. For arm 2, MTL was displayed on the FOP of all products. In arm 3, Nutri-Score labels were displayed on the FOP of all products. Prior to each shopping trip,	Both FOP nutrition labels showed statistically significant improvement in the dietary quality of the shopping carts. The estimated increase was 1.09 in Nutri-Score and 1.16 in MTL compared to the control condition. The effect was not significantly different between labels. In MTL, energy decreased by 19.75kcal, fat decreased by 1.03g, and protein decreased by 0.83g per serving compared to control. In Nutri-Score, total SFA per order decreased by an estimated 29.29g compared to control. Nutri-Score performed better than both MTL and the control condition (no FOP nutrition labels) based on average Nutri-Score of the shopping basket but, unlike MTL, it

Table 31 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Finkelstein *et al.* (2019) *(cont.)*		a 60 second introductory video briefly explaining the MTL or Nutri-Score labels was shown to participants in the corresponding condition. The primary outcome is diet quality per shopping trip as measured by a modified index of diet quality, AHEI 2010. Higher scores on the AHEI are strongly associated with a lower risk of major chronic diseases and cardiovascular disease. A secondary measure of diet quality, was the average Nutri-Score of the shopping basket, weighted by serving size, which was calculated by applying A =5 down to E = 1 for each food purchased.	did not reduce calories or sugar from beverages.
Talati *et al.* (2019b)	11 000 participants from Argentina, Australia, Bulgaria, Canada, Denmark, France, Germany, Mexico, Singapore, Spain, the United Kingdom, and the United States	Respondents were shown foods of varying nutritional quality (with no label on package) and selected which they would be most likely to purchase. The same choice sets were then shown again with one of five randomly allocated FOP nutrition labels on the package. Three nutritional profiles were created within each food category to represent lower, intermediate, and higher nutritional quality.	Improvements in the healthiness of products chosen occurred for 12% of choice pairs and a deterioration occurred for 6%. There were differences according to FOPNL type, with exposure to the Nutri-Score and MTL resulting in the greatest proportions of healthier choices (14%). MTL and Nutri-Score improved the healthiness of food choices to a significantly greater extent than the RIs and HSR. In countries where labels were already in use, their difference with other labels was greater (i.e. Nutri-Score in France, MTL in UK).
Billich *et al.* (2018)	994 participants 18-35 years old	At the beginning of the survey participants were asked to report their consumption of	All labels significantly reduced the selection of SSB in the choice scenario.

Table 31 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Billich *et al.* (2018) *(cont.)*		SSBs. Four FOP nutrition labels were delivered via an online choice experiment. Participants were randomly assigned to one of five study conditions (Control group - no labels, Graphic warning label group, text warning label group). In each scenario, participants were asked to imagine they were entering a convenience store, take away café or approaching a vending machine to buy a pre-packaged drink. Participants were then presented with 15 cold non-alcoholic drink alternatives and were asked which drink they would choose from the selection of drinks.	Compared to the control group, the HSR label group had a significantly higher proportion of participants who selected a drink with a high HSR.
Machín *et al.* (2018a)	437 Uruguayan adults at least occasionally responsible for household purchase of food products	Participants were asked to select products they would buy for their weekly grocery shopping on an online shopping simulation. 232 products split in 17 categories were available. There were 3 experimental conditions for consumers' exposure: control (no nutritional information), TL system, and Chilean warning systems.	No significant difference in energy and nutrient content (SFA, salt; sugars) of products purchased when MTL or Chilean warnings were added compared to control group.
Machín et al (2018c)	1 182 Uruguayan adults that were at least occasionally responsible for household purchase of food products	3 experimental conditions: control with no FOPNL, modified version of TL system, and Chilean Warning system. Participants were asked to select products they would buy to prepare a healthy dinner for them and their family on the website of an online grocery store.	Healthiness of products in shopping cart of control group was lower than in groups with FOPNL. In both groups with FOPNL, the average content in energy density, SFA and sugars was reduced in purchased foods. Only warning system allowed a significant reduction in average salt content of purchased foods.

Table 31 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Machín et al (2018c) *(cont.)*			Total content of nutrient in shopping cart was significantly higher in control group for energy, SFA and sodium. Calorie content was lower in both groups with FOPNL. The number of products with high content of a nutrient (sodium, sugars, SFA) was significantly lower in groups with FOPNL compared to control group.

AHEI, Alternate Healthy Eating Index; DFLF, dynamic label with real-time feedback; FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; SFA, Saturated fat; SSB, Sugar-Sweetened Beverage.

3.8.4 Effects of FOP nutrition labels on diet and health – food selection in offline choice tasks

In most of the offline experimental studies participants were randomly assigned to different FOPNL conditions, were presented with different food products and were asked to select among them (Clarke *et al.*, 2020; Defago *et al.*, 2020) or to shop for groceries (Egnell *et al.*, 2019b; Lima *et al.*, 2019a; Machín *et al.*, 2019; Poquet *et al.*, 2019). In all studies, it has been shown that the presence of FOP nutrition labels is associated with better nutritional quality of the selected food products, as the selected products were generally lower in energy and in nutrients of public health concern such as SFA, salt and sugars.

One study used home scan grocery data in combination with nutritional intake data and food habits questionnaire in order to assess the effect of FOPNL use on consumers' diet. They concluded that the use of FOPNL slightly improved dietary quality (Rønnow, 2020).

Based on the offline food choice experimental studies identified in this literature search (Table 32), the presence of FOPNL can result in better dietary quality for the foods and beverages selected by consumers. The available evidence does not allow to draw consistent conclusions regarding the differences in the effectiveness of the different FOPNL schemes that were tested. The effectiveness of a given FOP scheme and its beneficial effect on diets may be affected by the social context as well as the consumer's familiarity with the scheme.

Table 32 Studies assessing the impact of front-of-pack nutrition labelling schemes on food selection in offline choice tasks

Study (most recent first)	Population	Intervention/Comparator	Outcome
Clarke *et al.* (2020)	4 134 adults in the UK that regularly consumed energy-dense snacks	Participants were randomised in five experimental groups: • Image-and-text Health warning label with calories • Text-only Health Warning Label with calories • Calorie only, image-and-text Health Warning Label • Text-only Health Warning Label • no label. Participants were shown images of snacks in turn and then simultaneously viewed images presented in randomised order similar to a vending machine layout, and were asked to select a snack.	Energy-dense snack selection was lower for all label types compared to no label. The group with Image-and-text Health Warning Label selected the least mean number of calories.
Ronnow (2020)	Approximately 1 210 households in Denmark	Questionnaires were used in order to identify participants' health habits, health attitudes, and health behaviour in 2013 and 2015 during their last shopping trip. To investigate the effect of food labels on dietary quality, home scan data was combined with questionnaires and nutritional data. Dietary quality was assessed via the HEI and compared among users and no users of FOPNL.	The use of FOPNL increased dietary quality (but the effect was small).
Defago *et al.* (2020)	100 Peruvian students recruited at a university campus in Lima–Perú	Participants were offered three options of crackers, and three options of beverages, presented in two different baskets. Each basket comprised products of similar size and prices. Participants were asked to pick one item of each category. The treatment group was offered products with MTL labels (fat, sugar and sodium), while the control group received the same options but in their usual displays.	Exposure to MTL labels significantly increased the probability of avoiding the least healthy options and of choosing the healthiest items among the alternatives provided.

Table 32 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2019b)	Experimental study: 691 French participants in charge if grocery shopping for household and regular supermarket consumers. Observational study: 81 421 participants from the Nutri-net santé cohort	Field experiment: 5 FOPNL groups; Nutri-Score, HSR, MTL, RIs and SENS. Participants were asked to purchase food for their household for the next 2 days first without FOP nutrition labels, and then with FOP (same products). Observational Study: (dietary data) from Nutri-Net santé cohort to assess dietary intakes of the French population using repeated 24h dietary recalls (2 week days and 1 weekend day). Modelling scenario: PRIME model (Preventable Risk Integrated ModEL). Age and sex distribution of the French population were computed to be representative. The model estimates number of deaths from diet with reference scenario using dietary data from Nutri-Net santé cohort. Then, it calculates number of deaths from diet using 'labelled diet' scenario. The difference in these numbers is number of averted deaths owed to implementation of FOPNL.	All FOPNL schemes but SENS were associated with lower amounts of energy, fat, SFA and salt and higher fibre resulting in better nutritional quality of the shopping cart. Increase in fruit intake in the Nutri-Score, GDA and RIs conditions. The decrease in averted or delayed deaths from diet-related non-communicable diseases approximately correspond to: -3.4% with Nutri-Score -2.8% with HSR -1.9% with RIs -1.6% with MTL -1.1% with SENS
Lima *et al.* (2019a)	400 adults and 400 children recruited in Rio de Janeiro	Participants were divided in 2 groups: grape nectar and chocolate flavoured milk (200 adults and 200 children per product). For each product, they were randomly assigned to the TL or the Chilean warning condition. Participants were exposed to 3 evaluation conditions: blind (participants received samples in disposable plastic cups, and were asked to taste them), expected (participants only received the three packages) and informed (they	When adults and children had to decide between packages featuring FOPNL schemes that highlighted high sugar content, they tended to select the product version with the largest sugar reduction in both product categories. Nutritional warnings were more effective than TL in this reduction for one beverage category

Table 32 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Lima *et al.* (2019a) *(cont.)*		received the packages accompanied by disposable plastic cups containing the product's sample) and 3 samples of products: control, small sugar reduction, large sugar reduction. In each condition, participants had tell which product they would choose to consume.	(grape nectars), in adults. The presence of a FOP nutrition label did not modify participants' choices when they had tasted the product. No significant differences between TL and nutritional warnings, except for grape nectars for adult consumers. Both TL and nutritional warnings encouraged adults and children to select the package of the product with the lowest sugar concentration.
Machín *et al.* (2019)	199 students and workers in Montevideo (Uruguay) who are bread consumers.	15 products from 6 categories were presented to participants and were randomly assigned to control (product as commercialised in marketplace at the time of the study) and experimental condition featuring FOPNL on the product (warnings for excess of SFA, sugars, sodium). Participants were first distracted from the true experiment with an experiment on bread, and then they were told to have a snack (randomly positioned on shelf) as a token for their participation, which was the real experiment.	Nutritional warnings contributed to healthier food choices among consumers. Significant differences in the nutritional composition of products selected were found between control and nutritional warnings conditions. There was reduction in sodium, SFA and sugars content (no significant reduction in total fat between the groups).
Poquet *et al.* (2019)	95 French mother-child dyads	Participants were asked to select one beverage and two food items for a snack for themselves and then for the other member of the dyad first among products without	Food choices were significantly healthier after labelling than before. The nutritional quality of snacks that

Table 32 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Poquet *et al.* (2019) *(cont.)*		label; then the same task among products with Nutri-Score label.	participants chose for themselves was increased and it was higher in children than in mothers.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s) (now Reference Intakes); HEI, Healthy Eating Index; HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; SENS, Système d'Etiquetage Nutritionnel Simplifié; SFA, Saturated fat; TL, Traffic Light(s).

3.8.5 Effects of FOP nutrition labels on diet and health – meal selection/preparation studies

A few studies, since the previous report, investigated whether FOP schemes have an impact on people's selection or preparation of meals. Overall, labelling (warnings and Nutri-Score) oriented people towards the selection of healthier snacks (Machín *et al.*, 2019).

Table 33 Studies assessing the impact of front-of pack nutrition labelling schemes on people's selection or preparation of meals

Study (most recent first)	Population	Intervention/Comparator	Outcome
Machin *et al.* (2019)	199 students and workers in Montevideo (Uruguay) who are bread consumers.	The aim of the present study was to evaluate the influence of nutritional warnings (for SFA, sugars, sodium) on consumers' choice of a snack in a choice experiment involving real products. Participants were asked to select a snack product from a shelf after as a token of appreciation for their participation in an experiment involving bread labels in a computer. 15 products from six categories were presented to participants (who did not know the aim of the study to avoid bias)	When the warnings were present, participants chose products with fewer warnings and lower average sodium, SFA, and added sugar content.
Poquet *et al.* (2019)	95 mother-child dyads (190 total) in France	Participants (mothers and children aged 9–11), in dyads, were asked to choose, for themselves and for the other dyad member, a snack composed of one beverage	Children's and mothers' choices for themselves and for the other dyad member were significantly more oriented towards

Table 33 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Poquet *et al.* (2019) *(cont.)*		and two food items selected among several products with different nutritional quality. In the first step, the products were presented without any information. In the second step, after participants received information on the Nutri-Score, the products were labelled with the Nutri-Score.	products with good nutritional quality after labelling than before labelling.

SFA, Saturated fat.

3.8.6 Effects of FOP nutrition labels on diet and health – theoretical modelling studies

Given the difficulty in conducting real- life experiments on the effect of FOPNL on diet and health, modelling studies have been developed that explore the changes in diet and health outcomes using data from nutrition surveys and predicting the dietary changes that would result from shifting towards consumer choices that have a more positive FOP nutrition label.

Only two recent modelling studies have been found that evaluated the impact of FOPNL, and the TL label in particular, on nutritional intake (Fichera & von Hinke, 2020; Labonté *et al.*, 2019). Dietary intake data in combination with nutritional composition information (Labonté *et al.*, 2019) as well as data on grocery purchases from retailers (Fichera & von Hinke, 2020) were used in order to estimate dietary intake. The effect of the introduction of FOPNL was evaluated by comparing the dietary intake before and after substituting products with lower score with healthier alternatives. Both studies agree that the introduction of TL labelling could result in better dietary intake, lower energy intake, and better nutritional quality of the food basket (Table 34).

Table 34 Studies modelling the impact of front-of-pack nutrition labelling schemes on people's energy or nutrient intake

Study (most recent first)	Population	Intervention/Comparator	Outcome
Fichera & von Hinke (2020)	Grocery purchases data from 9 retailers in the UK	Data on grocery purchases, including all household purchases for a set of food categories were used. The differential timing of the introduction of FOP nutrition labels was used as a quasi-experiment. Four of the retailers had applied a type of	It was shown that the introduction of FOPNL (TL System or a hybrid version of TL System with GDA) generally improved the nutritional quality of the food

Table 34 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Fichera & von Hinke (2020) *(cont.)*		FOPNL; the other five hadn't. The FOP nutrition labels used by these four retailers were a) the TL System, a colour-coded scheme denoting amount of calories, fats, salt and sugars as green (low), amber (medium) and red (high); and b) a hybrid version of the TL System and GDA, which displayed both colour coding and percentage contributions on the key nutrients. The effect of FOPNL was estimated using a difference-in-difference design comparing the change in spending, quantity and nutritional value of food purchases before and after the introduction of the labels. It was also examined whether household substitute products between or within food groups as a result of the introduction of the labelling.	basket with no statistically significant changes in quantity, total spending and expenditure. Labelling led to an improvement in the nutritional composition of the purchased food products.
Labonté *et al.* (2019)	19 915 Canadian adults ≥ 19 years old	24h recall combined with nutritional composition information was used to estimate dietary intake. Foods consumed were assigned colour codes according to UK's Guide to creating a FOP nutrition label (TL Label). When possible, foods assigned a red light for a nutrient were replaced by a healthier product with no red light, as similar to the original as possible. Intakes were calculated with actual food list (baseline) and with revised food list (TL label scenario). PRIME model was used to evaluate annual averted/ delayed deaths by sex and age.	Implementation of the TL system was associated with a reduction in SFA, energy, total fat and sodium (total sugars were not changed in TL scenario in regards to baseline scenario) if food labelled with red TL are avoided.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; GDA, Guideline Daily Amount(s); SFA, Saturated fat; TL, Traffic Light(s).

Going beyond modelling the changes in nutrient intakes, three modelling studies estimated the impact of FOPNL schemes on health (Table 35). Studies used dietary intake data from national surveys, and simulation models were created in order to explore the impact of the adoption of FOPNL on health. In these studies, products assigned with low nutritional quality scores were substituted with healthier alternatives. Models have been used in order to calculate the impact on the prevalence of obesity (Basto-Abreu *et al.*, 2020) as well as the number of averted/ delayed deaths (Egnell *et al.*, 2019b; Labonté *et al.*, 2019). All of the studies report positive effects of FOPNL on population health, with reduction in the prevalence of obesity, as well as in decrease in mortality, with evaluative schemes being the most effective.

Table 35 Studies modelling the impact of front-of-pack nutrition labelling schemes on people's health

Study (most recent first)	Population	Intervention/Comparator	Outcome
Basto-Abreu *et al.* (2020)	6 049 Mexican adults	Baseline anthropometric data and intake data for snacks and beverages were collected using the 2016 National health and Nutrition Survey. A simulation model was used to estimate the future impact on obesity that could be reduced by introducing warning labels to packaged products. The impact on reduction of calories, BMI and obesity prevalence were estimated.	Warning labels are estimated to reduce energy intake by 36.8kcal/day (23.2 kcal from beverages and 13.6 kcal from snacks). Body weight is estimated to decrease by 1.68 kg. Obesity prevalence is estimated to be reduced by 14.7% compared to 2016 data.
Egnell *et al.* (2019b)	Experimental study: 691 French participants in charge if grocery shopping for household and regular supermarket consumers. Observational study: 81 421 participants from the Nutri-net santé cohort	Experimental study: Five FOPNL groups: Nutri-Score, HSR system, MTL, RIs and SENS. Participants were asked to purchase food for their household for the next 2 days first without FOP nutrition labels, and then with FOP nutrition labels (same products). Observational Study: (dietary data) from Nutri-Net santé cohort to assess dietary intakes of the French population using repeated 24h dietary recalls (two weekdays and one weekend day). Modelling scenario: Using PRIME model (Preventable Risk Integrated ModEL), age and sex distribution of the French population were computed to be representative. The model estimates number of deaths	All FOPNL but SENS were associated with lower amounts energy, fat, SFA and salt and higher fibre resulting in better nutritional quality of the shopping cart. Increase in fruit intake in the Nutri-score, GDA and RIs conditions. The decrease in averted or delayed deaths from diet-related non-communicable diseases approximately corresponds to: -3.4% with Nutri-Score -2.8% with HSR -1.9% with RIs -1.6% with MTL -1.1% with SENS

Table 35 *(cont.)*

Study (most recent first)	Population	Intervention/Comparator	Outcome
Egnell *et al.* (2019b) *(cont.)*		from diet with reference scenario using dietary data from Nutri-Net santé cohort. Then, it calculates number of deaths from diet using 'labelled diet' scenario. The difference in these numbers is number of averted deaths owed to implementation of FOPNL.	
Labonté *et al.* (2019)	19 915 Canadian adults ≥19 years old	24h recall combined with nutritional composition information was used to estimate dietary intake. Foods consumed were assigned colour codes according to UK's Guide to creating a FOP nutrition label (TL Label). When possible, foods assigned a red light for a nutrient were replaced by a healthier product with no red light, as similar to the original as possible. Intakes were calculated with actual food list (baseline) and with revised food list (TLL scenario). PRIME model was used to evaluate annual averted/delayed deaths by sex and age.	11 715 deaths per year could be averted or delayed with TLL system from a reduction in SFA, energy, total fat and sodium (total sugars were not changed in TLL scenario in regards to baseline scenario) if food labelled with red TL are avoided. 1390 deaths per year (1.5%) could be averted or delayed through modifications in dietary intakes independently from energy intake modifications (95%CI: 956-1858). This represents 1.5% of deaths from diet related non-communicable diseases.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; HSR, Health Star Rating; MTL, Multiple Traffic Light(s); RIs, Reference Intakes; SENS, Système d'Etiquetage Nutritionnel Simplifié; SFA, Saturated fat.

Only a few studies have examined the effect of FOPNL on population's diet and health. Some of these studies considered the diet overall but many of them focused on specific foods and beverages. Additionally, in all experimental choice studies, consumers had limited choices based on the selected groups and products, and the main parameter affecting their choice was the presence or absence of FOP nutrition labels. This is a limiting factor considering the amount of choices and confounding parameters present in real-life conditions.

At the same time, more data regarding the association of FOP nutrition labels and dietary intake is needed in order to inform modelling studies. Another limiting aspect of modelling studies is that they assume that the presence of FOPNL influences all consumers in the same way and that a complete shift will be achieved towards products with more positive FOPNL- something which behavioural studies do not suggest (see sections 3.2 to 3.6).

3.8.7 Conclusions regarding the effects on diet and health

Based on the literature reviewed up to May 2018, the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) highlighted that:

I. To date, there is no empirical evidence that unequivocally links the introduction of FOPNL in general or a specific FOP scheme in particular to a healthier diet or better health. This is largely owing to the inherent difficulty of proving such causal links and the extensive research effort required.

II. Modelled scenarios of replacing commonly consumed foods with more nutritious options, as identified by FOP nutrition labels that are based on nutrient profile models, indicate potential changes in nutrient intakes. These changes are largely beneficial and become more pronounced with more ambitious scenarios.

III. FOP nutrition labels that make the health goal more salient in consumers' minds when shopping might help improve food choices and overall diets. However, this may have to be balanced against the risk of decreasing consumers' liking of products perceived as healthy and thus of inferior taste.

In general, the conclusions drawn in the previous report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) remain unchallenged. Additional insights can be added to Conclusion I as online and offline choice experiments show that the presence of FOP nutrition labels can have a positive impact on consumer's dietary intake. Strengthening Conclusion II, the modelling studies included in the present report support that the adoption of FOPNL schemes, and in particular evaluative schemes, positively influences the nutritional intake and health outcomes of the population. Conclusion III is strengthened by new evidence suggesting that the presence of evaluative FOPNL schemes is associated with positive changes in the nutritional content of the foods and beverages that consumers select. More research is needed in order to precisely identify the effect of FOPNL schemes on the overall diet and, eventually, on health. Despite new evidence becoming available since the previous report, it remains difficult to draw conclusions regarding the exact effect of FOP nutrition labels on diet and health given the lack of available real-life evidence, and given the difficulty to set up studies to generate such evidence.

3.9 Effects of FOPNL on reformulation/innovation, and other supply chain behaviour

In addition to helping consumers make healthier dietary choices, FOPNL could incentivise the reformulation of foods and beverages towards more healthful products. From a public health point of view, the aim of product reformulation is improving the overall nutritional profile of foods and beverages placed on the market. Such changes increase the availability of more healthful products in the marketplace and encourage consumers to make healthier choices. However, the combination of the selected FOP scheme and the type of implementation (i.e., voluntary or mandatory), provides different incentives for modifying the content in nutrients associated with non-communicable diseases (i.e. lowering the content of SFA, trans-fat, sodium, sugars, or increasing the content of fibre.

3.9.1 Effects of FOPNL schemes on food reformulation/innovation

The implementation of the Nutri-Score in Belgium (Vermote *et al.*, 2020), HSR in Australia and New Zealand (Bablani *et al.*, 2020; Morrison *et al.*, 2019), Facts-Up-Front in the U.S. (Lim *et al.*, 2020), the Dutch Choices Logo (van der Bend *et al.*, 2020), and warning labels in Colombia and Chile (Lowery *et al.*, 2020; Quintiliano Scarpelli *et al.*, 2020; Reyes *et al.*, 2020) resulted in changes in the energy content of packaged foods and beverages as well as in the reduction in the content of nutrients of interest such as sodium and sugars. Moreover, the introduction of the Nutri-Score and the HSR resulted in small increases in the fibre and protein content of some food products (Morrison *et al.*, 2019; Vermote *et al.*, 2020). A detailed description of the relevant studies and their main outcome is included in Table 36.

Table 36 Studies assessing the impact of front-of-pack nutrition labelling schemes on food reformulation

Study (most recent first)	Intervention/Comparator	Outcome
Vermote *et al.* (2020)	In anticipation of the implementation of the Nutri-Score FOPNL in Belgium, this study examined the nutritional content, labelling and marketing of breakfast cereals and, more specifically, the changes in nutrient content and reformulation. 330 cereals were included and average nutrients contents were compared (per 100g) between 2017 and 2018.	The authors report some reformulation of cereals within that year. In particular, they suggest that total sugar was reduced by 5%, sodium by 20%, whereas they found increases in fibre (3%) and proteins (2%).
Bablani *et al.* (2020)	Annual nutrition information panel data were collected for 58 905 unique packaged foods over 14 major food groups sold in major supermarkets in Auckland from 2013 to 2019 and in Sydney from 2014 to 2018. The analysis sample covered 58 905 unique products over 14 major food groups. A difference-in-differences design was used to estimate reformulation associated with HSR adoption, in the density of energy, sugars, SFA, sodium, protein and fibre.	Products that took up HSR were healthier at baseline across all nutritional measures, with higher imputed HSR ratings, fibre, and protein content and lower energy, sodium, sugar, and SFA content. In New Zealand, the HSR rating increased by 0.07 stars for labelled versus unlabelled foods, indicating that products that voluntarily adopt HSR labels reformulated to be healthier. The highest reformulation was found for sodium, which declined by −4.0% in NZ, and −1.4% in Australia. Sugar content also decreased by more than 1%, declining by −2.3% in New Zealand and −1.1% in Australia. Energy density reductions were modest to negligible: −0.6 kJ/100 or −0.1% and not statistically significant in New Zealand and −4.6kJ/100 or −0.5% but statistically significant in Australia.

Table 36 *(cont.)*

Study (most recent first)	Intervention/Comparator	Outcome
Bablani *et al.* (2020) *(cont.)*		Reformulation was generally lowest for the healthiest products in both countries and highest for the least healthy products. In the least healthy products category, the HSR score increased by roughly 0.1 stars in both countries. For sodium content, reductions in New Zealand were roughly 15 times greater for the 0.5 to 1.5 HSR category compared with the 4.0 to 5.0 category, and this pattern was also noted for Australia. Likewise, sugar content reductions were greater for the least healthy products in New Zealand and in Australia. A similar pattern was noted for energy density, and SFA content in the 2 countries. Some evidence of increases in fibre content for unhealthy products was also observed in Australia, and no evidence of a change in protein content was found across either country.
Lim *et al.* (2020)	Data from Mintel Global New Products Database for 21 096 food and beverage products across 44 product categories in the US for over 16 years (1996-2011) was used in order to examine the effect of FOP nutrition labels adoption on the nutritional quality of the food products. The photos of the products were manually examined, the products with FOP nutrition labels were identified and it was recorded when the FOP nutrition label was introduced. The products' nutritional quality was measured using the Nutrient Profile model developed by the UK FSA and the British Heart Foundation health promotion research group at Oxford University.	The introduction of Facts-Up-Front label reduced calorie levels by approximately 42.21 kcal in 100 g of food or 100 mL of beverage product when there is no change in other nutritional contents and decreases SFA, sugar, and sodium by approximately 0.53 g, 2.37 g, and 47.45 mg, respectively. FOPNL adoption led to a reduction in calories (-12.50%), SFA (-12.97%), sugar (-12.62%), and sodium (-3.74%). The effect of FOPNL introduction was greater for unhealthy (vs. healthy) product categories.
Lowery *et al.* (2020)	Information for more than 15 000 packaged foods and beverages in Bogota, Colombia were collected. Trends in product reformulation among packaged food and beverages from in Colombia between 2016 and 2018 are analysed. Changes in the quantities of nutrients of concern, which were selected based on two nutrient	Between 2016 and 2018, median calories in beverages declined from 41.7 to 25.0 kcal while median calories in food products remained relatively stable. Changes in SFA content were not statistically significant for foods or beverages. Changes in median quantities of

Table 36 *(cont.)*

Study (most recent first)	Intervention/Comparator	Outcome
Lowery *et al.* (2020) *(cont.)*	profile models frequently used to develop and inform food policies in the Latin American region are explored. The Nutrition Facts Panel data of more than 15 000 packaged foods and beverages were collected in 2016 and 2018 using the Kanter photographic method.	nutrients of concern were not significant for any food group. There were no changes in the number of products containing trans fat or the amount of trans fat they contained. Median total fat remained the same among beverages alone, but declined slightly among food products, from 7.5 to 7.0g/100 g. Median total sugar content among beverages decreased from 9.2 to 5.2 g/100 mL and free sugar content declined from 7.8 to 5.0 g/100 mL. The decreases in sugar content were accompanied by a substantial rise in the proportion of beverages containing non-nutritive sweeteners, from 0.33 to 0.64. The proportion of foods containing non-nutritive sweeteners was largely unchanged. Under the Chilean model, the percentage of beverages that would receive at least one label decreased from 78% to 50%, while the percentage of foods that would receive a label remained approximately the same.
Quintiliano Scarpelli *et al.* (2020)	Package data for 551 food products was collected with photos taken in supermarket in Santiago, in 2013 and 2019. To analyse energy and nutrient content the limits for nutrient profiles from Chilean Food Law were used. Then using this references the presence or absence of 'high in' labels on the products package was simulated.	There was an extensive decrease in energy, total sugar and sodium content for the most consumed food products between 2013 and 2019. Total sugars had highest reduction over the period: -15.0%. Sodium content was reduced by 9.2%, energy by 3.9% and SFA by 1.5% (p>0.05).
Reyes *et al.* (2020)	A nutritional information 2015 to 2017 data set was developed with data collected in supermarkets from Santiago, Chile, in periods pre- (T0: January–February 2015 or 2016; n = 4 055) and post-implementation (T1: January–February 2017; n = 3 025) of the law. A total of 26 748 products were photographed. Nutrient information declared on the food labels was compared between T0 and T1.	The overall proportion of products with any "high in" warnings significantly decreased from 51% to 44% after the initial implementation of the law, mostly in food and beverage groups in which regulatory values were below the 75th percentile of the nutrient of energy distribution. There was a significant decrease in the proportion of any "high in" from 52% to 42%. Decreases were most

Table 36 *(cont.)*

Study (most recent first)	Intervention/Comparator	Outcome
Reyes *et al.* (2020) *(cont.)*		common in 'high in' sugars (for beverages, milks and milk-based drinks, breakfast cereals, sweet baked products, sweet and savoury spreads) and 'high in' sodium (savoury spreads, cheeses, sausages, and soups, and ready-to-eat meals). The proportion of products 'high in' SFA only decreased in savoury spreads, and the proportion of products 'high in' energy significantly decreased among breakfast cereals and savoury spreads.
van der Bend *et al.* (2020)	4 343 products carrying the Dutch Choices Logo between 2006 and 2012 were categorised into product categories as described in the Healthy Choices product criteria. For each product category, nutrients considered most relevant in the debate on healthy product reformulation were included in the NEVO (i.e., the Dutch Food Composition Database) FOPNL comparisons. To compare changes in mean nutrient composition of FOP-labelled product categories with comparable NEVO product categories, the nutrient content of the NEVO product categories in 2006 were set at 100%. The nutrient composition of NEVO product categories in 2016, and of FOP-labelled product categories in the starting year and in 2015/ 16 were analysed as a percentage of the NEVO nutrient composition in 2006.	Overall, the number of products with a FOP nutrition label increased over time, mainly due to a relatively large increase in the number of non-basic products with the Healthy Choices Logo since 2006. Overall, the energy density of all 'New' FOP nutrition labelled products was significantly lower than the energy density of all 'Old' labelled products. The caloric content changed significantly in 11 product categories, of which four showed a significant reduction, mostly non-basic categories, i.e. processed vegetables, sauces on water basis, bread toppings and fruit juices. For some labelled product categories significant changes in energy density were observed that were less favourable for health. The energy density of bread, cheese, hard cheese, soft cheese, processed meat and meat substitutes, and candy, increased significantly. For cheese, this increase could partly be linked to a less strict criterion for SFA in 2011. Over time, SFA content of all labelled products has significantly decreased. Trans-fat content decreased significantly in all products. Changes in added sugar content were not consistent over

Table 36 *(cont.)*

Study (most recent first)	Intervention/Comparator	Outcome
van der Bend *et al.* (2020) *(cont.)*		time. In basic products, the added sugar content decreased significantly. Sodium content decreased significantly from 'Old' to 'New' in all products. Fibre content increased significantly in all products carrying the Dutch Choices Logo. Fibre content of non-basic products increased significantly, while for basic products no significant changes were detected over time.
Morrison *et al.* (2019)	Cross-sectional study to assess nutritional quality of 252 packaged food products targeted to children in July 2016 in Australia. Food packages were photographed and comparisons with products available in 2013 were made. 2 methods were used to assess nutritional quality: 1. NPSC : apply same criteria used by Food Standards Australia New Zealand to allow use of health claim, 2. core food method: considers top 3 ingredients on the package list and classifies as unhealthy if one of them provides added sugar, SFA or sodium.	The proportion of reformulated products was higher in those displaying HSR compared to non-labelled products, with 48% having a positive change in nutrient profile system. One third of the products available in 2013 and 2016 have been reformulated. Significant decrease in mean sodium content but not in mean energy content /100g or mL. In cereal-based products, there was a decrease in sugar (-1.62g/100g) and SFA (-0.36g/100g) content. There were no differences for fruit-based and dairy products. 65% of products that displayed HSR in 2013 were reformulated with improved nutritional composition (increase in protein or fibre, or decrease of at least one of energy, SFA, total sugar, sodium).
Kanter *et al.* (2019)	In Chile (Santiago), a sample of packaged food and beverage products from six different supermarkets were photographed in February 2015 (n = 5 421) and in February 2016 (n = 5 479), before the Chilean Law of Food Labelling and advertising was implemented (June 2016). This law requires warning labels for products with high nutrients. The study estimated the average change in energy and critical nutrient (sodium, total sugars, and SFA) content by product category for the products that were collected in both years (n = 2086).	The outcome variable was the average change in energy and critical nutrient content by product category. Data suggests that overall there was minimal reformulation to avoid products being labelled by warnings. However, less than 2% of products would have avoided a warning label through reformulation. Overall, no category experienced reductions higher than a 5% change in energy or critical nutrient content, on average. Some even increased these contents.

FOP, Front-Of-Pack; FOPNL, Front-of-pack nutrition labelling; FSA, Food Standards Agency; HSR, Health Star Rating; NPSC, Nutrient Profilling Scoring Criterion; SFA, Saturated fat.

3.9.2 Potential risks from FOPNL schemes related to food composition or reformulation

It should be noted that healthier products are more likely to display a FOP nutrition label than unhealthy ones (Kim *et al.*, 2019; Shahid *et al.*, 2020); however, it is not clear how consumers perceive such absence of a FOP nutrition label and how this affects the choices they make (see also section 3.7.2). In addition, the choice of the FOPNL scheme may impact the amount and type of reformulation that occurs. For example, Lowery *et al.* (2020) demonstrated decreases in sugar content were accompanied by a substantial rise in the proportion of beverages containing non-nutritive sweeteners, thus maintaining sweet taste, when the model didn't regulate their use.

Table 37 Studies highlighting potential risks from front-of-pack nutrition labelling schemes related to food composition or reformulation

Study (most recent first)	Outcome
Shahid *et al.* (2020)	The voluntary use of FOPNL by the industry was shown to highlight the best products available, while dismissing those with a worse nutrient profile. In 12/15 categories the mean HSR of products displaying the HSR logo was significantly higher than the mean of those products not using the HSR system or displaying the energy icon only. Non-alcoholic beverages receiving a higher HSR were more likely to use the HSR logo (with a mean HSR of 4.1) compared to those which did not display the HSR logo (mean HSR 2.3). The confectionery and non-alcoholic beverage categories were responsible for 54.4% of products using the energy icon only. The majority of products (70.4%) using the energy icon would receive a HSR between 0.5–2.0.
Bablani *et al.* (2020)	Healthier products are more likely to show HSR scores than unhealthy ones: >35% of products that should have achieved 4 or more stars displayed the label compared to <15% of products that should achieve 2 stars or less.
Lowery *et al.* (2020)	The choice of nutrient profile model may impact the amount and type of reformulation that occurs. The decreases in sugar content were accompanied by a substantial rise in the proportion of beverages containing non-nutritive sweeteners, from 33% to 64%. Based on the PAHO model, no change was observed over time in the percentage of products that would be regulated (nearly 100%). A slight increase in the number of labels each product would receive over time, was observed due to the increase in the number of beverages receiving an added non-nutritive sweeteners label. Because the PAHO model regulates non-nutritive sweeteners, manufacturers would likely have less incentive to reformulate products to reduce sugar. The Chilean model, which does not regulate non-nutritive sweeteners, would have allowed half of all beverages in the sample to avoid a warning label in 2018.
Kim *et al.* (2019)	There was no difference in the HSR or nutrient profiles of similar branded and generic products that display HSR. Branded products however appeared to exploit the voluntary nature of the HSR scheme, preferentially displaying an HSR on healthier products compared with their generic counterparts.

FOPNL, Front-of-pack nutrition labelling; HSR, Health Star Rating; PAHO, Pan American Health Organization.

3.9.3 Conclusions regarding the effect of FOPNL on reformulation/ innovation, and other supply chain behaviour

Based on the literature reviewed up to May 2018, the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a) concluded that:

I. Most of the evidence that FOP nutrition labels actually influence food product composition is based on self-reported data. A few empirical studies support this evidence, but others fail to find any correlation between the nutritional composition of the food and the presence of FOP schemes. More objective data would be needed to conclude about a causal link between the presence of FOP nutrition labels and changes in the formulation of products.

II. Some studies highlight that although reformulation or product innovation may occur, it may only involve nutrients that appear on the FOP nutrition labels or which are considered in underlying nutrient criteria, while reducing the incentive to improve on the others.

III. The available evidence suggests that evaluative FOPNL schemes actually influence food product composition.

IV. FOP nutrition labels seem to influence consumers' perception of producers and retailers adopting them because these would be viewed as more transparent and caring. FOP nutrition labels seem to be present more on private label products than on branded ones.

The current report, on the basis of the recently added literature reviewed, provides updates to Conclusion I by adding evidence on food and beverage reformulation that took place after the mandatory implementation of various FOPNL schemes at a national level; energy content of packaged foods and beverages was reduced, while reductions were also observed in the content of nutrients of interest such as sodium and sugars. Effects of FOPNL schemes on reformulation have been better demonstrated in the food products categories with overall lower nutritional quality.

3.10 Unintended consequences of FOPNL

Some studies report findings that point toward unexpected differences or suggest unintended consequences of specific nutrition labels, label aspects, or nutrition labelling in general.

For example, whereas there is ample support in this update, as well as in the previous JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a), of the evidence that the use of colour in FOPNL is beneficial for attention to and understanding of labels (see 3.2.2 and 3.4.2.2), there has also been research reporting country differences (Pettigrew *et al.*, 2021). Pettigrew and colleagues (2021) observed noticeable country differences in their study conducted in Australia, Canada, China, India, New Zealand, the UK, and the USA. While in most countries a coloured version of their tested label performed significantly better than the monochrome version, this was not the case in Canada and the positive effect of colour was significantly smaller in China than in the other countries. This suggests that it may be advisable to take into account that country differences may exist.

As shown in the preferences section, consumers prefer coloured to monochrome FOP nutrition labels. However, one reviewed article suggests that the colours used in coloured labels may have unintended affective consequences on consumers' preferences (Lemos *et al.*, 2020). Specifically, in two studies using behavioural and electrophysiological measures the authors found that seeing a red circle just before seeing a sweetened food may elicit more arousing and positive affective reactions in consumers toward the sweetened food items. This may make consumers consequently prefer products that are accompanied by the red colour, thus having an inverse effect for unhealthy foods of that intended by the label.

Another reported effect of using colour labelling has been that products with a colour-coded label, in this case a colour-coded GDA label, were more often chosen when participants had to choose the healthiest product. This effect was seemingly independent of the information provided on the label (Bialkova *et al.*, 2020). However, it has to be taken into account that this finding has not been reported across studies conducted on the use of colour in FOP nutrition labels. Additionally, if labelling becomes mandatory and is applied to all products, such an effect will disappear.

Regarding purchases, one study (Zhu *et al.*, 2019) showed that the voluntary implementation of a FOPNL scheme not only led to an increase in the purchases of the products (ready-to-eat cereals) that bore the scheme but also resulted in a spillover effect of fewer purchases of products not bearing the label, and led consumers to purchase relatively healthier alternatives from both participating and non-participating manufacturers. Such spillover effects should be taken into account when assessing the effectiveness of a FOPNL policy.

Also, there seems to be some evidence of what behavioural scientists call a "rebound effect", that is a diminished overall impact of the introduction of FOP nutrition labels, as consumers may feel 'morally licensed' to consume more of the healthier foods. Indeed, in a study, participants were found to be willing to pay more for products with added labels, and selected larger portions for "healthier choice" products (McCrickerd *et al.*, 2020).

In addition, some research points to the possibility that the introduction of a FOP nutrition label may be used for product differentiation and may result in reduced competition, leading to increases in prices, and ultimately in shopping costs. Velasco Vizcaino & Velasco (2019) observed that TL labels are only taken into account when the brands are not familiar. Since consumers are likely to attach favourable nutritional perceptions to brands they trust, the authors state that FOP nutrition labels may "create a double burden for small food manufacturers" hindering competition and may "also take up space on the packaging that could otherwise be used to communicate positive attributes to differentiate unfamiliar brands from familiar brands".

When it comes to food reformulation, Lowery *et al.* (2020) demonstrated decreases in sugar content were accompanied by a substantial rise in the proportion of beverages containing non-nutritive sweeteners, thus maintaining sweet taste, when the model didn't regulate their use.

4 Knowledge gaps and suggestions for further research in FOPNL

Research on FOPNL has increased substantially in the past decade and also in recent years, coinciding with the implementation of new FOP nutrition labels such as the Nutri-Score across several European countries, and warning labels that are primarily used in South America. Nevertheless, the evidence remains largely fragmented (see Storcksdieck genannt Bonsmann et al., 2020a). This can be ascribed not only to a diversity in methodology, research questions, tested labels, and the population being addressed, but also to policy developments (e.g. the implementation of labels in different countries) and evolution of FOP nutrition labels (e.g. from the 5-Colour Nutrition Label design to the final Nutri-Score design), which are integrated into new studies. This section provides an update of the knowledge gaps identified in the previous report and discusses potentially new knowledge gaps and future research needs on the basis of the reported literature.

4.1 Attention to, preference for and understanding of FOP nutrition labels – knowledge gaps and suggestions

Attention and attitudes toward labels as well as understanding of FOP nutrition labels are aspects determining whether these labels are used by consumers to guide their consumption decisions. The previous report (Storcksdieck genannt Bonsmann et al., 2020a) mentioned that these aspects are, amongst other things, strongly influenced by consumers' socio-economic background and culture. Knowledge gaps previously identified pertain to methodological and graphic design issues, and challenges in the structured comparison of different FOP schemes.

4.1.1 Methodological issues and potential improvements

Several studies on attention and awareness of FOP nutrition labels rely on self-report measures. Because respondents are specifically prompted about their awareness of the label, over-reporting of awareness and attention is likely (cf. 3.2.1.; Grunert et al., 2010; Storcksdieck genannt Bonsmann et al., 2020a). In recent years, the use of experimental studies has increased in which aspects of a FOP nutrition label are changed in order to assess its effects on attention. This approach provides relevant insights into causal relationships of which aspects of a label have the potential to increase attention as well as preferences and understanding. Studies could benefit from refraining to explicitly prompt participants' to focus on FOP nutrition labels in order to resemble real-life shopping situations further.

When it comes to consumers' preferences for FOP nutrition labels, the same knowledge gaps as in the 2020 report remain with respect to preference variation according to consumers' characteristics. Studies that take consumer characteristics into account, including sociodemographic variables, dietary habits, health, and other factors are useful. For example, in contrast to the previous report, the studies reviewed here suggest an inverse (negative) relationship between preferences towards FOP nutrition labels and obesity. Because the studies reviewed in the 2020 report relied on self-reported obesity while those in the current review relied on

measured obesity, future studies should be careful when using obesity measures. More generally, there is a great need for studies that assess preferences across a wide range of European populations and regions.

4.1.2 Graphic design-related issues

A limited number of studies has also been conducted on ideal design features of a particular label including size, positioning, background contrast etc. to draw consumers' attention. These studies have been promising and further testing of ideal features and positioning of the label would be beneficial in order to draw reliable conclusions.

4.1.3 Structured comparisons of different FOPNL schemes

The previous report also highlighted that comparisons between FOP nutrition labels in specific countries are often biased by the familiarity that participants have with the labelling schemes. Consequently, results tend to show that participants prefer the FOP scheme to which they are more accustomed (or that they perceive as their own). Future studies should aim at consistently testing preference for the most common FOPNL schemes as well as at better understanding the reasons why some labels may be preferred over other schemes. In addition, because many of the identified studies were conducted in non-EU countries, future studies should seek to understand whether such preferences hold in and across EU countries.

Lastly, it is also important to examine the interplay of FOPNL preferences, objective understanding of FOPNL as well as its impact on purchasing and consumption behaviour in order to understand their respective relevance in supporting healthy diets.

4.1.4 New knowledge gaps identified

This report also addressed some new questions for which the scientific evidence did not allow us to draw robust conclusions (i.e. knowledge gaps). These are further outlined below.

First, more in-depth studies are necessary that investigate the effect of FOPNL schemes on consumer understanding for and behaviour regarding highly processed food compared to single-ingredient products. Only a handful of papers addressed differences between processed and unprocessed foods with regard to FOP nutrition labels, none of which compared the interpretation of different FOP nutrition labels for highly processed compared to single ingredient foods.

Second, due to a lack of evidence, no robust conclusions could be drawn on the effect of combining different FOPNL schemes on consumers' understanding of the nutritional quality of a food product. To address shortcomings of FOP nutrition labels currently available, a combination of schemes may be interesting. Consumers who have less time, motivation, and resources to process detailed information may benefit more from a simpler, evaluative FOP nutrition label, whereas consumers who are motivated, and have sufficient time and resources may additionally want to receive further information through a more detailed FOP nutrition label. However, combining FOPNL schemes also bears the risk of consumer confusion or loss of trust. This may especially be the case if the labels provide seemingly contradictory information. This has been one of the issues raised regarding non-summary labels, which present an evaluation of several different

components separately, on the basis of which consumers have reportedly found it complex to derive a summary evaluation of the healthfulness of a product (Machín *et al.*, 2018b; Zlatevska *et al.*, 2019).

Related to the previous knowledge gap is the scarcity of research on the effectiveness of FOP nutrition labels in the presence of nutrition or health claims. More data is needed on the effects on consumer understanding and impact on consumer behaviour of the combined presence on labels of FOPNL schemes and nutrition and health claims.

4.2 Effects of FOPNL on purchasing behaviour, food choices, and overall diet and health – knowledge gaps and suggestions

Despite the large number of new studies since the previous JRC report (Storcksdieck genannt Bonsmann et al., 2020a), adequate evidence from real-life studies is still lacking in order to precisely identify the effects of FOPNL on purchasing behaviour, food choice, and overall diet and health.

4.2.1 Methodological issues and potential improvements

When it comes to *purchasing behaviour and food choice*, first of all, some of the knowledge gaps stem from the limitations characterising the reported findings. Indeed, as often acknowledged by the authors themselves, caution should be paid at interpreting findings which are influenced by the research design (e.g., because of self-selection, or because the results are mainly based on respondents' self-reported information, or because other concomitant interventions cannot be controlled for). More effort should be paid to obtaining the *net* impact of FOP nutrition labels on purchase behaviour - by adopting a more rigorous research approach (possibly in a real-life setting as opposed to a hypothetical one). It has to be noted that most of the reviewed evidence comes from laboratory experiments with no real incentives, and relatively fewer studies are conducted in real shopping contexts. In real-life studies, the observed impact of FOP nutrition labels on purchasing behaviour is observed to be smaller, limiting the extent to which lab experiment findings can be generalised. Therefore, more well-designed studies in real shopping contexts are needed.

Second, the impact of FOP nutrition labels seems to be small. However, any potential spillover effect of the implementation of a (voluntary) FOPNL on other products not bearing a FOP nutrition label is usually not examined. In addition, most studies examine either the implementation of FOPNL schemes boosting purchase of healthier products (i.e. evaluative ones) or that of FOPNL discouraging purchase of products with low nutrition value (i.e. "high-in" Warning Labels). Further research may investigate the effect of interventions combining both types of FOP nutrition labels.

Third, future evidence, for example from studies monitoring prices, may be needed to better investigate any possible impact of FOPNL schemes on shopping costs, across socio-economic groups, and by type of products (e.g., known brands vs. own brands) or food categories.

When it comes to *diet and health*, most of the current data is based on online and offline experiments and modelling studies. Similarly to what holds for purchasing behaviours, more analysis of empirical nature (e.g.

based on real-life retail data) would be helpful to corroborate the current findings of the effect of FOPNL on overall diet and health. More research and better data are needed to fill the remaining knowledge gaps.

There are different suggestions to improve the design of such studies and increase the usefulness of the obtained results. For example, laboratory experiments or simulated supermarkets are useful tools to understand behaviour, but the design of experiments in this field could be enriched with new features. New studies that involve monetary incentives and trade-offs could shed more light on the topic. In addition to experimental data, more empirical analyses that exploit natural experiments or field interventions would be helpful to better understand the role of FOP nutrition labels on purchasing behaviour. These research methods should be complemented by data provided by retailers and producers. Given the growing popularity of online grocery shopping, one promising avenue for such future research seems to be the study of the impact of FOP nutrition labels in a real online setting, where real incentives apply, where different groups of consumers can be routed to slightly different pages, and their shopping journey can be studied in-depth, while controlling for socio-demographic characteristics. Such a setting seems to combine the specific advantages of research in a real-life setting with the merits of an experimental approach conducted in a controlled environment.

4.2.2 Interaction of FOPNL schemes and moderating conditions

Additionally, it is important to understand the interaction between FOP nutrition labels, their features and consumer characteristics (Ikonen *et al.*, 2020). More data is needed on the actual choices and shopping behaviour of consumers, with studies where various confounding parameters (such as time pressure, consumer's health-consciousness, prices) will be taken into consideration. Such data could also be enriched with information on how the presence of FOP nutrition labels interacts with other elements of the shopping environment such as shelf labelling.

Furthermore, it is important to explore how socio-economic and personal characteristics interact with the use of FOPNL. Despite a wealth of available evidence (see section 3.6), there are still some grey areas that would benefit from sound studies, notably on the interaction between socio-demographic factors and FOP schemes. Data from studies with clear stratification of the population groups in terms of educational level, socio-economic status, health literacy, nutrition knowledge as well as health and weight status should be taken into consideration.

4.3 Use of FOPNL by producers, effects on reformulation and on product pricing – knowledge gaps and suggestions

There is evidence supporting that the adoption of FOPNL could lead to reformulation towards products with a better nutritional content. However, more data is needed in order to explore better the causal links between the presence of FOP schemes and changes in nutritional quality.

Second, there is little research comparing the different FOPNL schemes to define which ones would be the most perceptive to reformulation and would be the most helpful to shift the food supply towards overall better nutritional quality of foods and beverages.

Additional studies should be conducted in order to better understand which kind of producers adopt which kind of FOP schemes more often and what characteristics are important for producers or how FOP nutrition labels might relate to prices. Additional insight could also be gleaned from studies on the cost-effectiveness of FOPNL.

5 Conclusions

Front-of-pack nutrition labelling is considered to be of growing significance in the effort of tackling non-communicable diseases, and the World Health Organization includes it as one of the measures for improving population diets (Kelly & Jewell, 2018; WHO, 2013). In 2020, the JRC published a detailed analysis of current FOPNL schemes regarding consumer understanding, their use, and effect on consumers' behaviour, dietary choices and health (Storcksdieck genannt Bonsmann et al., 2020a). The current report is an update of this comprehensive review on FOPNL schemes.

The conclusions drawn on the basis of the reviewed literature are organised by the following sections included in the report: consumer attention; consumer preferences and acceptance; consumer understanding; food purchasing; impacts on different socio-economic group; implementation effects of different labelling aspects; diet and health; and food reformulation and innovation.

Before turning to specific impacts of FOP schemes on consumer behaviour, it is important to note that consumer behaviour is largely variable and influenced by multiple factors – situational and personal. Consumers differ by age, education, health consciousness, cognitive capacities, culture, and many other attributes. At the same time, the same consumer may behave differently in varying situations, whether making purchases under time pressure, in stressful situations, when preoccupied, or when making purchases for oneself or for others. Any FOP scheme should thus be conscientiously tested in varied and large samples.

Additionally, and as stated earlier in this report, a comparison of FOP schemes remains challenging due to the use of various methodologies, outcome variables, and different comparisons. Familiarity of the tested sample with a particular label is also of importance for consumer responses (Hagmann & Siegrist, 2020; Santos *et al.*, 2020). In the interpretation of any study, it is important to take these methodological differences into account since they can favour one nutrition label over another (cf. 3.3 and 3.4.2).

ATTENTION

1. Attention to FOP nutrition labels is a prerequisite for these labels to inform consumers' product choices. Attention to FOP nutrition labels varies according to features of the labels themselves as well as according to features of the person and the situation. Visual design aspects (e.g. colour, size, position, complexity, contrast, amount of information, 'visual clutter') can facilitate or impede that consumers notice labels. Visual design aspects may be especially relevant for consumers who are under time constraints, have less capacity to process the information, or are less interested in health-related information.
2. Several characteristics can increase attention to FOP nutrition labels. The use of colour makes FOP nutrition labels more salient and stimulates attention paid to the labels. Using sufficient contrast and size to stand out on food packages can help attract consumer attention to FOPNL. Attention is greater when the type of label and its location on the package does not change.
3. Less complex labels require less attention to be processed.

PREFERENCES AND ACCEPTANCE

4. Consumers are generally positively predisposed towards FOP nutrition labels and find them useful and insightful. Given the self-report nature of studies on FOP nutrition label preference, there may be a gap between FOP nutrition labels that consumers say they prefer and FOP nutrition labels that actually help consumers make informed food decisions for better nutrition (objective understanding of the label).
5. Several studies reveal an overall positive attitude towards FOP nutrition labels but do not reveal a clear preference for specific schemes. However, most of the reviewed studies suggest consumer preference for coloured FOP nutrition labels.
6. Preference for FOP nutrition labels varies with consumers' socio-demographic characteristics. (Semi-)Directive FOP nutrition labels seem to be especially preferred by low and middle-income consumers.
7. In general, consumers appear to prefer simple labels and colourful and directive FOPNL schemes.
8. Semi-directive schemes (like MTL) are often seen as trustworthy and as providing the nutritional information needed while directive schemes are often seen as easiest to understand.

UNDERSTANDING

9. Simpler, evaluative, colour-coded labels (most of which use a TL colour coding) are more easily understood than more complex, reductive, monochrome labels.
10. Salient, consistent and simple reference quantities are preferred and consumers generally understand nutritional information better when it requires less "mental math" to process the information.

IMPACT ON PURCHASING

11. Despite some promising findings on the impact of FOPNL schemes on actual purchasing behaviour, many aspects remain unanswered or not fully understood. Effects of FOP labels on purchasing behaviour observed in real shopping contexts are clearly smaller than in controlled experimental laboratory settings.
12. There is more converging evidence showing that FOP nutrition labels boost the purchase of healthier products more than they discourage the purchase of products with medium or low nutritional value.
13. "High-in" warning labels seem to be more effective than other types of labels in discouraging purchase of less healthy products. Other FOPNL schemes (TL/MTL, HSR and Nutri-Score, and to a lesser extent RIs/GDA) seem to work better at improving overall healthiness of choices – i.e. combining both increase of the healthy and decrease of the unhealthy products- and not at effecting changes on the purchases of solely healthy or solely unhealthy products.
14. Evidence from experimental studies suggests that colour-coded FOP schemes serve consumers better than their monochrome versions in encouraging overall healthier food purchases.

IMPACT ACROSS DIFFERENT POPULATION GROUPS

15. No consistent evidence is found regarding the effect of FOPNL on purchasing behaviour across different socio-economic groups.

16. There is converging evidence that knowledge and use of FOPNL schemes was lower in groups of lower socio-economic status.
17. Evidence suggests that the understanding of FOP nutrition labels is more limited within lower socio-economic status groups.
18. Evidence shows that the understanding of FOPNL by consumers of different socio-economic groups varies according to the type of scheme displayed. Evaluative FOP nutrition labels seem to be preferred by consumers with lower income.

EFFECTS OF THE IMPLEMENTATION OF DIFFERENT LABELLING ASPECTS ON CONSUMER UNDERSTANDING, PREFERENCES, AND IMPACT ON BEHAVIOUR

19. Some evidence points to the suggestion that mandatory labelling may be beneficial for consumers' understanding of labels as well as their trust in the labels, and that consumers prefer a mandatory implementation of FOPNL schemes.
20. There is insufficient evidence to draw robust conclusions regarding consumer understanding and behaviour when combining summary labels with more detailed label on the same package, as well as regarding the interpretation of FOP nutrition labels when present on highly processed compared to single ingredient products.
21. While the evidence on the effect of adding voluntary claims to FOP nutrition labels on food products is mixed, there seems to be a tendency that voluntary claims and marketing images can interfere with the efficacy of FOP nutrition labels.

IMPACT ON DIET AND HEALTH

22. There is still no sufficient real-life data to assess the impact of FOPNL on dietary intake and health outcomes.
23. Experimental studies suggest that the presence of FOP nutrition labels can have a positive impact on consumers' dietary intake.
24. Moreover, modelling studies support that adopting (in particular evaluative) FOPNL schemes positively influences nutritional intake and health outcomes of the population.

IMPACT ON REFORMULATION, INNOVATION, AND OTHER SUPPLY CHAIN BEHAVIOUR

25. Evidence suggests that the adoption of FOPNL schemes is associated with food and beverages reformulation.
26. Data from food retailers suggests that the adoption of FOPNL is associated with improvement in the nutritional content of foods and beverages especially for specific nutrients such as sugar and sodium.

To reiterate conclusions drawn from the 2020 JRC report on FOPNL (Storcksdieck genannt Bonsmann et al., 2020a), FOPNL has the potential to guide consumers towards healthier diets and can stimulate food product reformulation and innovation. Simpler, evaluative, colour-coded labels seem better suited in meeting consumers' information needs in a busy shopping context.

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