



**Non-thermal physical technologies to preserve
fresh and minimally processed fruit and vegetables**

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Abbreviations and Acronyms

Abbreviation / Acronym	Description
BM	Business model
F&V	Fruit and vegetables
FTN	Food Technology Neophobia
H2020	Horizon 2020
OR	Odds Ratios
SME	Small and medium-sized enterprises
WP	Work package

Table 1: Abbreviations and Acronyms

Executive Summary

The SHEALTHY project aims to assess and develop an optimal combination of non-thermal sanitization, preservation and stabilization methods to improve the safety, while preserving the nutritional quality and prolonging the shelf-life of mildly processed fruit and vegetables (F&V) products. By combining and modulating mild technologies (MT), the project seeks to respond to consumers' demand for fresh, healthy, convenient, sustainable and locally produced and additive-free food.

In order to assess the commercial feasibility and enable the development of business models for mildly processed F&Vs, it is necessary to understand consumers' needs and possible barriers to acceptance of these technologies. In this context, this report summarizes the main findings from activities undertaken within the SHEALTHY project aimed at investigating European consumers' perception and expectations towards mildly processed F&V. Additionally, consumers' use of package information and household storage and waste of F&V was also studied, in order to estimate the possible contribution of mild processing to reducing household food waste.

A combination of activities involving literature reviews, as well as qualitative and quantitative consumer research in six European countries (Denmark, Italy, Germany, Serbia, Spain, and the Netherlands) were undertaken to address the aims of the tasks.

The main findings indicated that innovative food processing technologies are not in the top of mind of European consumers. Lack of basic knowledge and trust towards MTs was identified as the major potential impediment to consumer acceptance of F&V products treated with these technologies. Therefore, targeted communication is necessary to enhance public awareness and trust.

Specific benefits associated with F&Vs were found to be more relevant for consumer acceptance than processing information per se. Health and nutritional benefits were found to be the most effective type of claims, so focusing on the possibility of better preservation of nutritional values by the use of MT should be emphasized in consumer communication. Besides health and nutritional benefits, better sensory quality, and more hygienic/safer products were important benefits perceived by consumers. Overall, communicating about specific benefits from the use of innovative processing technologies should increase acceptance. In fact, communicating benefits from the use of these new technologies has a potential towards future differentiation strategies, especially for F&V derived products like juices, for which consumers were found to prefer mild processing to the conventional processing (pasteurization).

Impacts on product sensory quality, safety risks, higher price and environmental costs were the concerns most often mentioned by consumers. Sensory quality was identified as the main driver of consumers' choices of F&V, and losses to taste and aroma were most frequently mentioned as concerns related to processing with MTs. Therefore, it is crucial that sensory studies be conducted to evaluate that the acceptability for F&Vs treated with MT products is at least on par with that of their conventionally processed counterparts, as that will most likely be a prerequisite for marketplace success.

With respect to consumers' food waste behaviour, the findings indicated that European consumers mostly discard F&V after visual inspection and mainly due to the presence of mold or adverse sensory qualities (such as diminished appearance, presence of smells, etc) after storage. This confirms the great potential of MT in reducing food waste at household levels, given that many MTs have antimicrobial effects against a variety of microorganisms. The results indicated that leafy greens and tomatoes were the two categories of F&Vs most often discarded at the household levels. Besides product-related factors, lack of/insufficient knowledge of correct storage practices, and suboptimal package sizes were identified as additional important reasons behind F&V waste behaviour of European consumers.

The research findings included in this report are expected to provide guidelines to the successful introduction of mildly processed F&V products, which could hopefully contribute to an increased intake of high-quality F&V.

Introduction

The SHEALTHY project aims to assess and develop an optimal combination of non-thermal sanitization, preservation and stabilization methods to improve the safety, while preserving the nutritional quality and prolonging the shelf-life of mildly processed fruit and vegetables (F&V) products. By combining and modulating non-thermal technologies, the project seeks to respond to consumers' demand for fresh, healthy, convenient, sustainable and locally produced and additive-free food.

The present report summarizes the main findings from activities undertaken within SHEALTHY with reference to subtasks 3.1.1 and 3.1.2., whose aim was, respectively, to investigate European consumers' perception and expectations towards mildly processed F&V (3.1.1) and to investigate the consumer behaviour that may determine food wastage at household level (3.1.2). The purpose of these two subtasks was to contribute to the definition of new business models (BMs) tailored to SMEs needs and consumers expectations (Task 3.1.), specifically by identifying value propositions based on consumer preferences.

A combination of activities involving literature reviews, as well as qualitative and quantitative consumer research in six European countries (Denmark, Italy, Germany, Serbia, Spain, and the Netherlands) were undertaken to address the aims of the tasks.

This report is organized as follows: first, it provides a short literature review elucidating the background for this research (§ 1). Secondly, it provides a list on the main activities conducted to fulfil the aims of the task (§ 2). This is followed by a discussion of the main findings (§ 3). Outreach dissemination activities, as well as linkages to other tasks in SHEALTHY are also highlighted in this section. The final section summarizes the main conclusion highlighting how the findings can guide targeted launching of mildly processed F&V within the EU (§ 4).

1. Background

Fruit and vegetables (F&V) are key elements of a healthy and balanced diet providing humans with essential nutrients and bioactive compounds (Liu, 2013). Increased consumers' interest to the "healthy" food attributes (such as "freshness", "naturalness" and "nutritional value") and overall sustainability of processing methods has contributed to a growing demand for the less processed F&V (Pollard, Kirk, & Cade, 2002).

In recent years, a wide variety of non-thermal minimally processing technologies has seen continuous development (e.g., Bruhn, 2007; Rollin, Kennedy, & Wills, 2011). During the processing of F&V, non-thermal minimal processing technologies use mild temperatures and limited amounts of physical and chemical processing aids – for this reason, they are often referred to as “mild processing”. Mild processing is expected to better preserve the original quality of food products and by-products, such as increase products' shelf-life, maintain the nutritional value, freshness and some other sensory attributes of F&V products for longer time, and reduce the use of added preservatives (Ragaert, Verbeke, Devlieghere, & Debevere, 2004; Honorio et al., 2019). Additional benefits include longer product shelf-life with potential to reduce food waste, especially at the household level (Aschemann-Witzel, De Hooge, Amani, Bech-Larsen, & Oostindjer, 2015; Amani & Gadde, 2015). Previous studies reported that F&V waste accounted for a large percentage of total food waste (Aschemann-Witzel & Ares, 2019), which is considered to be one of the significant sustainability issues that needs to be addressed, as a cause of negative economic, environmental and social effects (Aschemann-Witzel et al., 2015).

While food scientists are focusing on the physico-chemical advantages of mild processing, consumers have been known to take a more conservative approach and do not always readily see the benefits or risks of new processing methods. The literature documents several instances of consumer perception being influenced by production characteristics, including the way the products have been processed, specifically that some consumers have mistrust and dislikes for processing method (e.g., irradiation), despite the fact that production technologies are highly regulated issues, and the average consumer probably only has a vague idea about how these processing actually work (Bredahl, 2001; Frewer, Howard, & Shepherd, 1995; Grunert, Bredahl, & Scholderer, 2003).

Additionally, it is important to consider that consumers evaluate products as a whole rather than as individual features, and accordingly, several factors have been reported to influence acceptance of novel food technologies. For instance, consumers' perceived benefits and risks, price, and perceived “naturalness” have been found to affect acceptance of new food technologies (Honorio et al., 2019; Siegrist, 2008; Frewer, Scholderer, & Lambert, 2003; Krumreich et al., 2019). Previous studies also showed that social trust, e.g. in national food and health authorities and certification systems, also plays significant role in influencing consumer perceptions and attitudes towards new food processing methods. Consumers were found to have very limited knowledge of minimal processing technologies, such as pulsed electric field (PEF) and high-pressure processing (HPP; Nielsen et al., 2009). As a result, most consumers are unable to decide whether new foods produced by such technologies are associated with possible risks or benefits. New food technologies may be used to produce food products with benefits that cannot be directly experienced by the consumer. One way that consumers cope with the lack of knowledge is to rely on trust in familiar brands or institutional labels to reduce the complexity of decisions (Earle & Cvetkovich, 1995). Nevertheless, from a consumer advocacy standpoint, it is very important that consumers be informed and educated about possible benefits of novel food technologies.

Situated within this context, partners in the SHEALTHY project have conducted several consumers studies with the aim to better understand consumers' perception and attitudes towards non-thermal mildly processed F&V and derived products among EU consumers. Moreover, consumers' use of package information and household storage and waste of F&V was also discussed, in order to estimate the possible contribution of mild processing to reducing household food waste.

2. Methods

The work conducted employed a combination of qualitative and quantitative consumer research methods. To ensure representativeness of the target population, studies have included a total of 1,037 consumers across six European countries: Denmark, Italy, Germany, Serbia, Spain, and the Netherlands.

2.1. Focus groups

All the focus groups were conducted between November 2019 and February 2020. The focus group protocol was followed throughout the discussion to ensure the consistency of focus groups in all six countries. Each group discussion lasted about 90 to 120 minutes. Both video and audio recordings were collected for subsequent data analysis.

In total 94 consumers took part in this study in six European countries: Denmark, the Netherlands, Germany, Spain, Italy, and Serbia were chosen for this study to obtain a pan-European outlook of consumers' perception and attitudes. More specifically, the focus groups addressed the following four themes: 1) participants' preferred quality attributes of fruit and vegetables; 2) participants' knowledge and perceptions toward mild technologies; 3) participants' use of packaging information at point of purchase; 4) household storage and waste of fruit and vegetable products. Table 2 provides a more detailed breakdown including specific sub-themes used by the FG moderators.

Themes	Details
PREFERRED QUALITY ATTRIBUTES OF F&V	General info on consumption of F&V and F&V-based products in general; Consumers' preferred quality attributes of F&V and F&V based products in general.
CONSUMERS' PERCEPTION OF MINIMALLY PROCESSING METHODS FOR F&V	Familiarity and/or knowledge of F&V processing, including mild processing methods; Consumers' perception towards mildly processed F&V and F&V-based products; Perceived benefits and risks of mild processing methods; Attitudes towards information (or lack thereof) regarding processing information of F&V.
CONSUMERS' USE OF PROCESSING AND PACKAGE INFORMATION OF F&V	Consumers' use of processing information and other package information of F&V at point of purchase and at home; Perceived importance of different package information categories;
CONSUMERS' HOUSEHOLD STORAGE BEHAVIOR OF F&V	Household storage behaviour of F&V at home in general; Reasons for disposing of F&V at home; Consumers' behaviour and actions related to reduction of F&V waste; Retailers' and producers' possible contributions to reduction of F&V waste.

Table 2: Interview guide for the focus groups.

In each country, two age groups were addressed: young-age (YA, 18-30 years old) and middle-age (MA, 45-60 years old) population. These two groups were selected as target groups due to their known differences in purchasing power and attitudes towards technology. Besides age and nationality, participants were screened using the following criteria: (a) be responsible for grocery shopping; (b) not affiliated with the project; (c) not working professional with food and nutrition. Finally, each focus group had a balanced number of female and male participants. The exact breakdown of information for the FG is given in Table 3.

Recordings of the FG discussions from the six countries were translated and transcribed into English text. NVivo 12 (QSR International, UK) was used to code the transcriptions based on the standard content analysis procedures (Morgan, 1997; Patton, 1999; Banovic et al., 2015). This was done by looking for common categories across interview stages in each focus group, and the results of the focus groups are discussed with emphasis on the differences occurring in the most recurrent discussed categories during the focus group stages.

COUNTRY	NUMBER OF PARTICIPANTS	BY AGE	BY GENDER (M/F)
DENMARK	17	10 YA	5/5
		7 MA	3/4
THE NETHERLANDS	16	8 YA	4/4
		8 MA	4/4
GERMANY	16	8 YA	4/4
		8 MA	5/3
ITALY	14	8 YA	3/5
		6 MA	2/4
SPAIN	15	7 YA	4/3
		8 MA	4/4
SERBIA	16	8 YA	4/4
		8 MA	4/4

Table 3: Demographic information of the focus groups participants in the six countries.

2.2. Online survey

To extend and validate the findings from the qualitative research, a large online survey (N= 848 in total, aged 19 to 88) across four countries: Denmark, Italy, Serbia, and Spain. The survey was structured in three main parts. The first part was a choice-based conjoint task (DeSarbo, Ramaswamy, & Cohen, 1995) in which participants were presented with multiple options of different F&V products (orange juice, iceberg salad and cherry tomatoes) systematically varying in three features: benefits, processing and price. Table 4 provides a detailed breakdown of the design including the levels for each feature, and Figure 1 shows an example of the choice-based task.

The second part is a series of questions focusing on consumers knowledge and attitudes regarding processing methods as well as storage and consumption of fruit and vegetables. The third and final part contains a few questions on the participants background (sex, age, education), as well as and the food technology neophobia scale (FTN, Cox, & Evans, 2008) and a composite index measuring their knowledge of food processing and storage, to use for segmentation purposes.

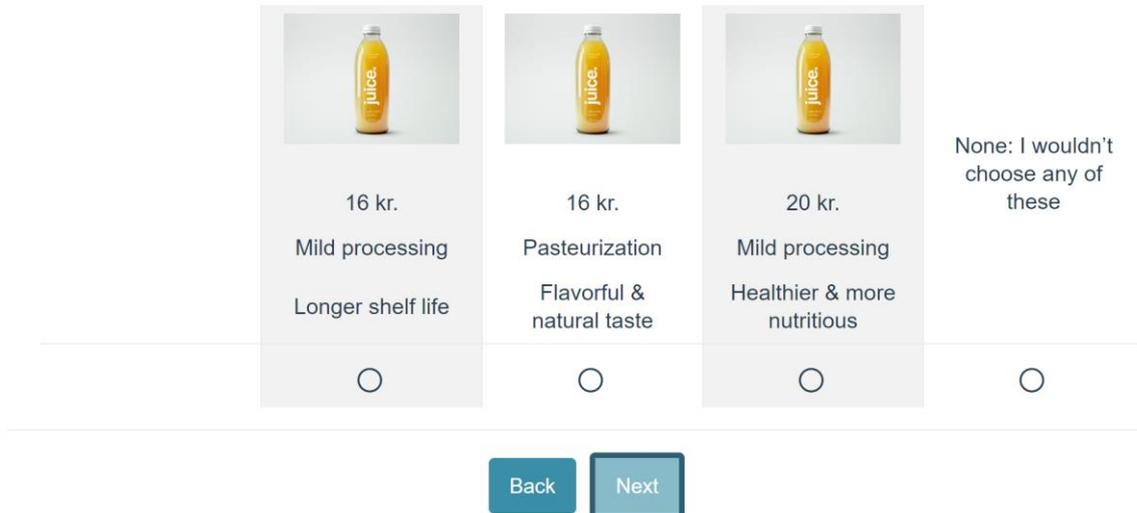
Feature	Levels		
	ORANGE JUICE	ICEBERG SALAD	CHERRY TOMATOES
PROCESSING	Mild Processing Pasteurization	Novel washing Conventional washing	Active Packaging Conventional packaging
BENEFIT	Healthier & more nutritious Flavorful & natural taste Longer shelf-life	Healthier & more nutritious Flavorful & natural taste Longer shelf-life	Healthier & more nutritious Flavorful & natural taste Longer shelf-life
PRICE	Reference (DK= 16 DKK, IT = 1.0 EUR, ES = 1.46 EUR, SE = 2.1 EUR) Premium (DK= 20 DKK, IT = 1.3 EUR, ES = 1.89 EUR, SE = 2.7 EUR)	Reference (DK= 12 DKK, IT = 1.9 EUR, ES = 1.5 EUR, SE = 1.6 EUR) Premium (DK= 16 DKK, IT = 2.5 EUR, ES = 1.95 EUR, SE = 2.1 EUR)	Reference (DK= 18 DKK, IT = 1.99 EUR, ES = 1.99 EUR, SE = 2.4 EUR) Premium (DK= 23 DKK, IT = 2.6 EUR, ES = 2.59 EUR, SE = 3.1 EUR)

Table 4: Experimental design used to create product options for the conjoint task of the survey.

1. You will find below 3 orange juice products (500ml) with different features.

Please check the descriptions below each image carefully and choose the one you would be most likely to purchase.

You may choose the "none" option if you wouldn't purchase any of these. *



The screenshot shows a survey interface with four options for orange juice products, each with a radio button for selection. The options are:

- Option 1:** 16 kr. Mild processing, Longer shelf life.
- Option 2:** 16 kr. Pasteurization, Flavorful & natural taste.
- Option 3:** 20 kr. Mild processing, Healthier & more nutritious.
- Option 4:** None: I wouldn't choose any of these.

At the bottom of the interface, there are two buttons: "Back" and "Next".

Figure 1: Screenshot of the choice-based conjoint survey. Participants had to indicate had to evaluate triads of products and indicate which of the options they were more likely to purchase.

	DENMARK	ITALY	SERBIA	SPAIN	AGGREGATE
N RESPONDENTS	293	252	124	179	848
AGE RANGE	19-88	20-85	19-82	20-71	19-88
MEAN AGE	48.1±18.2	48.9±15.8	38.4±12.1	40.6±10.3	44.1±14.6
MALE	45%	44%	26%	32%	39%
FEMALE	55%	56%	74%	68%	61%
EDUCATION					
HIGH SCHOOL OR LESS	40%	51%	6%	15%	33%
UNDERGRADUATE	43%	29%	63%	30%	39%
POSTGRADUATE	17%	20%	31%	55%	28%
INCOME					
< 13,000 €	13%	22%	54%	12%	21%
13,001 – 40,000 €	39%	61%	30%	61%	49%
40,001 – 67,000 €	34%	14%	11%	21%	22%
> 67,000 €	14%	3%	5%	6%	8%
DIETARY STATUS					
OMNIVORES	92%	83%	82%	91%	88%
VEGETARIAN/VEGAN	3%	14%	7%	5%	7%
OTHER	5%	4%	10%	4%	5%

Table 5: Background information on the consumers who participated in the online conjoint study, on a country by country basis and aggregate (last column).

3. Main findings

3.1. Focus group results

The FG gave insights into several aspects of consumers' perceptions and attitudes towards mildly processed F&V. General factors most often mentioned by participants as important for their choice of F&V (Fig. 2) included sensory quality (31%), seasonality (13%), origin (12%), naturalness (10%), personal habits (10%). Sensory quality, especially appearance and taste, was regarded as the most important features, in accordance with previous studies (Ragaert et al., 2004).

Seasonal and local products were regarded as preferable and many participants expressed a specific preference towards organic products and concerns over whether the products contain additives and preservatives. Consumer perception of F&V derived products was slightly different than that towards fresh produce: for example, some participants tried to avoid purchasing F&V derived juices and smoothies due to the sugar and additive content in some industrial products.

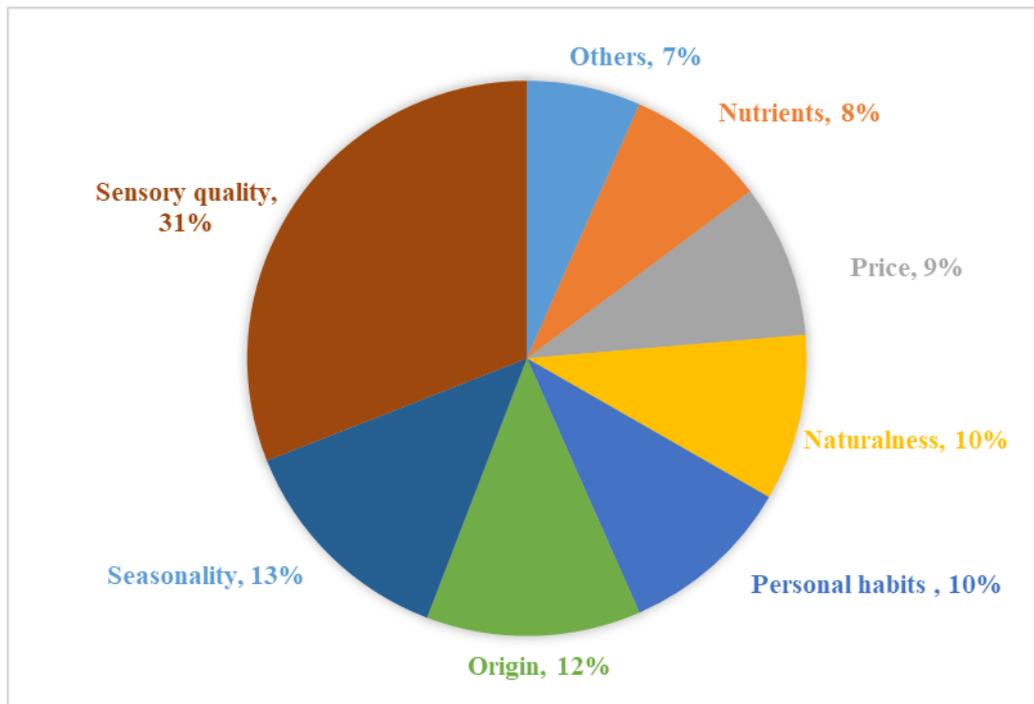


Figure 2: Frequency distribution of factors considered by consumers when purchasing F&V and derived products.

Overall, participants lacked knowledge regarding processing of F&V products. Some participants showed some knowledge and concerns about the cultivation stage (especially pesticides usage), but less so with regards to the post-harvest phase. Accordingly, participants were very unfamiliar with the concept of mild technologies (MT). After the FG moderator introduced the concept of mild processing and provided some examples, a few of the participants declared that they were familiar with some technologies, (e.g. ultrasound), but not in the context of F&V processing.

The FG discussion then moved on to exploring participants' thoughts about consuming mildly processed F&V, their concerns as well as the benefits they expected MT might bring. Many participants stated that even though MT sounds good in theory, they still felt hesitant, or even outright objected, to purchasing and consuming of mildly processed F&V. The possible effects of MT on the quality of the products was one of the major concerns among our participants, followed by safety and health-related concerns, price, shelf-life, energy cost and environmental impacts, and naturalness. The pie chart in Figure 3 the prevalence of concerns and expected benefits participants associated with mildly processed products (based on the responses from all countries).

As shown in Figure 3, participants' concerns regarding damages to the sensory quality of products were most frequently stated (23%). Accordingly, they stated that they would be more open to consuming mildly processed products if the novel processing methods did not cause loss of taste and aroma. Safety and health-related concerns were also frequently expressed (22%). In this case, even though some of the participants acknowledged that mild processing methods could reduce the use of chemical additives and preservatives in the final products, they were worried that it may introduce other harmful compounds into the products.

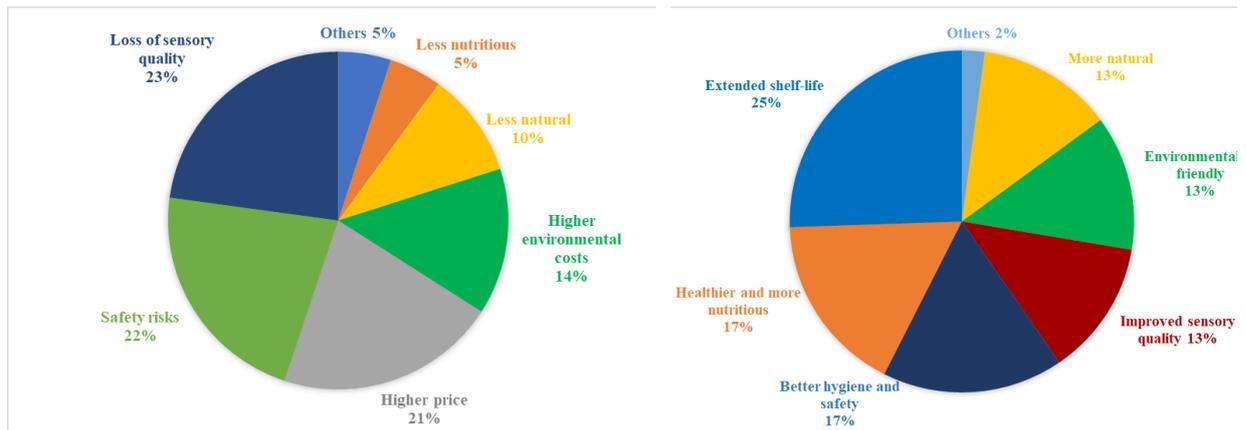


Figure 3: Focus group participants' concerns (left) and expected benefits (right) associated with mildly processed F&V.

Many participants, however, added that they would feel more confident in consuming mildly processed F&V if the effects of MT on both the products and human health were thoroughly studied and endorsed by trustworthy institutions. Other frequently mentioned concerns about mild processing technologies was the possibility that this could result in higher prices (21%, Figure 3), and that it might result in higher energy and environmental impacts (13% - this concern was mostly expressed with regards to the amount of water needed by novel washing techniques and whether it would be higher than conventional washing).

By contrast, frequently mentioned perceived benefits (Figure 3, right piechart) of mild processing including extension of shelf-life (25%), possibly healthier and safer products (17%), lowering the environmental impact of F&V processing (13), and possibly improving the product sensory quality (13%).

As for processing, participants had no formal knowledge of best practices for storing F&V at home, and instead rely on what their parents taught them or try to replicate the storage conditions at the supermarket or shops where they bought the products. For fresh products, only a few participants declared that they used to check the storage instruction from the label or searched online to confirm whether they chose the best storage methods. Accordingly, the participants' behavior in terms of F&V storing was not always compliant with recommendations: for instance, some participants stored potatoes and onions inside the fridge. Participants discarded different kinds of F&V, mainly due to the sensory decays of the F&V. Sometimes, they made mistakes in shopping plans and bought more amount than needed, or just forgot what they have at home beforehand. Some participants, most notably YA who lived alone, complained about the package size of some F&V being too big for their consumption needs, but they had no choices of smaller packages or loose ones.

Importantly, many participants reported increased awareness of the societal costs of F&V waste, and had made some active efforts to reduce it, for example by making better shopping plans. For instance, some participants mentioned that they used some apps or websites to make recipes for their leftover F&V at home. Participants (especially young, living alone) expressed that the options of buying loose items and/or smaller packages would likely reduce their own food waste. Smart packaging with freshness indicator attracted interests from some participants, especially for package of products whose ripeness is hard to tell by touching and/or looking. They saw the advantages from the convenience, food sanitation, and waste reduction point of view.

A selection of quotes exemplifying participants' stated concerns and benefits associated with mild technologies are given in Annex I.

In conclusion, the FG identified lack of knowledge and trust among consumers as the major potential impediment to their acceptance of mildly processed F&V products. Specifically, consumers have difficulties in assessing relevant benefits and risks, which engenders concerns and impedes the establishment of social trust. These findings suggest that increase in public interest in novel MT and mildly processed F&V products may be a long-term process. Consumer-oriented communication and

education is necessary to enhance social awareness and trust. Information that incorporate benefits for the consumer could have a positive impact on consumers food choice, particularly when the message is concise and from trusted sources and the benefits are directly related to product quality and safety. Furthermore, consumers had higher willingness in consuming F&V processed by more environmental-friendly technologies which could save energy and benefit F&V waste reduction.

3.2. Online survey results

3.2.1. Aspects influencing consumer choice of mildly processed F&V and derived products

Figure 4 and Table 6 show the main results from the conjoint analysis part of the online survey. Results are presented for the three individual F&V products (orange juice, iceberg salad, and cherry tomato) Figure 4 plots the relative importance of the three experimental design factors (processing, benefit, and price level) for consumer choice, estimated using their part-worth utilities. A utility is a measure of relative desirability or worth. The higher the utility, the more desirable the attribute level. Levels that have high utilities have a large positive impact on influencing respondents to choose products.

The barplot shows clearly that – for all products and in all countries – stated benefit (the orange bar) was the most important aspect out of the three. Processing information and price levels had similar influence on consumer choice of iceberg salad and cherry tomatoes, but not for orange juice, where processing information had a larger effect than price.

Danish consumers appeared more price oriented than consumers in the other three countries, which were comparatively more affected by processing information (again, the difference mostly pertained to orange juice). The finding that expected benefit had a larger importance for consumer choice confirms and validate the results of the qualitative study pertaining to factors of importance for consumer purchasing behaviour (Song et al., 2020). For instance, it can be seen in Fig. 2 that a majority of consumer quotes related to different benefits (taste, healthy, etc) compared to a minority of quotes relating to price and processing¹.

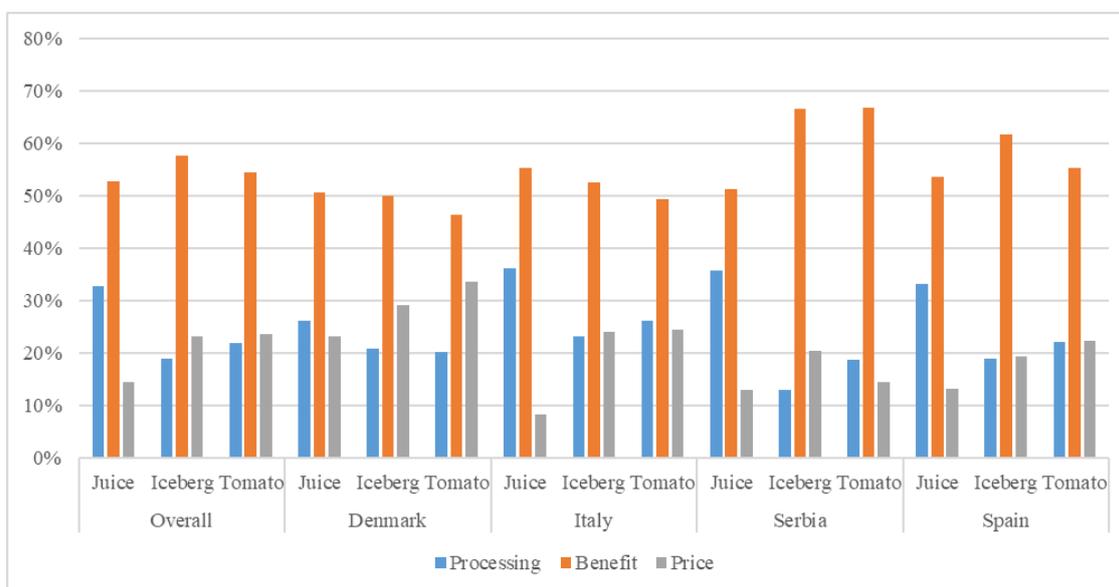


Figure 4: Relative importance of price, processing, and benefit for consumer choice of juice, iceberg salad, and cherry tomato products – overall and on a country by country basis.

Table 6 shows the direction of these effects, i.e. the actual part-worth utility values for the contribution of each design levels to consumer choice, both at an aggregate and on a country by country basis.

¹ Processing isn't directly mentioned in that figure, but the concept of "naturalness" can be seen as a reasonable proxy.

Overall, mild processing is associated with a positive increase in likelihood of choice for orange juice, and had no effect on the other two F&V product categories. This result is promising in relation to the aims of the SHEALTHY project as it shows that treatment with mild technologies, when communicated in consumer-friendly terms, could increase consumer willingness to buy F&V, or at least not pose a barrier as originally expected. As mentioned, mild processing was significantly preferred to conventional processing for orange juice in all countries, and in Italy only, also for iceberg salad and cherry tomatoes. Regarding the effect of stated benefits, “healthier and more nutritious” and “flavourful and natural taste” were more positively received, and Table 6 shows, accordingly, that consumers were 2 to 3 times more likely to choose products when these claims were present compared to the longer shelf-life claim. “Healthier and more nutritious” was the best claim as it significantly increased consumers’ interest in all countries and for all products, whereas effect sizes for “flavourful and natural taste” were generally smaller and most were not statistically significant (Table 6). With regards to developing BMs based on consumer preferences, it can therefore be concluded that a value proposition built around health and better retention of nutrients will be most likely to encounter the favour of most consumers.

Price played a more important roles for consumer choice of iceberg salad and cherry tomatoes, where consumers preferred the reference price (i.e., the less expensive one), as one would expect. Interestingly, however, this was not the case for orange juice where the presence of a higher price did not significantly affect consumer choice.

The results appeared very stable across countries when considering the direction of the effects. Some minor differences in the effect sizes were observed. For instance, the health/nutrition claim has a stronger effect on Serbian consumer than in the other three countries, where that taste claim had a slightly higher influence on the choice of all products among Spanish participants.

		PROCESSING		BENEFIT			PRICE	
		Mild	Conventional	Healthier & more nutritious	Flavourful & natural taste	Longer shelf-life	Ref	Premium
OVERALL	Juice	49% (1.7) ***	30% (-)	36% (2.7) ***	29% (2.2)	12% (-)	45% (0.8)	34% (-)
	Iceberg	46% (0.9)	35% (-)	37% (2.9) ***	26% (1.9)	19% (-)	49% (1.6) *	32% (-)
	Tomato	45% (0.9)	36% (-)	38% (2.9) ***	30% (2.4)	16% (-)	52% (1.7) **	29% (-)
DENMARK	Juice	48% (1.6) ***	31% (-)	37% (2.9) ***	32% (2.5) ***	10% (-)	50% (1.3)	30% (-)
	Iceberg	45% (1.0)	34% (-)	37% (3.1) ***	25% (2.0)	17% (-)	53% (2.4) ***	25% (-)
	Tomato	48% (0.9)	38% (-)	35% (2.2) **	34% (2.3)	16% (-)	60% (2.6) ***	26% (-)
ITALY	Juice	45% (1.3) ***	28% (-)	36% (2.3) ***	25% (1.9)	11% (-)	38% (0.3)	34% (-)
	Iceberg	45% (1.5) ***	27% (-)	34% (3.0) ***	22% (2.0)	17% (-)	44% (1.7) **	28% (-)
	Tomato	51% (1.3) ***	32% (-)	39% (2.7) ***	27% (2.0)	18% (-)	53% (1.7) ***	30% (-)
SERBIA	Juice	55% (1.9) ***	29% (-)	43% (3.0) ***	25% (1.6)	15% (-)	45% (0.7)	38% (-)
	Iceberg	47% (0.4)	41% (-)	45% (3.2) ***	29% (2.0)	13% (-)	47% (1.1)	40% (-)
	Tomato	47% (0.6)	41% (-)	44% (4.5) ***	30% (3.0) ***	14% (-)	51% (0.7)	37% (-)
SPAIN	Juice	50% (1.9) ***	26% (-)	33% (2.5) ***	32% (2.7) ***	11% (-)	43% (0.8)	33% (-)
	Iceberg	49% (0.6)	38% (-)	37% (2.4) ***	28% (1.7)	22% (-)	53% (1.3)	34% (-)
	Tomato	48% (0.6)	39% (-)	37% (2.1) **	33% (2.3) **	17% (-)	55% (1.7) ***	32% (-)

*** P < 0.001; ** P < 0.01; * P < 0.05.

Table 6: Percentages and part-worth utilities (O.R. from logistic regression) showing the contribution of the design levels to consumer choice - both overall and on a country by country basis.

Additional analyses were conducted to assess the degree of segmentation in terms of relevant demographic-, psychographic- and behavioural variables (see Annex IV). Generally, results for different segment were rather similar. Possibly the largest differences were due to related to consumers' FTN level: specifically, consumers with high FTN were less likely to choose F&V treated with MT, which makes sense given that this psychological trait measures consumers' fears of novel food technologies (about 15% of the consumers in our sample were classified as having a high FTN). Another difference was due to dietary status where omnivores appeared to be more sensitive to price compared to vegetarian/vegans, whereas vegetarians/vegans gave more importance to health and nutrition aspects. Finally, younger consumers (19-34) were slightly more positive towards mildly processed F&V than older consumers (51+). Overall, however, differences between segments appeared small and transient. This would suggest that products treated with MT have a broad appeal and could target the population as a whole.

3.2.2. Determinants of household food waste behaviour

The second part of the online survey pertained specifically to subtask 3.1.2 and focused on consumer behaviour that may determine food wastage at household level. The data collected show the frequency, portion and categories of F&V often discarded by European consumers.

In general, participants reported quite low frequency of discarding F&V (3 times per month on average – see Annex II for exact figures and country breakdown), with a majority of participants reportedly only discarding one portion or less each time.

Figure 5 shows the most frequently discarded F&V products. At an aggregated level, the most often discarded F&V according our data are leafy greens (e.g. iceberg and spinach), follow by tomatoes, bananas, allium (e.g. onion and garlic), and stone fruit (e.g. apricots, peaches and plums). F&V juices and smoothies by contrast feature amongst the least frequently mentioned option.

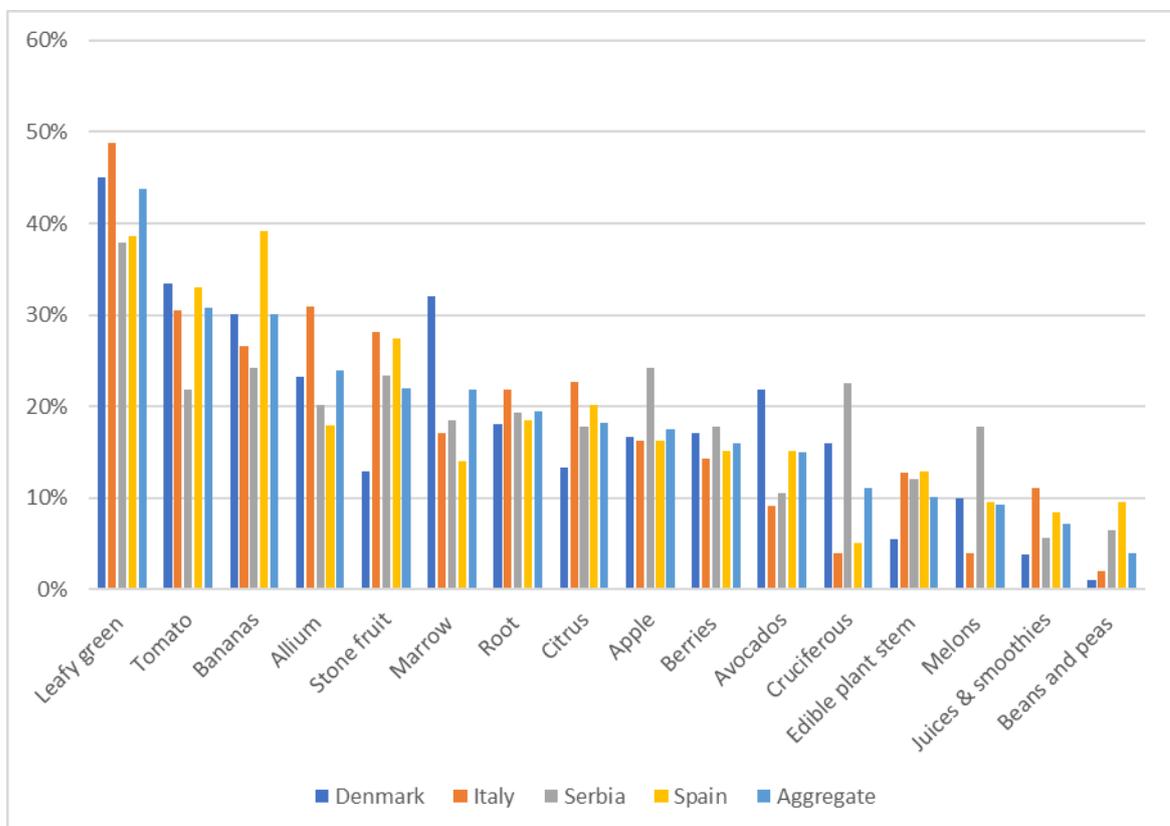


Figure 5: Types of F&V discarded – aggregate and by country. Items are arranged by most to least frequently discarded based on aggregated data.

The survey also probed consumers to report reasons for discarding F&Vs. Fig. 6 reports the relative frequency of each response. Presence of visible mould on the product was the most often mentioned reason for discarding F&Vs, followed by adverse sensory qualities in the product (bad smell, bad taste or bad appearance). Additional reasons included incorrect storage, expiration date having passed, and mistake in shopping planning, and the package sizes being too big for their consumption needs. Also in this case a good correspondence could be observed between the qualitative findings of the focus groups and those of the online survey, especially concerning sensory decay being the primary reason for discarding D&Vs. No major differences between countries were observed, although it appeared that sensory quality had a relatively larger influence in Spain and Denmark compared to Serbia and Italy (see Annex II for country breakdown).

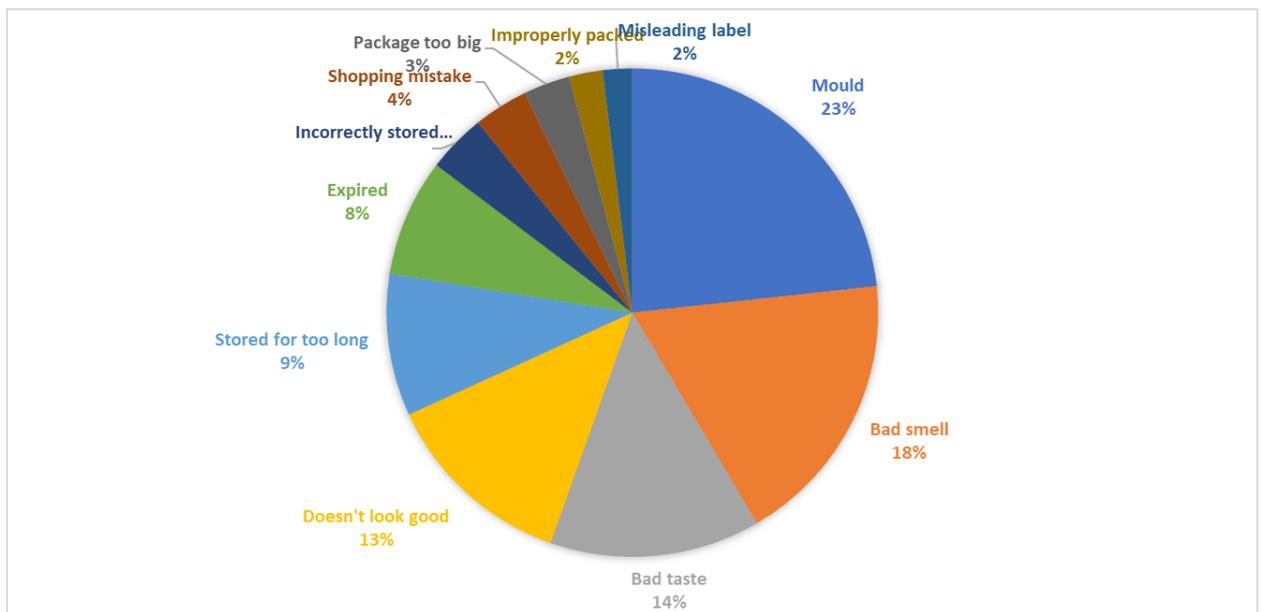


Figure 6: Types of F&V discarded – aggregate and by country.

Finally, consumers reported on what could contribute, in their opinion, to reduce their own F&V wastage, by selecting them from a checklist. The most frequently mentioned answer was that package sizes optimized to their household needs (Fig. 7). This mirrors the finding of the qualitative research where packages being too large was mentioned as the primary reason for wastage, especially among young and single consumers. Better shopping plans and checking the household pantry before shopping were other frequently mentioned answers. Many consumers also reported that having more knowledge of how to correctly store F&V would be helpful. Less frequently mentioned answers included having to pay proportional to the amount of F&V discarded, and having more information on the environmental and economic impact of F&V waste. Only very few participants thought that increasing the price of F&V would lead them to waste less.

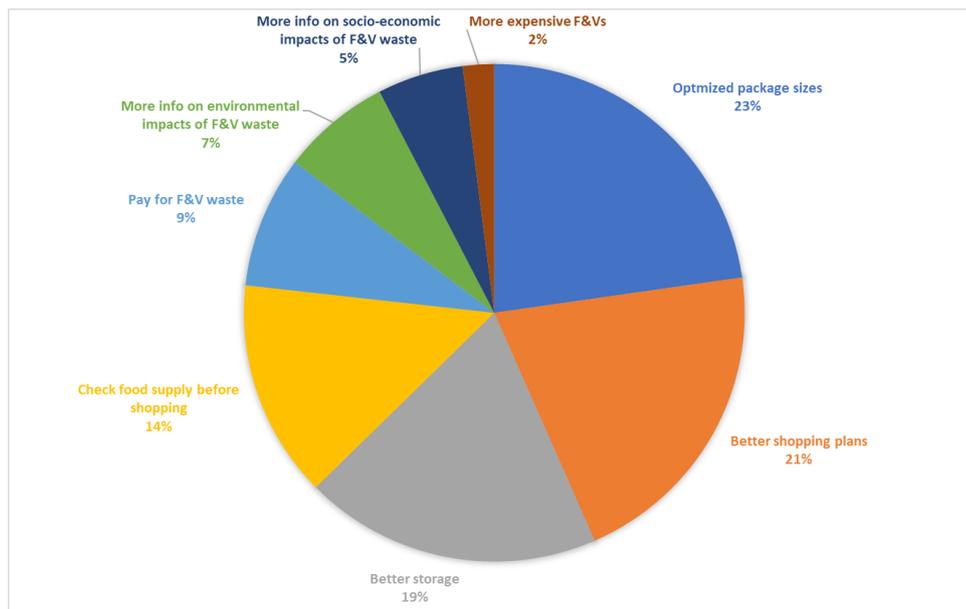


Figure 7: Factors which could contribute to F&V waste reduction.

4. Outreach and dissemination

Results presented in this report have so far been disseminated throughout the project homepage, via the official SHEALTHY Twitter handle (@ShealthyP), as well as in other social media channels operated by the project partners.

At the time of writing (August 2020) dissemination in the scientific research community has been limited due to the outbreak of the Covid-19 pandemic, which have led to the cancellation or postponement of many conferences and professional meetings in the first half of 2020. Project results are expected to be presented in December this year at the upcoming 2020 European Conference on Sensory and Consumer Research (<http://www.eurosense.elsevier.com/>), and at the Pangborn Sensory Science Symposium scheduled for next year (<http://www.pangbornsymposium.com/>). Eurosense and Pangborn are the leading important conferences in the field of sensory and food consumer research and have approximately 1000 delegates with an almost equal representation of academia and industry. Should they be cancelled or further postponed due to the Covid-19 situation, relevant electronic conferences will be identified to ensure outreach within the research communities.

At the same time, three peer-reviewed papers are expected to be published based on the results presented in this deliverable. The first paper, based on the qualitative studies, has been submitted and is currently under consideration at the open access journal *Foods* (IF: 4.092). The other two papers are currently been prepared with an expected submission date in 2020. Also, these publications will be published open access to maximize impact.

Additional outreach activities to the general public are planned in the remainder of the SHEALTHY project, most notably as part of the project communication campaign. Educational materials as well as demo videoclip based on the material and results collected during the studies will be developed to showcase the project results to consumer panels in all participating countries.

Conclusion

This report summarized the main findings from activities undertaken within the SHEALTHY project with reference to subtasks 3.1.1 and 3.1.2. The aim of these tasks was respectively, to investigate European consumers' perception and expectations towards mildly processed F&V, and to investigate the consumer behaviour that may determine food wastage at household level. A combination of activities involving literature reviews, as well as qualitative and quantitative consumer research in six European countries (Denmark, Italy, Germany, Serbia, Spain, and the Netherlands) were undertaken to address the aims of the tasks. The research findings included in this report are expected to provide guidelines to the successful introduction of mildly processed F&V products, which could hopefully contribute to an increased intake of fresh F&V in the general population.

Innovative food processing technologies are not in the top of mind of European consumers. Lack of basic knowledge and trust among consumers was identified as the major potential impediment to their acceptance of F&V products, as consumers reportedly have difficulties in assessing relevant benefits and risks associated with MTs. Therefore, targeted communication is necessary to enhance social awareness and trust.

Additionally, communicating about specific benefits from the use of innovative processing technologies should increase acceptance. In fact, communicating benefits from the use of these new technologies has a powerful potential towards future differentiation strategies, especially for F&V derived products like juices, for which consumers were found to prefer mild processing to the conventional processing (pasteurization) for this product category. By contrast, consumers paid less attention to processing information for whole F&Vs.

Overall, specific benefits associated with F&Vs were found to be more relevant for consumer acceptance than processing information per se. Health and nutritional benefits were found to be the most effective type of claims, so focusing on the possibility of better preservation of nutritional values by the use of MT should be emphasized in consumer communication. With respect to developing BMs centered on the adoption of MT, it can be concluded that a value proposition built around health and better retention of nutrients will be most likely to encounter the favour of most consumers.

Besides health and nutritional benefits, better sensory quality, and more hygienic and safer were important benefits perceived by consumers. Impacts on product sensory quality, safety risks, higher price and environmental costs were the concerns most often mentioned by consumers. It is important to emphasize here that sensory quality was identified as the main driver of consumers' choices of F&V, and losses to taste and aroma were most frequently mentioned as concerns related to mild processing. Therefore, it is crucial that sensory studies be conducted to evaluate that the acceptability for F&Vs treated with MT products is at least on par with that of their conventionally processed counterparts, as that will most likely be a prerequisite for marketplace success.

With respect to consumers' food waste behaviour, the findings indicated that European consumers mostly discard F&V after visual inspection and mainly due to the presence of mold or adverse sensory qualities (such as diminished appearance, presence of smells, etc) after storage. This confirms the great potential of MT in reducing food waste at household levels, given that many MTs have antimicrobial effects against a variety of microorganisms. The results indicated that leafy greens and tomatoes were the two categories of F&Vs most often discarded at the household levels. Besides product-related factors, lack of/insufficient knowledge of correct storage practices, and suboptimal package sizes were identified as additional important reasons behind F&V waste behaviour of European consumers.

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Annexes

Annex I – Exemplary quotes from focus groups interviews

Perceived concerns associated with mild technologies

Impact on sensory quality and “naturalness”

- *“The taste is very important. I have lived in South America and the bananas there are tastier. While they have to come all the way from there to our supermarkets, you need this kind of technology.” (23 yo, male, Dutch)*
- *“Everyone’s producing them now not to have taste and smell, but to look pretty. I don’t want to look at it, I want to eat it.” (46 yo, male, Serbian)*
- *“It’s not normal that something that should last for 2-3 weeks lasts 2 months.” (46 yo, female, Serbian)*
- *“...with the aim of preserving its freshness to make it more durable over time, but compromising its nutritional characteristics and taste is not natural.” (23 yo, female, Italian)*
- *“The more a product is closer to the original status, without any processing, the better.” (22 yo, male, Serbian)*

Impact on health

- *“I think it's important to say that these procedures assure me that I won't get any kind of disease or any kind of bacteria by ingesting them.” (27 yo, male, Spanish)*
- *“How can that affect my health?” (26 yo, female, Serbian)*
- *“When you look not only at profit but also at the good of the consumer. If you do not think that the product is intended for use by the consumer which could be dangerous to health.” (52 yo, male, Italian)*
- *“Suspicious. What is the actual process like? Will that affect my health and how?” (22 yo, male, Serbian)*

Lack of knowledge/trust

- *“I don’t know if it [i.e., the processing method, A/N] is important knowledge for me and I think I would rather trust the government. Living in Denmark, if the producers are allowed to produce and sell it, I would trust that I can just buy it without any risk.” (57 yo, male, Danish)*
- *“I am not an expert. I can believe that mild processing is useful, but there must be a predisposed institute that confirmed that it is a positive process, if it is certified.” (26, male, Italian)*
- *“If it is a widely used thing... if there are many who do this, then I would feel safer.” (52, female, Italian)*
- *“I am confused about what I don’t know.” (26 yo, female, Danish)*
- *“I don’t feel I have the knowledge to choose. I don’t know how to.” (52 yo, female, Danish)*
- *“Knowing about technologies, a person is more confident about what to buy.” (22 yo, male, Italian)*
- *“I would be 90% sure if it has a certification.” (26 yo, female, Italian)*
- *“I would definitely not trust it if the benefits information was from the producer's side. They have an interest in selling more apples. So it would need to come from like an external source ... for it to be credible enough.” (25 yo, male, Danish)*

Possible price increases

- *“If it cleans 99% of the bacteria instead of 90%, then I don’t know if it’s worth for me to pay 10 or 20 cents more.” (23 yo, male, German)*

- *"I will take the cheaper one first, unless the other one has something recognizable at first glance, it has the organic label on it, or something like this. Otherwise I don't have the patience to compare."* (22 yo, female, German)
- *"As a student, I just prefer products that are cheaper."* (23 yo, male, Dutch)

Perceived benefits associated with mild technologies

Longer shelf-life

- *"When it comes to shelf-life, we may have less food wasted, I think it's an important item."* (55 yo, male, Dutch)
- *"There are definitely benefits with the processing technologies. You do it for a reason. You do it to get rid of bacteria and germs, to extend the shelf-life... you throw out less food and be able to ship it further over longer distance."* (25 yo, male, Danish)

Improved safety

- *"These technologies give me an idea of disinfected, clean food, probably without microbes."* (56 yo, male, Italian)
- *"When I hear the word 'mild', I'm assuming it'll use much less chemicals... and other additives."* (58 yo, male, German)

Better sensory and nutritional quality

- *"If they are able to enhance its taste and texture and everything, then that is exciting."* (52 yo, female, Danish)
- *"We even buy those products that are "heavily processed" already, as opposed, if it is processed by some mild version, I would probably prefer it."* (30 yo, female, Serbian)
- *"Perhaps the preserving of nutrients."* (25 yo, male, German)

Annex II - Frequency, portion and types / categories of F&V discarded, overall and by country

	Denmark	Italy	Serbia	Spain	Aggregate
Times / month ¹	3.3	1.9	3.6	3.6	3
Portion / time ²					
Fewer than one or nothing	30%	42%	44%	35%	37%
1 portion	48%	48%	44%	46%	47%
2-3 portions	19%	9%	10%	17%	14%
More than 3 portions	2%	1%	5%	2%	2%
F&V type					
Leafy green – e.g. iceberg and spinach	45%	49%	38%	39%	44%
Tomato	33%	31%	22%	33%	31%
Bananas	30%	27%	24%	39%	30%
Allium – e.g. onion, garlic and shallot	23%	31%	20%	18%	24%
Stone fruit – e.g. apricots, peaches and plums	13%	28%	23%	27%	22%
Marrow – e.g. pumpkin, cucumber and zucchini	32%	17%	19%	14%	22%
Root – e.g. potato and sweet potato	18%	22%	19%	18%	19%
Citrus – e.g. oranges, grapefruits, and limes	13%	23%	18%	20%	18%
Apple	17%	16%	24%	16%	18%
Berries – e.g. strawberries and blueberries	17%	14%	18%	15%	16%
Avocados	22%	9%	10%	15%	15%
Cruciferous – e.g. cabbage and cauliflower	16%	4%	23%	5%	11%
Edible plant stem – e.g. celery and asparagus	5%	13%	12%	13%	10%
Melons – e.g. watermelons and honey melons	10%	4%	18%	9%	9%
Juices & smoothies	4%	11%	6%	8%	7%
Fresh beans and peas - e.g. green peas and beans	1%	2%	6%	9%	4%
¹ More rarely or never = 0; once per month = 1; 2-3 times per month = 2.5; 1-2 times per week = 6; 3-5 times per week = 16; 6-7 times per week = 26; ² One handful of F&V was defined as one portion.					

Annex III – Frequency of mentions (%) for reasons to discard F&V, overall and by country

Causes of F&V waste	Denmark	Italy	Serbia	Spain	Aggregate
The F&V is mouldy	94%	83%	56%	88%	84%
The F&V has a bad smell	71%	65%	42%	74%	66%
The F&V has a bad taste	52%	48%	35%	62%	50%
The F&V doesn't look good	51%	29%	35%	70%	46%
The F&V has been stored for too long	33%	31%	48%	31%	34%
The F&V product has expired	15%	37%	18%	43%	28%
Wrong storage	6%	21%	10%	18%	14%
Made mistakes when planned shopping	3%	21%	13%	16%	13%
Package is too big	9%	9%	6%	21%	11%
Not properly packed	2%	5%	7%	24%	8%
The label information is misleading	1%	4%	5%	22%	7%

Annex IV – Breakdown of consumer choices in the conjoint survey (%) by age, gender, dietary status and level of Food Technology Neophobia (FTN)

		Processing			Benefit				Price		
		Mild	Conventional	p [§]	Healthier & more nutritious	Flavourful & natural taste	Longer shelf-life	p	Ref	Premium	p
Age	19-34	54%	34%	**	40%	31%	17%	***	54%	34%	**
	35-50	47%	32%	*	38%	27%	14%	**	48%	31%	*
	51+	43%	33%	n.s.	33%	28%	15%	*	48%	28%	**
Gender	Female	49%	33%	*	38%	28%	15%	**	50%	32%	**
	Male	46%	34%	n.s.	35%	29%	16%	**	50%	30%	**
Dietary status	Omnivores	48%	34%	*	37%	29%	16%	**	51%	31%	**
	Vegetarian/ Vegan	44%	28%	*	43%	20%	9%	***	42%	30%	n.s.
	Other	46%	23%	***	37%	24%	7%	***	39%	29%	n.s.
FTN level	Low	56%	32%	***	42%	27%	19%	**	52%	35%	*
	Medium	49%	34%	*	37%	30%	16%	**	51%	32%	**
	High	33%	30%	n.s.	32%	23%	9%	**	41%	23%	**

[§] Within each segment, percentages are compared by binomial test. *** p < 0.001; ** p < 0.01; * p < 0.05, n.s. p > 0.05