



Original article

## Public preferences for nutritional, environmental and food safety characteristics of upcycled foods in Sweden

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**Summary** This study investigates people's preferences for nutritional, environmental and food safety characteristics of upcycled foods according to their age group and assesses the association between age and the importance of these characteristics in a Swedish population. A food choice questionnaire was used for data collection, and 681 Swedish residents aged  $\geq 18$  years participated in this study. In young, middle-aged and older adults, environmental (environmentally friendly preparation and packaging, local production and contribution to food waste reduction) and food safety (absence of additives, chemicals, genetically modified ingredients and contamination) characteristics of upcycled foods were more important than most nutritional characteristics (low energy and fat content and high fibre and protein content). There was a positive association between age and the importance score of nutritional characteristics, such as rich in vitamins and minerals, low energy and fat content and minimal food processing ( $P$ -value  $< 0.05$ ). A negative association was observed between age and the importance score of contribution to food waste reduction ( $P$ -value = 0.014). There was a positive association between age and the importance score of food safety characteristics, such as the absence of additives, chemicals and genetically modified ingredients ( $P$ -value  $< 0.05$ ). Therefore, the environmental benefits and food safety aspects of upcycled foods can be considered for product development and marketing to facilitate the acceptability of these foods in all age groups. Since the nutritional attributes of upcycled foods were less important than their environmental and food safety characteristics, strategies should be introduced to educate people regarding desirable nutritional features to enable them to choose healthy upcycled foods.

**Keywords** consumer preferences, environmental benefits, food safety, food sustainability, nutritional value, public perception, sustainable consumption, upcycled food.

### Introduction

The World population is growing and will rise to 9.1 billion in 2050; thus, food production must increase by 70% to prevent food insecurity (Food and Agriculture Organization, 2009). On the other hand, food waste reduction can decrease food insecurity (Reynolds *et al.*, 2015) as a significant amount of wasted food (1.3 billion tonnes/year) is still edible (Food and Agriculture Organization, 2013). Therefore, sustainable food production and food waste management are crucial for preventing food insecurity. Zero hunger and responsible consumption and production are part of the United Nations Sustainable Development Goals (United Nations, 2015). One of the strategies to address these goals is upcycled food production. Upcycled foods use ingredients that

otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment (The Upcycled Foods Definition Task Force, 2020).

Upcycled foods use unmarketable ingredients generated during harvesting, processing and preparation, such as imperfect crops, by-products and scraps from food preparation (The Upcycled Foods Definition Task Force, 2020) to produce new foods and contribute to the circular economy (Ali *et al.*, 2021). Upcycled food production returns wasted food to the supply chain to address sustainable food production and food waste management (Moshtaghian *et al.*, 2021). According to Farm to Fork Strategy, a sustainable food system should have a positive environmental impact; alleviate biodiversity loss and climate change effects; ensure access to adequate, nutritious, safe and affordable food and generate fairer economic returns (European

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Commission, 2020). Creating a fair, healthy and environmentally friendly food system is the focus of the Farm to Fork Strategy (European Commission, 2020), and upcycled food production can facilitate achieving this objective.

The food waste management aspect of upcycled food is appealing to people (McCarthy *et al.*, 2019, 2020; Yilmaz & Kahveci, 2022). For example, consumer demand for upcycled food increased when they considered upcycled food production as an approach for helping farmers to reduce food waste (McCarthy *et al.*, 2019, 2020). The food waste management feature of upcycled food is a distinctive attribute. From the consumer perspective, upcycled foods are different from organic and conventional foods, and people regard them as a new food category (Bhatt *et al.*, 2018). Thus, the acceptability of these products plays a vital role in the circular economy. Several factors influence upcycled foods' acceptability, including their nutritional content, environmental features and food safety attributes (Rahmani & Gil, 2018; Moshtaghian *et al.*, 2021).

The nutritional and environmental characteristics of upcycled foods play a crucial role in their acceptability (Coderoni & Perito, 2020, 2021; Grasso & Asioli, 2020; Asioli & Grasso, 2021). Nutritional and environmental messages such as high protein content and low carbon footprint can be used to communicate the advantages of upcycled foods to consumers for marketing purposes (Asioli & Grasso, 2021). Informing consumers regarding the environmental and health benefits of upcycled foods has a positive influence on their attitude towards these foods (Altintzoglou *et al.*, 2021) and increases purchasing intention (Coderoni & Perito, 2020; Grasso & Asioli, 2020; Ali *et al.*, 2021; Asioli & Grasso, 2021).

On the other hand, the food safety characteristics of upcycled foods are also important for consumers as they express their concern about the traceability of the ingredients and uncertainty regarding current legislation (Rahmani & Gil, 2018). Therefore, manufacturers' transparency in communicating and disclosing their sustainability efforts can positively or negatively impact acceptability (Peschel & Aschemann-Witzel, 2020). Moreover, the perception of the safety of these novel foods is also important because food neophobia and food technology neophobia negatively impact the purchasing intention of upcycled foods (Coderoni & Perito, 2020, 2021).

Since nutritional, environmental and food safety characteristics of upcycled foods influence their acceptability, understanding consumers' views on the importance of these characteristics benefits food manufacturers, retailers and supply chain stakeholders and improves the acceptability of upcycled foods. Furthermore, gaining insight into the nutritional, environmental and food safety

preferences of upcycled foods can identify areas for interventions to facilitate the selection of healthy and sustainable upcycled foods. The planet's health should not be at the expense of public health. People's food preferences play a crucial role in the food system transformation for achieving public health and planet sustainability (Chen & Antonelli, 2020).

Different generations have different attitudes towards upcycled foods, and it is, therefore, interesting to know if their preferences for nutritional, environmental and food safety characteristics of these foods also differ. For example, young and older generations are inclined towards upcycled foods, and middle-aged consumers are reluctant (Zhang *et al.*, 2021). Hence, their preferences for nutritional, environmental and food safety characteristics of these foods might also be different. To our knowledge, previous studies have not assessed different generations' perspectives on the importance of nutritional, environmental and food safety characteristics of upcycled foods (Coderoni & Perito, 2020; McCarthy *et al.*, 2020; Peschel & Aschemann-Witzel, 2020; Ali *et al.*, 2021; Asioli & Grasso, 2021; Zhang *et al.*, 2021). Therefore, this study investigates public preferences for nutritional, environmental and food safety characteristics of upcycled foods according to their age group and assesses the association between age and the importance of these characteristics in a Swedish population.

## Methods

Public preference for nutritional, environmental and food safety characteristics of upcycled food was investigated through an upcycled food choice questionnaire. Details of this questionnaire have been described elsewhere (Moshtaghian *et al.*, 2023). Briefly, an online self-administered upcycled food choice questionnaire was developed. In the questionnaire, upcycled foods were defined as foods that use ingredients that otherwise would not have gone to human consumption or would be wasted. Some examples of upcycled foods were also provided. The questionnaire collected information on sociodemographic background, attitudes towards food waste and upcycled foods, and factors motivating upcycled food choices. The questions on sociodemographic characteristics (Mousel & Tang, 2016), attitudes and food choice motives were adapted from previous questionnaires and upcycled food literature (Steptoe *et al.*, 1995; Lockie *et al.*, 2002; Evans & Cox, 2006; Lea *et al.*, 2006; Chen, 2007; Ares & Gámbaro, 2008; Asma *et al.*, 2010; Abdul Rahman *et al.*, 2013; Asraf Mohd-Any *et al.*, 2014; Aschemann-Witzel & Peschel, 2019; Coderoni & Perito, 2020; Köpcke, 2020; The Upcycled Foods Definition Task Force, 2020). A scientific panel at the University of Borås reviewed the questionnaire.

The sociodemographic questions collected data on age, gender, education, employment, household income

and living situation. The attitude questions asked about concern for the environmental impact of food waste and preference for conventional food over upcycled food (scored from 1: strongly agree to 5: strongly disagree), previous experience of consuming upcycled foods (yes, no and I do not know), intention for upcycled food consumption (definitely avoid, may avoid, may eat and definitely eat) and the importance of the value-added feature of upcycled foods (scored from 1: not at all important to 5: very important). Value-added products were defined as products which are altered, added to or enhanced during production to increase their economic value (United States Department of Agriculture, 2021; University of California Agriculture Ombudsman, 2021).

In addition to the above questions, the food choice motive questions assessed how important it is to the respondent that the upcycled food they eat has specific characteristics (e.g. low fat content), and the responses were scored from 1 (not at all important) to 5 (very important). This study focuses on food choice motive questions related to nutritional value (e.g. energy and nutrient content of food and its processing status), environmental factors (e.g., food production activities with environmental impact) (Nordic Council of Ministers, 2014) and food safety topics (e.g. additives, hormone residues, genetically modified ingredients, poison and contaminants) (European Food Safety Authority, 2022).

The questionnaire was developed in English and translated by a professional translator into Swedish. Native researchers checked the translated questionnaire to ensure the intended meaning of the questions was understood correctly. The questionnaire was released in English and Swedish on the SUNET platform on the University of Borås website and advertised on social media (Facebook, Instagram and LinkedIn). The Swedish residents who were at least 18 years old and lived in Sweden during the data collection phase (September to December 2021) were

eligible to participate. Online informed consent was obtained from all participants. Six hundred and eighty-three individuals participated in the study, and 681, who provided information about their age, were included in data analyses.

Respondents were categorised into three age groups: young adults (aged 18–39), middle-aged adults (aged 40–64) and older adults (aged 65+) (Chopik et al., 2018). The percentage of the following participants was compared between the three age groups using the Cross tabulation (z-tests for comparing column proportions with Bonferroni correction): respondents who agreed with the environmental impact of food waste and with the preference for conventional food over upcycled food (responded as agree and strongly agree), those who previously consumed upcycled food and were inclined towards upcycled food consumption (mentioned definitely eating upcycled food) and participants who considered the value-added feature, and nutritional, environmental and food safety characteristics as important (responded as important and very important).

Furthermore, the association between participants' age and the importance score of nutritional, environmental and food safety characteristics was assessed by linear regression analyses (Generalized Linear Models: GLM). First, the GLM analyses were adjusted for gender (Model 1), and then further adjustments were made for education, employment status and household income (Model 2). All analyses were performed with the SPSS software (Version 27, SPSS Inc., Chicago, IL, USA), and statistical significance was set at  $P$ -value < 0.05.

## Results

The participants' sociodemographic characteristics are presented in Table 1. The majority of participants in all age groups were women. The percentage of older adults who lived alone, without children at home and

**Table 1** Participants' sociodemographic characteristics across three age groups ( $n = 681$ )

	Young adults	Middle-aged adults	Older adults
<i>n</i>	238	328	115
Age, mean (SD)	32 (5)	52 (7)	70 (4)
Female, <i>n</i> (%)	184 (77.31)	289 (88.11)	106 (92.17)
Postgraduate education, <i>n</i> (%)	85 (35.71)	89 (27.13)	21 (18.26)
Living alone, <i>n</i> (%)	45 (18.91)	72 (21.95)	48 (41.74)
Household without children, <i>n</i> (%)	144 (60.50)	197 (60.06)	114 (99.13)
Small household, <i>n</i> (%) <sup>a</sup>	180 (75.63)	252 (76.83)	113 (98.26)
Full-time employment, <i>n</i> (%)	126 (52.94)	217 (66.16)	7 (6.09)
High household income, <i>n</i> (%) <sup>b</sup>	64 (26.89)	126 (38.41)	7 (6.09)

<sup>a</sup>Small household consists of three persons or less.

<sup>b</sup>High household income earns more than 55 000 SEK/month.

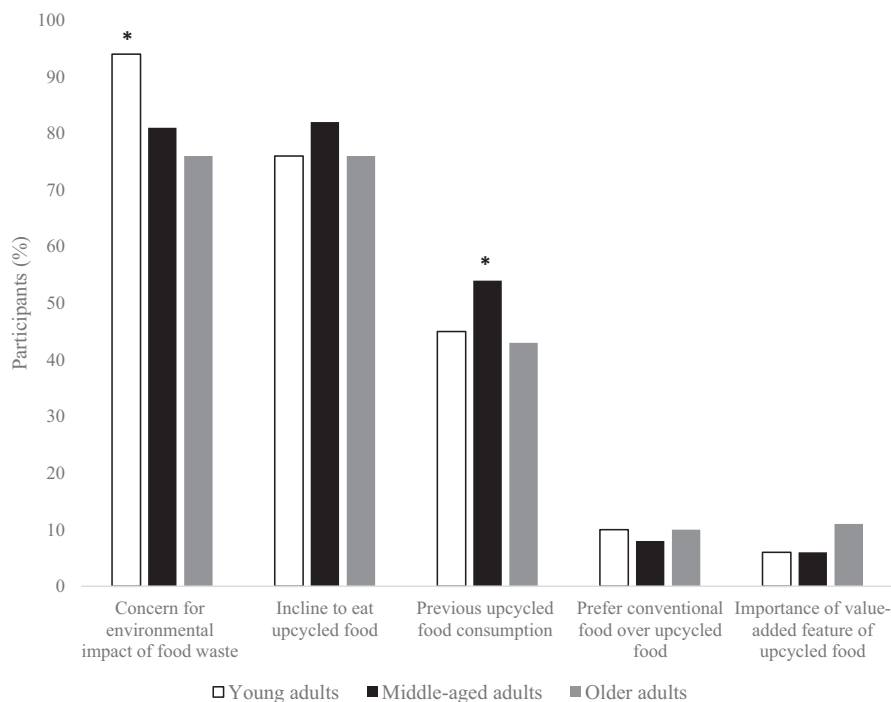
had a small household was higher than in other age groups. A higher percentage of young participants had postgraduate education compared to other age groups. A higher percentage of middle-aged respondents had full-time employment and high household income compared to other age groups.

The attitudes of different age groups towards food waste and upcycled foods are displayed in Fig. 1. A higher percentage of younger people expressed their concern for the environmental impact of food waste compared to other age groups. Most participants in all age groups were inclined to consume upcycled foods, and depending on the age group, 43% to 54% of the participants had previously tried upcycled foods. It is worth mentioning that a similar percentage of participants did not know whether they had previously eaten upcycled foods (young: 49.16%, middle-aged: 40.85% and elderly: 52.17%). In all age groups, less than 10% of respondents preferred conventional foods over upcycled foods, and less than 11% considered the value-added feature of upcycled foods as important.

Table 2 shows the importance of nutritional, environmental and food safety characteristics for upcycled foods across different age groups. In all age groups, participants preferred the nutritious feature, followed by the unprocessed/minimally processed feature, more than other nutritional characteristics. Low energy and

low fat content were the least important nutritional characteristics in all age groups. The percentage of middle-aged and elderly participants who preferred unprocessed/minimally processed upcycled foods was higher than younger participants ( $P$ -value  $< 0.05$ ). Furthermore, a higher percentage of the older generation considered the importance of upcycled foods' vitamin and mineral content and their nutritious feature compared to the young age group.

For environmental characteristics, contribution to food waste reduction was the most important feature for all age groups. The second most important environmental characteristic in the younger age group was the environmentally friendly preparation of upcycled foods. The environmentally friendly packaging of these foods ranked second in middle-aged and older participants. Locally produced upcycled food was the least important environmental characteristic. The middle-aged and older generations were more likely to consider environmentally friendly packaging as an important feature than the younger generations ( $P$ -value  $< 0.05$ ). The local upcycled food production was more important for the older generation than the younger people ( $P$ -value  $< 0.05$ ). There was no statistically significant difference between the middle-aged and older generations regarding environmental characteristics ( $P$  value  $> 0.05$ ). In terms of food safety



**Figure 1** Attitudes towards food waste and upcycled foods across three age groups. \*Significantly different from other age groups ( $P$ -value  $< 0.05$ ).

**Table 2** Percentage of participants who believed in the importance of nutritional, environmental and food safety characteristics for upcycled foods

	Young adults (%)	Middle-aged adults (%)	Older adults (%)
<i>Nutritional characteristics</i>			
Rich in vitamins and minerals	40.76	47.24	56.14 <sup>a</sup>
Nutritious	62.61	66.26 <sup>c</sup>	78.26 <sup>a</sup>
High in protein	14.71	11.96	15.65
High in fibre	16.39	17.13	19.30
Low in energy	5.04	6.12	4.35
Low in fat	6.72	8.26	11.30
Unprocessed or minimally processed	41.77 <sup>b</sup>	62.65 <sup>c</sup>	73.04 <sup>a</sup>
<i>Environmental characteristics</i>			
Environmentally friendly preparation	79.41	82.21	83.19
Environmentally friendly package	76.05 <sup>b</sup>	83.49	85.22 <sup>a</sup>
Local production	41.60	46.13	56.52 <sup>a</sup>
Contribution to food waste reduction	90.76	91.08	91.30
<i>Food safety characteristics</i>			
Additive-free	50.63 <sup>b</sup>	65.75 <sup>c</sup>	78.26 <sup>a</sup>
Chemical and hormone-free	78.81 <sup>b</sup>	87.73	92.98 <sup>a</sup>
Non-genetically modified	52.52 <sup>b</sup>	70.55	78.95 <sup>a</sup>
Absence of contamination and poison	93.70	96.62	96.52

<sup>a</sup>Significantly different from the young adults (*P*-value < 0.05).

<sup>b</sup>Significantly different from the middle-aged adults (*P*-value < 0.05).

<sup>c</sup>Significantly different from the older adults (*P*-value < 0.05).

characteristics, the absence of contamination and poison was the most important food safety feature for all participants. A higher percentage of middle-aged and elderly participants preferred the absence of additives, chemicals and hormones and genetically modified ingredients compared to younger participants (*P*-value < 0.05).

The mean importance score of nutritional, environmental and food safety characteristics for each age group and the findings of association between age and the importance of these characteristics are presented in Table 3. There was a positive association between age and the importance score of all nutritional features after adjusting the analyses for gender in Model 1 (*P*-value < 0.05). In multivariate analyses (Model 2), the positive association between age and the importance

score of all nutritional features remained statistically significant except for the nutritious feature and high protein and fibre content.

In terms of environmental characteristics, there was no statistically significant association between age and the importance score of environmentally friendly preparation and packaging in both Model 1 and Model 2. There was a positive association between age and local production in the gender-adjusted model (Model 1), but no statistically significant association was observed after adjusting the analysis for other sociodemographic factors in Model 2. On the contrary, although age and contribution to food waste reduction were not statistically associated in Model 1, there was a negative association between age and this environmental feature in Model 2 (*P*-value < 0.05). Similar to nutritional characteristics, there was a positive association between age and the importance score of all food safety characteristics in Model 1 (*P*-value < 0.05) that remained statistically significant in Model 2 except for the absence of contamination and poison.

## Discussion

Upcycled food production is increasing, and thus it is important to identify people's preferences for these foods. Most participants of this study, particularly the younger generation, expressed concern about food waste's environmental impact. However, the attitudes towards upcycled food did not differ between age groups except for middle-aged people who had more previous experience in consuming this type of food compared to other generations. The findings of this study also revealed that in all age groups, upcycled foods' energy, protein, fat and fibre content was less important than environmental and food safety characteristics. Furthermore, as age increased, the importance of most nutritional and food safety characteristics also increased. However, no association was observed between age and the importance score of environmental characteristics except for the contribution to food waste reduction, where its importance decreased as age increased.

In this study, which is based on people living in Sweden, the proportion of middle-aged participants interested in upcycled food consumption was slightly higher than in other age groups. Middle-aged consumers might be more interested in trying upcycled foods when the emphasis is on the environmental benefits rather than nutritional value (Perito *et al.*, 2020). However, the findings of different studies are inconsistent. Zhang *et al.* (2021) reported reluctance towards upcycled foods in middle-aged and high acceptability in younger and older age groups, whereas another study found lower acceptability in older people (Köpcke,

**Table 3** Mean (SD) importance score of nutritional, environmental and food safety characteristics in three age groups and the association between age and the importance score of these characteristics

	Young adults	Middle-aged adults	Older adults	Model 1 <sup>a</sup>		Model 2 <sup>b</sup>	
	Mean (SD)	Mean (SD)	Mean (SD)	Coefficient <sup>c</sup> (95% CI)	P-value	Coefficient <sup>c</sup> (95% CI)	P-value
<i>Nutritional characteristics</i>							
Rich in vitamins and minerals	3.19 (1.15)	3.40 (1.02)	3.54 (0.98)	0.009 (0.003, 0.014)	0.002	0.008 (0.001, 0.016)	0.031
Nutritious	3.65 (1.12)	3.83 (0.96)	4.10 (0.86)	0.008 (0.002, 0.013)	0.003	0.006 (−0.001, 0.014)	0.076
High in protein	2.27 (1.11)	2.27 (1.04)	2.57 (0.91)	0.007 (0.001, 0.012)	0.015	0.002 (−0.005, 0.010)	0.547
High in fibre	2.28 (1.15)	2.50 (1.06)	2.73 (0.96)	0.008 (0.002, 0.013)	0.005	0.003 (−0.004, 0.011)	0.391
Low in energy	1.63 (0.91)	1.88 (0.97)	1.93 (0.89)	0.014 (0.009, 0.019)	<0.001	0.013 (0.005, 0.020)	0.001
Low in fat	1.71 (1.01)	1.99 (1.05)	2.23 (1.06)	0.009 (0.004, 0.014)	<0.001	0.011 (0.004, 0.017)	0.002
Unprocessed or minimally processed	3.16 (1.32)	3.67 (1.23)	3.99 (1.15)	0.020 (0.014, 0.026)	<0.001	0.020 (0.011, 0.029)	<0.001
<i>Environmental characteristics</i>							
Environmentally friendly preparation	4.15 (0.95)	4.26 (0.88)	4.32 (0.86)	0.002 (−0.003, 0.006)	0.438	0.002 (−0.004, 0.009)	0.453
Environmentally friendly package	4.11 (1.05)	4.26 (0.93)	4.34 (0.89)	0.002 (−0.003, 0.007)	0.457	0.002 (−0.005, 0.009)	0.592
Local production	3.28 (1.08)	3.36 (0.97)	3.66 (0.85)	0.007 (0.002, 0.012)	0.005	0.003 (−0.005, 0.010)	0.481
Contribution to food waste reduction	4.57 (0.78)	4.52 (0.75)	4.56 (0.70)	−0.003 (−0.007, 0.001)	0.095	−0.007 (−0.012, −0.001)	0.014
<i>Food safety characteristics</i>							
Additive-free	3.40 (1.32)	3.80 (1.15)	4.24 (0.92)	0.020 (0.015, 0.026)	<0.001	0.021 (0.013, 0.030)	<0.001
Chemical and hormone-free	4.16 (1.17)	4.53 (0.90)	4.65 (0.78)	0.013 (0.008, 0.018)	<0.001	0.016 (0.009, 0.023)	<0.001
Non-genetically modified	3.29 (1.51)	3.95 (1.35)	4.21 (1.28)	0.024 (0.017, 0.031)	<0.001	0.026 (0.016, 0.036)	<0.001
Absence of contamination and poison	4.73 (0.70)	4.81 (0.55)	4.85 (0.52)	0.003 (0.0002, 0.006)	0.032	0.002 (−0.002, 0.007)	0.279

<sup>a</sup>Model 1 adjusted for gender.<sup>b</sup>Model 2 adjusted for gender, education, employment status and household income.<sup>c</sup>Unstandardized B coefficient.

2020). Upcycled products should be tailored to the relevant age group. For example, since older generations cook for themselves and younger generations consume ready-to-eat foods, the older generation might be more interested in upcycled ingredients and younger generations in packaged upcycled foods and snacks (Zhang *et al.*, 2021).

Approximately half of the participants in all age groups had previous experience consuming upcycled foods, and a similar proportion did not know if they had ever consumed these foods. Since there is no specific labelling or logo for upcycled foods in Sweden, people may not recognise these products as upcycled foods. The presence of a logo is important as it increases the acceptability of upcycled foods (Bhatt *et al.*, 2021). Moreover, most participants (more than 76%) in all age groups were inclined to consume upcycled foods, and less than 10% preferred conventional over upcycled foods. In other studies, when the details of an upcycled food were described or samples of upcycled foods were provided, most people preferred conventional foods over these products, which might be due to some attributes of these foods, such as sensory characteristics (Grasso *et al.*, 2019b; Hellwig *et al.*, 2020; Stelick *et al.*, 2021) or unfamiliarity of the innovative upcycled ingredients (Aschemann-Witzel & Peschel, 2019). Therefore, in reality, people may not choose upcycled foods,

although they believe in the preference for upcycled over conventional foods.

Regarding the value-added feature of the upcycled food, less than 11% of all age groups considered it an important feature. Therefore, the common concept of value-added food focussing on increasing economic value (United States Department of Agriculture, 2021; University of California Agriculture Ombudsman, 2021) does not appear attractive to consumers as it does not mean that the nutritional value of the food has improved. The nutritional concept of value-added foods has a different aspect. From a nutrition perspective, value-added foods are scientifically modified in terms of their nutrient content, shape, size and appearance (in the post-harvest stage of production) to enhance their function (Olaiya *et al.*, 2016). This nutritional concept of value-added food may be more convincing for consumers than the marketing definition. There is a positive association between the nutritional value and purchasing intention of upcycled foods (Ali *et al.*, 2021).

In terms of nutritional characteristics, the energy and macronutrient (fat, protein and fibre) content of upcycled food was not among the most important nutritional features for any age group. Although upcycled foods' nutritional value, such as increased protein content, improves the purchasing intention (Grasso &

Asioli, 2020; Asioli & Grasso, 2021), the consumer perception of increasing protein intake through specific sources is also important (Banovic *et al.*, 2018). If people do not consider upcycled foods as a food source for increasing protein intake, their high protein content will not be deemed important. This can justify the findings of this Swedish study regarding the lack of interest in the protein content of upcycled foods as well as other nutritional indicators of healthy foods such as high fibre, low energy and low fat content. On the contrary, the micronutrient (vitamins and minerals) content of upcycled foods was more important than their protein, fibre, fat and energy content. Therefore, it can be assumed that the participants of this study are more interested in upcycled foods' micronutrient content and the related health benefits rather than energy and macronutrient content.

Another explanation for the unimportance of most of the healthiness indicators of upcycled foods is that consumers may consider these foods as vice foods rather than virtue foods. Foods in the vice category provide immediate benefits (*e.g.* sensory appeal), but the cost of their consumption appears in the long term (*e.g.* disease manifestation) (Yan *et al.*, 2017). In contrast, the virtue category has an immediate cost (*e.g.* unappealing sensory characteristics) and long-term benefits (*e.g.* good health) (Yan *et al.*, 2017). Unhealthy and healthy foods are in the vice and virtue food categories, respectively (Yan *et al.*, 2017). Since the sensory appeal of upcycled foods is a more important food choice factor than their healthiness (Moshtaghian *et al.*, 2023), people may consider these foods in the vice food category. The consumer acceptability of vice foods is higher than virtue foods (Aschemann-Witzel & Stangherlin, 2021).

Regarding the association between the importance of nutritional characteristics and age, an increase in age was associated with the increased importance of some nutritional characteristics (energy, fat and processing status). As people age, their dietary preferences lean towards the existing illness rather than disease prevention (Szakos *et al.*, 2022). Thus, their priority will be nutrients associated with a specific existing disease (*e.g.* cardiovascular disease). Accordingly, the increase in the importance of low fat and low energy content of upcycled foods can be due to their association with these diseases. On the other hand, young consumers follow fast-food style dietary patterns mostly known as unhealthy due to high energy, fat and sugar, although they have knowledge of healthy eating practices (Brown *et al.*, 2000).

Most consumers are interested in upcycled foods because of their environmental benefits rather than their healthiness (Grasso & Asioli, 2020). Different age groups appear to have a similar attitude towards environmental sustainability (Wiernik *et al.*, 2013), which is

consistent with the findings of this Swedish study. However, our results demonstrated that the importance of contribution to food waste reduction decreased with an increase in age. As people age, they generate less food waste (Grasso *et al.*, 2019a). In other words, they follow efficient food waste management practices and thus may not feel the need for additional emphasis on the food waste reduction aspect of upcycled foods. Despite this finding, the most important environmental characteristic of upcycled food among all age groups of this study was its contribution to food waste reduction. Informing people about the food waste reduction aspect of upcycled foods increases their willingness to pay premium price for these foods (Köpcke, 2020). Therefore, for marketing purposes, focussing on the environmental benefits of upcycled food might improve consumer acceptance.

Consumers perceive upcycled foods as more environmentally friendly products than conventional foods (Bhatt *et al.*, 2018). Communication regarding the environmental sustainability of upcycled foods improves their acceptability (Aschemann-Witzel & Peschel, 2019). Other positive environmental characteristics of upcycled foods include reducing the environmental impact of agricultural production, local origin (Coderoni & Perito, 2020) and low carbon footprint (Grasso & Asioli, 2020; Asioli & Grasso, 2021). It is worth mentioning that the environmental benefits of upcycled foods still need to be confirmed by Life Cycle Assessment (LCA). It is essential to determine whether upcycled food production is more environmentally friendly than conventional food production and other food waste management strategies, such as animal feed production (Moshtaghian *et al.*, 2021).

Food safety characteristics are one of the food choice motives for sustainable foods, and their importance increases with age (Sautron *et al.*, 2015). In this Swedish study, an increase in age was associated with the increased importance of food safety features (absence of additives, chemicals, hormones and genetically modified ingredients). The older generation is more concerned about the food safety issues such as additives, chemical and hormone residuals and genetically modified ingredients than young people (European Food Safety Authority, 2022). In EU countries, approximately 60% of all adult age groups are aware of the risk of food poisoning from contamination (European Food Safety Authority, 2022). In this Swedish study, the most important upcycled food safety feature in all age groups (more than 90% of participants) was the absence of contamination.

Recycled products are often perceived as materials with a high risk of contamination (Baxter *et al.*, 2017), and this perception can also be applicable to upcycled foods (Aschemann-Witzel & Stangherlin, 2021). People may deem upcycled foods as contaminated due to the

source of ingredients, which are often by-products or food scraps. It is worth mentioning that food law prohibits the provision of inedible and unsafe food, that is, injurious to health or unsuitable for human consumption (Bradshaw, 2018). In food waste management, edibility becomes critical when the material is diverted for redistribution (reuse); thus, food law is a legitimate constraint for reusing food (Bradshaw, 2018). Currently, there is no specific regulation for upcycled foods, and these foods should follow the general food law. Understanding the possible food safety issues is vital for developing appropriate standards for this type of food (Food and Agriculture Organization, 2022).

According to the Upcycled Food Association, upcycled ingredients should be obtained from verifiable sources (The Upcycled Foods Definition Task Force, 2020), which can address food safety concerns. The manufacturers have to provide food safety attestation to the Upcycled Food Association when they apply for upcycled food certification (Upcycled Food Association, 2020). It is worth noting that all food manufacturers should comply with food safety legislation before releasing the product to the market (European Commission, 2002, 2010). Therefore, acknowledging upcycled food producers' compliance with food safety measures can facilitate acceptance. Moreover, informing consumers about the food safety characteristics of upcycled foods can be considered for marketing campaigns to increase their willingness to try them.

This study has some strengths and limitations. It had a relatively large sample size, and participation was anonymous to reduce the social-desirability bias. However, a higher proportion of participants were women; hence, men's perspective has been under-represented. Another limitation of this study was the provision of prompted responses. In a prompted response, it is uncertain if the respondents believed in the importance of the factor or, due to the novelty of upcycled foods, they consider any factor important (Goodman-Smith *et al.*, 2021). Nevertheless, it is less likely to influence the respondents of this study because some nutritional features were considered less important by the participants. It is worth mentioning that this study investigated selected features of nutritional, environmental and food safety characteristics, and thus a more comprehensive assessment can broaden the understating of consumers' perspectives. Furthermore, since this study was conducted in Sweden, the findings of upcycled foods' nutritional, environmental and food safety preferences may not be generalisable to other countries.

## Conclusion

This study identified the preferred nutritional, environmental and food safety characteristics of upcycled

foods in different age groups. Most participants were inclined to consume upcycled foods, and in all age groups, their main preferred nutritional, environmental and food safety characteristics were similar. These main similar characteristics were the nutritious feature, the contribution to food waste reduction and the absence of contamination and poison, respectively. The environmental and food safety characteristics of upcycled foods were more important than their energy, fat, fibre and protein content. As age increased, the importance of most nutritional (rich in vitamins and minerals, low fat and low energy content, and minimal processing) and food safety (absence of additives, chemicals and hormones and genetically modified ingredients) characteristics also increased. In contrast, the importance of contribution to food waste reduction, as the main environmental characteristics of these foods, decreased.

The environmental benefits and food safety aspects of upcycled foods should be considered for product development and marketing to facilitate the acceptability of these foods. However, increasing the incorporation of upcycled food in a daily diet requires more attention to nutritional aspects. Thus, the findings of this study have important implications for public health nutrition as there is a need for education on healthy eating for all types of upcycled foods. Nutrition campaigns should advocate for public awareness of healthy upcycled foods. Educating all age groups on upcycled foods and their desirable nutritional, environmental and food safety characteristics will increase the demand for healthy, environmentally friendly and safe foods. Future research should explore public perception of upcycled foods through a qualitative approach to comprehensively understand the underlying age-related reasons for these preferences. Moreover, future studies should investigate the nutritional, environmental and food safety preferences of different generations in other countries.

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## Author contributions

**Hanieh Moshtaghian:** Conceptualization (lead); data curation (lead); formal analysis (lead); funding acquisition (equal); methodology (lead); project administration (lead); writing – original draft (lead); writing – review and editing (lead). **Kim Bolton:** Methodology (supporting); supervision (lead); writing – review and editing (supporting). **Kamran Rosta:** Funding acquisition (equal); methodology (supporting); supervision (supporting); writing – review and editing (supporting).



**Conflict of interest**

The authors declare no conflicts of interest.

**Ethical guidelines**

According to the Swedish Ethical Review Authority, this study did not require ethics approval. All participants provided informed consent.

**Data availability statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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