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Consumer preferences for upcycled ingredients: A case study with biscuits

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A R T I C L E I N F O

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A B S T R A C T

Nowadays, there is a growing interest to add value to food industry by-products and incorporate them as new ingredients for novel food products. However, there is very little knowledge about consumers' reactions towards novel food products made with upcycled ingredients. This manuscript provides the first critical scientific investigation of UK consumers' preferences for novel food products made with upcycled ingredients using four attributes: price (£0.40/300 g pack or £1.50/300 g pack), flour ("with wheat flour" or "with upcycled sunflower"), protein ("source of protein" or no information) and Carbon Trust label ("with Carbon Trust label" or no label). Using a hypothetical ranking experiment involving biscuits, results showed that consumers prefer biscuits made with conventional (i.e., wheat) flour and tend to reject biscuits made with upcycled sunflower flour. Results suggest there is heterogeneity in consumers' valuation, with three groups identified: the first group with price sensitive consumers and the strongest preferences for low price biscuits, the second group with traditionalist consumers and strongest rejection for upcycled sunflower-flour, the third group with environmentalist consumers and the strongest preference for biscuits with the Carbon Trust label. Most consumers had not heard of upcycled ingredients before, but they would consider buying foods with upcycled ingredients. These findings provide insights into the psychology of consumers' preferences, which can be used to most effectively communicate the benefits of upcycled ingredients to the public. This will also have important implications for future labelling strategies for policy makers providing valuable insights to upcycled food products' manufacturers.

1. Introduction

Every year about 30% of the total food produced in the world for human consumption is lost or wasted both at food supply chain (i.e., food loss) and consumption levels (i.e., food waste), corresponding to approximately 1.3 billion tonnes (FAO, 2011). In Europe, industrial food loss quantities range between 19% and 39% of the total food loss in food supply chains (Stenmarck, Jensen, Quested, Moates, Buksti, & Cseh, 2016). In the UK, according to a recent report by the Waste & Resources Action Programme (WRAP, 2017), in 2015 the manufacturing sector was the main producer of food loss in the supply chain, with 1.85 million tonnes of waste produced (which increased by 9% compared to the previous 2016 WRAP report). Out of this total amount, almost 1 million tonnes were estimated to be edible parts. Thus, although there is high recognition of the importance of food loss within food supply chains, a large part of research in industrialized countries has focused more on food waste research on the consumer end (Parfitt, Barthel, & Macnaughton, 2010), while the contribution of the food processing stages on food loss have been overlooked. Fruit and vegetable loss represents the wasting of food commodities, but also includes wasting of important resources such as land, water, fertilisers, chemicals, energy, and labour (Augustin, Sanguansri, Fox, Cobiac, & Cole, 2020). The food loss produced by the manufacturers from processing raw materials into food are usually referred to as food by-products (Galanakis, 2012). These by-products include both loss from animal processing (i.e., meat, seafood, and dairy) and fruit and vegetable-derived processing (i.e., peels, stems, seeds, bran, residues after extraction of oil or juices, etc.) (Helkar, Sahoo, & Patil, 2016). Since the fruit and vegetable processing industry is one of the greatest producers of by-products (FAO, 2015; Parfitt et al., 2010), during the last few years, particular attention has been given to the valorization of this by-product category (Galanakis, 2012; Gómez & Martinez, 2018; Trigo, Alexandre, Saraiva, & Pintado, 2019). Valorizing fruit and vegetable by-products would make our bio-economy more circular and would help to lower the high environmental impact of by-product disposal (Kroyer, 1995). Considering the vast amount of by-products available, even a small increase in their value could have significant economic advantage to food manufacturers, provided that food supply chains adapt and work towards integration (Garcia-Garcia, Stone, & Rahimifard, 2019).

Scientists are continuously exploring new ways to add value to food

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by-products. Examples include extracting and purifying valuable health-promoting compounds from by-products using new technologies (Barba, Zhu, Koubaa, Sant'Ana, & Orlien, 2016; Galanakis, 2013), exploring the effects of feeding such by-products to animals (Mirzaei-Aghsaghali & Maheri-Sis, 2008; Molina-Alcaide & Yáñez-Ruiz, 2008) or using by-products for energy production (Hagman, Eklund, & Svensson, 2019; Martin & Parsapour, 2012). Within valorization, it is believed that the most valuable approach with by-products would be to upcycle them rather than recycling them, which means using them as food, rather than feed or energy (Roth, Jekle, & Becker, 2019). A similar concept is explained in the Food Recovery Hierarchy of the US Environmental Protection Agency (Bhatt et al., 2018), where energy recovery, composting or incinerating are considered less preferred options to reduce food waste compared to the most preferred options of "source reduction and reuse" and "feed hungry people".

Fruit and vegetable by-products can be processed to become functional and nutritious ingredients that can re-enter the food chain as part of new foods (Trigo et al., 2019). Despite the technological challenges related to the processing, functionality and sensory quality of such ingredients, some upcycled ingredient manufacturers have already launched (or are about to launch) their products into the market. Examples are brewers' spent grains in cereal bars (such as Remashed in the UK and Regrained in the US), coffee grounds in baked goods (Coffee Cherry Company in the US and Kaffe Bueno in Denmark), oil cakes such as rapeseed or sunflower in high-protein flours (Planetarians in the US and NapiFeryn BioTech in Poland) (Fastcompany, 2019; News, 2019; Food Navigator, 2018).

In order to successfully market food products with upcycled ingredients it is essential to investigate consumers' preferences and willingness to pay (WTP) towards these novel food products. So far, very little is known about how consumers might perceive foods made with upcycled ingredients. Some of the few available investigations include the research from Bhatt et al. (2018) in the US on "value-added surplus products (VASP)", Aschemann-Witzel and Peschel (2019) in Denmark on potato protein in a mock-up soy-based cocoa drink, and in Italy with two studies by Coderoni and Perito (2020) and Perito, Di Fonzo, Sansone, and Russo (2019) on consumer acceptability of foods with by-products deriving from olive oil production. The concept of foods made with upcycled ingredients is new and in the available literature the names used to refer to these products vary greatly among studies. We will discuss them here in more detail.

Bhatt et al. (2018) referred to foods created from surplus ingredients as "value-added surplus products (VASP)". The authors tried to identify the best term to describe VASP products by asking consumers to rank the appropriateness of nine product labels (i.e., upcycled, reprocessed, reclaimed, upscaled, rescued, up-processed, rescaled, resorted) and found that the word "upcycled" was the most preferred. Then, they investigated whether VASP products were perceived by consumers as having benefits for the individual or for the society, concluding that the VASP foods scored higher as a benefit for society than as an individual. The authors concluded that appropriate product descriptions, labels and benefits could all positively influence consumers' decision-making on this new food category.

Aschemann-Witzel and Peschel (2019) explored how Danish consumers of cocoa drinks react to the use of potato protein, a by-product of potato starch production, in a mock-up soy-based cocoa drink. The authors refer to upcycled ingredients as "waste-to-value" products. They found that consumers did not perceive the new potato protein-based cocoa drink more favourably than the conventional version, nor did they consider it better in quality. The authors concluded that brand, design, and information on why a "waste-to-value" ingredient is used could improve attitudes towards the product.

In Italy, Perito et al. (2019) focused on what they called "foods from olive by-products" and assessed consumers' willingness to accept (WTA) them. They found that consumers perceived the use of olive by-products as a new technology to prepare well-known foods. Consumers were concerned about the technology used in the production process, rather than the product itself. The study concluded that information on the characteristics of olive by-products could offset consumer technophobia and the authors recommended suitable marketing campaigns centred on the by-product benefit to increase consumer WTA the products.

Coderoni and Perito (2020) carried out a web based questionnaire in Italy using the same concept of olive by-product as Perito et al. (2019), testing purchase intentions for what they refer to as "waste-to-value" foods and analysing other drivers such as aversion to new foods or foods processed in new ways. The authors concluded that to deliver new "waste-to-value" products in the market, their health and environmental benefits should be indicated on the label. However, based on findings from Vega-Zamora, Torres-Ruiz, and Parras-Rosa (2019) and Agovino, Cerciello, and Gatto (2018), they suggest that attention must be paid to the messages conveyed as failure to notice or interpret labels could hinder the final market uptake.

Consumers' acceptability provides important information for producers and marketers when developing new food products, however simply asking consumers for their acceptability without considering price may not provide the needed practical information (Asioli et al., 2017). Thus the inclusion of price as an attribute to estimate consumers' WTP in monetary terms is relevant for several reasons (Jaeger, 2006). Firstly, a large number of studies indicate that price is one of the most relevant factors that affect consumer choices (Asioli, Næs, Granli, & Lengard Almli, 2014; Lusk & Briggeman, 2009; Steenhuis, Waterlander, & de Mul, 2011). Secondly, for new food products that are not yet in the market and for which there are no market data available (i.e., scanner data), an estimation of consumers' WTP could help industry to suggest retail prices when launching new products (Lusk & Shogren, 2007; Shogren, 2011). Thirdly, an estimation of new food products' prices is useful for industry to compare with production costs, conduct a costs/benefits analysis and evaluate the economical/business sustainability of the new products (Lusk & Shogren, 2007). However, to the best of our knowledge, no study has directly investigated consumers' preferences and WTP in monetary terms and individual differences for food products containing upcycled ingredients. Due to the new nature of upcycled ingredients, it would be valuable to gather insights on how to best introduce this new upcycled food category to the market and how to communicate the nutritional and environmental advantages of foods made with by-products to consumers through appropriate labelling strategies. This study aimed at understanding the most preferred attribute composition for upcycled foods using the attributes price (low or high), type of flour (conventional or upcycled), protein content ("source of protein" or no information) and Carbon Trust label ("with Carbon Trust label" or no label).

A ranking experiment was used to investigate UK consumers' preferences for hypothetical biscuits made with defatted sunflower cake flour. The upcycled sunflower flour was chosen as an ingredient for this study because the company Planetarians[1] successfully manufactured it from sunflower cake, the residue left after sunflower oil extraction. Through a steam flashing and extrusion process, the sunflower cake is transformed into a high protein food grade ingredient (Manchuliantsau & Tkacheva, 2019). This protein-rich ingredient could be potentially used by the food industry in a variety of applications, such as bakery, pasta and meat products. This ingredient was also recently used in baked goods with promising results (Grasso, Liu, & Methven, 2020; Grasso, Omoarukhe, Wen, Papoutsis, & Methven, 2019). Biscuits were chosen as a base food for this study due to their popularity and appeal amongst consumers, in addition to being ready to eat, affordable, having a long shelf life and a wide range of tastes (Turksoy & Özkaya, 2011).

[1] See details: https://www.planetarians.com/

Table 1
Attributes and levels used in the study.

Attributes	Levels
Price	0 – £0.40/300 g 1 – £1.50/300 g
Flour	0 – with wheat flour 1 – with upcycled sunflower
Protein	0 – no information reported 1 – source of protein
Carbon Trust label	0 – no label 1 – with Carbon Trust label

2. Materials and methods

2.1. Experimental design

In the online ranking experiment four attributes were used to describe the different types of biscuits: "price", "flour", "protein" and "Carbon Trust label" (Table 1). In terms of the attribute "price", two price levels were specified to approximately reflect the upper and lower market prices of a typical 300 g pack of biscuits in UK shops (£0.40/300 g pack and £1.50/300 g pack). Price was chosen as an attribute because, as indicated in the introduction, it is one of the most relevant factors that affect consumer choices (Lusk & Briggeman, 2009). For the attribute "flour", two levels were specified: the most conventional type of flour used to make biscuits (i.e. "with wheat flour") or the innovative flour (i.e. "with upcycled sunflower"). This attribute was used to test consumers' WTP for new foods with upcycled ingredients. The attribute "protein" was included with two levels: "source of protein" or no information about this was reported. "Source of protein" refers to the nutrition claim as per European Food Safety Authority wording (EFSA, 2012), indicating that at least 12% of the energy value of the food is provided by protein. Protein content in food products overall has a positive consumer perception, especially if the protein is of plant-origin (Banovic et al., 2018). Finally, we included information about the environmental impact of biscuit production because it has been shown that sustainability information may affect consumers' WTP (Reimers & Hoffmann, 2019). We used the "Carbon Trust label" referring to the environmental impact of food production, transportation and use of the food products in terms of CO_2 emissions. Thus, two levels of Carbon Trust label were used: "with Carbon Trust label" or no label was reported.

The selected attributes and their levels were used to generate a balanced incomplete design that resulted in the creation of sixteen product alternatives. These were then divided into two blocks of eight product alternatives each using Minitab v. 19.1.1 (Minitab Inc., Coventry, UK) to prevent respondents' fatigue. A series of mock-up product images of biscuits packs varying in four design attributes were created (see Fig. 1 for an example).

The randomisation was conducted within each block of eight choice sets. The ranking experiment was introduced with an explanation and description of the attributes and levels. Participants were presented with biscuit packs and asked to rank them from the most preferred to the least preferred option. Before starting the ranking tasks, respondents were asked to read a cheap talk script as an attempt to mitigate possible hypothetical bias that typically affects WTP estimates in stated preference studies (Cummings & Taylor, 1999).

To ease the cognitive burden of the participants, this ranking was conducted similarly to Øvrum, Alfnes, Almli, and Rickertsen (2012) as a series of choices over seven screens. On the first screen all eight biscuit packs were shown and the participants were asked to mark their four most preferred biscuits. The six next screens proceeded as follows. On screen (2) the four selected biscuit packs from screen (1) were shown and the participants were asked to select the most preferred biscuits among these (i.e., their top-ranked biscuit pack). On screen (3) the three remaining biscuit packs from screen (2) were shown and the participants were asked to select the most preferred biscuit among these. On screen (4) the two remaining biscuits from screen (3) were shown and the participants were asked to select the most preferred option among these. Screens (5)–(7) proceeded in the same way as screens (2)–(4) but now for the four least preferred biscuit packs.

Upon completion of the ranking task the respondents were asked to fill out a questionnaire on attitudes, knowledge of upcycled food ingredients and socio-demographics characteristics. In terms of attitudes, consumers' aversion towards new food products was investigated using the Food Neophobia Scale (FNS) (Pliner & Hobden, 1992) with a scale anchored from 1 (strongly disagree) to 7 (strongly agree). In terms of knowledge towards upcycled food ingredients, we asked if consumers had heard of the term "upcycled" in relation to a food ingredient before the study. If consumers had heard of the term, they were asked to self-report their level of knowledge on upcycled ingredients using a scale anchored from 1 (very low knowledge) to 7 (very high knowledge). All consumers were then asked if they would consider buying foods with upcycled ingredients. Depending on their answer, consumers were asked why they would or would not consider buying foods with upcycled ingredients. To answer these questions consumers were given a choice of five different reasons as well as a free text entry. At the end of the survey socio-demographic information was gathered. A pre-test involving fifty consumers was performed to test the survey. Informed consent was obtained by all study participants and the study was approved by a University Ethical committee.

2.2. Data

The data used in this study are drawn from an online survey composed of a ranking experiment followed by a questionnaire conducted during summer 2019 involving 106 consumers in the UK using the online platform Qualtrics LLC (Provo, US). Consumers where randomly recruited by Qualtrics using sampling quotas in terms of age and gender. Consumers were informed about the opportunity to participate in a survey on consumers' evaluation of biscuits. Only consumers who were at least 18 years old, who bought and ate biscuits and did not follow gluten-free diets were included in the study.

The socio demographic characteristics of the sample are presented in Table 2. Given the quota sampling, the final sample was composed of 50% females and 50% males, which is very similar to the most recent UK population census data, composed of 50.64% females and 49.36% males (Office for National Statistics, 2019). In terms of age, 30.19% of participants were 18–32 years old, 19.81% were 33–46 years old, 32.80% were 47–61 years old and 17.92% were 62–75 years old. These age ranges are similar to the UK census population, respectively 27.30%, 25.09%, 27.99% and 16.63% (Office for National Statistics, 2019). One or two people composed more than 50% of households and 2/3 of the respondents did not have children under 18 years old. Almost 50% of the sample had annual income before tax less than £30,000 while more than 50% of the respondents were public or private sector employees. In terms of education, almost 85% of the consumers had at least an undergraduate university degree.

2.3. Econometric analysis

Ranking data are analysed within the utility framework by so-called discrete choice models (DCMs) (Hensher, Rose, & Greene, 2005; Louviere, Hensher, & Swait, 2000; Train, 2009). DCMs are based on modelling "Utility", which is the net benefit a consumer obtains from selecting a specific product in a choice situation, as a function of the design attributes. The utility of a product j for individual n in a choice occasion t (choice set) is written:

$$U_{njt} = \beta_n' x_{jt} + \varepsilon_{njt} \quad (1)$$

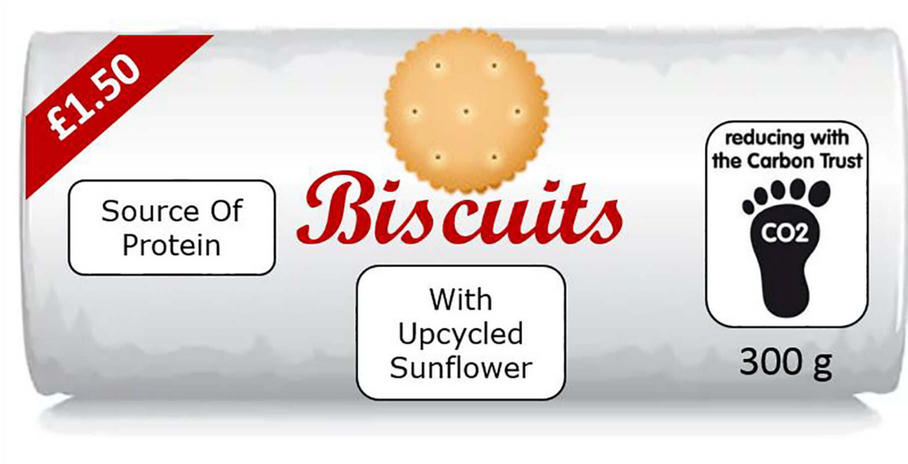

Fig. 1. Example of mock-up product image created for the study.

Table 2
Socio-demographic characteristics of the UK consumers in this study.

Socio-demographics: number (%)	Sample (N = 106)
Gender	
Male	53 (50.00%)
Female	53 (50.00%)
Age	
18–32	32 (30.19%)
33–46	21 (19.81%)
47–61	34 (32.80%)
62–75	19 (17.92%)
Household size (n° members)	
One	10 (9.73%)
Two	47 (44.34%)
Three	20 (18.87%)
Four	22 (20.75%)
Five+	7 (6.60%)
Number of children under 18	
No children	67 (63.21%)
Children	39 (37.69%)
Annual household income before taxes	
Less than £10,000	10 (9.43%)
£10,000 to £19,999	13 (12.26%)
£20,000 to £29,999	23 (21.70%)
£30,000 to £39,999	18 (16.98%)
£40,000 to £49,999	13 (12.26%)
£50,000 to £59,999	6 (5.66%)
£60,000 to £69,999	9 (8.49%)
£70,000 to £79,999	4 (3.77%)
£80,000 to £89,999	2 (1.89%)
£90,000 to £99,999	1 (0.94%)
£100, 000 to £149,999	3 (2.83%)
£150,000 or more	1 (0.94%)
I do not want to declare/I do not know	3 (2.83%)
Employment	
Student	7 (6.60%)
Independent worker	5 (4.72%)
Private-sector worker	34 (32.08%)
Public-sector worker	23 (21.70%)
Retired	17 (16.04%)
Unemployed	8 (7.55%)
Not seeking work	11 (10.38%)
Other work	1 (0.94)
Education	
Secondary school (e.g. GCSE)	29 (27.36%)
Sixth form College qualification (e.g. A level, BTEC)	40 (37.74%)
Undergraduate University Degree (e.g. BA, BSc)	21 (19.81%)
Postgraduate University Degree (e.g. Masters, PGCE)	9 (8.49%)
Postgraduate University Degree (PhD)	5 (4.72%)
Other	2 (1.89%)

where β_n is a vector of individual-specific parameters accounting for preference heterogeneity, x_{jt} is a vector of design attributes, and ε_{njt} is a random error term. Under the assumption that the random errors follow a so-called extreme value distribution (Train, 2009) and are independent and identically distributed (i.i.d) the choice probability for product j and choice set t given the parameter β_n has a simple form:

$$P_{njt} = \frac{\exp(\beta'_n x_{jt})}{\sum_{i=1}^{J_t} \exp(\beta'_n x_{it})} \quad (2)$$

where J_t is the number of products in choice set t.

Among the different DCMs we focused on two of the most applied choice models: the Mixed Logit (ML) model to investigate the pooled sample and the Latent Class Logit (LCL) model to investigate consumers' heterogeneity (Greene & Hensher, 2003; Train, 2009). ML models are widely applied due to their flexibility and because they allow models that may better match real-world situations (Train, 2009). This flexibility comes from the fact that one may freely include random parameters of any distribution and also correlations between random factors. Thus, in the main specification of the model the design attributes for "flour" (i.e., FLOUR), "protein" (i.e., PROTEIN), "Carbon Trust label" (i.e., CARBON) and "price" (i.e., PRICE) were included. The utility ML model for biscuits j for individual i in choice occasion t is written:

$$U_{ijt} = \beta_{1i}FLOUR_{ijt} + \beta_{2i}PROTEIN_{ijt} + \beta_{3i}CARBON_{ijt} + \beta_{4i}PRICE_{ijt} + \varepsilon_{ijt} \quad (3)$$

The ML model used here assumes random parameters with normal distributions for all design attributes. These random coefficients are further assumed to be independent. This model provides estimates of the mean and the standard deviation of the random conjoint parameters. The ML model was estimated using the module *mixlogit,* to obtain the regression coefficients, and the module *wtp* to obtain the corresponding WTP in monetary terms (i.e., £) (Hole, 2007) run in STATA 15.1 software (StataCorp LP, College Station, US). We run different ML models using different number of draws both with correlated and not correlated variables. Based on LL, AIC and BIC parameters the best model was two thousand Halton draws with no correlated variables used in the simulations. More details on estimation of ML models are found in Train (2009) and Hole (2007).

Next, in order to investigate if consumers' socio-demographics characteristics and consumers' aversion towards new food products have an effect on consumers' preferences for biscuits, starting from the base model (3) a ML including interactions with socio-demographics (i.e., age, gender and education) and FNS (Cronbach alpha: 0.901) was performed. A similar approach was used by Asioli, Næs, Øvrum, and

Almli (2016).

Thus, in the model we interacted design attributes for "flour" (i.e., FLOUR), "protein" (i.e., PROTEIN), "Carbon Trust label" (i.e., CARBON) and "price" (i.e., PRICE) with the socio-demographics characteristics such as age (i.e., AGE), gender (i.e., GENDER) and education (i.e., EDUCATION). In addition, we interacted for "flour" the consumers' aversion towards new food products (i.e., FNS). The utility ML model for biscuits j for individual i in choice occasion t is written:

$$\begin{aligned}U_{ijt} = {} & \beta_{1i}FLOUR_{ijt} + \beta_{2i}PROTEIN_{ijt} + \beta_{3i}CARBON_{ijt} + \beta_{4i}PRICE_{ijt} + \beta_{5i}(FLOUR*AGE)_{ijt} + \beta_{6i}\\ & (PROTEIN*AGE)_{ijt} + \beta_{7i}(CARBON*AGE)_{ijt} + \beta_{8i}(PRICE*AGE)_{ijt} + \beta_{9i}\\ & (FLOUR*GENDER)_{ijt} + \beta_{10i}(PROTEIN*GENDER)_{ijt} + \beta_{11i}(CARBON*GENDER)_{ijt} + \beta_{12i}\\ & (PRICE*GENDER)_{ijt} + \beta_{13i}(FLOUR*EDUCATION)_{ijt} + \beta_{14i}(PROTEIN*EDUCATION)_{ijt}\\ & + \beta_{15i}(CARBON*EDUCATION)_{ijt} + \beta_{16i}(PRICE*EDUCATION)_{ijt} + \beta_{17i}(FLOUR*FNS)_{ijt} + \varepsilon_{ijt}\end{aligned} \tag{4}$$

Next, to investigate consumers' heterogeneity, the LCL model was used. The LCL model assumes constant model parameters within each group and captures consumer heterogeneity assuming a mixing distribution for the groups (Greene & Hensher, 2003; Hess, Ben-Akiva, Gopinath, & Walker, 2011). The LCL model assumes that the consumer group can be split in subgroups with a constant β vector in each group (Greene & Hensher, 2003). The choice probability that an individual of class s chooses alternative j from a particular set constituted of J_t alternatives, is expressed as:

$$P_{j/s} = \frac{\exp(\beta'_s x_{jt})}{\sum_{i=1}^{J_t}\exp(\beta_s x_{it})} \tag{5}$$

where $s = 1,\ldots S$ represents the number of classes and β'_s is the fixed (constant) parameter vector associated with class s. In order to establish the likelihood, these choice probabilities have to be multiplied over the choice sets and finally combined over all individuals. To estimate the LCL model it is possible to use the Expectation – Maximization (EM) algorithm which allows for a good numerical stability and good performance in terms of run time (Bhat, 1997; Pacifico & Yoo, 2013; Train, 2008). One of the main issues in the LCL model is the choice of S, which is the number of latent classes. Given the fact that S is not a parameter, it is not possible to test it directly (Shen, 2009). Louviere et al. (2000) suggested a number of methods to guide the model selection. Specifically, they suggested that the model that minimizes AIC, BIC and CAIC should be preferred (see for more details, Louviere et al. (2000). In this study, the Latent Class Logit (LCL) model used will include main effects in order to calculate the class parameters β_s. The main results from the method are the subgroups, the regression parameter within each group and indications of how well each consumer fits into the different subgroups. The method is invariant to the relative scale of the input variables. The LCL model was estimated using the modules *lclogit2, lclogitml2, lclogitwtp* and *lclogitpr2* (Yoo, 2019) run in STATA 15.1 software (StataCorp LP, College Station, US).

3. Results

3.1. Questionnaire results on upcycled ingredient knowledge

The majority of consumers (85%) had not heard of the term "upcycled" in relation to a food ingredient before this study. The remaining 15% of consumers who had heard of upcycled ingredients before the study, had on average a midpoint self-reported knowledge of 3.7 in the 1–7 scale from very low to very high knowledge. The majority of consumers (85%) would consider buying foods with upcycled ingredients. Consumers were asked why they would (or would not) consider buying foods with upcycled ingredients. For consumers that would consider buying foods with upcycled ingredients, the three most chosen reasons were "because they would be good for the environment" (49%), "because I would contribute to food waste reduction" (47%), "because I would like to know what they taste like out of curiosity" (46%). The least popular answers for consumers that would consider buying foods with upcycled ingredients were "because they would be cheaper than conventional foods" (21%) and "because they would be healthier than conventional foods" (25%). On the other hand, consumers who would not consider buying foods with upcycled ingredients, selected as the main reason for their choice "I have a feeling they would not taste nice" (8%), followed by "I am not interested in their health benefits" and "they are waste products and I would not like to have them in new foods" (5%). Finally, "they would be more expensive than conventional foods" and "I am not interested in their environmental benefits" were the least selected reasons (3%).

3.2. Estimation results from Mixed Logit (ML) model

The ML model was estimated in three steps. Firstly, we estimated the regression coefficients of ML model using the command *mixlogit* (Hole, 2007) run in STATA 15.1 software (StataCorp LP, College Station, US). The results from the estimation of the regression coefficients of the ML model using equation (3) are shown in Table 3. Specifically, in Table 3 the regression coefficients of "price" "flour", "protein" and "Carbon" are reported, as well as the corresponding standard errors and significances for the design attributes. On average, consumers preferred biscuits of a low price, produced with conventional wheat flour and with the labelling information "source of protein" and Carbon Trust. Looking specifically at the coefficients for the design attributes, price had the highest magnitude suggesting that this attribute was the one that mostly affected consumers' preferences. The second most important attribute that influenced consumers' preferences was the Carbon Trust label as, on average, consumers preferred biscuits with the Carbon Trust label information. The third most important attribute that affected consumers' preferences was the information on protein content, with consumers on average preferring biscuits with the information "source of protein". Finally, the least important attribute that influenced consumers' preferences was the type of flour, with the data showing that on average consumers preferred biscuits with conventional wheat flour.

It is interesting to note all the design attributes have significant SDs indicating that there were large individual differences in preferences for the design variables with particular reference to "price", "flour" and "Carbon".

Secondly, based on the ML model presented above and on Table 3, we calculated the consumers' WTP for the attributes "flour", "protein"

Table 3
Estimated parameters for Mixed Logit (ML) model with design attributes' main effects.

Attribute	Mixed Logit (ML) Model			SD		
	Coefficient	SE	P-value	Coefficient	SE	P-value
Price	−3.25	0.40	0.00	2.89	0.41	0.00
Flour	−0.72	0.23	0.00	1.93	0.25	0.00
Protein	0.90	0.17	0.00	1.21	0.19	0.00
Carbon	1.66	0.24	0.00	1.81	0.27	0.00
Model parameters						
LL	−878.36					
AIC	1772.72					
BIC	1822.47					

Table 4
Estimated willingness to pay in preference space.

Attribute	WTP (£/300gr)
Flour	−0.22
Protein	0.28
Carbon	0.51

Table 5
Estimated parameters for Mixed Logit (ML) model with design attributes' main effects and interactions with the age, gender, education and the interaction of "flour" with consumers' aversion towards new food products (FNS).

Attribute	Mixed Logit (ML) Model		
	Coefficient	SE	P value
Flour	0.69	1.09	0.53
Protein	1.46	0.63	0.02
Carbon	1.86	0.81	0.02
Price	−3.05	1.16	0.01
Flour*Age	0.05	0.21	0.80
Protein*Age	0.20	0.15	0.90
Carbon*Age	−0.06	0.20	0.77
Price*Age	−0.45	0.28	0.11
Flour*Gender	−0.01	0.44	0.98
Protein*Gender	0.22	0.32	0.50
Carbon*Gender	0.31	0.42	0.45
Price*Gender	−0.46	0.59	0.44
Flour*Education	−0.40	0.20	0.05
Protein*Education	−0.32	0.14	0.02
Carbon*Education	−0.10	0.18	0.57
Price*Education	0.49	0.26	0.06
Flour*FNS	−0.16	0.20	0.41
Model parameters			
LL	−866.47		
AIC	1774.94		
BIC	1905.54		

and "Carbon" (Table 4) using the command *wtp* (Hole, 2007) run in STATA 15.1 software (StataCorp LP, College Station, US). Table 4 displays the same information reported in Table 3, but expressed in monetary terms, using the marginal WTP. This is the ratio of the coefficient of an attribute ("flour", "protein" or "Carbon") divided by the coefficient for price (-1). In line with the results from Table 3, consumers were willing to pay a lower price for biscuits made with upcycled flour (i.e., -£0.22/pack), and a higher price for biscuits with both the "source of protein" nutrition claim (i.e., +£0.28/pack) and the Carbon Trust label (i.e., +£0.51/pack).

Lastly, we investigated the effect of socio-demographics (i.e., age, gender and education) and consumers' aversion towards new food products (FNS) on consumers' preferences for biscuits. The results from the estimation of the regression coefficients of the ML model using equation (4) are shown in Table 5. Specifically, in Table 5 the regression coefficients of "flour", "protein", "Carbon" and "price", as well as the interactions' terms of the design attributes with "age", "gender", "education" and "FNS" are reported. Table 5 also shows the corresponding standard errors and significances for the design attributes. Looking at the interactions among design variables and socio-demographic characteristics, we found that only the interaction between "protein" and "education" was significant at 5% p-value, but negatively correlated meaning that more educated people preferred biscuits with lower protein content. It is interesting to note that the link between "flour" and "FNS" was not significant, indicating no link between aversion to new food products and the use of upcycled ingredients.

3.3. Estimation results from Latent Class Logit (LCL) with design attributes' main effects

The final stage of the study was to estimate the LCL model in two steps. Firstly, we estimated the regression coefficients for each design attributes of LCL model for the different consumers' segments using the command *lclogit2* (Yoo, 2019) run in STATA 15.1 software (StataCorp LP, College Station, US). Based on the BIC parameter (see for details Yoo (2019)), the optimal number of groups for the LCL model was found to be three. The BIC value was 1875.93 with two groups[2]. This value reduced for three groups (1861.63) and raising it to four groups resulted in numerical convergence problems. Therefore, a three-group solution was considered. The results of the LCL model with the three-group solution are reported in Table 6 showing two large and one small groups. Specifically, in Table 6 the regression coefficients of "flour", "protein", "Carbon" and "price" are reported as well as the corresponding standard errors and significances for the design attributes. In group 1 (52 consumers) consumers had the strongest rejection for the upcycled sunflower flour (i.e., "traditionalist consumers") while in group 2 (41 consumers) consumers had strong preferences for low price biscuits (i.e., "price-sensitive consumers"). The p-value for price in group 2 is due to the substantial amount of statistical noise at the point of estimate. Finally, in group 3 (13 consumers) consumers had strong preferences for biscuits with the Carbon Trust label (i.e., "environmentalist consumers"). The main difference among the three groups was therefore the difference in preference for price and the Carbon Trust label.

Secondly, based on the LCL model presented above and in Table 6, for each consumers' group we estimated the consumers' WTP for "flour", "protein" and "Carbon". We used the command *lclogitwtp* (Yoo, 2019) in STATA 15.1 software (StataCorp LP, College Station, US) which calculates the ratio of the coefficient of an attribute ("flour, "protein" or "Carbon") divided by the coefficient for price (−1). Results are shown in Table 7. Consumers' WTP for a 300 g pack of biscuits for "flour", "protein", "Carbon" and "price" for each group are reported as well as the corresponding standard errors and significances for the design attributes. Table 7 is therefore similar to Table 6, but it expresses information in monetary terms using the marginal WTP. "Traditionalist" consumers were willing to pay a much lower price for biscuits made with upcycled flour (i.e., −£0.77/pack) and a higher price for biscuits that were a "source of protein" (i.e., +£0.82/pack) and that carried the Carbon Trust label (i.e., +£0.62/pack). "Price-sensitive" consumers did not show any significant WTP for a particular attribute level, as price was the dominating attribute (see Table 3). This means that consumers in this group are interested only in low price products. "Environmentalist" consumers were willing to pay a much higher price for biscuits that were a "source of protein" (i.e., +£0.57/pack) and that carried the Carbon Trust label (i.e., +£3.71/pack).

4. Discussion & conclusions

This study aimed to explore consumers' preferences, WTP and heterogeneity for biscuits made with upcycled ingredients and test the use of the "source of protein" claim and Carbon Trust label on the pack. We will discuss here how the results from this study advance theory, add to other studies on upcycled ingredients and provide useful managerial insights into the new area of foods made with upcycled ingredients.

Results from the questionnaire revealed very poor consumers' knowledge of upcycled ingredients with only 15% of consumers claiming to have heard of foods with upcycled ingredients before taking part in the study. These results suggest that, although foods with upcycled ingredients can be manufactured (Grasso et al., 2019, 2020; Spinelli, Padalino, Costa, Del Nobile, & Conte, 2019), the concept of

[2] The 2-cluster solution was composed by group 1 (N = 41 consumers) and group 2 (N = 65 consumers) as following, (i.e., attribute and regression coefficient): Group 1: Price (−12.79), Flour (−0.38), Protein (0.57) and Carbon (1.13); Group 2: Price (−0.67), Flour (−0.37), Protein (0.48) and Carbon (0.73).

Table 6
Estimated regression coefficient from Latent Class Logit (LCL) model.

Attribute	Group 1 "Traditionalists" (N = 52)			Group 2 "Price sensitive" (N = 41)			Group 3 "Environmentalist" (N = 13)		
	Coefficient	SE	P-value	Coefficient	SE	P-value	Coefficient	SE	P-value
Price	−0.60	0.13	0.00	−7.17	5.63	0.20	−1.42	0.40	0.00
Flour	−0.46	0.14	0.00	−0.37	0.17	0.03	−0.13	0.40	0.77
Protein	0.50	0.13	0.00	0.57	0.15	0.00	0.81	0.36	0.03
Carbon	0.38	0.14	0.01	1.14	0.17	0.00	5.30	1.84	0.00

Table 7
Estimated Willingness to Pay in Preference Space (£/300gr).

Attribute	GROUP 1 "Traditionalist" (N = 52)			GROUP 2 "Price sensitive" (N = 41)			GROUP 3 "Environmentalist" (N = 13)		
	WTP (£/300gr)	SE	P-value	WTP (£/300gr)	SE	P-value	WTP (£/300gr)	SE	P-value
Flour	−0.77	0.28	0.01	−0.05	0.50	0.30	−0.09	0.32	0.78
Protein	0.82	0.27	0.00	0.08	0.07	0.23	0.57	0.27	0.04
Carbon	0.62	0.06	0.02	0.16	0.13	0.21	3.71	1.41	0.01

upcycled ingredients and related benefits might be too novel for consumers and therefore suitable information campaigns should be designed to address this in the UK. More positive results on consumer knowledge of upcycled ingredients were obtained in Italy by Coderoni and Perito (2020). In their study, 61% of respondents declared to have heard about waste to value foods (and they also knew what the term meant), 20% had heard about those products (but did not know what they meant) and finally 19% did not know about the existence of waste to value foods. These different results might be linked to country-specific differences or to the different methods used to gather the data.

Despite the low knowledge, the majority of consumers (85%) would consider buying foods with upcycled ingredients. This is an important outcome, since the concept of upcycled ingredient overall was not rejected. Coderoni and Perito (2020) also reported positive findings in Italy, with 56% of respondents in their study claiming that they would buy a food product made with wastes/by-products. The percentage rose to 69% if the food made with wastes/by-products also reduced the environmental impact of production.

Looking at the reasons why consumers would consider buying foods with upcycled ingredients, it seems that environmental and food waste prevention were the most important factors, followed by curiosity, while the nutritional benefit did not seem to be considered as important for consumers. The relationship between food consumption, food waste and the environment has received a lot of attention by the UK media and retailers in recent times (BBC, 2019; SkyNews, 2019) and consumers might have been favourably influenced by this communication. Future marketing strategies and labelling information should consider these factors to maximise the reach of foods with upcycled ingredients. Coderoni and Perito (2020) found that Italian respondents in their study were also more likely to buy waste-to-value foods if they thought that this could provide health benefits and a lower environmental impact.

Results from the FNS indicate that upcycled ingredients were not significantly linked to food neophobia. This is a positive outcome, since several studies have shown that the FNS correctly forecasts responses to new foods (Siegrist, Hartmann, & Keller, 2013; Sogari, Menozzi, & Mora, 2019; Verbeke, 2015). Previous studies on FNS and foods made with upcycled ingredients reached different conclusions. Coderoni and Perito (2020) reported that FNS negatively correlated with purchase intentions, while the willingness to try foods made with olive oil by-products had a significant negative correlation with technophobia but not with neophobia in Perito et al. (2019).

Price was the attribute that mostly affected consumers' WTP followed by the Carbon Trust label, protein and finally information on the type of flour. These results are in accordance with other studies where positive consumers' preferences towards the carbon footprint label (Echeverría, Hugo Moreira, Sepúlveda, & Wittwer, 2014) and nutrition claim on proteins (Van Wezemael, Caputo, Nayga, Chryssochoidis, & Verbeke, 2014) were found. Since "price", "protein" and "Carbon" were all more important to consumers than the ingredients used (i.e. "flour"), consumer acceptance of foods with upcycled ingredients could be shaped by promoting these foods with a lower price, with the Carbon Trust label and with appropriate nutrition protein claims.

On average, consumers preferred biscuits made with conventional (i.e., wheat) flour and tended to reject biscuits made with upcycled sunflower flour. However, we found significant consumers' heterogeneity with three different groups of consumers identified. The "environmentalist" group had the lowest rejection towards upcycled sunflower flour in biscuits and the strongest preference for the protein claim and the Carbon Trust label. This group might therefore be the most suitable to target the marketing and promotional strategies for the launch of the new biscuits made with upcycled ingredients, as it has been reported that a strong environmental consciousness can lead towards more sustainable lifestyle choices (Truelove & Parks, 2012).

This manuscript has two main limitations. Firstly, the sample size is small which could limit the representativeness of our findings. Secondly, being this a hypothetical study, it might suffer from hypothetical bias which could have affected the estimation of consumers' WTP. Although this study was anonymous and a cheap talk was used to limit hypothetical bias effect, it is also possible that social desirability bias might have influenced consumers' responses. Preferences for the Carbon Trust label might have been due to this label being more known to consumers compared to the concept of upcycled ingredients.

Appropriate consumer-friendly definitions and labelling for upcycled ingredients need to be developed and suitably communicated before these new products are launched on the market. Indeed, in the food context, there have been many examples that reflect how the name of a dish, a food product or a label affect consumers' perceptions (Irmak, Vallen, & Robinson, 2011; Kunst & Hohle, 2016). Further work also needs to be conducted to find the most suitable way to communicate the nutritional and environmental advantages of upcycled ingredients to consumers. It is possible that increasing consumer familiarity with the concept and benefits of upcycled ingredients will improve the acceptability of new foods made with such by-products and this hypothesis should be tested in future studies. In general, exposure has been reported to be an important driver of acceptance and should be an element to secure new product acceptance alongside with taste (Lease, MacDonald, & Cox, 2014). Other studies on consumers' preferences towards food by-products also concluded that appropriate definitions, information on benefits and marketing strategies are key to success (Aschemann-Witzel & Peschel, 2019; Bhatt et al., 2018; Coderoni & Perito, 2020; Perito et al., 2019).

In addition to communicating information on upcycled ingredients to consumers, there are further areas to explore. While currently there are no specific regulations concerning foods made with by-products, many regulatory challenges are likely to affect the sale of upcycled ingredients in Europe. Some upcycled ingredients might in fact be considered novel foods, because they were not produced or used in the EU before 1997, and might need to be authorized by the European Food Safety Authority (EFSA) before entering the EU market (EFSA, 2016). It would be important for the regulatory authorities to consider the environmental and nutritional benefits of upcycled ingredients in order to allow for procedures that would simplify their entrance into the market and make a positive impact on our societies. This would in turn encourage food ingredient manufacturers to invest in the development of upcycled ingredients and offer more cost-effective options to food manufacturers for the development of healthier and more sustainable foods.

Future research should include the replication of this study using larger samples of UK consumers and in other countries, the use of different food products and testing the effect of different message framing information (i.e., private and public benefits of using upcycled ingredients) about upcycled ingredients to consumers. In addition, future studies should include sensory tests of these new products as it is well known in the literature that sensory attributes are key drivers of consumers' preferences (Asioli et al., 2017; Grunert, 2005; Lima, de Alcantara, Ares, & Deliza, 2019). Sensory testing of foods with upcycled ingredients could therefore provide further realistic valuable consumer insights into this topic. It is also recommended to carry out real experiments using real products in the field, in supermarkets, using real choice experiments (RCE) or experimental auctions which will provide further external validity of these results (Alfnes & Rickertsen, 2011; Lusk & Shogren, 2007).

Finally, a multidisciplinary effort bringing together regulators, new product developers, food manufacturers and marketers will be needed to ensure that foods with upcycled ingredients can enter the food market and find a stable position on the supermarket's shelf.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Transparent reporting

Questionnaire, data, analysis codes and other supplements are available on request, while pre-registration of the study is available in https://aspredicted.org/blind.php?x=z7cy6b.

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