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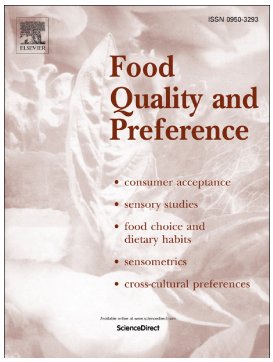

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PII: S0950-3293(25)00186-7

DOI: https://doi.org/10.1016/j.foodqual.2025.105611

Reference: FQAP 105611

To appear in: *Food Quality and Preference*

Received date: 21 March 2025

Revised date: 3 June 2025

Accepted date: 4 June 2025

Please cite this article as: Q.C. Nguyen, T. Næs, V.V.M. Le, et al., Consumer preferences for upcycled foods: The role of product attributes and label information, *Food Quality and Preference* (2024), https://doi.org/10.1016/j.foodqual.2025.105611

Consumer Preferences for Upcycled Foods:

The Role of Product Attributes and Label Information

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ABSTRACT

Over the last decade there has been an increasing interest by food industry in upcycled foods as a way to reduce food waste and loss through the food supply chain. This manuscript investigates the effect of nutritional and environmental information on Vietnamese consumer preferences for upcycled biscuits containing brewer's waste grain (BSG). Results revealed that when consumers are informed about the nutritional and environmental benefits of the upcycled biscuits, they exhibited a higher purchase intent compared to the absence of such information. The inclusion of sustainability or nutrition information changed repurchase intent, with the effect driven by sensory perception. Food companies must carefully assess the impact of product information and sensory perception on consumers' purchase and repurchase intent to effectively advocate for sustainable or nutritional food choices. These findings provide useful insights for product development and marketing activities for upcycled food businesses.

Keywords: Consumer preferences; Environmental information; Nutritional information; Upcycled biscuits; Vietnam.

1. INTRODUCTION

According to FAO (2019) approximately 14% of the total world food produced valued at $400 billion, is lost along the food supply chain. These losses have significant economic implications, with an estimated annual economic loss of $1 trillion (Food Forward NDCs, 2024). Furthermore, food loss and waste contribute significantly to environmental damage, accounting for 8-10% of global greenhouse gas (GHG) emissions (FAO, 2022). By reducing food losses and waste, we can support the fight against climate change, save nutritious food components, helping to eradicate hunger and malnutrition, save money for companies and households, etc. (European Commission, 2024; Moshtaghian, Bolton, & Rousta, 2021; Reynolds, Piantadosi, & Boland, 2015).

Upcycling food[1] presents a promising method for mitigating food loss and waste, since it entails converting food by-products and waste materials into new food items (Aschemann-Witzel et al., 2023; Bhatt et al., 2018; Moshtaghian et al., 2021). Indeed, the food and beverage industry produce large quantities of by-products (Augustin, Sanguansri, Fox, Cobiac, & Cole, 2020; Schaldach et al., 2022; Tai, Minh, & Thuy, 2023). These by-products represent an unexploited source of nutrients including fibre, proteins, minerals, vitamins, and antioxidants (Melios, Johnson, & Grasso, 2025). If appropriately processed, they can be reintegrated as food-grade ingredients into new upcycled foods, presenting significant opportunities for food businesses (Trigo, Alexandre, Saraiva, & Pintado, 2019).

[1] Upcycling foods are foods that 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).

Lu, Parrella, Xu, and Kogut (2024) conducted a comprehensive review of investigating consumers' preferences for upcycled foods across various countries. This review encompasses thirteen studies in European countries, seven studies in North America, five studies in Asian countries, two studies in the Oceania region, two studies in the South American, and one study was conducted in the African country. Lu et al. (2024) identified three key groups of factors influencing consumer acceptance of upcycled foods, namely sociodemographic characteristics, psychographic characteristics, and product characteristics. Furthermore, the consumer profile most accepting of upcycled foods includes younger, more educated consumers who are less food and food technology neophobic, are sustainability-minded, seek convenience, and pay attention to labels and logos.

When communicating about upcycled foods, providing information about their positive contributions to health, nutrition, sustainability, food waste reduction, and the economy is effective at increasing acceptance among diverse consumer groups (Altintzoglou, Honkanen, & Whitaker, 2021; Asioli & Grasso, 2021; Cattaneo, Lavelli, Proserpio, Laureati, & Pagliarini, 2019; Coderoni & Perito, 2021; Ghazanfar, Abdullah, Ummar, Shabbir, & Saqib, 2022; Stelick, Sogari, Rodolfi, Dando, & Paciulli, 2021). However, information about food waste should be presented carefully to avoid negative associations with trash, landfills, garbage or lead them to perceive upcycled foods as unsafe, unappealing, or suitable for disposal (Altintzoglou et al., 2021; de Visser-Amundson, Peloza, & Kleijnen, 2021). Effective information frames include rational framing, environmental benefits framing, and frugal benefits framing (Aschemann-Witzel, Asioli, Banovic, Angela Perito, & Odile Peschel, 2022; Bhatt, Ye, Deutsch, Ayaz, & Suri, 2020).

Other studies have examined the role of tasting on consumer preferences for upcycled foods. To illustrate, Proserpio et al. (2020) found that consumers who received information about the sustainability and pro-health activity of value-added ingredients without tasting reported higher

degree of liking than those who both received the information and tasted the upcycled samples. Furthermore, Yilmaz and Kahveci (2022) discovered that consumers' willingness to buy upcycled foods was positively correlated with higher sensory expectations. Similarly, Perito, Di Fonzo, Sansone, and Russo (2020) found that consumers who perceived sensory (e.g., taste) benefits were more inclined to accept food products enriched with by-products. Maw, Sae-Eaw, Wongthahan, and Prinyawiwatkul (2022) found that product information (environmentally friendly and/or nutrition advantages) and prior consumption experience strongly affected liking. Consumers were positive about the products before obtaining the information, but thereafter they were negative. Cela, Giorgione, Fassio, and Torri (2024) investigated how circular economy information affects consumers' sensory acceptability, purchase intention, and perceived value of upcycled foods. The study found that while additional information did not significantly impact the sensory characteristics or overall liking of the samples, consumers' willingness to pay for biscuits and cheese was significantly lower after being introduced to circular economy information.

When buying food products, there are three steps in the purchase process: (1) the purchase of the product, (2) the consumption of the product, during which, consumers experience some of its characteristics (e.g. taste), and (3) the re-purchase of the product, based on satisfaction (Grunert, 2002, 2003). Thus, for a new product, however, the purchase process lacks the experience step. When first purchasing a new product, consumers choose it by considering

search and credence attributes[2], creating sensory expectations (e.g. taste, flavour). After consumption, these expectations are transformed into real experiences of the product's sensory characteristics. Therefore, in the case of satisfaction, the re-purchase stage draws on the three characteristics (i.e. search, credence and experience) (Ballco, Caputo, & de-Magistris, 2020; Ballco & Gracia, 2020). The relationship between product expectation and product experience is commonly believed to determine consumer satisfaction with the product and, hence, is a strong determinant of repeated purchases (Bollinger, Leslie, & Sorensen, 2011; Elbel, Gyamfi, & Kersh, 2011; Holmquist, McCluskey, & Ross, 2012). To the best of the authors knowledge, there is a scarcity of studies examining the effect of nutritional and/or environmental information on consumer preferences for upcycled foods in real context in Vietnam.

This manuscript investigates the effect of nutritional and/or environmental information on Vietnamese consumers' preferences for biscuits containing upcycled BSG flour (hereafter "upcycled biscuits") using a ranking experiment. In addition, we examine the relation among purchase intent, liking and repurchase intent (after tasting samples) when different types of information are provided.

We chose BSG because it is a by-product of the brewing industry, characterised by its high content of hemicelluloses, proteins, cellulose, lipids, and lignin (Mussatto, Dragone, & Roberto,

[2] Search characteristics are those can be evaluated before purchasing the product (e.g., colour, size), experience characteristics are those can only be evaluated after the product is consumed (e.g., taste) and credence characteristics are those that cannot be evaluated by consumers unless additional information is provided (e.g., organic labels) (Nelson, 1974).

2006). BSG has been utilised as upcycled ingredient in many products, including pasta (Chetrariu & Dabija, 2022), muffins (Combest & Warren, 2022), bread (Sileoni, Alfeo, Bravi, Belardi, & Marconi, 2022), and cereal bar (Stelick et al., 2021).

The nutritional and environmental information were chosen as extrinsic cues because they have been found to increase consumer WTP for upcycled food (Altintzoglou et al., 2021; Asioli & Grasso, 2021; Coderoni & Perito, 2021; Stelick et al., 2021). We also included the intrinsic cue (i.e. sensory attributes) because it is one of the top attributes affecting consumer preferences for food products (Lusk & Briggeman, 2009; Perito, Coderoni, & Russo, 2020; Proserpio et al., 2020; Yilmaz & Kahveci, 2022).

The United Nations Environment Programme (UNEP) Food Waste Index Report 2024 indicates that the global food waste reached 1.05 billion tonnes in 2022, with Vietnam positioned second in the Asia-Pacific region after China (Ngan, Ghi, & Tien, 2024). Specifically, Vietnam discards over 8,000,000 tonnes of still-edible food annually across various cities, resulting in financial losses of US$3.9 billion per year, which constitutes nearly 2% of the current (Gross Domestic Product) GDP (UNEP, 2024).

In Vietnam, agricultural production waste accounts for 10-30% of total food produced annually in the country (Thuy et al., 2020; Zarina & Tan, 2013). Agriculture and fishery produces a large variety of different by-products, for example rice bran/husk, fruit peels (e.g. pomelo, banana), seafood processing waste (e.g. shrimp shells/heads), manufacturing side-streams (e.g. spent grains, coffee pulp), etc. (Tai et al., 2023). Previous studies demonstrate that suitable treatment methods can facilitate the transformation of these wastes into valuable by-products, namely upcycled foods (Tai, Linh, & Thuy, 2021a, 2021b). Vietnam's by-products are nutritionally rich in essential nutrients such as dietary fibre (pomelo peel, rice bran), protein (shrimp shells, spent grains), antioxidants (astaxanthin from shrimp, naringin from pomelo),

vitamins, and minerals (RMIT Vietnam, 2025). However, the nutritional value is significantly influenced by the final product formulation which may provide limited benefit (Thorsen et al., 2022).

Upcycled food can provide a significant economic advantage by generating revenue from waste, potentially lowering input costs, enhancing farmer incomes, and decreasing dependence on imported raw materials (The Upcycled Foods Definition Task Force, 2020). Nonetheless, substantial economic obstacles remain, such as ensuring reliable sourcing from fragmented waste streams, the high cost of specialised processing technologies, managing complex logistics, and attaining market size (Vietnam Fisheries Magazine, 2025). The economic feasibility frequently depends on potentially premium prices, which may conflict with consumer price sensitivity (Circle Economy Foundation, 2024).

Consumer acceptance is critical for achieving market success. While Vietnamese consumers exhibit increasing environmental awareness and concern regarding food waste (Pham et al., 2021), familiarity with the concept of "upcycled food" is likely low (Verified Market Research, 2025). A choice experiment assessing biscuits formulated using upcycled spent coffee grounds (SCG) revealed that Vietnamese consumers were inclined to pay premiums for tangible product benefits (antioxidant content, coffee flavour) (Le Nguyen Doan, Huynh Diep, & Nguyen, 2025). Nevertheless, participants in this study did not exhibit a willingness to pay premium based only on the ingredient type (SCG flour vs. regular flour) or the inclusion of a "carbon trust" environmental label. It indicates that Vietnamese consumers prioritise tangible, perceived benefits such as improved nutrition (antioxidants) or desired sensory attributes (flavour) over the abstract concept of "upcycled" or general environmental claims when making purchasing decisions for these novel products. Trust in labels and certifications is also crucial (Pham, Nguyen, Do, & Dao, 2025). While some studies suggest that sustainability claims can enhance purchase intent for upcycled products (Ghazanfar et al.,

2022), others reveal that consumers are reluctant to pay a premium price over conventional products unless explicit benefits are communicated or if the consumer possesses a strong environmental consciousness (Zaraska, 2021). Overcoming barriers necessitates effective communication that highlights tangible benefits such as safety, nutrition, and sensory perception, while also considering sustainability.

This manuscript provides several contributions to the existing literature. First, our objective is to deliver more accurate insights regarding consumer purchase intent, degree of liking, and repurchase intent for upcycled foods through direct tasting experiences. Second, we aim to investigate the role of tasting in relation to the provision of nutritional and environmental information. Third, we seek to present findings from a developing country, especially Vietnam.

2. MATERIALS AND METHODS

2.1 Experimental design

The experimental design includes two experiments: (i) experiment 1 (Sensory test) aims to identify the most different samples in terms of sensory features from all samples investigated, and (ii) experiment 2 (Consumer test, using the selected samples from experiment 1), aims to investigate consumer preference for upcycled BSG biscuits and examine the relations among consumer purchase intent, informed degree of liking, and repurchase intent under different informational treatments.

2.1.1 Experiment 1 (Sensory test)

We conducted a sensory analysis using Check-all-that-apply (i.e. CATA) approach. From the scores plot of these data, we selected four products to be tested with consumers in experiment 2 based on two conditions, namely (i) the samples must evenly cover the sensory space, seeking

the maximum spread of samples across the first and second dimensions, and (ii) the samples should include variability in both experimental factors (i.e. percentages of BSG and oat flakes), ensuring that samples with different percentages of BSG and oat flakes are presented to each consumer. The methodology for selecting the products has been presented and used in prior research (Menichelli, Olsen, Meyer, & Næs, 2012).

2.1.2 Samples

The main ingredients were wheat flour, oat, and BSG. While the first two ingredients were commercial products, the last one was collected from a brewing company in paste format. The paste was dried, grinded, and further processed to obtain BSG powder. A similar BSG preparation was also described in previous studies (Guo, Du, Zhang, Zhang, & Jin, 2014; Öztürk, Özboy, Cavidoğlu, & Köksel, 2002; Tran, Ton, Le, & Le, 2020).

The ingredients[3] were 30g of butter and 35g of water; when applicable, 0.8g of baking powder was also added. The biscuits were prepared in a single stage in a mixer at 120rpm for 4 min. The dough was sheeted and moulded to 3.5mm thick. After moulding, the dough was cut into small discs (60 mm diameter), which were placed in the oven and baked at 170 °C for 20 min.

Table 1 shows the nine biscuit formulations that were prepared with two factors of BSG (three levels: 0%, 10%, 20%) and oat flakes (three levels: 0%, 10%, 20%). The percentages were calculated based on total weight of the ingredients. The flake size (oval shaped) was approximately 8×5×1 mm (length×width×thickness) for the small flakes and 11×6×1 mm

[3] Expressed in g/100g.

for the large flakes. Except for the ingredient differences all the others biscuit ingredients, formulations, and calorie content were identical.

Table 1. Biscuit formulations (N (none), L (low), H (high) are 0%, 10%, 20% percentage of ingredients).

	Oat flakes: 0%	**Oat flakes: 10%**	**Oat flakes: 20%**
BSG: 0%	NN	NL	NH
BSG: 10%	LN	LL	LH
BSG: 20%	HN	HL	HH

2.1.3 Testing Procedure

Figure 1 shows the experiment 1 which includes two steps: (i) Attributes development and (ii) CATA test as follows.

ATTRIBUTES DEVELOPMENT: Selection of sensory attributes

Attributes and definitions were created in two pre-trial sessions. In the first session, 10 consumers tasted the nine biscuits and listed all sensory attributes they perceived while in the second session, other 10 consumers tasted nine biscuits with the predefined list of attributes from the first session. Then these consumers were asked to refine and clarify attributes where applicable and confirm that the attributes described the sensory properties of the biscuits they tasted during this session. By the end of pre-trials, the final list of attributes and definitions were obtained upon agreement among 10 consumers (in the second session) by open communication. The final list of attributes included 3 colour attributes *(i.e. yellow, brown–yellow, brown)*, 15 texture attributes *(i.e. hard, foamy, dense, crumbly, sandy, gritty, pasty, sticky, soft, dry, easy–to–swallow, hard–to–swallow, malt flavour, oat flavour, flour flavour)* and 1 taste attribute *(i.e. sweet*) with their definitions (see Appendix Table A1).

Serving protocols

The biscuits were stored under refrigeration (4°C) until the tests took place. Samples were evaluated by consumers at room temperature (25°C). Each sample (30g of biscuit) was served in a plastic container coded with a 3-digit random code. Samples were presented in a sequential monadic manner following a Williams Latin square design (Williams, 1949). The test was conducted in standardized individual booths according to ISO standards (ISO 8589:2007) under white light with adequate ventilation. Water was provided to clean the palate between samples.

CHECK-ALL-THAT-APPLY TEST: Sensory description by consumers

For the formal assessment, consumers were asked to taste each sample and answer to a Check-all-that-apply (CATA) question, by checking the attributes that applied to describe the sensory characteristics of sample. Consumers were asked to rinse their mouths with water during the two-minute break between samples. The attributes position on the screen were balanced across consumers following a Williams Latin square design (Williams, 1949), but each consumer used the same attribute list order to evaluate all samples (Meyners & Castura, 2016). Before the formal tasting, consumers were provided a list of sensory attributes and definitions (Appendix Table A1). They were instructed to read the attribute descriptions and confirm their understanding.

At the start of the test, consumers were served a warm-up sample (commercial biscuit without BSG). They reviewed the arrangement of the attributes on the screen, then evaluated the warm-up sample. This warm-up sample familiarized consumers with the CATA task (Adams, Williams, Lancaster, & Foley, 2007). After that, they proceeded to the formal assessment of the 9 samples.

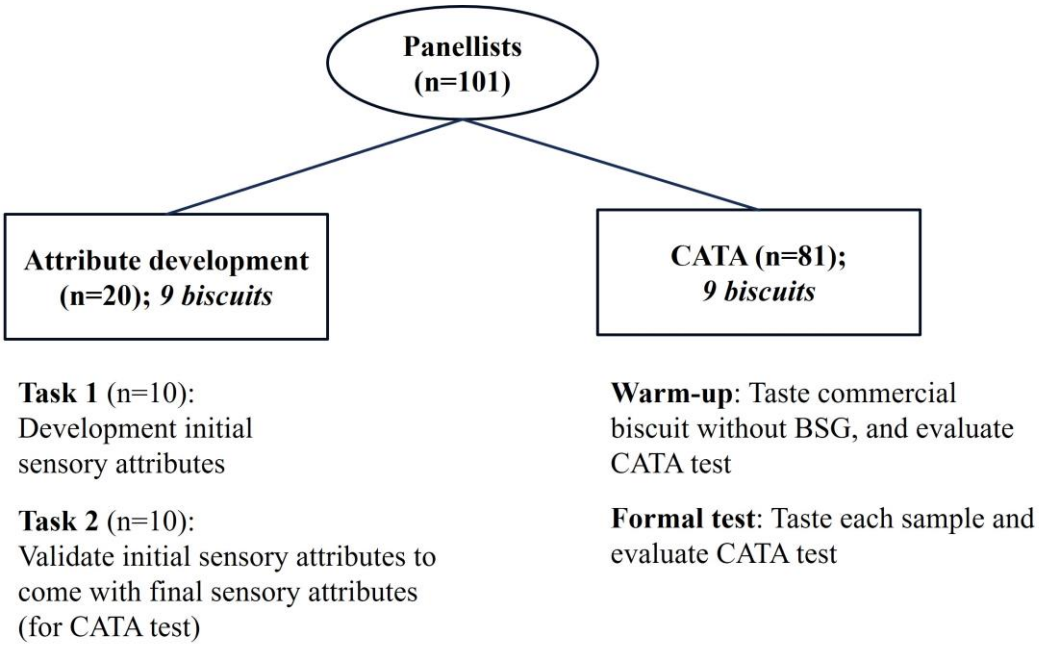

Figure 1. The protocol of experiment 1.

2.1.4 Participants

Consumer recruitment

Consumers were recruited for the test at the Ho Chi Minh City University of Technology (HCMUT) campus (53% males, 47% females; aged 18 to 25 years). Their recruitment was based on the following criteria: consumption of biscuits at least 2–3 days a week, not on a special diet, and neither celiac, gluten sensitive, nor aversive to wheat or oats. Consumers were instructed not to use products with persistent flavours at least 30 min before. Only consumers with complete data were retained in this experiment.

Human ethics statement

The study was covered by a general approval from the Ethics Review Board at the University (Ref. No. ERB-01/2022). Participants were instructed to read an information sheet and sign a consent form. Participants gave voluntary consent and were assured that their responses would remain confidential, they were informed they could withdraw at any point without any

consequences. Participants received a monetary compensation (50,000 VND) for their participation.

2.1.5 Data analysis

Data were analysed using the multiple-response correspondence analysis (MR-CA) for investigating associations between products and sensory attributes (Mahieu, Schlich, Visalli, & Cardot, 2021). MR-CA is deemed superior to traditional CA (Greenacre, 2007) for examining associations between products (rows) and attributes (columns) in the matrix of CATA citation rates (Castura, Meyners, Varela, & Næs, 2022). MR-CA performs PCA on the average citation proportions of products, while weighting the descriptors proportionally to their citation rates, similar to standard CA (Mahieu et al., 2021). When products and attributes are shown together, the uncertainty of the products is represented via 95% confidence ellipses derived from the total bootstrap procedure (Cadoret & Husson, 2013). The MR-CA scores and loadings, exhibiting relation between products and sensory descriptors, were used for selecting representative products for subsequent experiment. We used the software R version 4.3.3 using the package *MultiResponseR* (Mahieu, 2021) to analyse data.

2.2 Experiment 2 (Consumer test)

To investigate consumer preferences for the different biscuits we used a ranking method[4]. The ranking approach has the advantage that – differently than rating method – forces the

[4] A common approach based on asking to rank the products (Lawless & Heymann, 2010) according to their degree of liking or (re)purchase intention.

respondents to compare and discriminate among products based on their preference. The ranking experiment has been largely applied in many consumer studies (Almli, Øvrum, Hersleth, Almøy, & Næs, 2015; Asioli, Næs, Øvrum, & Almli, 2016; Grasso & Asioli, 2020; Yangui, Akaichi, Costa-Font, & Gil, 2014).

2.2.1 Samples

In experiment 1, four biscuits (NN, NL, HL, HN in Table 2) were selected according to the MR-CA scores plot of sensory profile for all nine biscuits (shown in Table 1) which were used for the rest of the study.

2.2.2 Experimental design and procedure

Consumers (n=305) were split in three groups, corresponding to three different treatments. The three treatments differed only in terms of the different information provided to consumers. Specifically, in treatment T0 (Control), 101 consumers were not provided any information about the benefits of the BSG ingredients. In treatment T1 (Sustainability), 102 respondents were exposed to the products and provided information about sustainability benefits of the BSG biscuits. In treatment T3 (Nutrition), 102 respondents were exposed to the products and provided information about nutritional benefits of the BSG biscuits. A between-subjects design was chosen to avoid carryover and demand effects that may occur with within-subjects designs (Charness, Gneezy, & Kuhn, 2012). Only consumers with complete data were retained for all treatments.

Each of the four biscuits (NN, NL, HL, HN) was combined with two extrinsic categorical attributes: sustainability (two levels: upcycled certified logo and no logo) and nutrition (two levels: fibre claim and no claim). Biscuit labels are different in the ingredient description and

logo/claim provided (always true information). All biscuits labels for the three treatments are in Table 2.

Table 2. Biscuit labels in different treatments.

Sample		**Treatment 0 – Control** ***(N=101)***	**Treatment 1 – Sustainability** ***(N=102)***	**Treatment 2 – Nutrition** ***(N=102)***
NN	Ingredient description	-	-	-
	Logo/ claim	-	-	-
NL	Ingredient description	Adding 10% oat flake	Adding 10% oat flake	Adding 10% oat flake
	Logo/ claim	-	-	-
HL	Ingredient description	Adding 20% brewer's spent grain and 10% oat flake	Adding 20% brewer's spent grain and 10% oat flake	Adding 20% brewer's spent grain and 10% oat flake
	Logo/ claim	-	"Upcycled certificate" logo	"Source of fibre" claim
HN	Ingredient description	Adding 20% brewer's spent grain	Adding 20% brewer's spent grain	Adding 20% brewer's spent grain
	Logo/ claim	-	"Upcycled certificate" logo	"Source of fibre" claim

The images of biscuit labels have been presented in Appendix Table A2.

The experiment was structured as follows (Table 3). First, consumers were asked to imagine the following situation: "You have gone to the store to buy biscuit for yourself and your family. In front of you, different biscuits are displayed. The biscuits vary according to the ingredients". Second, consumers were introduced to the information of BSG as a by-product of brewing industry. Then, different information about sustainability (i.e. treatment T1) or nutrition (i.e. treatment T2) benefits of these biscuits or nothing (i.e. treatment T0) was provided to consumers depending on the treatment. Third, consumers were instructed to recognize different biscuit labels and then ranked their purchase intent of biscuits labelled with these labels in terms of purchase intent (high rank (4) corresponds to high preference). After that, biscuit samples with

their labels were presented to consumers. Consumers were asked to taste all samples and rank their hedonic liking and repurchase intent (from the highest level to the lowest one).

Table 3. Experimental flow for experiment 2.

	Treatment 0 – Control ***(N=101)***	**Treatment 1 – Sustainability** ***(N=102)***	**Treatment 2 – Nutrition** ***(N=102)***
STEP 1: General introduction	Introduction of BSG "Brewer's spent grain (BSG), which is a by-product of the brewing industry"		
STEP 2: Benefit information	No further information is provided	Environmental benefits of BSG are provided	Nutritional benefits of BSG are provided
STEP 3: Logo introduction	No further information is provided	Upcycled logo is introduced	High-fibre claim is introduced
STEP 4: Ranking for purchase intent *(without tasting)*	Rank purchase intent for 4 samples with different labels		
STEP 5: Tasting samples with true information	Receive and taste 4 samples		
STEP 6: Ranking for liking *(after tasting with label information)*	Rank liking for 4 samples with different labels		
STEP 7: Ranking for repurchase intent *(after tasting with label information)*	Rank repurchase intent for 4 samples with different labels		

2.2.3 Consumer recruitment and data

Consumers for the experiment were recruited from a university campus, comprising 302 individuals (172 males, 133 females), aged between 18 and 25 years. The requirement for consumers is similar to that outlined in the experiment 1 (section 2.1.1).

Given the randomisation to treatments, we checked if we had achieved balance for the observable characteristics across the treatments. Table 4 shows that the hypotheses of equality

of means between socio-demographic characteristics across treatments failed to be rejected at the 0.05 level.

Table 4. Consumers' gender and age for each treatment.

	Treatment 0 – Control ***(N=101)***	**Treatment 1 – Sustainability** ***(N=102)***	**Treatment 2 – Nutrition** ***(N=102)***
Gender	female: 47% male: 50% others: 3%	female: 40% male: 60%	female: 39% male: 58% others: 3%
Age	under 19 y/o: 23%, 19 to 25 y/o: 77%	under 19 y/o: 10%, 19 to 25 y/o: 76%, 26 to 29 y/o: 14%	under 19 y/o: 8%, 19 to 25 y/o: 73%, 26 to 29 y/o: 19%

2.2.4 Data analysis

Regression analysis using the Sequential and Orthogonalized PLS (SO-PLS)

To investigate the differences in prediction ability of the repurchase from purchase with and without tasting, we used the Sequential and Orthogonalized Partial-Least Square (SO-PLS) method (Jørgensen & Næs, 2004, 2008). This is a useful a multi-block regression method for investigating incremental improvement when adding input blocks to the model (Menichelli, Hersleth, Almøy, & Næs, 2014; Nguyen et al., 2020; Niimi et al., 2018).

Let us now assume that data consists of three blocks in which **X1** (purchase intent), **X2** (liking) are the explanatory blocks and **Y** (repurchase intent) is the response block. For these data blocks, rows represent consumers, columns represent purchase intent, degree of liking, repurchase intent for four different samples. For example, in each treatment, if 101 consumers rank 4 samples regarding purchase intent (**X1**), degree of liking (**X2**), repurchase intent (**Y**), each block of data **X1, X2, Y** has a dimension of 101×4.

First, **Y** is regressed onto block **X1** (purchase intent) to obtain the scores $\mathbf{T}_{X1}$. Then, the block **X2** (degree of liking) is orthogonalized with respect to the PLS scores $\mathbf{T}_{X1}$ of **X1** to obtain the orthogonalized $\mathbf{X2}^{orth}$. After that, the deflated **Y** (deflated by $\mathbf{T}_{X1}$) is fitted to $\mathbf{X2}^{orth}$ using

standard PLS regression, which estimates the PLS scores $\mathbf{T}_{X2}^{orth}$. Finally, $\mathbf{T}_{X1}$ and $\mathbf{T}_{X2}^{orth}$ are used as independent variables to predict response variables **Y** using an ordinary least squares regression model. With SO-PLS, we can calculate the additional predictive contribution of new blocks (i.e. additional explained variance) as they are incorporated. Detailed description of SO-PLS regression can be found in Næs, Tomic, Afseth, Segtnan, and Måge (2013) and Smilde, Næs, and Liland (2022).

Standard PLS regression (Höskuldsson, 1988; Martens & Næs, 1989; Wold, Ruhe, Wold, & Dunn, 1984) is also used on one occasion. Note that PLS corresponds to the first step of SO-PLS. The SO-PLS is used for each treatment separately. The cross-validation is applied to determine the optimal components for prediction and to assess the quality of the predictor obtained, often quantified by the root mean square error of prediction (RMSEP) (Martens & Næs, 1989) and/or explained variance. The optimal number of components can be selected using global or sequential optimization (Næs, Tomic, Mevik, & Martens, 2011). This paper will employ the sequential approach as it aligns most effectively with the emphasis on additional explained variance.

Data were analysed using the R version 4.3.3. The computations of SO-PLS and PLS regression are implemented using the functions *sopls*, *plsr* in the *multiblock* package (Liland, 2023).

3. RESULTS

3.1 Sample selection from sensory data

Results from the MR-CA are presented in Figure 2. The first two components together explain 88.7% (Comp 1: 76.2% and Comp 2: 12.5%) of the variation, thus two components are used to select the samples for experiment 2. The first component discriminated samples according to

the "ingredients" of the biscuits. Indeed, oat-flake samples (NL, NH) were on the right-side of component 1 while BSG samples (HN, HH, HL) were on the left-side. The oat-flake samples were mostly associated to flour flavour and yellow colour while the BSG samples were linked with brown colour, malt flavour, and soft texture. The second component was mostly related to "texture", characterised by foamy, gritty vs. pasty, and dense. On the second component, it seems that sample LH (low level of BSG, high level of oat-flakes) was separated by sample HL (high level of BSG, low level of oat-flakes). The former was characterised by "sandy" whereas the latter was by "soft".

Since the main aim of the sample separation is the selection of representative samples for further investigations (i.e. experiment 2), we decided to choose four samples that expand the sensory space and represent the various ingredients. Given that the explained variances from the first two components are substantial (88.7%), the sample selection is sufficiently robust. The samples selected were the NN, NL, HN, and HL. Sample HN was selected instead of LH because the latter contained two ingredients (BSG and oat-flakes) as in sample HL (difference in levels).

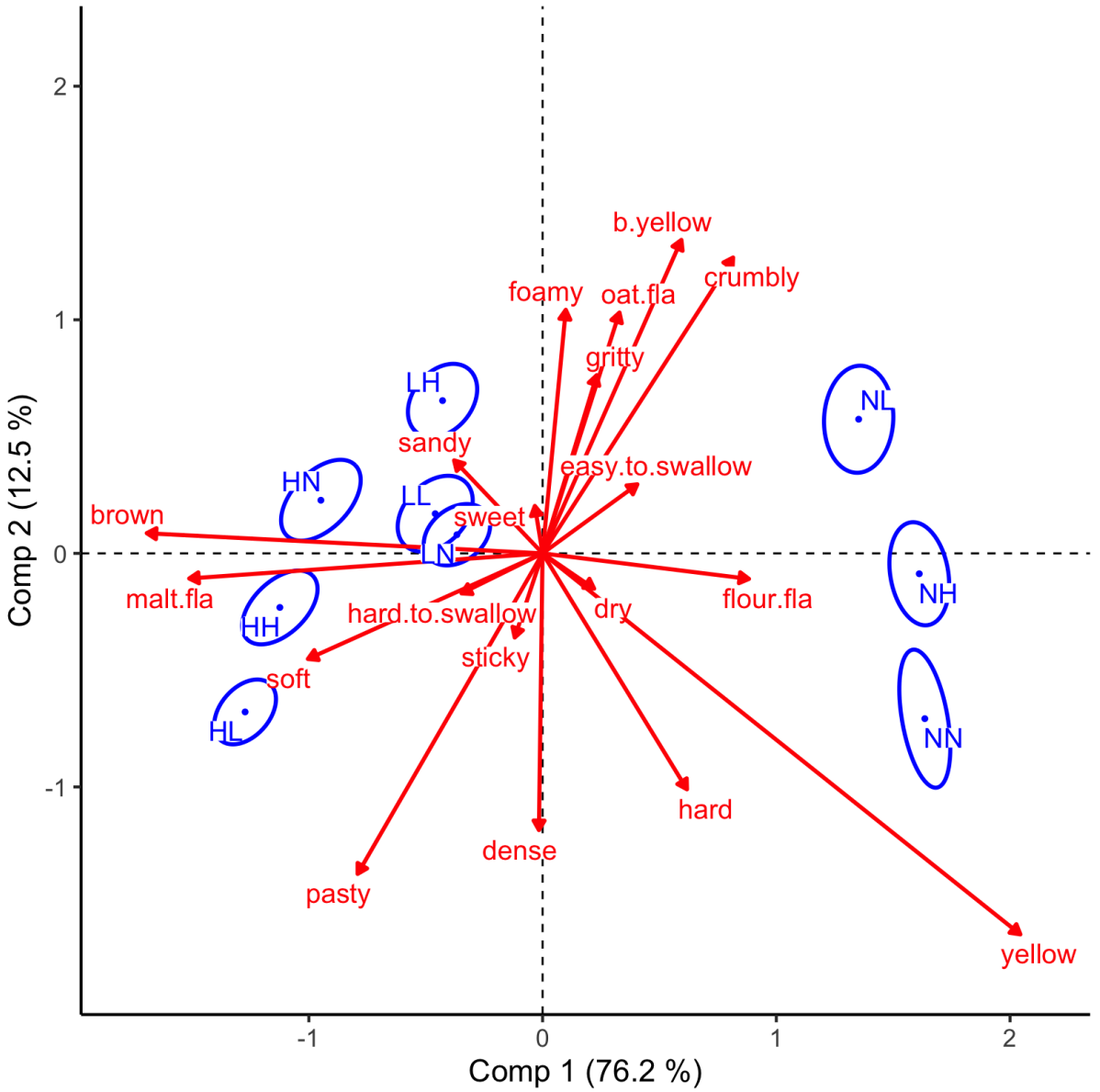

Figure 2. Biscuits and their relevant sensory attributes based on the multiple-response correspondence analysis (MR-CA) analysis.

3.2 Difference of consumer purchase intent, informed degree of liking, and repurchase intent among treatments

Next, we examine the differences in consumer purchase intent (Figure 3), degree of liking (Figure 4), and repurchase intent (Figure 5) across the different treatments.

Regarding consumer purchase intent (Figure 3), when they were not provided either sustainability or nutrition information about BSG biscuits (i.e. treatment T0), their purchase intent for the samples HL (BSG-oat biscuit) and NL (oat biscuit) were higher than the remaining samples HN (BSG biscuit) and NN (traditional biscuit). The percentages of rank 4 for samples NN, NL, HL, and HN were 7.9%, 26.7%, 59.4%, and 5.9%, respectively. Furthermore, when information (sustainability or nutrition) was provided (treatment T1 or T2), consumer purchase intent for the sample NL decreased (percentages of rank 4 decreasing from 26.7% to 8.8% or 26%), whereas it increased for sample HN (percentages of rank 4 increasing from 5.9% to 21.6%, 17%). It is important to note that regardless of the information provided (sustainability or nutrition), consumer purchase intent pattern was similar, with HL presenting the highest purchase intent, followed by samples HN, NL, and sample NN.

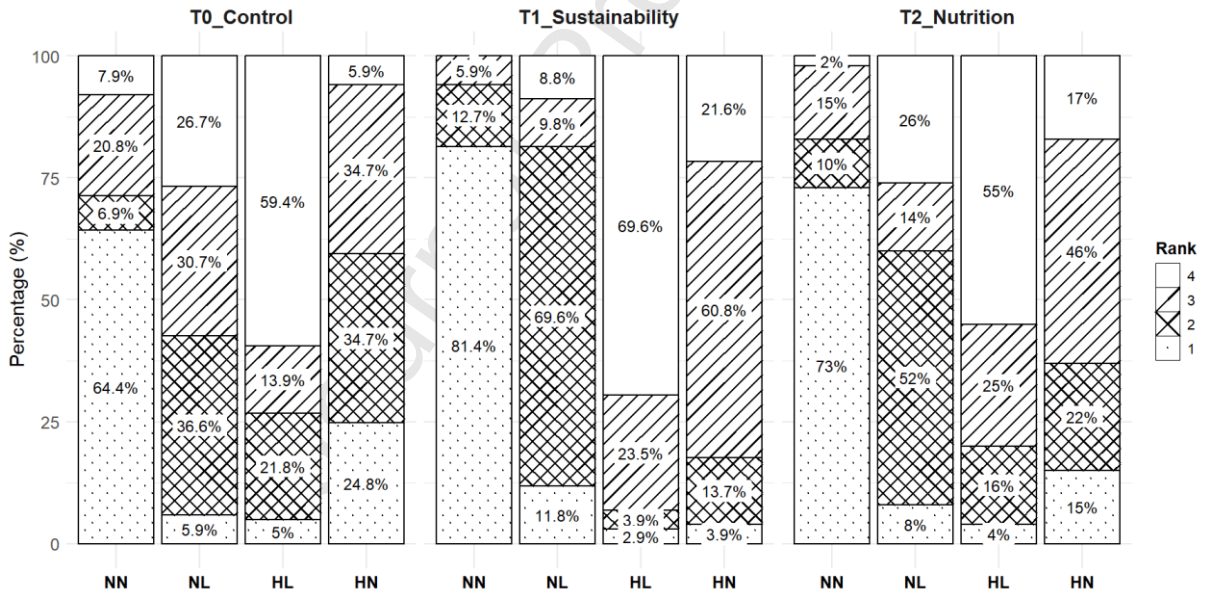

Figure 3. Consumer purchase intent (1=lowest rank, 4=highest rank) for biscuits across treatments.

Note: NN (0% BSG, 0% oat flakes), NL (0% BSG, 10% oat flakes), HL (20% BSG, 10% oat flakes), HN (20% BSG, 0% oat flakes)

For the consumer informed degree of liking (Figure 4), the main differences among treatments (i.e. consumers were provided no information, and sustainability or nutrition information) were on consumer degree of liking perception for the samples NL (oat biscuit), and HN (BSG biscuit). When nutrition or sustainability information was given (treatment T1 or T2), samples NL and HL were less liked by consumers, while the opposite was found for the sample HN. In sample NL, the percentage of rank 4 fell from 35.6% (control treatment) to 13.7% (sustainability treatment) or 15% (nutrition treatment). In sample HL, the percentage of rank 4 decreased from 33.7% (control treatment) to 17.6% (sustainability treatment) or 15% (nutrition treatment). For sample HN, percentage of rank 4 rose from 17.8% (control treatment) to 54.9% (sustainability treatment) or 57% (nutrition treatment).

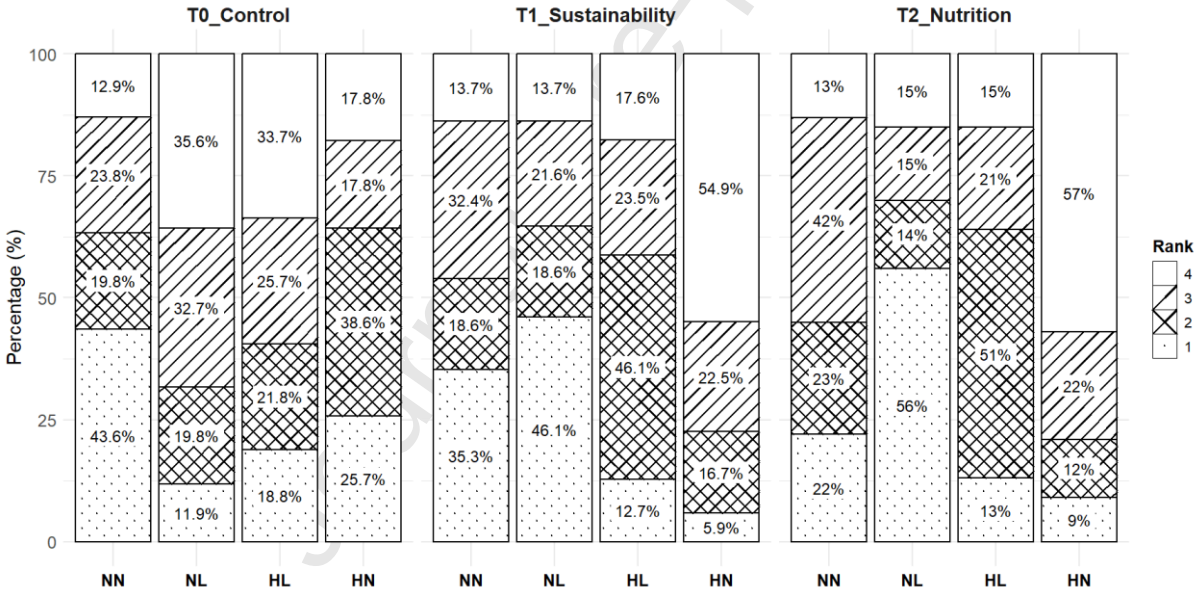

Figure 4. Consumer (informed) degree of liking (1=lowest rank, 4=highest rank) for biscuits across treatments.

Note: NN (0% BSG, 0% oat flakes), NL (0% BSG, 10% oat flakes), HL (20% BSG, 10% oat flakes), HN (20% BSG, 0% oat flakes).

After evaluating purchase intent and informed liking, consumers evaluated their repurchase intent (Figure 5). Across the three treatments, when information was provided, consumers had

higher repurchase intent for the sample HN (BSG biscuit) (percentages of rank 4 being 56.9%, 50% for sustainability and nutrition treatments) compared to the other biscuits. Before tasting, sample HL (BSG-oat biscuit) had the highest purchase intent (Figure 3), whereas, after tasting, sample HN (BSG biscuit) had the highest valuation (Figure 5). This finding confirms the joint effect of sensory perception and product information on consumer repurchase intent.

We note that consumer repurchase intent varied based on the type of samples, sample HN (BSG biscuit) or sample NL (oat biscuit), when provided with information regarding sustainability or nutrition. In sample HN, the provision of sustainability or nutrition information enhanced consumer repurchase intent (percentage of rank 4 from 17.8% to 56.9% and 50%), whereas in sample NL, such information diminished repurchase intent relative to the absence of information (percentages of rank 4 from 26.7% to 7.8% and 12%). The findings indicate that, irrespective of the provision of sustainability or nutritional information, consumers exhibited heightened repurchase intent for sample HN (biscuit featuring a sustainable or nutritional claim, i.e. a 'upcycled' logo or 'source of fibre') and diminished intent for sample NL (lacking such information).

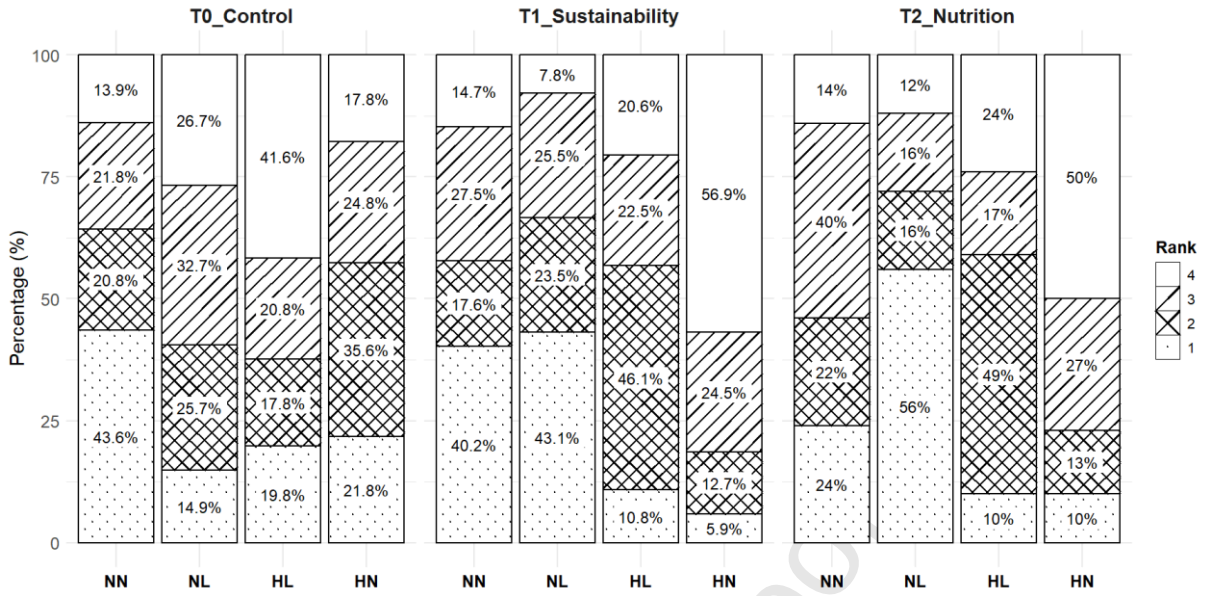

Figure 5. Consumer repurchase intent (1=lowest rank, 4=highest rank) for biscuits across treatments.

Note: NN (0% BSG, 0% oat flakes), NL (0% BSG, 10% oat flakes), HL (20% BSG, 10% oat flakes), HN (20% BSG, 0% oat flakes)

3.3 Relation between consumer purchase intent, informed degree of liking and repurchase intent

Next, for each treatment, using the SO-PLS regression model, we predicted the consumer repurchase intention based on purchase intent and informed liking.

The *purchase intent – liking* model consisted of blocks **X1** (*purchase intent*) followed by orthogonalization of **X2** (*liking*). The RMSEP (data not shown) suggests that only the second block **X2** gave prediction ability, thus we decided to consider the opposite order (i.e. "*liking – purchase intent*").

The Måge plot for the order *liking – purchase intent* for treatments T0, T1, and T2 (see Appendix Figures A1, A2, and A3) demonstrates that the consumer degree of liking was the dominating block, indicating that most variability in repurchase intent was accounted for by the degree of liking. Both models (*purchase intent – liking – repurchase intent* and *liking –*

purchase intent – repurchase intent) show that purchase intent had minimal influence on the variability of repurchase intent. From this, we focus on the effect of consumer degree of liking onto consumer repurchase intent by using PLS regression (i.e. consumer degree of liking as predictor and consumer repurchase intent as response). The correlation loadings plots for the model based on predicted values of repurchase intent for each of treatments are shown in Figure 6 (treatment T0), Figure 7 (treatment T1), and Figure 8 (treatment T2). The RMSEP and cross-validation explained variances are presented in Appendix Table A3. The distribution of residuals versus fitted values are shown in Appendix Figures A4, A5 and A6.

For the control treatment T0 (Figure 6), the first two components explained 41.7% and 29.3%, respectively (71% for the first two components). The first component separated the sample NN (traditional biscuit) from sample HL (BSG-oat biscuit). The second component pointed out the difference of sample NL (oat biscuit) to other samples. Consumer degree of liking was an important predictor since repurchase intent (suffix 'r') of the samples NN, HL, NL closely related to consumer degree of liking (suffix 'l') of samples NN, HL and NL. Consumer degree of liking and repurchase intent for the sample HN (HNl, HNr) were close to each other; however, it was not well explained in this treatment since they were in the centre of the correlation loading plot.

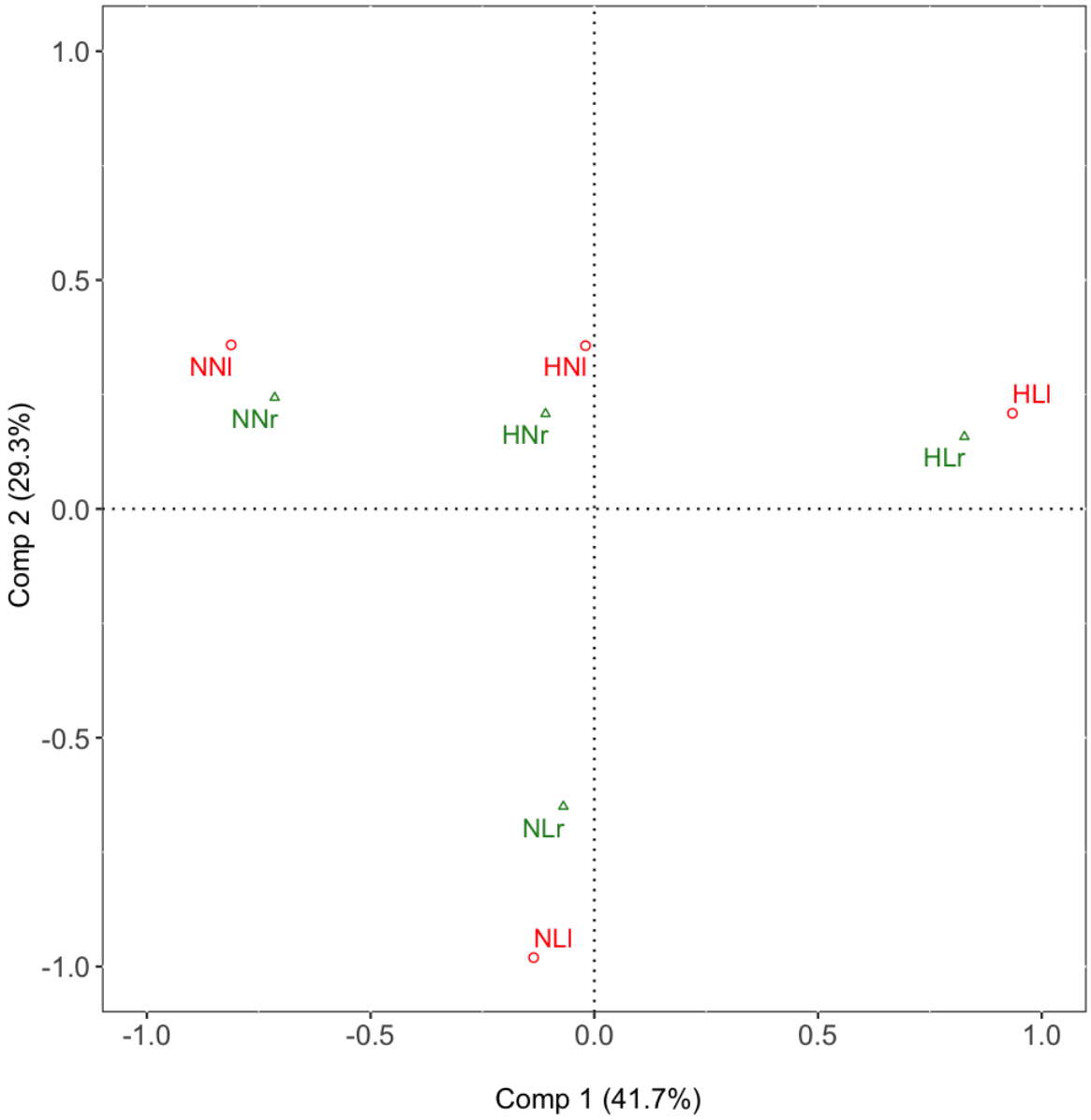

Figure 6. Relation between consumer informed degree of liking (suffix 'l') and repurchase intent ('r') for treatment T0 (control).

Note: NN (0% BSG, 0% oat flakes), NL (0% BSG, 10% oat flakes), HL (20% BSG, 10% oat flakes), HN (20% BSG, 0% oat flakes).

When product information was provided, a PLS regression was applied. Then, the correlation loading plots for each treatment are plotted in Figure 7 (treatment T1) and Figure 8 (treatment T2). We can see that for the sustainability treatment (i.e. T1), the first two components explained 74.5% of total variability (component 1 and 2 explained 49% and 25.5%,

respectively) while for the nutrition treatment (i.e. T2), the explained variance was 83.4% in which components 1 and 2 contributed 57.6% and 25.8%, respectively.

Comparing the explained variances of three prediction models corresponding to the three treatments, it was found that the prediction model in the nutrition treatment (i.e. T2) explained a little bit better than in the sustainability treatment (i.e. T1) and control treatment (i.e. T0) (83.4% compared to 74.5%, and 71%). Furthermore, the main difference between these prediction models came from consumer degree of liking - repurchase intent relation of sample HN, and sample NL. In treatments T1 and T2, the relation consumer degree of liking - repurchase intent of sample HN was well explained; in particular, sample HN discriminated from samples HL, NL on the component 1, and from sample NN on the component 2 (Figure 7 and Figure 8). Considering the relation consumer degree of liking - repurchase intent of sample NL, while this relation is characterised by the component 2 in treatment T0 (Figure 6), it is by the component 1 in treatment 1 (Figure 7) and treatment 2 (Figure 8). This implies that when consumers are provided with product information and taste samples, they will change their perception for some products.

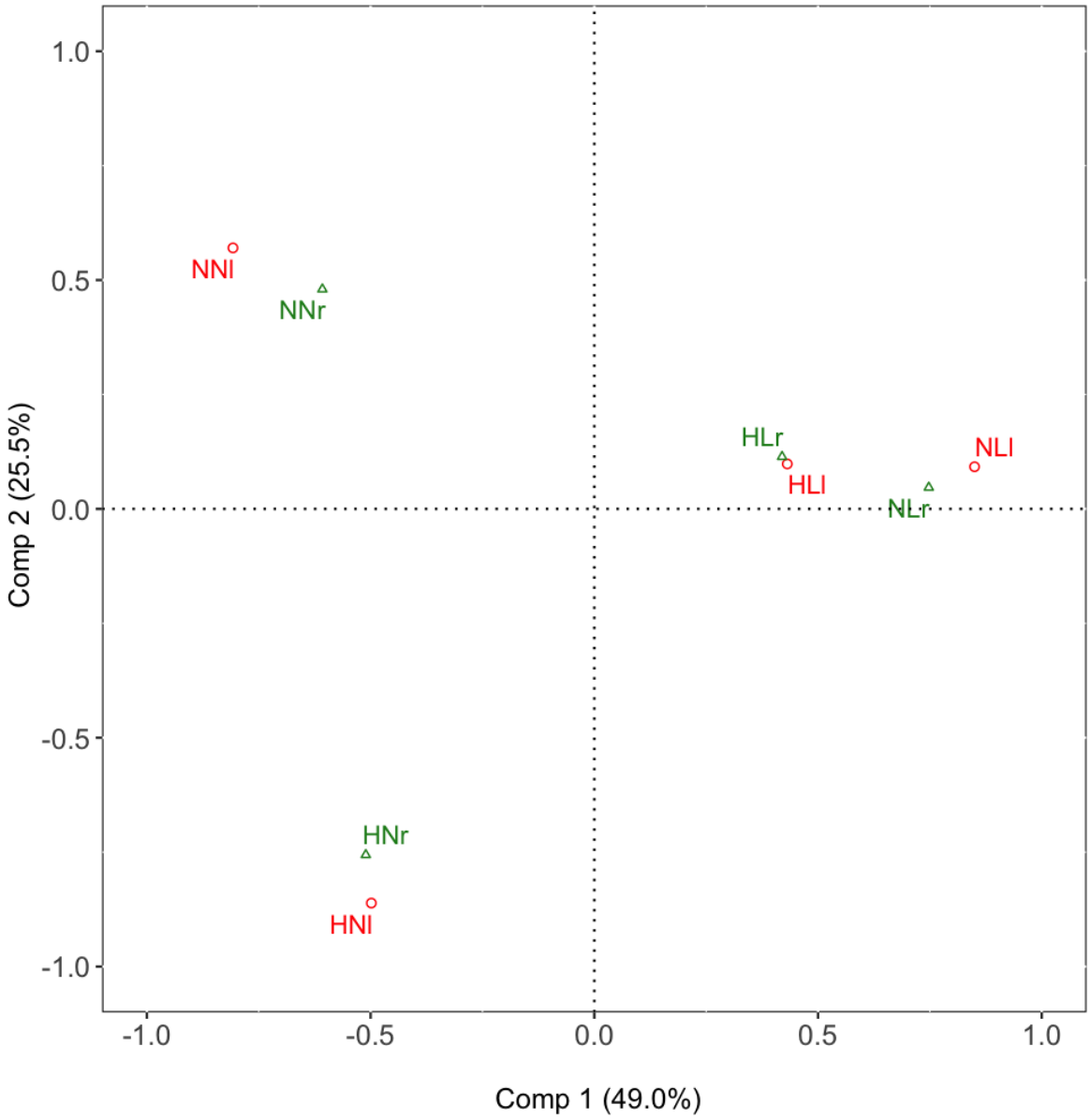

Figure 7. Relation between consumer informed degree of liking (suffix 'l'), repurchase intent ('r') for treatment T1 (sustainability).

Note: NN (0% BSG, 0% oat flakes), NL (0% BSG, 10% oat flakes), HL (20% BSG, 10% oat flakes), HN (20% BSG, 0% oat flakes).

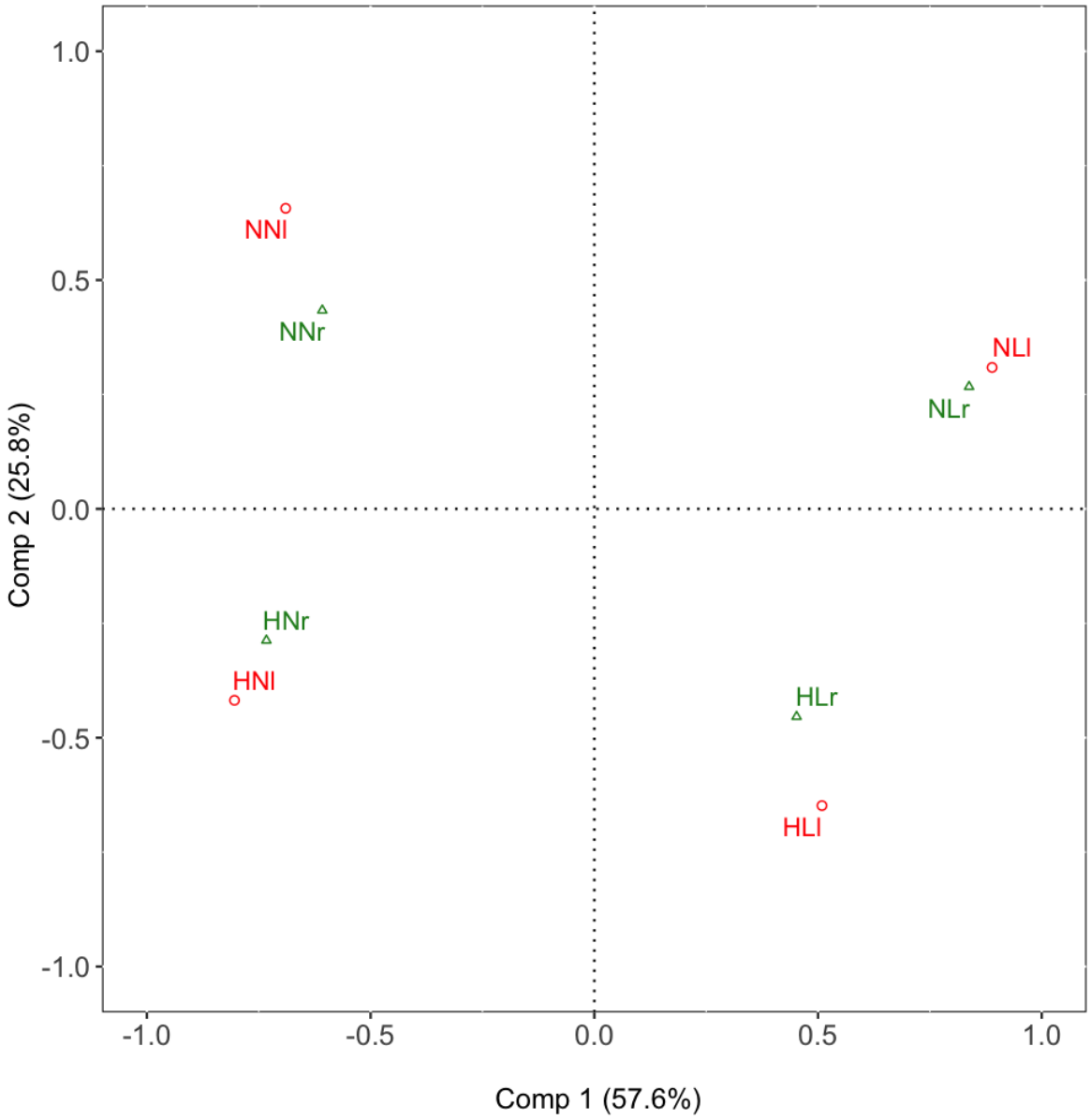

Figure 8. Relation between consumer informed degree of liking (suffix 'l'), repurchase intent ('r') for treatment T2 (nutrition).

Note: NN (0% BSG, 0% oat flakes), NL (0% BSG, 10% oat flakes), HL (20% BSG, 10% oat flakes), HN (20% BSG, 0% oat flakes).

4. DISCUSSION

This manuscript investigates the effect of the provision of sustainability and nutrition information on consumer purchase intent, degree of liking and repurchase intent for BSG

upcycled biscuits. The impact of tasting experience on the provision of nutrition and environmental information on consumer preferences is studied.

We found several noteworthy outcomes. First, we found that when nutritional or sustainable benefits of the upcycled biscuits were provided, consumers changed their purchase intent compared to when such information was not provided. This finding is corroborated by Asioli and Grasso (2021), Bhatt et al. (2020), and Cattaneo et al. (2019) and can be explained by the fact that consumers are increasingly interested in sustainable foods (Asioli, Aschemann-Witzel, & Nayga Jr., 2020). Similarly, nutritional information is among the top attributes affecting consumer purchasing of food products (Lusk & Briggeman, 2009). Our study reveals an increasing awareness of environmental concerns and food waste within the population, as well as its influence on consumer acceptance of upcycled foods. This is also emphasised in other studies conducted in Vietnam (Nguyen, 2023; Nguyen, Nguyen, Nguyen, & Greenland, 2021). Specifically, Nguyen (2023) observed that environmental awareness appears to be increasing, influencing consumer purchase behaviour. In another study, Nguyen et al. (2021) found that a majority (85%) of Vietnamese consumers express loyalty to brands that support environmental activities, and environmental concern drives positive attitudes towards sustainable choices. For success in upcycled food development, Vietnamese manufacturers must create compelling brand narratives that emphasise the source of the ingredients, the innovation applied, and the beneficial effects on farmers, communities, and the environment.

Second, we have not identified differences in consumer purchase intent between sustainability and nutritional treatment. This aligns with the findings obtained by Asioli and Grasso (2021). This contrasts certain research that emphasise consumer preferences for immediate and tangible benefits, such as nutrition, above longer-term environmental or social considerations (Barbu, Catană, Deselnicu, Cioca, & Ioanid, 2022; Kim & Lee, 2023). Potential misinterpretations of sustainability and nutrition information may arise from overlapping nature

of these concepts, information overload from marketing claims related to both sustainability and nutrition (Cook et al., 2023; Hsu, Wang, Ho, & Chen, 2020), unfamiliarity with the upcycled concept (Yang et al., 2021), and uncertainty surrounding the nutritional value of upcycled foods (Thorsen et al., 2022). In certain instances, tasting perception might play a stronger role in purchase decisions, potentially overshadowing sustainability or nutritional considerations (Hansen & Melbye, 2020).

Third, a positive relationship (for sample HN) has been identified between nutrition information and both repurchase intent and sensory perception, as evidenced by several studies (Banovic, Aschemann-Witzel, & Deliza, 2021; Banović, Grunert, Barreira, & Fontes, 2009; Jo & Lusk, 2018; Werle, Trendel, & Ardito, 2013), whereas other studies present contradictory findings (Huang & Wu, 2016; Raghunathan, Naylor, & Hoyer, 2006). Consumers frequently possess the perception that "healthy equals less tasty" (Raghunathan et al., 2006), stemming from a general utilitarian approach to consumption, wherein individuals identify food with biological necessity and assess it from nutritional and health perspective (Werle et al., 2013). The positive effect can be understood through the healthy = tasty intuition; specifically, when a neutral food described as healthy is considered tastier, more pleasurable and of better quality than when it is described as unhealthy (Rozin, Fischler, Imada, Sarubin, & Wrzesniewski, 1999; Werle et al., 2013). Similarly, sustainability information can lead to higher repurchase intent, although the effects differ according to consumer group and product category (Li & Kallas, 2021). In contradiction to the findings from Grunert, Seo, Fang, Hogan, and Nayga Jr (2024), we have found that the effect of information on repurchase intent was influenced by sensory perception. Our findings, similar to those of Cela et al. (2024), highlight the potential of fortified biscuits. The study indicated a positive correlation between purchase intention and the importance of "health value" among circular economy consumers. This suggests that fortified

biscuits made with functional ingredients from agri-food by-products could encourage healthier eating habits.

Fourth, we also found a negative effect (for sample NL) of sustainability information on sensory perception and on repurchase intent. Previous research has indicated negative sensory expectations concerning more sustainable food alternatives, primarily focussing on substitute products (Michel, Knaapila, Hartmann, & Siegrist, 2021), where consumers tend to compare these products to established benchmarks. The negative effect of sustainability information has been documented and characterised as "compensatory beliefs" (Chernev & Blair, 2021), suggesting that consumers may develop beliefs indicating that enhanced sustainability comes at the cost of other relevant product attributes. In our study, consumers may believe that biscuits fortified with BSG are inferior to those made with traditional ingredients, and this expectation may influence their sensory perception.

It should be mentioned that the SO-PLS and PLS are here used for ranking data although they were originally developed for continuous data. The results correspond very well to the results in other sections. No theoretical work exists for this extension, but there are empirical results on the differences between using the closely related PCA on rank and continuous data (Næs, Monteleone, Segtnan, & Hersleth, 2013; Næs, Varela, & Berget, 2018) which may indicate that the differences are not necessarily so large. We therefore decided to keep the results in here.

Outliers are defined as data points that fall below Q1 - 1.5 * IQR or exceed Q3 + 1.5 * IQR. The Interquartile Range (IQR) is the range between the first and third quartiles (Q3 - Q1) and represents the middle 50% of the data. In our study, outliers are observed in purchase intent within the sustainability treatment. We systematically removed the outliers from each sample (NN, NL, HL, HN) in the sustainability treatment to evaluate their impact and analysed any resulting changes in the outcomes. If a consumer has an outlying value for one of the samples,

all the four values associated with that consumer are removed for testing changes in the outcomes. The findings suggest that the removal of outliers did not lead to any significant change of conclusions. Additionally, purchase intent exerted a negligible effect on the variability of repurchase intent. As a result, we chose to keep the data without removing outliers in the PLS regression of informed degree of liking onto repurchase intent.

This study focused on young, highly educated consumers for several reasons. Younger demographic consumers demonstrate a preference for eco-friendly products (Jain & Kaur, 2006; Pham, Nguyen, Phan, & Nguyen, 2019). Moreover, a positive association exists between higher education levels and healthier dietary choices (Knudsen et al., 2014; Moe et al., 2022). However, a limitation of the study is that our consumer sample is not representative of the country's overall population, meaning that the findings cannot be generalized to the entire country.

5. CONCLUSIONS, IMPLICATIONS AND FUTURE OUTLOOK

In conclusion, our findings suggest that consumer purchase intent and degree of liking for upcycled foods are contingent upon the availability of information regarding the nutritional and/or sustainability benefits of these products. Sensory perception significantly influences the impact of information on consumer purchase intent as well as degree of liking. Our findings provide useful insights into consumer preference that can inform the development of upcycled foods and facilitate effective communication of the benefits of upcycled foods to the public, thereby enhancing their economic viability.

Implications and recommendations can be provided. First, producers should develop the upcycled biscuits according to consumer sensory expectations. Second, food companies ought to convey the sustainability and nutritional benefits of upcycled foods to consumers through product labelling. Third, it is crucial to prioritise consumer education by disseminating information via various communication channels, including websites, social media, packaging, and in-store displays. Last, policy makers should develop educational campaigns to raise consumer awareness about sustainability and nutrition benefits of upcycled foods, work with food producers, retailers, and consumer organisations to provide educational resources, and incorporate sustainability and food systems education into school curricula to promote responsible consumption from a young age.

Several suggestions for future research can be identified. First, similar studies should be conducted using other upcycled foods and conducted in other countries. Second, future studies should examine consumers' willingness to pay for upcycled foods using non-hypothetical experiments (e.g. real choice experiments, experimental auctions, etc.) in real shopping scenarios (e.g., shops) to obtain more realistic results. Third, future research should examine the impact of other benefits information of upcycled foods (e.g. food safety, price sensitivity, ethical consumption). Last, more studies should investigate consumer preferences for sustainability and nutritional information in the long term by conducting longitudinal studies.

HUMAN ETHICS STATEMENT

The study was covered by a general approval from the Ethics Review Board at the University (Ref. No. ERB-01/2022). Participants were instructed to read an information sheet and sign a consent form. Participants gave voluntary consent and were assured that their responses would remain confidential, they were informed they could withdraw at any point without any consequences. Participants received a monetary compensation (50,000 VND) for their participation.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Quoc Cuong Nguyen: Conceptualization, Data curation, Formal analysis, Methodology, Writing - Original Draft, Writing - Review & Editing. **Tormod Næs**: Conceptualization, Methodology, Writing - Review & Editing. **Van Viet Man Le**: Project administration. **Daniele Asioli**: Writing – Review & Editing. **Paula Varela:** Conceptualization, Methodology, Writing - Review & Editing.

ACKNOWLEDGEMENTS

Author Quoc Cuong Nguyen was funded by the Postdoctoral Scholarship Programme of Vingroup Innovation Foundation (VINIF), code VINIF.2023.STS.46. We acknowledge Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for supporting this study.

Authors Paula Varela and Tormod Næs thank for funding to the Research Council of Norway and Norwegian Fund for Research Fees for Agricultural Products (FFL) through the project "InnoSense" (project number 354153).

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TABLE CAPTION

FIGURE CAPTION

Conflict of Interest and Authorship Conformation Form

☑ All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

☑ This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

☑ The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript

Credit Author Statement

Quoc Cuong Nguyen: Conceptualization, Data curation, Formal analysis, Methodology, Writing - Original Draft, Writing - Review & Editing.

Tormod Næs: Conceptualization, Methodology, Writing - Review & Editing.

Van Viet Man Le: Project administration.

Daniele Asioli: Writing – Review & Editing.

Paula Varela: Conceptualization, Methodology, Writing - Review & Editing.

Human ethics statement

- The study was covered by general approval from the Ethics Review Board at the University of Social Sciences and Humanities, VNUHCM (USSH, VNUHCM) ERB-02/2022
- The paper is designed and written in accordance with the guidelines laid out in the Declaration of Helsinki (revised 2008).
- Participants were instructed to read an information sheet and sign a consent form.
- Participants gave voluntary consent and were assured that their responses would remain confidential, they were informed they could withdraw at any point without any consequences.
- Participants received a monetary compensation for their participation.

Highlights

- This study investigates impact of information provision on consumers' behaviours for biscuits with upcycled ingredients.
- Two types of information, including sustainability and healthiness, were under investigation.
- When consumers were informed about nutritional and environmental benefits, they exhibited a higher purchase intent.
- Sustainability or nutrition information provision changed repurchase intent, with the effect driven by taste perception.
- The study offers new insights on Vietnamese consumer preferences for upcycled foods.