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Understanding sensory and emotional drivers of plant-based fish analogues acceptance in children and adults

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ABSTRACT

Children play a crucial role in the transition to a sustainable diet, but research on their perception of plant-based alternatives remains scarce. This study aimed to investigate the sensory drivers of liking and consumer perceptions of plant-based breaded fish among children (9-11 years; n=98) and adults (n=104). Participants evaluated five plant-based analogues and two animal-based samples for liking (9-point scale), sensory properties using Check-All-That-Apply method, and emotional responses. Despite higher liking for animal-based samples (Adults: 6.5 – 7.3; Children: 7.1 – 7.5), analogue samples were accepted by both age groups (Adults: 4.9 – 5.9; Children: 5.1 – 6.1). Age-related differences were observed: adults preferred the wheat protein-based sample, while children preferred the rice flake-based one. Plant-based samples were associated with sensory attributes, such as unappealing appearance, off-flavour, legume and spicy odour and flavour, bitter taste and pasty and gummy filling, which negatively impacted liking, particularly among children. Emotional responses influenced acceptance in both age groups, with positive emotions linked to animal-based products and negative emotions to plant-based ones. However, the wheat protein sample evoked curiosity and surprise in adults, contributing to its liking. In contrast, children's preference for the rice-based sample was driven by familiarity and sensory similarity to traditional products, with emotions providing no additional insights beyond liking. These findings underscore the importance of age-specific preferences and emotional responses in promoting plant-based foods, with the potential for targeted products to engage both children and adults in sustainable eating. No effect of food neophobia was found on acceptance in either group.

1. Introduction

Current demographic, consumption, climate, and technological shifts are reshaping the agri-food sector, which must adapt to challenges such as population growth, urbanization, policy changes, and environmental degradation (Borsellino et al., 2020). Animal-based food production raises key concerns related to environmental impact, animal welfare, and human health (Clay et al., 2020; Falkeisen et al., 2022). Addressing these issues requires coordinated efforts across the food chain (European Commission, 2020). The food industry is called to develop sustainable alternatives—e.g., products based on legumes, algae, insects, cultured meats, and plant-based analogues—while consumers are encouraged to adopt more sustainable diets (Aschemann-Witzel & Schulze, 2023). Despite limited awareness of sustainability and the impacts of animal-based diets, interest in alternatives is growing, driven by health, ethical, and environmental concerns (Falkeisen et al., 2022; Hartmann & Siegrist, 2017). As a result, consumption habits are shifting, with more consumers incorporating plant-based products or combining them with animal proteins (Taufik et al., 2019). This trend has led to increased production and market availability of plant-based foods, particularly dairy and meat alternatives. On the contrary, according to the Good Food Institute Report (2021), plant-based fish and seafood alternatives currently make up less than 1% of the plant-based food categories.

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) recommend fish consumption for its nutritional value (FAO/WHO, 2011), but growing aquaculture may harm ecosystems and spread diseases (Marwaha et al., 2020). Water pollution also exposes consumers to toxins like mercury in fish such as tuna (Bosch et al., 2016). These issues, alongside dietary shifts,

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are driving interest in plant-based fish alternatives, a market expected to grow from $183.95 million in 2023 to $2.19 billion by 2033 (https://www.researchandmarkets.com/report/vegan-food#product–related-products).

While adults' views on meat and dairy alternatives have been studied, research on fish analogues is scarce, especially among children (Appiani et al., 2023). Children are important for shaping sustainable diets as future consumers (Ares et al., 2024; Hosany et al., 2022) and influence family food choices (Pater et al., 2022). Between ages 7 and 11, they develop reasoning and negotiation skills (Pater et al., 2022), and early food preferences often persist into adulthood. Since children are recognized as key agents of change for a sustainable future by the United Nations, as outlined in the Sustainable Development Education Plan and the Sustainable Development Goals (United Nations, Department of Economic and Social Affairs, 2015; UNESCO, 2018), understanding their perceptions of plant-based food products is crucial to foster a more sustainable future (Ares et al., 2024). However, sensory characteristics can limit children's acceptance of plant-based foods (Laureati, 2022). These products often have a bitter taste (Appiani et al., 2023), which is generally disliked by children due to their natural preference for sweet and salty flavors (Mennella & Bobowski, 2015). In terms of texture, children favor foods that are easy to chew and avoid slimy, grainy, or hard textures (Chow et al., 2024). While perceptual barriers have been explored in adults, little is known about how young consumers perceive plant-based alternatives (Appiani et al., 2023). To date, only one study compared cow's milk with plant-based milk in children and adolescents, showing a preference for cow's milk, with younger children (8–12 years) being less critical than older ones (Palacios et al., 2010). Instead, Pater et al. (2022) investigated children's attitudes toward plant-based meat analogues without including sensory testing, yet found that children are generally open to trying such products and may be less demanding about sensory similarity to traditional versions than adults. Notably, no studies have focused on fish analogues in the pediatric population (Appiani et al., 2023). Given the distinct dietary needs and expectations of children, understanding their perception of plant-based products is essential to foster their acceptance among a broader range of consumers.

However, other factors beyond sensory attributes drive product acceptance and identifying them is a current key challenge (Kergoat et al., 2010). Multidisciplinary and multidimensional approaches are necessary to better understand the determinants of food appreciation (Jaeger et al., 2023). A comprehensive understanding of consumer experience requires gathering diverse information, such as emotions elicited by products and context appropriateness (Spinelli et al., 2019; Spinelli & Monteleone, 2018).

Emotions are increasingly studied in food product development due to their significant influence on eating and drinking behaviors (Spinelli & Monteleone, 2018). Emotions, for example, strongly influence food choices and help differentiate products more than liking alone (Jaeger et al., 2018; Schouteten et al., 2018; Sick et al., 2020; Spinelli et al., 2019; Spinelli & Monteleone, 2018). In adults, emotional responses affect acceptance of plant-based alternatives (Cardello et al., 2022; Onwezen et al., 2022). In children, emotional profiling may support healthier product development (Jiang et al., 2014).

Additionally, personality traits and attitudes, especially food neophobia, affect food choices in both adults (Keller & Siegrist, 2015) and children (Laureati, Bergamaschi, & Pagliarini, 2015). Indeed, one of the major challenges to encouraging healthy and sustainable eating habits in children is the prevalence of food neophobia, the reluctance to try new or unfamiliar foods (Laureati, Bergamaschi, & Pagliarini, 2015). By functioning as a defense against potentially toxic foods, neophobic individuals are less likely to consume foods with sour, bitter, or astringent qualities (Laureati et al., 2018), risking reducing the variety and the quality of the diet (Knaapila et al., 2015).

Including such variables in research is vital to fully understand food acceptance and to guide effective strategies for encouraging healthier and more sustainable eating habits.

In the light of the above, the main objective of this study was to examine the acceptability and factors influencing perceptions of plant-based fish samples among both adults and children aged 9 to 11 years. Breaded fish samples were chosen as experimental product being a widely available fish analogue (Leonard & Fang, 2023; Lankatillake et al., 2023). This product, being generally served in school lunch programs and liked by children (Donadini et al., 2013; Højer & Frøst, 2022; Laureati et al., 2016), may therefore present a more familiar and promising alternative to other plant-based options. Food neophobia, and emotional responses have also been investigated to take a more comprehensive approach and explore how different sensory characteristics might influence consumers' acceptability. Obtaining a complete characterization of these foods, encompassing both the hedonic, sensory and emotional dimensions, can be useful for developing alternative plant-based fish products that meet the expectations of different target consumers, thus promoting their consumption on a larger scale.

2. Materials and methods

2.1. Recruitment of participants

One-hundred-four adults (age range: 18 and 60 years, mean age ± SD: 27.7 ± 8.9 y.o., 52% women) and 98 children (age range: 9 and 11 years, mean age ± SD: 9.9 ± 0.8 years, 57% girls) with no known food allergies were involved in the study. The number of participants involved in the study, both children and adults, meets the requirements for collecting hedonic data according to ISO 11136:2014 (2014), is appropriate for performing sensory characterization using the Check-All-That-Apply method (Varela & Ares, 2012) and is consistent with previous studies that investigated the emotional profile of products (e.g., Sick et al., 2020; Spinelli et al., 2015). Participants were recruited form the Milan metropolitan area by the professional agency Chelab S.r.l, Mérieux NutriSciences Company, which selected candidates from their internal database. The agency conducted the recruitment with the aim of balancing key sociodemographic variables in both adult and child groups. Specifically, only children aged 9 to 11 years were selected from the database, as this age group is considered cognitively capable of performing the sensory tasks reliably, while younger age groups were excluded for this reason. Additionally, the sample was designed to be representative of school-aged children in Milan who regularly use school canteen services. Moreover, the selection included only participants who consumed regularly breaded fish fillets or sticks (at least 1 per month) and adhered to either an omnivorous diet (which incorporates a wide range of foods from both animal and plant sources) or a flexitarian diet (primarily vegetarian but occasionally including meat and/or fish) (Derbyshire, 2017). The research was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013), and the protocol was approved by the Institutional Ethics Committee (n. 95/23) of the University of Milan. Adult participants and children's caregivers received written information about the study beforehand and provided written voluntary consent to participate or to allow the child participation. Before evaluation, children were informed about the test and gave verbal consent. All participants were assured of the confidentiality of their responses and informed of their right to withdraw from the study at any time.

2.2. Selection of plant- and animal-based products

The final set of samples evaluated in the present study was selected stepwise. In brief, an inventory of the Italian online marketplace, focusing on plant-based products labeled as fish analogues was performed. This included major Northern Italian retailers (such as Esselunga S.p.a., Bennet S.p.a., Carrefour S.p.a., Conad S.c., Coop Italia S.c., and others) and specialized online shops in vegetarian and vegan products (NaturaSì ShopSì, Macrolibrarsi Golden Books S.r.l.,

Greenweez Italia S.r.l. società benefit, iVegan S.r.l., Cuore Vegano, Bio salute di Franchetto Fabio, Vegano Bio Chiccoteca S.r.l). A database of 50 fish analogues was created, featuring products such as plant-based breaded fish, canned tuna, sliced salmon, fish fillets, spreads, caviar, shrimps, and fish salads. The best-represented brands and market availability products were plant-based canned tuna (Appiani et al., 2025) and breaded fish.

A pilot test with eight sensory expert judges (62.5% women) was conducted to taste and select breaded fish samples from the inventory. As a result, seven commercial breaded fish fillets or sticks (five plant-based and two animal-based) were chosen. The selection criteria included commercially available samples and diversity in plant-based ingredients (wheat, rice or a blend) and sensory properties. Plant-based products were purchased from supermarkets or online vegan shops. The animal-based products (breaded fillets and sticks) belonged to the market leader company in European frozen food and one of the largest in the world (https://www.worldbenchmarkingalliance.org). The samples included in the present study and relevant ingredients are listed in Table 1. Each sample was cooked at 200°C in an air fryer following the packaging instructions or data obtained in a preliminary test for the time-cooking.

2.3. Experimental procedure

Participants were asked not to smoke (only for adults), eat, or drink anything, except water, at least one hour before the tasting sessions. For both children and adults, the evaluations were performed in individual sensory booths under white light and lasted approximately 1 hour. Each product was evaluated by participants for overall liking, sensory characteristics through the Check-All-That-Apply questionnaire, and emotional responses during consumption. Additionally, they completed the food neophobia questionnaire.

Samples were portioned out into servings of approximately 20 g, allowing one bite for each sample for each procedure, and were monadically presented in plastic carriers labeled with a random three-digit number to the participants, following a completely randomized design. Participants also received a glass of distilled water to cleanse their palates after each sample.

Table 1
Characteristics of the samples included in the study.

Type of product	Label	Description	Ingredients	Nutrients per 100g	Brand	Cooking conditions
Plant-based samples	*WHEAT_Fillet* 	Plant-based fillet (rehydrated textured wheat proteins as main protein source)	Rehydrated textured wheat proteins 44.7% (water, wheat proteins 11.3%, wheat flour 3.3%), water, breadcrumbs (wheat flour, salt, yeast, rapeseed oil, spice extract (paprika)), vegetable oils (rapeseed, sunflower) in varying proportions, wheat flour, pea proteins 2.7%, alcohol vinegar, stabilizer: methylcellulose, salt, natural flavors, onion powder, dehydrated dill, white pepper, soy sauce (soy, wheat, salt)	Energy: 945kJ/226 Kcal Fat: 12.4 g Of which saturated: 0.9 g Carbohydrates: 14.2 g Of which sugar: 1.3 g Protein: 13.2 g Fibre: 2.5 g Salt: 1.0 g	Garden Gourmet (Nestlè S.p.A)	T: 200°C t: 7 min
	RICE_Fillet 	Plant-based fillet (rice proteins as main protein source)	Rice protein (water, rice flour) 46%, water, sunflower oil, breadcrumbs (wheat flour, salt, yeast, spices), wheat starch, lemon juice powder, salt, lemon oil, spices, fava bean protein 1.1%, pea protein 0.6%, emulsifier: methylcellulose, potato starch, flavorings, brandy vinegar	Energy: 864 kJ/207 Kcal Fat: 10.0 g Of which saturated: 1.1 g Carbohydrates: 21.8 g Of which sugar: 0.3 g Protein: 5.2 g Fibre: 4.4 g Salt: 1.0 g	Unfished (Prefera Foods S.A.)	T: 200°C t: 8 min
	RICE_Stick 	Plant-based sticks (rice proteins as main protein source)	Rice protein (water, rice flour) 46%, water, sunflower oil, breadcrumbs (wheat flour, salt, yeast, spices), wheat starch, lemon juice powder, salt, lemon oil, spices, fava bean protein 1.1%, pea protein 0.6%, emulsifier: methylcellulose, potato starch, flavorings, brandy vinegar	Energy: 864 kJ/207 Kcal Fat: 10.0 g Of which saturated: 1.1 g Carbohydrates: 21.8 g Of which sugar: 0.3 g Protein: 5.2 g Fibre: 4.4 g Salt: 1.0 g	Unfished (Prefera Foods S.A.)	T: 200°C t: 7 min
	RICE_Fl37_Stick 	Plant-based sticks (rehydrated rice flakes 37% as main protein source)	Rehydrated rice flakes 37% (water, rice flour), wheat flour, sunflower seed oil, wheat protein, water, linseed oil, starch (potato, pea), flavoring, salt, pea fiber, yeast extract, yeast, antioxidant: sodium ascorbate, paprika, caramelized sugar.	Energy: 1125 kJ/268 Kcal Fat: 10.0 g Of which saturated: 1.2 g Carbohydrates: 33.0 g Of which sugar: 2.9 g Protein: 10 g Fibre: 3 g Omega-3 fatty acids: 1.2 g Salt: 1.1 g	Valsoia S.p.a.	T: 200°C t: 7 min
	RICE_Fl40_Stick 	Plant-based sticks (rehydrated rice flakes 40% as main protein source)	Rehydrated rice flakes 40%, wheat flour, water, rapeseed vegetable oil, wheat gluten, potato starch, natural flavors, salt, wheat fiber, yeast, spices	Energy: 1073kJ/257 Kcal Fat: 13.0 g Of which saturated: 1.0 g Carbohydrates: 26 g Of which sugar: 1.7 g Protein: 7.9 g Fibre: 2.0 g Salt: 0.9 g	Findus (Nomad Food Ltd.)	T: 200°C t: 7 min
Animal-based samples	*COD_FILLET* 	Cod fillet	Alaska or Pacific cod fillets 51%, wheat flour, water, rapeseed oil, salt, wheat starch, mustard, yeast, dextrose, sugar, paprika, turmeric	Energy: 863kJ/205 Kcal Fat: 7.5 g Of which saturated: 0.6 g Carbohydrates: 23 g Of which sugar: 0.7 g Protein: 11 g Fibre: 0.9 g Salt: 0.95 g	Findus (Nomad Food Ltd.)	T: 200°C t: 15 min
	COD_STICK 	Cod sticks	Cod fillet 60%, wheat flour, rapeseed oil, water, salt, natural yeast, paprika, potato starch, turmeric	Energy: 892kJ/213 Kcal Fat: 8.3 g Of which saturated: 0.7 g Carbohydrates: 21 g Of which sugar: <0.5 g Protein: 13 g Salt: 0.86 g Selenium: 21 µg	Findus (Nomad Food Ltd.)	T: 200°C t: 7 min

Data acquisition was conducted using Fizz v2.31 software (Biosystèmes, Couternon, France).

2.3.1. Overall liking assessment

Participants (both adults and children) were instructed to give a bite to the sample and then express their overall liking. For adults, a 10 cm linear scale anchored by the extremes "*Extremely disliked*" (rated 0) and "*Extremely liked*" (rated 100) was used (Lawless & Heymann, 2010). In contrast, children rated their liking on nine-point hedonic scale anchored to the extremes "*Extremely disliked*" (rated 1) and "*Extremely liked*" (rated 9), with labels at every point (Lawless & Heymann, 2010). Although hedonic facial scales are a more common tool for evaluating children's liking (e.g., Laureati et al., 2016), several studies have shown that children from preteen age onwards can effectively use such hedonic scale (Laureati, Pagliarini, et al., 2015; Velázquez et al., 2022). Interpolation was performed on the 10 cm linear scale used by adults to compare liking with children's scores.

2.3.2. Sensory product characterization

The Check-all-that-apply (CATA) questionnaire was used to obtain a rapid sensory description of the samples. CATA attributes were generated during a pilot test, in which 8 expert judges (62.5% women) were involved (please refer to **Supplementary material S1** for a detailed description of the terms generation phase). The judges involved have at least five years of experience in sensory evaluation and are kept in continuous training across a wide range of food and beverage categories. A final list of 26 descriptors (listed in full in the result section) was retained for both adults and children. The number of attributes chosen aligns with previous research, which recommends using a word list ranging from 10 to 40 to prevent response dilution (Jaeger et al., 2015), and is comparable with the number of terms used in research with children (e.g., Rocha et al., 2021; Schouteten et al., 2017). The list was checked for clarity and appropriateness with a group of 20 children of the same age not involved in the main experiment. Moreover, examples of certain descriptors were provided to young participants by the researchers prior to the evaluation to enhance comprehension (e.g., associating a chewy texture with a chewy candy and a fibrous texture with meat). After the overall liking assessment, participants were asked to look at and smell the sample and to select any descriptor they found useful to describe its appearance and aroma. Then, they were asked to taste the sample and to select the descriptors for taste, flavour, texture, mouthfeel, and aftertaste. The position of attributes was randomized using the "to assessor" list order allocation scheme, meaning that attributes were listed in the same order within subject and in a different order between subjects (Meyners & Castura, 2016).

2.3.3. Emotional profile assessment

Emotions elicited by foods were measured both in adults and children. For adults, a product category-specific questionnaire was developed applying the EmoSemio approach (Spinelli et al., 2015; Spinelli et al., 2019; Spinelli & Monteleone, 2023). A detailed description of the procedure is reported in the **Supplementary materials S2**. In brief, the procedure involved two phases: i) individual interviews were conducted with a small group of subjects (n = 20) using a modified version of the Repertory Grid Method; ii) a questionnaire was created based on the semiotic analysis of these interviews. The questionnaire comprised 21 sentences (15 emotions and 6 Functional/Emotional concepts) that were used to quantitatively measure the emotional responses to the products of interest, by answering for each sample the question: *"How does it make you feel?"*. The participants were asked to indicate, using a 7-point scale ranging from 1 = *Strongly disagree* to 7 = *Strongly agree*, how much the sentence was suited to describe their experience of the product.

For children the emoji-based self-report questionnaire for preadolescents developed and validated for Italian children by Sick et al., 2022 was used. In details, 17 emoji pairs were evaluated on a categorical 5-point scale ranging from 1 = *Does not fit at all* to 5 = *Fits very well*. Each child was asked to taste one sample at a time and answer the Emoji Pair Rating Scale: *"How does this food make you feel? Look at the emoji pairs. For each group, indicate how much the emoji (one of the two or both) match the feeling you get from tasting the food sample"*.

The presentation order of sentences or emoji was balanced within questions across participants.

After completing the evaluation of all samples, both adult and child participants were asked to identify which samples they believed were animal-based.

2.3.4. Food neophobia assessment

Food neophobia was measured in both adults and children using the validated Italian versions. For adults, Food Neophobia Scale (FNS, validated in Italian by Laureati et al., 2018) was used. The questionnaire comprises 10 items: 5 related to neophilic attitudes and 5 to neophobic attitudes. Participants rated their level of agreement with each item on a 7-point scale, from 1 ("strongly disagree") to 7 ("strongly agree"). Children's food neophobia was assessed using the Italian Children Food Neophobia Scale (ICFNS, Laureati, Bergamaschi, & Pagliarini, 2015). They indicated their level of agreement with eight statements on a 5-point facial expression scale, ranging from "very false for me" to "very true for me". Scores for the neophilic items were reversed, and the responses to all the items were summed to obtain a food neophobia score ranging from 10 to 70 for adults and 8 to 40 for children, with higher scores indicating greater food neophobia.

2.3.5. Parental questionnaire

In order to investigate family and children seafood and plant-based foods consumption, parents were asked to complete a questionnaire. The frequency of consumption of fish and plant-based meat and analogues were investigated through the following questions: "How many times does your child eat fish at home?" and "How many times your family consume meat/fish analogues (e.g., plant-based burger or nuggets). The answers ranged from 1 "never" to 5 "every day". A question regarding the methods of fish consumption was also included: "In what form does your son/daughter most often consume fish?" (answers: "as ingredient in the first course", "pan-cooked with sauce", "au gratin baked", "breaded and fried (e.g., fried fish fingers)", "grilled", "fish burger"). For this last question, parents were allowed to provide up to two responses.

2.4. Data analysis

The XLSTAT (version, Addinsoft, Boston, MA, USA) statistical software packages was used for the data analysis. Effects showing a p-value of 0.05 or lower were considered significant, while a p-value ranged between 0.10 and 0.05 was considered as a trend.

Data on the identification of animal-based samples were compared between children and adults using the z-test.

The liking scores for each sample, provided by both children and adults, were calculated and checked for normality. According to the Shapiro-Wilk test, the distribution deviated from the normal distribution for all samples. However, inspection of the Q-Q plots suggested a normal pattern, and thereby all data were handled as normally distributed (Næs, Brockhoff, & Tomic, 2010).

Liking data were analyzed by meas of the Generalized Linear Model (GLM) procedure considering samples (COD_Fillet; COD_Stick; WHEAT_Fillet; RICE_Stick; RICE_Fillet; RICE_Fl37_Stick and RICE_Fl40_Stick), gender (women/girl and men/boys) and age groups (children and adults) and their second-order interactions as factors. Least-square means (LS-means) and relevant standard error of the mean (SEM) were computed for each factor. When the GLM showed a significant effect ($p \leq 0.05$), Fisher's Least Significant Difference test was used for post-hoc comparison of means.

The CATA data were subjected to Cochran's Q test to detect differences in participants' perception of the evaluated samples (Meyners &

Castura, 2016). Correspondence analysis was performed for each age group (children and adults) on the contingency table (samples × CATA terms) to get a bidimensional representation of the samples and the relationship between samples and terms from the CATA question. Chi-square statistic was applied to test the independence between samples and sensory attributes (significance level set at 5%). Penalty analysis was conducted to determine which CATA sensory attributes were positively or negatively related with liking scores.

Multiple Factor Analysis (MFA) was computed to explore the relationship between the emotions elicited by the products and sensory properties within the two age groups (Escofier & Pagès, 1994; Pagès & Husson, 2013). Each matrix included CATA attributes and emotional attributes. For adults only, the matrix also included functional-emotional concepts (e.g. "I associate it to an industrial/artificial product", "It gives me a sense of novelty"). Liking mean score and the categorical variable "type of product" (analogue or traditional) were included as supplementary variables. Only attributes that significantly discriminated between the samples, as determined by Cochran's Q test for CATA attributes ($p \leq 0.05$).

The internal consistency of the Food Neophobia questionnaire was assessed by Cronbach's alpha coefficient (adults: $\alpha = 0.86$; children: $\alpha = 0.81$). Both adult and younger participants were divided into High and Low Food Neophobia respondents splitting the individual scores on the median (Children = 19; Adults = 18). The association between Food Neophobia and sample liking was explored separately for the two groups of participants (adults and children) through GLM procedure considering samples (COD_Fillet; COD_Stick; WHEAT_Fillet; RICE_Stick; RICE_Fillet; RICE_Fl37_Stick and RICE_Fl40_Stick), food neophobia level within the two groups (Low *vs* High), gender (male *vs* female) and their second-order interactions as factors. Least-square means (LS-means) and relevant standard errors (SEM) were computed for each factor. When the GLM showed a significant effect ($p \leq 0.05$), Fisher's Least Significant Difference test was used for post-hoc comparison of means.

3. Results

3.1. Participants' characteristics

Table 2 presents the socio-demographic characteristics, mean scores for food neophobia dimensions for both age groups, and children's consumption of fish- and plant-based foods. Both age groups exhibited a low level of neophobia.

Parents reported that 55% of children consumed fish 2–3 times per week, while 30% consumed fish 2–3 times per month. The families' cooking habits were mainly having fish as a principal meal, particularly breaded and fried (69%) or baked au gratin (45%). Only 27% of families reported using fish as an ingredient in their first course. Additionally, the households involved in the study indicated that they consume plant-based meat or fish 1-2 times a week (41%) or 2-3 times a month (42%). Only 11% of families have never consumed plant-based meat or fish.

Table 2
Socio-demographic characteristics, food neophobia mean scores by age group and food consumption habits.

Variable	Adults	Children
	(n = 104)	(n = 98)
Socio-demographic characteristics		
Gender		
Men/Boys (%)	48	43
Women/Girls (%)	52	57
Age		
Mean (SD)	27.7 ± 8.9	9.9 ± 0.8
Food neophobia level (FNS)		
Mean (SD)	20.7 ± 9.3	19.6 ± 6.4
Low FNS (%)	50%	49%
High FNS (%)	50%	51%
Parental questionnaire		
Frequency of consumption of fish at home (%)		
Every day		0
3-4 times per week		15
2-3 times per week		55
2-3 times per month		30
Never		0
Methods of cooking fish (%)		
As an ingredient in the first course		27
As a principal meal:		
Pan-cooked with sauce		15
Au gratin baked		45
Breaded and fried (e.g., fried fish fingers)		69
Grilled		4
Fish burger		37
Frequency of consumption of plant-based meat and/or fish at home (%)		
Every day		0
3-4 times per week		6
1-2 times per week		41
2-3 times per month		42
Never		11

3.2. Overall liking assessment

The GLM results revealed a significant effect of the main factor *Samples* ($F_{(6,1413)}$=30.4, $p < 0.0001$) on the liking scores. COD_Fillet obtained the highest score (Ls-mean = 7.4 ± 0.2), followed by COD_Stick (Ls-mean = 6.8 ± 0.16). Although the plant-based samples received significantly lower liking scores compared to the traditional ones, they were well accepted, with mean liking scores equal or above the midpoint of the scale (range 5.2 – 5.7). The interaction *Samples*×*Age group* was also significant ($F_{(6,1413)} = 2.8$, $p = 0.01$) (Fig. 1). Specifically, children gave significantly higher liking scores to COD_Stick, RICE_Fl40_Stick and RICE_Fillet compared to adults. Additionally, although the RICE_Fl40_Stick (Ls-mean = 6.1 ± 0.22) received significantly lower liking scores than the traditional products, it was the most preferred plant-based sample among children. For adults, the most liked analogue was the WHEAT_Fillet (Ls-mean = 5.9 ± 0.22), which received liking scores comparable to those of the COD_Stick. No significant *Gender* and *Age groups* effects were found on liking scores, indicating that samples were equally liked by both men/boys and women/girls. Furthermore, in the two GLMs conducted separately for children and adults, only the effect of the main factor *Samples* (Children: $F_{(21,664)}$=14.9, $p < 0.0001$; Adults: $F_{(21,706)}$=19.0, $p < 0.0001$) was significant, while no significant *Gender* and *FNS levels* effects were observed, suggesting that the breaded fish samples were equally liked by participants regardless of their levels of neophobia (low or medium).

3.3. Sensory properties of the samples and their influence on liking

Results from the Cochran's Q-test showed that all the selected sensory terms significantly discriminated the breaded fish samples (p-values < 0.0001) for adults (**Supplementary Table S3a-b**). The same result was confirmed for the children, with the exception of the descriptors "*pasty filling*" and "*moist filling*" that did not discriminate between the samples. Chi-square tests of independence was significant for both adults ($p<0.0001$) and children ($p<0.0001$). The CAs performed on the total frequency participants counts for each attributes resulted in two dimensions accourting for 79.46% of the variance for adults (Fig. 2a) and 84.07% for children (Fig. 2b).

The bi-plots showed that children and adults perceived and

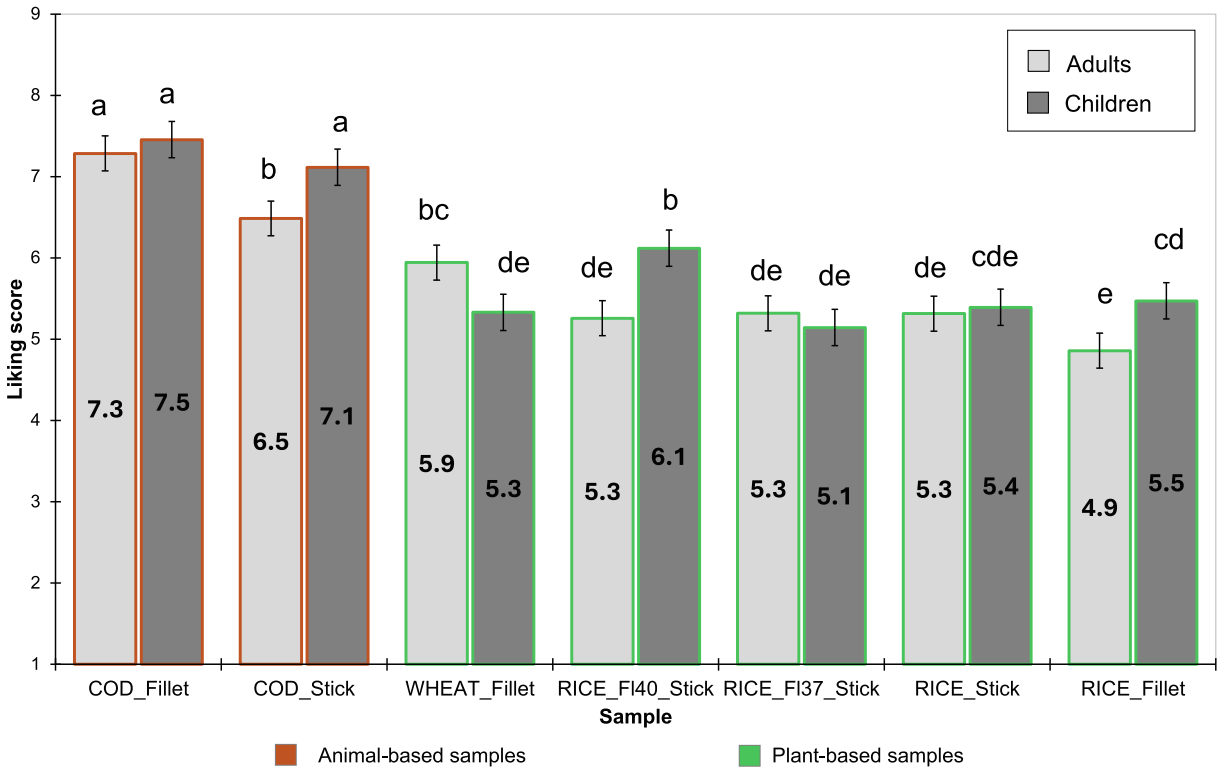

Fig. 1. Liking scores ± standard error of mean provided by age groups (children, adults) for each breaded fish sample. Different letters on histograms indicate significant differences according to Fisher's LSD post-hoc test.

described samples similarly. In both groups, along the first dimension, the samples were discriminated according to their protein source, with the plant-based samples positioned on the right side of Factor 1 and the animal-based samples on the left side. However, differences emerged between children and adults regarding the importance assigned to specific attributes. In children, the attributes most strongly influencing the first dimension were associated with undesirable appearance, legume and spicy odour/flavour, and bitter taste. Conversely, in adults, greater weight was assigned to texture-related attributes, such as chewy and fibrous fillings, soft breading, and spicy or fishy odour/flavour. In particular, the animal-based samples were described as having an appealing appearance and rough breading, a pleasant flavour of fish and breading and, finally, a soft and moist filling. Interestingly, the RICE_Fl40_Stick was the only plant-based sample perceived similarly to animal products by both age groups (Fig. 2b). In particular, children found it closely comparable to COD_Fillet sharing attributes such as a pleasant flavour (associated with fried and breading) and rough and crunchy breading. On the other hand, plant-based samples were associated by both age groups with terms such as Fine breading, Off-flavours, Legume/vegetable and Spicy odour/flavour, Bitterness, and Dried and Pasty filling. In both the adult and children's groups, the WHEAT_Fillet sample was perceived as significantly different from the traditional products, mainly due to its unappealing appearance, along with its soft breading and gummy and fibrous filling (Fig. 2a).

These results are supported by the percentage of individuals (both adults and children) who identified each sample as a traditional (animal-based) product. Concerning the identification of animal-based samples (Table 3), both children and adults accurately recognized COD_Fillet (Adults: 96%; Children: 90%) and COD_Stick (Adults: 98%; Children: 96%). Among adults, the RICE_Fl40_Stick was the sample most identified as traditional (41%). Overall, children were less able than adults to distinguish between plant-based samples (z-scores: 2.1-5.8; all $p < 0.05$).

In order to investigate the influence of the presence and absence of each CATA attribute on liking score, a penalty-lift analysis was performed separately by age group. Fig. 3 **(a–b)** shows the liking mean impact plot, highlighting attributes with a significant impact ($p < 0.05$). The penalty lift analysis results showed that for the adult group, 16 CATA descriptors significantly influenced the mean liking (11 positively, 5 negatively). In contrast, for younger participants, 20 descriptors were found to have a significant effect (12 positively, 8 negatively).

For adults, the top three sensory drivers were "Pleasant flavour" (Mean impact (MI) = + 2.47), "Appealing appearance" (adults: MI = + 1.47) and "Saltiness" (MI = + 1.30), aligning closely with higher liking scores for animal-based products. Conversely, although with a low impact, hedonic penalties were established for "Pasty filling" (MI = - 0.95), "O/F_Legume/vegetable" (MI = - 0.83) and "O/F_Spicy" (MI = - 0.57). Similarly, for children, "Pleasant flavour" (MI = + 2.47) and "Attractive appearance" (MI = + 2.06) held the strongest positive influence on children's liking, followed by "Soft filling" (MI = +1.30). Comparable positive lifts were found for "Easy to chew" (MI = +1.28) and "O/F_Fish" (MI = +1.27). In contrast, significant hedonic penalties were mainly associated with plant-based samples, with the top three penalties being "Off_flavour" (MI = - 3.11), "Unappealing appearance" (MI = - 2.11) and "Bitterness" (MI = - 1.99).

3.4. Differences in product experience within each age groups and linkages between sensory properties, emotions and functional/emotional concepts

3.4.1. Adults

All the emotions and functional-emotional concepts significantly discriminated among products ($p < 0.05$), with the exception of "It makes me feel guilty" which did not significantly discriminate among products (**Supplementary Table S4a**). Fig. 4a shows the representation of breaded-fish samples on the first two dimensions of the MFA, based on all the blocks of variables (sensory and emotional, including also functional/emotional in adults). The first two factors account for the 86.83%

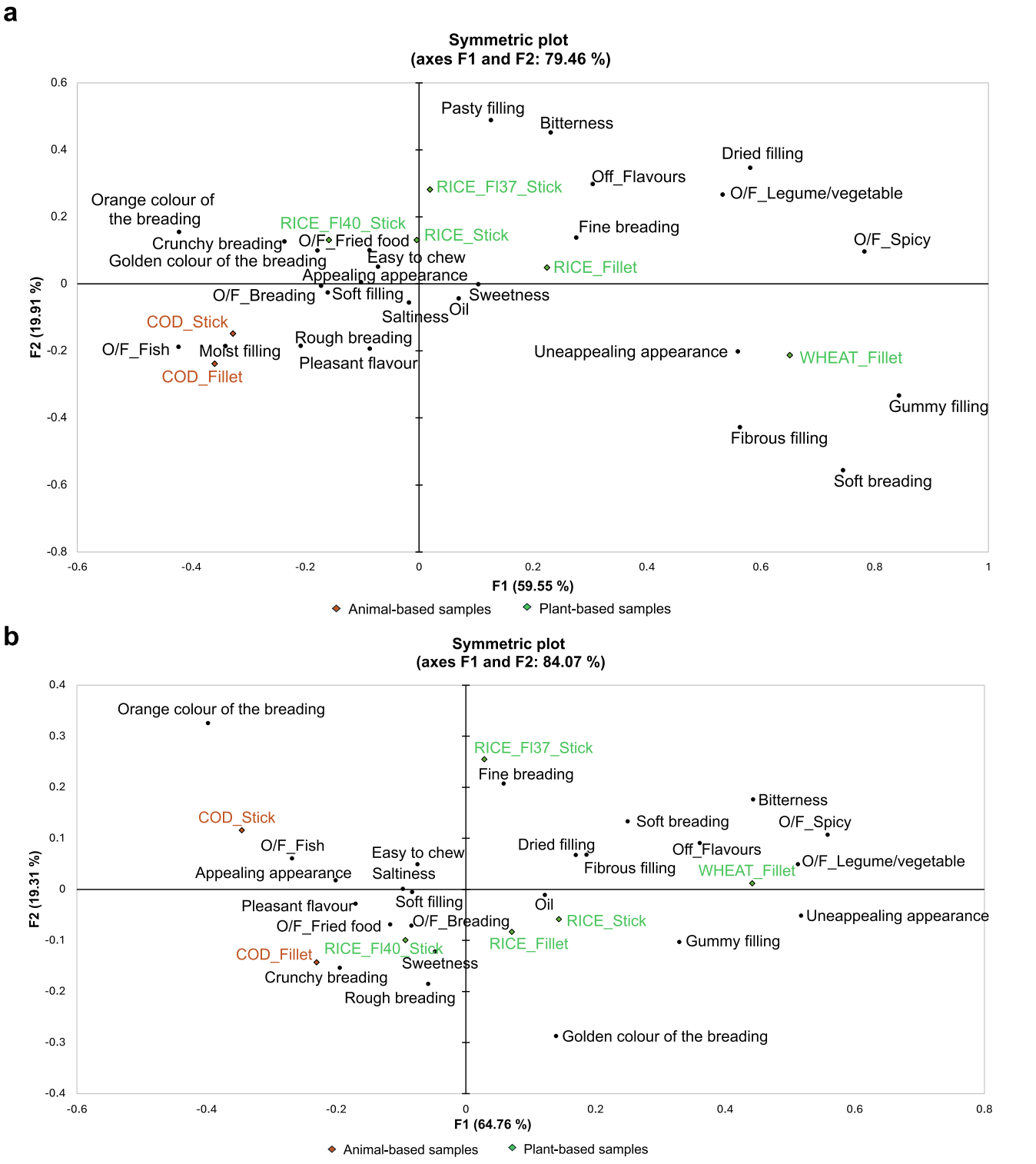

Fig. 2. (a-b). Correspondence analysis symmetric plots for (a) adults and (b) children based on Check-All-That-Apply data of seven breaded fish samples (O = Odour; F = Flavour)

of the variability. The first factor opposed the traditional products (COD_Fillet and COD_Stick) to analogues samples (WHEAT_Fillet, RICE_Fillet, RICE_Fl37_Stick, RICE_Fl40_Stick and RICE_Stick). The second factor opposed the COD_Fillet and WHEAT_Fillet to all other samples.

The sensory properties, emotion and associations were spread in the four quadrants (Fig. 4b): on the right side, liking and positive emotions ("It gratifies me, rewards me", "It makes me happy" and "I associate it to having fun") were associated with positive functional and emotional concept ("I associate it to happy memories of childhood"), and sensory descriptors emerged as drivers of liking. On the contrary, on the left side negative emotions (e.g., "It makes me confused, "It annoys me" and "It disgusts me"), were associated with functional and emotional concepts such as "It seems like a miserable product to me" and "I associate it to an industrial/artificial product, and sensory descriptors such as bitter taste, spicy and legume/vegetable odour/flavour and dried filling. On the

Table 3
Percentage of adults and children identifying samples as fish-based.

Identification of the sample as animal-based	*Adults* (%)	*Children* (%)
COD_Fillet	96	90
COD_Stick	98	96
WHEAT_Fillet	10	44
RICE_Fl40_Stick	41	57
RICE_Stick	28	58
RICE_Fillet	31	62
RICE_Fl37_Stick	36	71

second dimension, emotions associated with surprise and novelty ("It surprise me", "It piques my curiosity, it intrigues me"), positively correlated with sensory descriptors of breading and filling (e.g., "soft breading" and "gummy" and "fibrous filling") and the perception of the product as healthy ("It seems like a healthy product to me"). In contrast, emotions of boredom and indifference ("It bores me" and "It makes me feel indifferent") are associated with "O/F_Fried food" and "pasty filling", while "Easy to chew" and "Crunchy breading" are associated with the idea of a heavy product ("It gives me a sense of heaviness"). The mean values of each emotion and functional/emotional concepts, as reported in **Supplementary Material S4a**, further validated this interpretation of the MFA.

Nevertheless, the association between emotions, functional/emotional concepts and sensory descriptors indicated that adult consumer liking is associated with animal samples (COD_Stick and COD_Fillet) and correlated with positive emotional valence and memory-related emotion and associations and specific flavours (pleasant, fish and breading) and salty taste. On the other hand, , the spicy notes are associated with novelty while legume/vegetable odour and flavour in the plant-based samples, dired filling and fine breading often evoked confusion, while off-flavours and bitterness were linked to feelings of confusion, disgust, and disappointment, along with a sense of neglect. These sensory attributes and emotions contributed to an overall perception of almost all analogues as industrial and lacking in quality.

The correlation between emotions, functional/emotional concepts, and sensory descriptors connections, as shown in the map of the partial clouds (**Supplementary Fig. 1**) revealed that WHEAT_Fillet was the most distinct sample among all the analogues, as its consumption elicits emotions similar to those associated with COD_Fillet and COD_Stick. Moreover, despite the sensory characteristics associated with plant-based samples, WHEAT_Fillet was the ony sample to elicit curiosity in participants and left them pleasantly surprised.

3.4.2. *Children*

All the emotions significantly discriminated among products ($p < 0.05$), with the exception of "Indifferent-calm", "Worried-scared", "Surprised-curious" (**Supplementary Table S4b**). In children, the first two dimensions explained 86.45% of the total variability. Apart from "RICE_Fl40_Stick"sample, the first axis opposed the animal-based samples to the analogue products. Meanwhile, the second axis opposed the the RICE_Fl37_Stick and the COD_Stick to all other samples (Fig. 5a). The representation of the sensory properties and emotions is reported in Fig. 5b. A clear linkage between sensory properties, emotions and liking was found in children. The first dimension was positively correlated with positive emotions (e.g., "calm-quiet", "enthusiastic-festive", "cheerful-amused") as well as with sensory attributes including the odour and flavour of fried food and fish, salty taste, and soft filling. Conversely, it was negatively correlated with negative emotions such as "disgusted-nauseated", "dissatisfied-guily", and "angry-disgusted" and with sensory attributes like bitter taste, off-flavour related to legume and spicy, soft breading and dried filling. The second dimension was mostly related to the sensory characteristics of the samples' appearance and texture orange colour of the breading and easy to chew, and in particular to fine breading, characteristics shared by the RICE_Fl37_Stick and the COD_Stick. They were also the lowest in golden colour of the breading, rough breading and gummy filling.

The association between sensory and emotions terms indicated that

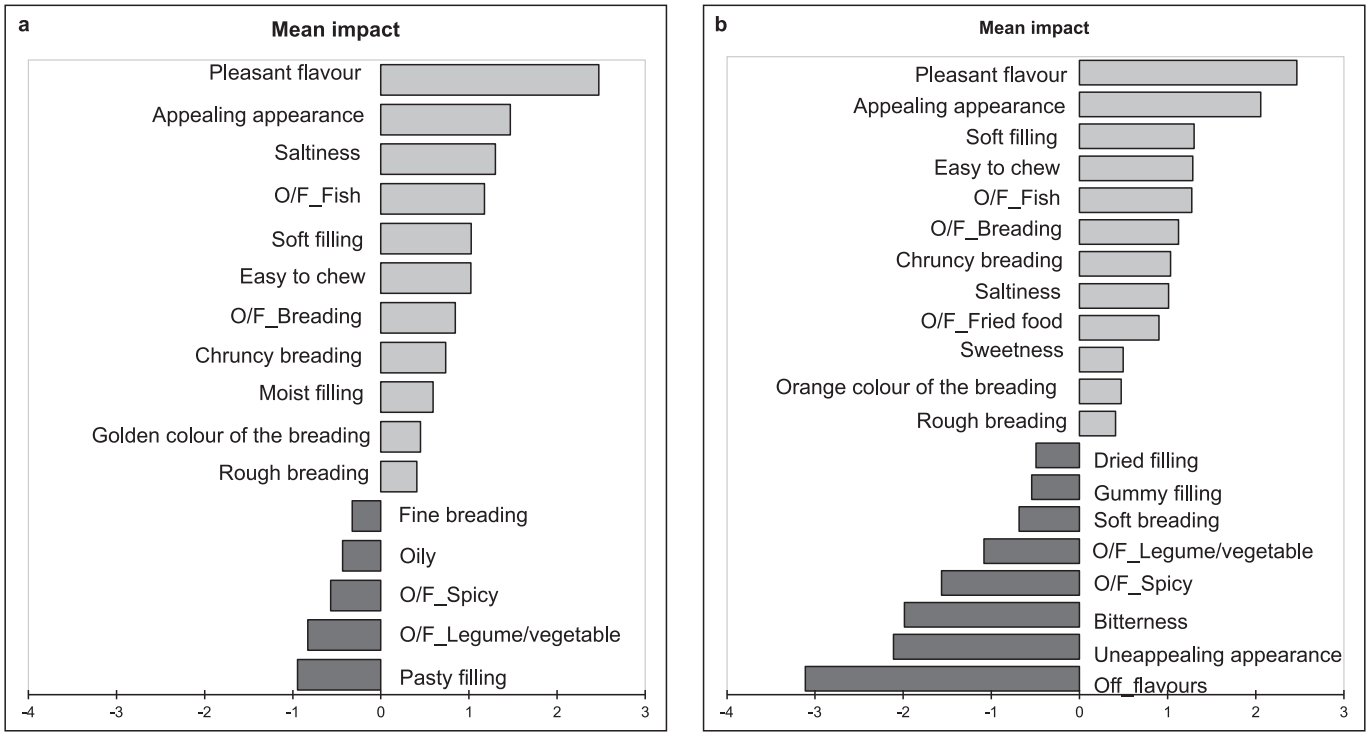

Fig. 3. (a-b). Liking mean impact plot representing the impact of sensory descriptors from the Check-All-That-Apply list in the overall liking of 7 breaded fish samples for (a) Adults (n =104) (a) and (b) Children (n =98). The dark grey bars indicate that the attribute's presence was correlated to decreases in overall liking and the light grey bars indicate that the attribute's presence was correlated to increases in overall liking. Only attributes that resulted in significant increase or decrease in overall liking are reported. (O/F=Odour/flavour).

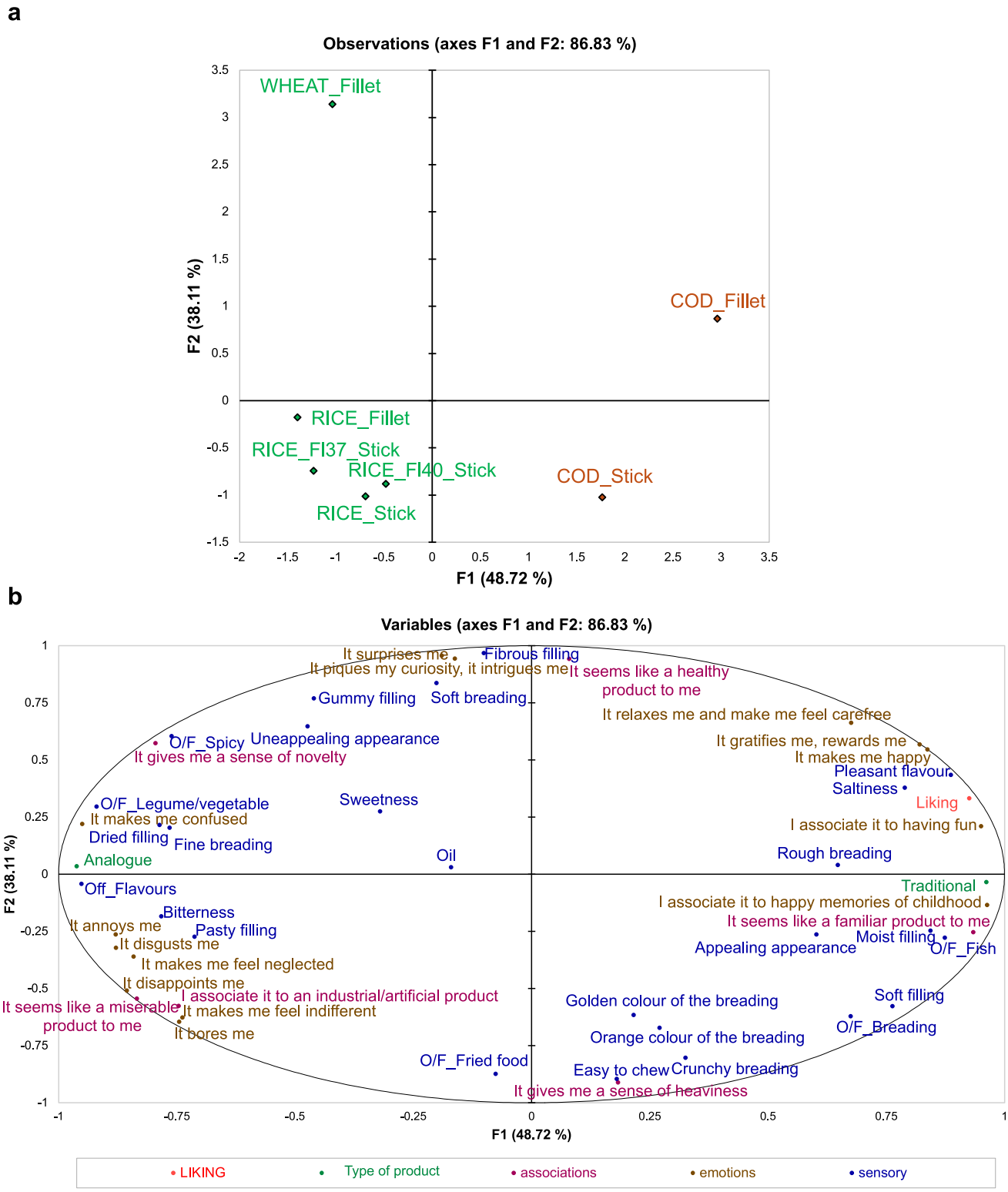

Fig. 4. (a-b). (a) Score plot and (b) correlation circle on the first and second dimensions of the Multiple Factor Analysis computed on the scores for emotions, Check-All-That-Apply attributes and functional/emotional concepts for the adult group.

consumer liking for related to COD_Fillet and RICE_FI40_Stick was highly correlated with positive emotions such as happiness, satisfaction and serenity, as well as with salty taste and flavour descriptors (pleasant and fried foods). Conversely, for children, bitter taste and unpleasant flavours associated with spiciness and legumes were correlated with feelings of disappointment, disgust, and anger. The interpretation of the MFA was further supported by the mean values for each emotion reported in **Supplementary Material S4b**.

4. Discussion

The present study investigated the liking and the drivers of acceptance of plant-based breaded fish among adults and children aged 9 to 11 years. Until now, little information exists about the perceptive

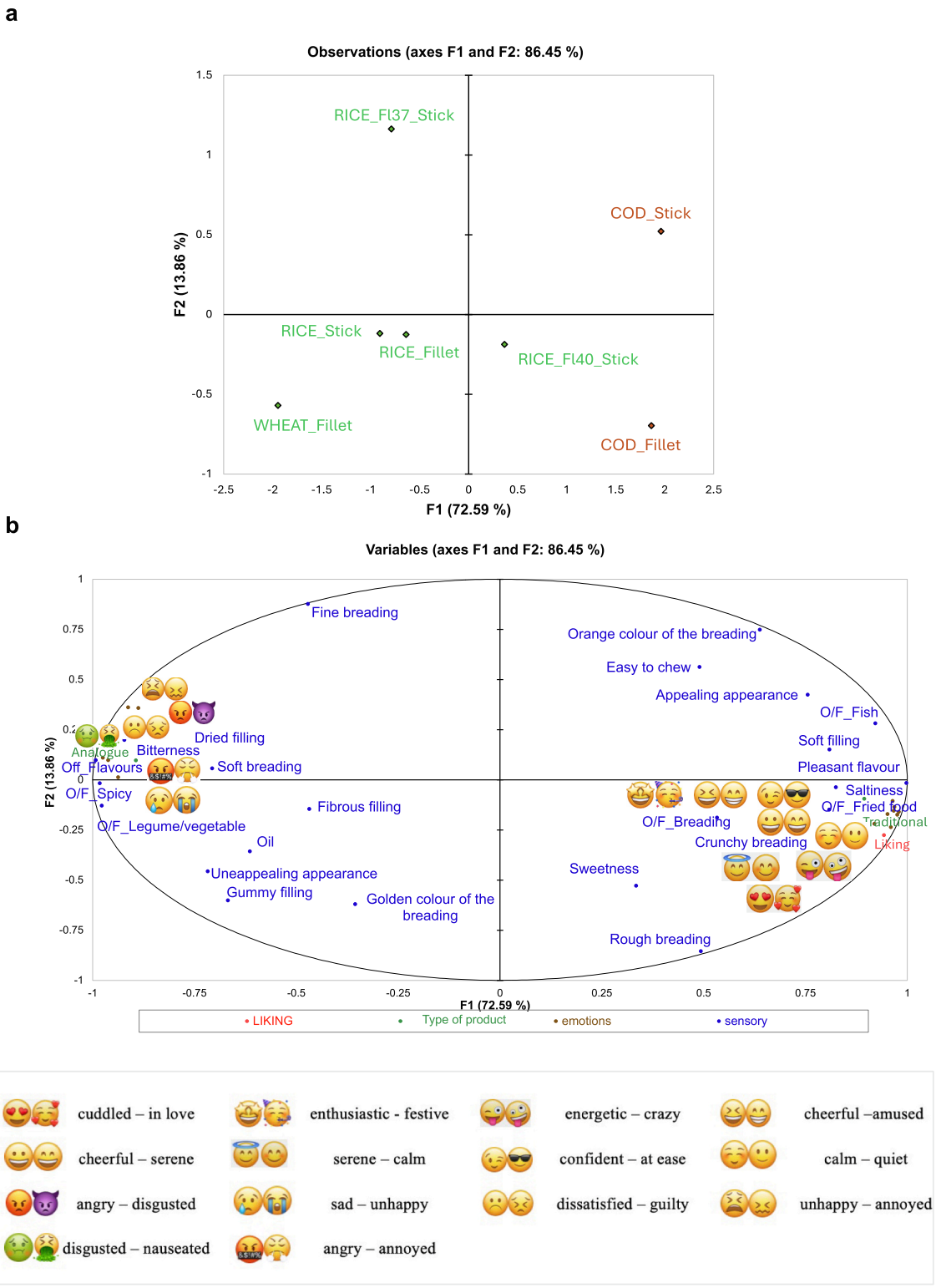

Fig. 5. (a-b). (a) Score plot and (b) correlation circle on the first and second dimensions of the Multiple Factor Analysis computed on the scores for emotions, Check-All-That-Apply attributes and functional/emotional concepts for the children group.

determinants of acceptance of plant-based analogues in children, particularly, plant-based fish analogues. In the present study, breaded fish alternatives were chosen because previous research found that fish stick is the most preferred method of consuming fish among school-aged children (Laureati et al., 2016; Donadini et al., 2013: Højer & Frøst, 2022), and is often included in school menus to promote fish intake (Laureati et al., 2016).

4.1. Overall liking

The present study first revealed that, although young and adult participants rated the animal-based samples significantly higher in

terms of liking, they also provided generally positive scores for the plant-based samples. Unlike other fish analogues, such as canned tuna (Appiani et al., 2025), these products appear to have a good chance of success being considered acceptable by participants, both adults and children, and could play an important role in encouraging sustainable consumption, especially among the latter.

Nevertheless, age-related differences were observed when comparing the liking scores of the two age groups. Specifically, adults had a stronger preference for wheat protein-based sample (WHEAT_Fillet), while the codfish-based (COD_Stick) and rice flake-based stick (RICE_Fl40_Stick) were preferred by younger participants. To the best of our knowledge, this is one of the few studies that gather information about the perceptions of analogue samples within the pediatric population and the unique which focused on fish analogues and compared children responses with those of adults. Previous studies, in fact, have investigated children's perception regarding meat or dairy analogues (Eustachio Colombo et al., 2021; Palacios et al., 2010; Pater et al., 2022; Westling et al., 2022), primarily using interviews, focus groups, or questionnaires (Eustachio Colombo et al., 2021; Pater et al., 2022; Westling et al., 2022).

4.2. Sensory characterization and drivers of liking

In this study, the application of the CATA method successfully enabled sensory profiling of the products by both children and adult participants. As shown in previous research (e.g., Sandvik et al., 2020), children were able to perform the CATA method. Although children were not directly involved in determining the attributes, they showed a clear understanding of the terms. The researchers' explanations before the test, along with the practical examples included in the descriptor list (e.g., linking a rubbery texture to chewy candy and a fibrous texture to meat), allowed most children to perform the test independently. Only a small number of 9-year-olds required additional guidance from a researcher during the test.

Nevertheless, despite the analogues being generally well-accepted by participants, these samples were significantly differentiated from their animal counterparts in sensory terms by both age groups, who described the samples in a similar manner. The only analogue sample described as comparable to traditional products from a sensory perspective was the COD_Fl40_Stick, which was also the most liked by children, and RICE_Fl37_Stick to a lower extent. Since the CATA questionnaire included various hedonic attributes (e.g., "appealing appearance", "pleasant flavour"), we limit our discussion on purely sensory attributes as drivers of liking/disliking.

Firstly, the animal-based samples (COD_Stick and COD_Fillet) were distinguished by their rough breading, which contributed to their appealing appearance, compared to the fine breading and less visually appealing appearance of the analogue samples, leading to reduced liking among children. This result aligns with findings from studies on other fish analogues, such as canned tuna (Appiani et al., 2025; Mahmud et al., 2024). Specifically, the visual characteristics of these foods are largely determined by the non-protein ingredients in their formulations, such as fats and colourings (Mahmud et al., 2024). The visual characteristics of food are key factors in determining its quality and acceptability among consumers of all ages (He et al., 2020). However, these factors have a particularly strong impact on children's food choices compared to adults (Dovey et al., 2012), making them one of the primary drivers of food acceptance or rejection (Sick et al., 2019). Unfamiliar visual properties in foods can provoke disgust in children, contributing to behavioral patterns like food neophobia that are typical during childhood (Brown & Harris, 2012). For this reason, the visual similarity of plant-based products to animal-based can significantly increase children's acceptance by evoking a sense of familiarity (Eustachio Colombo et al., 2021). However, this resemblance can also lead to unfulfilled expectations, which may result in disappointment, as seen with adults (Elzerman et al., 2022; Pater et al., 2024). Nonetheless, Pater et al. (2024) observed that children are less focused on the appearance of meat or fish analogues when these foods are included in a complete meal, rather than served alone. As well, Eustachio Colombo et al. (2021) and Pater et al. (2022) found that children identified taste, appearance, smell, and familiarity as important determinants of the acceptability of plant-based foods.

Likewise, breaded fish analogue samples showed unpleasant odours and flavours related to legumes and vegetables. This aligns with findings in other fish analogues (Abotsi et al., 2024; Appiani et al., 2025) and plant-based meat foods (e.g., Wang et al., 2022). The off-flavours and legume odour are caused by the binding of proteins to both volatile (e.g., furans, ketones, aldehydes, alcohols) and non-volatile (e.g., hydroxy fatty acids, saponins and polyphenols) compounds (Roland et al., 2017; Vatansever et al., 2024). For this reason, sensory improvements can be achieved by reducing the formation of these compounds, using strategies such as solvent extraction or modifying protein structures through denaturation, as well as chemical or enzymatic interventions (Vatansever et al., 2024). Currently, the addition of flavouring agents, particularly spices (e.g., black pepper, red pepper, garlic, and onion), is one of the most frequently used methods to mask off-odours and flavours. These spices are effective in reducing the formation of undesirable odours that arise during cooking, especially under high temperatures, during the Maillard reaction, or due to oxidation of unsaturated fatty acids (Yuan et al., 2023). As a result, the odour and flavour of spices are frequently observed as sensory characteristics in plant-based products (e.g., Forster et al., 2024; Giacalone et al., 2022). However, our findings indicate that this odour had a negative effect on the overall liking of the samples for both children and adults. This result differs from previous studies, where the inclusion of spices and herbs in plant-based food formulations was found to enhance liking (D'Adamo et al., 2016; Zellner & Cobuzzi, 2017). It is possible, however, that the children in this study were not familiar with these ingredients, which could have led to a decrease in their liking (Knaapila et al., 2017). For adults, who are likely more accustomed to spices, this finding suggests that the selection and balance of spices in these formulations should be reconsidered and potentially optimized to better align with consumer preferences.

Bitterness was a driver of disliking in children. In addition to tannins and phenolic compounds, non-volatile compounds contribute to the bitter taste that characterizes analogue products, representing a key sensory barrier to their consumption (Appiani et al., 2023).This sensory attribute has also been observed in breaded fish analogues, greatly affecting their liking, especially for younger participants. Indeed, it is well established that the perception of bitterness varies with age (Barragán et al., 2018;). Specifically, sensitivity to bitterness in childhood primarily acts as a defense against possible toxic substances, often leading to the rejection of vegetables (Agovi et al., 2022; Dinnella et al., 2016). Over time, during adulthood, sensitivity to bitterness tends to decrease, influenced by factors such as experience and adaptation (Mennella et al., 2008). Therefore, introducing children to a variety of foods, including vegetables that may not be immediately appealing, plays a vital role in familiarizing them with a range of tastes and flavours (Appleton et al., 2018).

Lastly, the analogue samples differed from the traditional ones in terms of their texture. Both age groups described the animal-based samples as having a soft, easy-to-chew filling and crispy breading, while the analogue samples had soft breading and a filling that was perceived as fibrous, dry, and gummy. Interestingly, the penalty analysis highlighted the same drivers of liking for both age groups, including the soft filling and crunchy breading of traditional products. Nonetheless, adults and children showed differences in rejection factors. For adult participants, the only texture attribute that significantly penalized liking was the pasty filling, whereas children were more discerning, identifying a wider range of texture attributes that contributed to their reduced liking, such as the soft breading and the dried and gummy filling. This outcome aligns with existing literature, which identifies

texture, along with taste and odour, as key factors influencing food rejection (e.g., Chow et al., 2024; Sick et al., 2019; Werthmann et al., 2015). The development of food processing capabilities and the oral cavity plays a significant role in shaping food preferences (Demonteil et al., 2019). Consequently, texture preferences evolve significantly with age (Chow et al., 2024; Tournier & Forde, 2024). During childhood, foods with chewy or rubbery textures are often rejected (Werthmann et al., 2015), while soft and crunchy textures are generally favoured. The importance of texture in children's rejection of certain foods is strongly associated with food neophobia, a personality trait commonly observed during childhood. Food neophobia often impacts the acceptance of various foods, particularly healthy options such as vegetables, which are frequently rejected due to their bitter taste (Siegrist et al., 2013) and plant-based analogues, which are avoided due to limited consumer experience with these products (Appiani et al., 2023; Jahn et al., 2021). However, in this study, food neophobia did not significantly influence the liking of the tested samples in either the adult or child populations. This result may be explained by a recruitment bias. Specifically, the mean food neophobia scores were generally low (Rabadán & Bernabéu, 2021), which might account for the lack of significant differences between the Low_FNS and High_FNS groups. Indeed, individuals who are less neophobic are typically more willing to participate in sensory tests and try novel food products (Prescott et al., 2022). Although the samples were tested in blind condition, participants were made aware, per ethics committee requirements, that both animal- and plant-based products would be included. This awareness may have led to lower participation among extremely neophobic individuals. An additional explanation could relate to the type of product tested. The product was fried, a food category generally familiar from childhood and, therefore, less likely to evoke neophobic responses (Siegrist et al., 2013), which was also reflected in the questionnaire data on family fish consumption habits.

4.3. Emotional profile

In recent years, it has become increasingly recognized that, alongside sensory factors, emotional drivers play a significant role in the acceptance of new products, helping to facilitate the shift from an animal-based to a plant-based diet (Onwezen et al., 2022; Zandstra et al., 2024). However, until now emotional responses have primarily been studied in relation to plant-based meat (Schouteten et al., 2016; Sogari et al., 2024) and dairy alternatives (Cardello et al., 2022; Jaeger et al., 2023) with no information available regarding fish analogues. Emotional responses across the two age groups were explored using two distinct tools: the EmoSemio approach (Spinelli et al., 2019) was employed to develop a product-specific questionnaire for adults, whereas the Emoji Pair Questionnaire (Sick et al., 2022) was utilized for the younger participants. In agreement with previous study (Ng et al., 2013; Schouteten et al., 2016; Spinelli et al., 2015), the overall outcomes of this study suggest that the emotional responses to the animal and plant-based breaded fish samples were mainly sensory driven. Traditional animal-based products, characterized by sensory attributes such as rough breading, pleasant flavour, saltiness, and O/F_Fish were strongly linked to positive emotions, including happiness, amusement, and relaxation, by both children and adults. This result aligns with previous studies, which have demonstrated that emotions with a positive valence are associated to liking (Onwezen et al., 2022; Prescott & Spinelli, 2024). Interestingly, COD_Sticks was strongly associated with happy childhood memories and the idea of a familiar product by adult participants. As previously reported, fish fingers are a product consumed mainly at home or in school canteens during childhood. This association to pleasant past eating experiences contributes to their perception as a type of comfort food. A similar finding was reported by Sogari et al. (2024), who demonstrated that happy memories play a significant role in driving liking for meat burgers. In children, this association could not be verified, as emotions related to memories were not a factor explored in the Emoji Pair Rating Scale for the age of the participants.

On the other hand, attributes like bitterness, a vegetable/legume odour, off-flavours and a pasty filling in breaded fish analogues were linked to negative emotions, including confusion, disgust, and disappointment and to idea of artificial products. These emotional responses significantly contributed to the reduced liking of these products (Gutjar et al., 2015), reflecting a pattern also observed in meat and dairy analogues, where plant-based samples often trigger less favorable emotional responses than traditional products (Cardello et al., 2022; Sogari et al., 2024; Zandstra et al., 2024).

However, among the plant-based samples, WHEAT_Fillet stood out due to the emotional responses it evoked in adults. Despite its soft breading and a filling described as fibrous and gummy, it evoked surprise and curiosity, probably explaining why the sample made with wheat proteins was the most preferred among plant-based analogues by adults. Curiosity, particularly when trying or purchasing new foods for the first time, plays a significant role (Ford et al., 2023; Stone et al., 2022). On the other hand, surprise has further sparked interest once consumers had tasted the product, thus enhancing their overall liking (Sogari et al., 2024). It is also associated with the idea of novelty, probably for its spicy taste due to paprika. This result is consistent with earlier research (Elzerman et al., 2022) indicating that the expectation of plant-based products being perfect substitutes for animal products can lead to disappointment when sensory characteristics differ. However, viewing these products as unique makes it easier to appreciate their distinct sensory qualities and fosters curiosity in trying these new foods.

These findings confirm that, for adults, emotions played a key role in distinguishing between samples, going beyond liking and sensory characteristics contribuiting to their differentiation on the market (Onwezen et al., 2022; Thomson, 2010). Conversely, this outcome was not observed in the child population where emotions were closely associated to liking responses.

To the best of our knowledge, this is the first study that investigated to investigate emotional responses to plant-based samples in a pediatric population and to employ a emoji-based self-reported validated questionnaire for assessing emotional responses among children (Sick et al., 2022) and preadolescents (Sick et al., 2023): the Emoji Pair Rating Scale (Sick et al., 2022). For children, emojis representative of positive emotions (e.g., *enthusiasm, happiness, calm*) were strongly correlated with liking and sensory characteristics of animal-based products (COD_Stick and COD_Fillet), while those representative of negative emotions (e.g., *sadness, anger, disgust, delusion*) were linked to plant-based products and their sensory characteristics. The only exception was RICE_Fl40_Stick, which elicited emotions similar to those generated by COD_Fillet, such as serenity, enthusiasm, and joy. This finding, coupled with the fact that RICE_Fl40_Stick shares several sensory characteristics with traditional products, helps explain why this sample was preferred among the analogues, with an average liking score comparable to that of the COD_Stick. However, although consistent with the responses provided by adults, this tool was less effective at distinguishing the samples for younger participants. In this context, important methodological limitations were identified. Firstly, children primarily used the questionnaire as a CATA (presence/absence of emotion) tool, then they primarily assigned extreme scores (1 = *Does not fit at all* to 5 = *Fits very well*) while neglecting intermediate points on the scale. Although the intensity of emotional responses could potentially increase the discriminatory capacity of emoji pairs in distinguishing between similar sensory profiles (Sick et al., 2022), for children aged 9 to 11 years, it proved challenging to rate the intensity of their emotions, leading them to focus on the presence or absence of specific emotions instead. This led children to discriminate samples based primarily on emotions that varied in valence, dividing the samples associated with positive emotions from those eliciting negative emotions. Arousal contributed little to discrimination. This result partly aligns with the findings of Gutjar et al. (2015) and Sick et al. (2023). Another important limitation identified in the Emoji Pair Rating Scale is the absence of the curiosity and surprise dimension, understood as a positive emotion, which was present in the

questionnaire developed and used with adults. Curiosity can serve as a key factor in helping children choose plant-based products (Pater et al., 2024). Therefore, incorporating it into emotional response questionnaires is crucial when evaluating new and unfamiliar foods, but requires words as it cannot be expressed easily with emoji.

5. Conclusions

In conclusion, the results highlighted the differences between the age groups, supporting the need to focus studies on plant-based foods, not only by involving adults but also by including vulnerable population targets, such as children, who have specific needs and expectations (Appiani et al., 2023). Moreover, the study of liking, sensory characteristics, and emotions identified two plant-based breaded fish samples targeted for each group. The textured wheat protein-based sample (WHEAT_Fillet) demonstrates strong market potential among adults, who appear more satisfied with products that, while lacking sensory characteristics similar to their animal counterparts, successfully attract consumers and make them curious likely due to their distinct identity. On the contrary, to promote the consumption of plant-based products in children, familiarity with well-known products must be sought, and sample like rice flake-based sticks (RICE_Fl40_Stick), very similar to the traditional cod sticks, could be introduced in school canteens as an option to encourage plant-based eating.

CRediT authorship contribution statement

Marta Appiani: Writing – original draft, Investigation, Formal analysis. **Camilla Cattaneo:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Sara Spinelli:** Writing – review & editing, Methodology, Conceptualization. **Monica Laureati:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Ethical statement

Ethical approval for the involvement of human subjects in this study was granted by the Ethical Committee of the University of Milan, Reference number 95/23, 19.09.23.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT in order to spell-check and grammar-check the language of the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2025.117024.

Data availability

Data will be made available on request.

References

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