

Developing vegan spreads with fish-like sensory attributes through co-creation

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ABSTRACT

Pulses and seaweed offer significant potential as alternative protein sources in the plant-based food sector. However, their combined use remains underexplored in participatory food innovation, particularly at the early stages of product development. This study addresses this gap by applying hands-on co-creation using LEGO® Serious Play® methodology to the development of vegan spreads. A three-phase collaborative framework was implemented to co-create vegan spreads with fish-like sensory attributes using pulses, seaweed, and essential oils. Online survey (n = 1000) identified key sensory drivers, market expectations, and opportunities for this type of plant-based spreads. Subsequently, 17 diverse stakeholders co-created 4 pulse-seaweed spread concepts through structured workshop activities. Expert panels evaluated developed prototypes through rapid sensory screening and quality assessment (n = 3) and technological assessments (n = 3). Two prototypes demonstrated superior sensory acceptability and commercial potential, characterized by balanced umami notes and seafood-reminiscent flavour profiles. The originality of this research lies in the integration of large-scale consumer insights obtained through a survey with multi-stakeholder, hands-on co-creation using the LEGO® Serious Play® methodology, complemented by expert-driven evaluation, forming a comprehensive early-stage innovation framework. Findings suggest that early-stage multidisciplinary co-creation can support consumer-informed product development in plant-based food sector by translating consumer expectations into practical formulation. Open innovation approach helped connect market insights with technical feasibility, but further research is needed to address the prototypes. The findings provide insights for the development of sustainable fish alternatives that better align with growing demand for vegan and plant-based diets, and consumer expectations regarding familiarity, ingredients and sensory direction.

1. Introduction

It is estimated that nearly 90% of new food products do not succeed within the first year of market launch, despite significant research and development efforts (Bogue and Repar, 2023; Nnadiębulam et al., 2025). One of the main reasons is the inadequate integration of consumer preferences and sensory perceptions in the product development stage (O'Sullivan et al., 2011; Nnadiębulam et al., 2025). Therefore, participatory approaches that actively involve consumers and other stakeholders have been identified as a critical success factor in food innovation, enabling a more effective alignment between product development and market expectations. These approaches emphasize collaborative, multi-actor engagement across the food system, which is

increasingly promoted by institutions worldwide to support the transition towards sustainable food systems and ensure food security (De Vries et al., 2024). Within this broader framework, co-creation represents a structured and widely applied participatory approach for integrating consumer insights into early-stage product development. The concept of co-creation, originating from business theory, refers to a collaborative process of value creation that enables diverse forms of cooperation among stakeholders within sustainable food systems (Galvagno and Dalli, 2014; De Vries et al., 2024).

Unlike traditional innovation models, where producers independently define product characteristics, co-creation fosters participatory processes in which consumers and stakeholders jointly contribute to idea generation, ensuring outcomes that align with consumer needs and

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market dynamics (Kokkorou et al., 2025). These approaches bring together diverse actors from research and sensory science, product development, marketing, gastronomy, nutrition, and design, thereby enabling the integration of scientific, technical, creative, and market-oriented perspectives in the new food product development process (Barone et al., 2021; Thomas et al., 2021; Kokkorou et al., 2025; Nnadiębulam et al., 2025). Beyond its role in product development, participatory approaches can also contribute to social impact by fostering inclusion, building trust, and broadening societal relevance and acceptance of novel products (Gerke et al., 2023; Girbes et al., 2022).

This approach has been applied to concept development for different types of food products and dishes, such as legume-based dishes for school canteens with adolescents (Kokkorou et al., 2025), healthy dairy products with adolescents (Pinesso Ribeiro et al., 2025), protein-rich appetisers for older adults (Domingie et al., 2025), plant-based dietary snack bars (Ketkaew et al., 2024), innovative meat products for flexitarians and omnivores (Domenici et al., 2025), functional beverages (Vrgović et al., 2022), and healthy snacks for pre-adolescents (Galler et al., 2022; Pinesso Ribeiro et al., 2025b). These studies have demonstrated the value of co-creation in developing healthier and more acceptable food products across diverse consumer groups, including children, adolescents, and older adults (Domingie et al., 2025; Kokkorou et al., 2025; Pinesso Ribeiro et al., 2025).

Plant-based and vegan food products have gained increasing attention in recent years due to their potential to support more sustainable food systems, reduce environmental impacts associated with animal-based food production, and address emerging consumer concerns related to health, ethics, and climate change. In this context, plant-based alternatives are no longer only niche products for vegetarians or vegans, but are becoming popular among mainstream consumers who want to reduce their consumption of animal-based foods (Apostolidis and McLeay, 2016; Curtain and Grafenauer, 2019). However, the success of plant-based alternatives depends not only on their nutritional and environmental benefits, but also on their ability to meet consumer expectations regarding sensory quality, familiarity, and trust, as environmental and health motivations alone have been shown to be insufficient to ensure acceptance (Szenderak et al., 2022). Evidence from consumer surveys and recent reviews indicates that poor sensory quality, a perception of artificiality, and limited understanding of processing remain key barriers to the wider acceptance of plant-based foods, particularly among consumers accustomed to animal-based products (McClements and Grossmann, 2021; Estell et al., 2021; Szenderak et al., 2022; Appiani et al., 2023; Predanőcyová et al., 2023). Compared with more established plant-based meat and dairy alternatives, seafood analogues represent a particularly challenging and less mature category due to the difficulty of replicating fish-specific sensory attributes and aligning with strong consumer expectations regarding freshness, naturalness, and nutritional value (Kazir and Livney, 2021; Nowacka et al., 2023; Boukid et al., 2022; Chehade et al., 2025). As a result, these products are especially prone to scepticism and rejection when sensory cues fail to meet expectations, particularly given their low familiarity and perceived lack of authenticity (Abotsi et al., 2024; Luo et al., 2025).

However, despite growing interest in co-creation, its application in the development of technologically complex and sensory-sensitive products such as plant-based seafood analogues remains limited (Durço et al., 2025). Therefore, the first research gap relates to the predominantly formulation-driven nature of existing studies. In particular, consumer insights are insufficiently integrated into the early-stages of ideation and concept development, and the involvement of diverse stakeholders, including industry, policy makers, and technical experts, remains limited (Vrgović et al., 2022; Domenici et al., 2025; Domingie et al., 2025; Nnadiębulam et al., 2025). The second research gap concerns the lack of unified frameworks that systematically integrate large-scale consumer insights, participatory co-creation, and expert-based evaluation, particularly for novel and sensory-complex

categories such as plant-based seafood analogues. Therefore, the objective of the present study is to address these gaps by applying a multi-phase, multi-stakeholder co-creation framework to the development of fish-like vegan spreads, integrating large-scale consumer insights, collaborative creative concept development, and expert assessment.

2. Theoretical background

In this study, the term “spread” is used to describe ready-to-eat, spreadable products comparable to pâté-type or pulse-based products (such as hummus), typically consumed on bread, and excludes fat-based spreads such as margarine or butter. The selection of spreads (pâtés) as the product format was guided by cultural, market, and nutritional considerations. Spreads are generally not consumed as main courses, but are commonly positioned as convenient foods for breakfast, snacks, and light meals (Županjac et al., 2025). In parallel, the development of such products aligns with the rapidly growing global demand for plant-based proteins, projected to exceed USD 27 billion by 2027 (Siddiqui et al., 2024). Embedding unfamiliar ingredients such as seaweed and algae into a familiar product format represents an effective strategy to reduce food neophobia and improve consumer acceptance, particularly in regions with low exposure to marine-based foods (Siddiqui et al., 2024; Costa et al., 2025). From a nutritional perspective, pulse-seaweed-based spreads offer a favourable profile compared to conventional animal-based pâtés, with lower saturated fat and higher dietary fibre, while providing essential amino acids, marine bioactives, and key micronutrients (Wells et al., 2017; Onwezen et al., 2021; Pointke and Pawelzik, 2022). This is particularly relevant for consumers avoiding fish, who may be at risk of insufficient intake of nutrients such as omega-3 fatty acids (Lane et al., 2022; Appiani et al., 2025).

2.1. The technological and sensory complexity of plant-based seafood analogues

A major technological constraint in plant-based seafood analogues lies in the formation of off-flavours, driven by volatile (e.g., aldehydes, alcohols, ketones, furans) and non-volatile compounds (e.g., phenolics, saponins, bitter peptides), leading to undesirable attributes such as bitterness and beany notes (Wang et al., 2022; Appiani et al., 2023; Saffarionpour, 2024; Leonard et al., 2023; Županjac et al., 2025). In parallel, replicating fish-like textures remains a persistent limitation across plant-based categories (Appiani et al., 2025). To address these challenges, recent innovation efforts increasingly combine plant-based proteins with marine-derived ingredients, particularly pulses and seaweed, to enhance sensory properties (Kurek et al., 2022; Lima et al., 2022; Nowacka et al., 2023). Pulse-based spreads (e.g., hummus-like matrices) represent a nutritionally rich and widely accepted platform for incorporating algae and seaweed, contributing to marine-like flavour, texture, and visual appeal (Reister et al., 2020; Mendes et al., 2022; Shanthakuma et al., 2022; Rogel-Castillo et al., 2023; Matheus et al., 2024; Županjac et al., 2025). These products are typically aligned with clean-label positioning (e.g., additive-free, high protein, omega-3 enrichment) and target premium, sustainability-oriented market segments (Boukid et al., 2022).

2.2. Familiarity, perceived risk and participatory approaches in early-stage food innovation

Consumer acceptance of novel foods is strongly influenced by familiarity, perceived risk, sensory expectations, and individual psychological traits. One of the most widely discussed constructs in this context is food neophobia, defined as the reluctance to try unfamiliar foods (Pliner and Hobden, 1992; Tuorila and Hartmann, 2020). Food neophobia has been identified as an important factor influencing the adoption of alternative protein sources, including algae- and

marine-based products (Giacalone et al., 2022; Appiani et al., 2025). However, beyond food neophobia as a stable psychological trait, consumer responses to novel foods are also shaped by product-specific unfamiliarity, perceived naturalness, trust, and expectations regarding sensory quality.

Seaweed-based foods are often associated with negative sensory expectations, such as unpleasant odour and unfamiliar texture, particularly in Western contexts (Losada-López, 2021; Govaerts and Olsen, 2022; Mellor et al., 2022; Gorman et al., 2023). Strategies aimed at increasing familiarity, such as repeated exposure, tasting experiences, and embedding novel ingredients into familiar product formats, have been shown to improve acceptance of novel food concepts (Tuorila et al., 1994; Siddiqui et al., 2024; Costa et al., 2025; Van Kerckhove et al., 2023).

Participatory approaches such as co-creation can support early-stage food innovation by increasing consumer engagement, transparency, and familiarity with novel food concepts (Durço et al., 2025). Through active involvement in the development process, consumers and other stakeholders are exposed to product ideas, ingredients, and sensory attributes, which can reduce uncertainty and support the formation of more positive expectations. In addition, the involvement of diverse stakeholders facilitates the alignment of sensory characteristics, technological feasibility, and consumer expectations, contributing to the development of products that are both practically feasible and more closely aligned with end-user needs (Girbes et al., 2022; Vrgović et al., 2022; Gerke et al., 2023).

3. Materials and methods

3.1. Study design

The study followed a multi-phase mixed-methods design integrating quantitative market research, participatory multi-stakeholders co-creation, and expert evaluation, as presented at Fig. 1.

The first phase explored consumer attitudes toward fish-like vegan spreads through a large-scale online survey ($n = 1000$). The findings from this phase were used to inform the design and content of the subsequent co-creation workshop by identifying key consumer dietary habits, preferences, and affecting factors related to fish-like vegan spreads. These insights informed the workshop design, ensuring that the co-creation process was directly grounded in consumer-derived evidence. The second phase consisted of a participatory co-creation workshop involving 17 stakeholders (consumers, food researchers, policy makers, and industry representatives) who engaged in structured creative activities and hands on prototype development. The final phase consisted of a technological assessment performed by three food technologists with expertise in spread production, who evaluated all prototypes, to identify the most promising solutions.

3.2. Consumer survey

The questionnaire, designed to assess consumer attitudes, preferences, and willingness to try vegan spreads, covered the following thematic areas: dietary patterns and openness to trying new foods; food consumption habits (including spread consumption) and preferences; awareness and acceptance of vegan spreads and socio-demographic information. It consisted primarily of closed-ended questions, including single- and multiple-choice items, Likert-type scales, and price-sensitivity measures, with optional open-response fields for selected items (Supplementary Material 1). Before starting the questionnaire, all participants were provided with an introductory briefing that clearly defined the product concept under investigation, specifically, fish-like vegan spreads formulated from a combination of pulses and seaweed, ensuring they were fully aware of the key ingredients being evaluated.

An anonymous online questionnaire was administered using the Computer-Assisted Web Interviewing (CAWI) methodology (Feng and

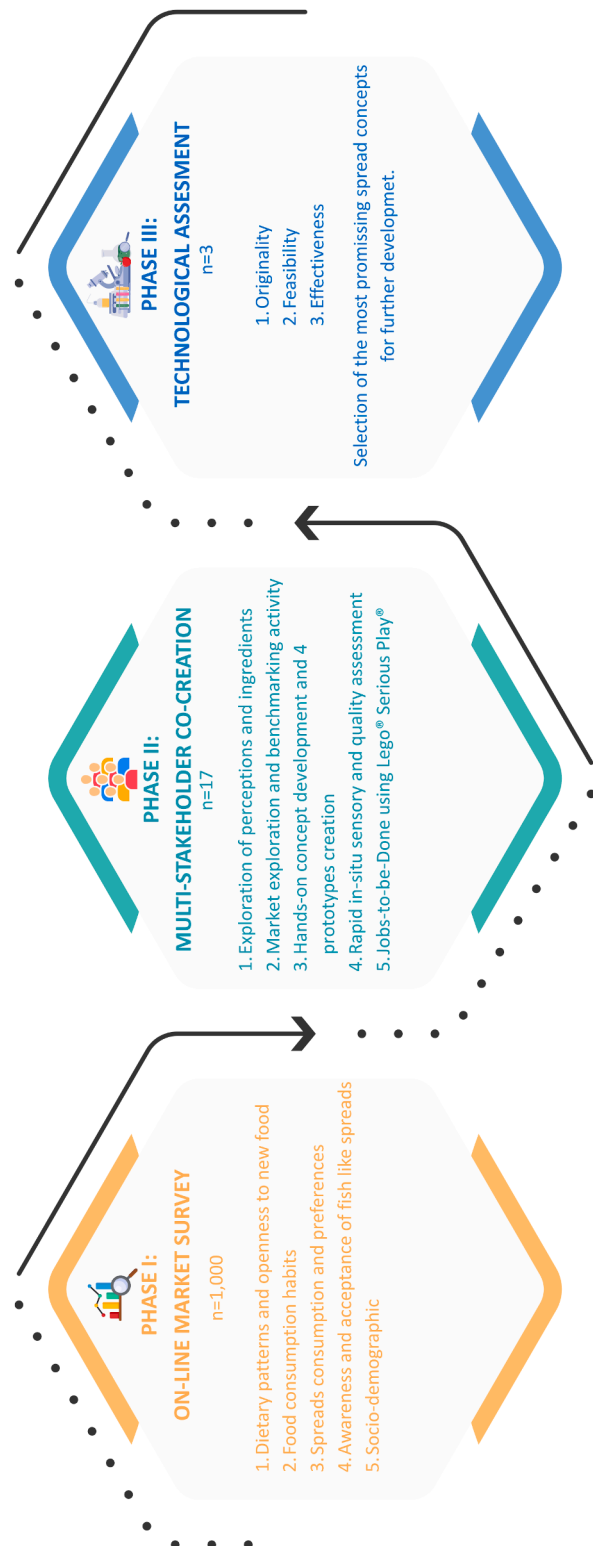


Fig. 1. Schematic overview of the integrated methodological framework (approximately here).

Huang, 2024). Data were collected in Serbia (September–October 2024). Prior to the main survey, a pilot study involving 20 participants was conducted to assess questionnaire clarity and comprehensibility, leading to minor wording adjustments. Participation was voluntary and anonymous, and informed consent was obtained from all respondents prior to data collection. The sample size was calculated with the Raosoft tool (Raosoft tool, 2024), yielding a minimum requirement of 385 participants. The final sample of 1000 respondents exceeded this threshold. Respondents were recruited through a professional market research agency using an established online panel. No prior consumption of spreads was required for participation, in order to capture a broad range of attitudes, including those of non-users. Quota sampling was applied to approximate the demographic structure of the Serbian adult consumer population aged 18–65, based on the latest official census data provided by the Statistical Office of the Republic of Serbia (2022). Stratification criteria included gender, age, and place of residence. The socio-demographic characteristics of the sample are presented in Table 1. To ensure a realistic representation of the general market landscape rather than a niche consumer segment, no exclusion criteria were applied regarding dietary patterns or prior consumption of plant-based products. This general-population approach was intentionally adopted to minimise selection bias and to enable the identification of both drivers and barriers to adoption, including food neophobia and sensory unfamiliarity.

3.2.1. Questionnaire data analysis

Questionnaire data were analysed using XLSTAT, 2025.2.0 (Addinsoft, NY, USA). Descriptive statistics were applied to summarise all variables. Associations between product attributes and socio-demographic variables were examined using chi-square tests, while differences in Likert-type ratings across independent demographic groups were assessed using ANOVA or Kruskal–Wallis tests, as appropriate. Spearman's rank correlations were used to explore relationships between ordinal and binary variables. To statistically validate factors affecting spreads consumption, a Friedman test followed by Nemenyi's post-hoc test was conducted. Furthermore, for the analysis of multiple-response binary data (e.g., consumer selection of preferred product labels, where participants could choose multiple options), Cochran's Q test followed by McNemar's post-hoc was applied to determine whether the proportion of selections differed significantly across the evaluated categories. For all applied statistical analyses, the significance level was set at $p < 0.05$.

3.3. Co-creation session

3.3.1. Stakeholder recruitment and composition

Workshop participants were recruited independently from the large-scale consumer survey, through a short online recruitment questionnaire designed to ensure a balanced representation of relevant stakeholder groups and collect essential background information. The questionnaire was administered via Google Forms and distributed through professional networks, social media and institutional mailing lists. Eligibility criteria required participants to belong to at least one of the following stakeholder groups: consumers, food scientists and technologists, food industry representatives, or policy makers. In addition, targeted invitations were sent to selected spread industry representatives and food policy stakeholders in Serbia to ensure domain-specific expertise and alignment with the quadruple helix approach. No prior consumption of spreads was required for participation among consumer stakeholders, in order to capture a broad range of perspectives, including both experienced users and non-users, which is particularly relevant for early-stage development of novel products. A total of 17 participants were selected to ensure diversity of perspectives while maintaining a manageable group size for effective interaction and hands-on activities. Participants were categorized into four stakeholder types: food industry representatives ($n = 4$), food scientists and technologists ($n = 4$), policy

Table 1

Socio-demographic characteristics, dietary habits, and openness to new foods.

Characteristic / Category	Percentage (%)
Socio-demographic characteristics	
Gender	
Male	49.3
Female	50.7
Prefer not to say	0.0
Age (years)	
18–29	25.9
30–44	30.7
45–59	29.4
60–65	14.0
Region	
Belgrade region	22.6
Vojvodina	25.4
Southern & Eastern Serbia	24.5
Šumadija & Western Serbia	27.5
Residence	
Urban area	59.4
Rural area	40.6
Education	
Primary	4.2
Secondary	59.6
Higher (Bachelor)	29.1
Postgraduate (Master, PhD)	7.1
Employment	
Employed	63.6
Unemployed	10.0
Retired	8.3
Self-employed	7.7
Student	7.1
Farmer	3.0
Other	0.3
Household composition	
With partner and children	41.7
With partner	20.9
With parents	21.1
Living alone	8.1
With children	5.6
With roommate(s)	0.5
Other	2.1
Income	
Above average	49.8
Below average	23.0
Not disclosed	27.2
Dietary habits and openness to new foods	
Diet	
Omnivorous	93.8
Vegetarian	2.3
Flexitarian	1.4
Vegan	0.9
Other	0.9
Pescatarian	0.6
Macrobiotic	0.1
Openness to new foods	
Yes	51.7
Depends on the type of food	29.3
No	19.0
Willingness to adjust current diet	
Yes, for health reasons	53.9
No, I am satisfied, no need for change	18.8
Maybe, if I had more information	15.8
Yes, for ethical reasons	7.6
Yes, for environmental reasons	3.4
I don't know	0.5
Future dietary adjustments*	
Higher proportion of fish	41.8
Higher proportion of plant-based foods	40.9
Other	20.6
Higher proportion of animal-based foods (meat, eggs, cheese, etc.)	19.5
Lower proportion of animal-based foods	16.8
Sources of dietary information*	
Internet	43.6
Friends/family recommendation	42.9
Social media	33.3
Television	25.6

(continued on next page)

Table 1 (continued)

Characteristic / Category	Percentage (%)
Cooking shows/books	23.4
Professionals recommendation	21.5
I do not seek information	16.4
Other	4.0
Scientific literature	1.9

* Multiple responses allowed.

makers (n = 4), and consumers (n = 5). Selected participants were assigned to four mixed groups to facilitate discussion from multiple perspectives, including consumer expectations, technological feasibility, and market potential.

3.3.2. Co-creation session design and procedure

The co-creation session was conducted in October 2024 at the Institute of Food Technology in Novi Sad, University of Novi Sad, and lasted approximately 3 h. Participants were challenged to develop early-stage concepts for vegan spreads with fish-like sensory attributes, adhering to clean-label formulation principles and considering essential oils as natural flavouring, stabilising, and preservative agents. The workshop was designed as a structured, facilitator-led, multi-phase process, integrating exploratory, analytical, and hands-on activities to guide participants from perception elicitation to prototype development. The design of the session was informed by key findings from the consumer survey, particularly in relation to consumer preferences, perceived barriers, and expectations regarding fish-like vegan spreads. Participants were provided with a structured set of facilitation tools designed to support each stage of the process. These included: (i) word association templates used during the warm-up activity to capture spontaneous perceptions of key ingredients; (ii) benchmarking analysis worksheets used for the market exploration task; (iii) ingredient information cards covering pulses, seaweeds, spices, edible oils, and essential oils, which summarized their sensory characteristics, nutritional composition, health-related properties, and potential technological functions; (iv) standardized recipe development templates used to document prototype formulations, including ingredient composition, product name, and additional observations related to taste, aftertaste, odour, colour, texture, consistency, and other relevant sensory characteristics; and (v) LEGO® Serious Play® bricks and accompanying instruction sheets used during the Jobs-to-be-Done activity.

More specifically, the survey findings were translated into practical design criteria for the workshop.

Key findings from the consumer survey were presented to participants at the beginning of the co-creation session through a short introductory presentation supported by summary slides. The presentation focused on the main factors influencing spread purchase decisions, such as quality of ingredients, taste and sensory acceptability, availability, acceptable price and presence of additives.

Consequently, the survey did not serve only as a preliminary market assessment, but functioned as a direct input for workshop design, prototype development, and subsequent Jobs-to-be-Done exploration. Participants provided written informed consent, received information on data protection, and signed a non-disclosure agreement to ensure confidentiality.

The co-creation process consisted of the following sequential phases:

- (1) **Exploration of perceptions and ingredients:** A warm-up activity based on a **word association task (WAT)** (Ares et al., 2008; Amyoony et al., 2023) was used to stimulate intuitive thinking and elicit spontaneous perceptions related to key ingredients (*pulses, oils, spices, essential oils, and seaweed*). Participants individually recorded the first three words associated with each stimulus on printed templates (approx. 5 min). This approach enabled the capture of immediate cognitive and sensory

associations, providing insight into participants' expectations and potential acceptance drivers. Responses were subsequently cleaned and standardised, and thematically categorised (e.g., sensory attributes, health and diet). Term frequencies were calculated for each ingredient, and the results were summarised in frequency tables and visualised as word clouds using **XLSTAT, 2025.2.0** (Addinsoft, NY, USA).

- (2) **Market exploration and benchmarking activity:** To contextualise product development, participants worked in small mixed stakeholder groups to explore fish-like vegan spreads and seaweed-based products available on domestic and international markets using online resources. Given that fish-like vegan spreads are currently not commercially available on the Serbian market, participants were primarily exposed to international examples, reflecting both the novelty of this product category in the local context and one of the key motivations for this study. Groups analysed product characteristics, ingredients, and market positioning. Each group briefly shared their insights (approx. 20 min) enabling knowledge circulation and alignment of perspectives across stakeholders. This phase aimed to establish a shared understanding of existing solutions and to identify gaps and opportunities for innovation.
- (3) **Hands-on concept development and prototype creation:** Participants developed early-stage vegan spread prototypes using pre-prepared legume-based spreads (lentil, chickpea, faba bean and tahini base in accordance to Makhouloufi and Yamani (2024)), seaweed powders (nori and wakame), selection of spices, oils (sunflower, olive, linseed and high-oleic sunflower oil), and selected essential oils (basil, winter savory, cumin, caraway and dill) (Šojić et al., 2023; Đorđević et al., 2025). Ingredient information cards describing sensory and functional properties were provided. Groups documented formulations using standardised templates, assigned product names, and defined target consumers and market positioning. All formulations were prepared following standard hygienic and food safety procedures. All prototype formulations were prepared at laboratory scale in batches of 1000 g per formulation. Minor ingredients, including spices and seaweed powder, were weighed individually using a laboratory balance with a readability of 0.01 g. After weighing, these ingredients were first dispersed in a small portion of the base matrix and then incorporated into the full batch to improve homogeneous distribution. Before prototype preparation, participants received a short practical briefing on the formulation procedure, ingredient handling, use of the laboratory balance, and mixing steps. The preparation process was conducted under the supervision of the research team and food technologists, who monitored and checked the weighing of minor ingredients and supported participants when needed. Four prototype concepts were developed and presented by the groups at the end of the session (approx. 60 min).
- (4) **Rapid expert sensory screening and quality assessment:** Recognising that the co-created prototypes represent early-stage conceptual solutions rather than fully optimised products, this component at this stage was designed as a rapid sensory screening and quality control assessment rather than a formal descriptive sensory panel. In agile co-creation frameworks, expert-based screening must precede more rigorous evaluation to filter out unfeasible ideas early, saving time and resources (Nnadiogbulam et al., 2025). Furthermore, expert involvement during early refinement stages is important for assessing formulation feasibility and identifying major sensory or quality defects. Accordingly, the rapid in-situ assessment was conducted by a three-member expert jury with experience in sensory evaluation of spread-type products, consistent with the specifications of DIN 10,964, which defines a minimum of three assessors as sufficient for conducting a simple descriptive test (DIN 10964:2014-11). In

addition, previous food sensory research has shown that small expert trained assessment can provide consistent and useful assessments in targeted product-quality evaluation contexts (Lozano et al., 2023). However, due to the small number of experts involved, the findings in the present study should be interpreted as exploratory screening only. The primary objective was to provide immediate expert feedback on formulation viability, identify potential off-flavours, and performs a basic quality screening of the four fish-like vegan spread prototypes generated during the co-creation session. Samples were coded with three-digit numbers and delivered monadically in a balanced order in plastic containers with lids. Each prototype was assessed using a structured 5-point scale (*Supplementary Material 4*) for the key quality attributes of appearance (colour and homogeneity), odour (evaluated by smelling the sample directly in the jar), taste (saltiness, acidity), overall flavour balance, texture spreadability (application on bread), and graininess (perception during consumption) and overall quality. It is important to note that in the context of this expert screening, the term “acceptability” was strictly operationalized as technological viability and the absence of critical defects, rather than hedonic consumer liking. Scores and qualitative comments were recorded on standardized evaluation forms to guide further product refinement. The scores obtained during the rapid expert sensory screening were summarized descriptively. For each prototype and attribute, a single aggregated score was presented for visualization purposes. No inferential statistical analysis was performed for these data. However, it is explicitly acknowledged that due to the limited number of expert assessors, this statistical approach served strictly exploratory and screening purposes to identify consistent descriptive trends, rather than generating statistically robust conclusions.

- (5) **Jobs-to-be-Done and LEGO® Serious Play®:** Recognizing that play stimulates creativity in both children and adults (Ind and Coates, 2013) and that gamification enhances engagement and enjoyment (Chou, 2019), LEGO® Serious Play® (LSP) sets were provided to participants to foster active involvement and creative storytelling. To explore stakeholder perspectives on the functional, emotional, and social “jobs” that the new spreads could fulfil, a Jobs-to-be-Done (JTBD) role-play session was conducted using the LSP methodology (Ulwick, 2017; Vrgović et al., 2022; Kokkorou et al., 2024). It is crucial to clarify the scope and timing of this activity: the session was conducted after the initial prototype development and rapid expert sensory screening. Therefore, the JTBD activities did not inform the initial prototype formulation. Furthermore, the JTBD exercise did not refer to innovative spreads in general, but utilized the specific winning prototype (Sample 1/2) as a tangible “boundary object” to explicitly inform its future commercial refinement, packaging, and market positioning. At the beginning of the session, participants received a brief introduction to the LSP approach as a creative facilitation tool that uses physical modelling to visualize ideas. Participants were introduced to the basic principles: those ideas are expressed tangibly through bricks, and that there are no “right” or “wrong” models, importance lies in the symbolic meaning the builder attributes to their creation. Working in four groups, participants were asked to develop a story and model inspired by the selected winning prototype. Each group represented one specific stakeholder role: (1) consumers focused on sensory preferences and functionality; (2) food technologists addressed formulation, quality, and safety; (3) marketing experts concentrated on branding and positioning; and (4) retailers/distributors tackled logistics and pricing constraints. Each group developed a LEGO model, symbolizing the ideal characteristics, challenges, and positioning of the winning spread from their assigned perspective, and accompanying narrative representing

the role and value of the product from their assigned perspective. The analytical approach was qualitative and interpretive: researchers systematically analysed both the physical structural elements of the models (e.g., specific blocks symbolising distribution flows or formulation stability) and the associated verbal narratives, and thematically mapped the insights into functional, emotional, and social job dimensions (Ulwick, 2017). These JTBD insights were subsequently used to identify key product requirements and inform further refinement and market-oriented positioning of the selected prototypes.

3.4. Expert technological evaluation

Following the conclusion of the co-creation workshop and in contrast to the quality screening which provided real-time, in-situ feedback, a structured, post-session evaluation of the prototypes was by a panel of three experienced food technologists. Each concept was independently rated by five-point scale (1-very low to 5-very high) for *originality* (novelty and uniqueness), *feasibility* (clarity and ease of implementation), and *effectiveness* (ability to meet consumer and market needs), as previously used by Vrgović et al., 2022. The individual ratings from all three experts were aggregated to calculate a cumulative score for each dimension (maximum 15 points per dimension) and an overall total score (maximum 45 points per concept). Concepts with the highest cumulative scores were selected for further refinement in the subsequent product development phase.

4. Results

4.1. Phase 1: consumer survey on attitudes toward fish-like vegan spreads

4.1.1. Sample description and general dietary patterns

The socio-demographic characteristics and general dietary habits of the sample (n = 1000) are detailed in Table 1. The sample was stratified by gender, age group, and region of residence to reflect the 2022 Census of Population, Households, and Dwellings (*Statistical Office of the Republic of Serbia*). The respondents represented a diverse consumer base; the majority were urban residents, had completed secondary or higher education, and were actively employed, with half of the sample indicating above-average household income.

Regarding dietary patterns and openness to new foods, the vast majority followed omnivorous diet (94%). However, more than half of the respondents (52%) expressed a general self-reported willingness to try new foods, and a similar proportion (54%) indicated a readiness to adjust their current diet for health reasons. Planned future dietary adjustments most often involved increasing the consumption of fish (42%) and plant-based foods (41%). In terms of general dietary information, Serbian consumers predominantly accessed data through informal channels such as the Internet (44%) and peer recommendations (43%), rather than through professional expert sources (22%).

4.1.2. Spread consumption patterns and selection criteria

Overall consumption of spreads was generally low across all categories (*Supplementary Material 2, Table 1*). Conventional meat-based spreads were consumed most frequently (22% several times weekly), followed by fish-based spreads (14%) and plant-based spreads (14%). Notably, nearly half of the respondents (46%) reported not consuming plant-based spreads at all, confirming their current niche market position. When evaluating factors that influence purchasing decisions for spreads in general (Table 2), consumers prioritized intrinsic product attributes. Specifically, ingredient quality and sensory acceptability ranked highest, followed by availability and price. Health-related attributes and convenience were moderately important, whereas environmental, ethical, and advertising factors were rated as the least important. The analysis confirmed that the consumer prioritization of intrinsic attributes (such as ingredient quality and sensory acceptability)

Table 2
Factors influencing consumer purchasing decisions for spreads (scale 1–5).

Attribute	Mean ^a	SD	Percentage of max score (%)	Rank
Quality of ingredients	4.18 ^a	0.99	83.6	1
Taste and sensory acceptability	4.07 ^{ab}	1.13	81.3	2
Availability	4.02 ^{ab}	1.02	80.4	3
Acceptable price	4.00 ^{ab}	1.03	80.0	4
Presence of additives	3.86 ^{bc}	1.12	77.1	5
I like spreads	3.82 ^{bc}	1.10	76.4	6
Nutritional value (health aspect)	3.81 ^{bc}	1.13	76.2	7
Convenience for consumption	3.80 ^{bcd}	1.17	76.1	8
Promotions or discounts	3.74 ^{cde}	1.20	74.8	9
Manufacturer and brand	3.71 ^{cde}	1.16	74.1	10
Recommendations from friends/family	3.69 ^{cde}	1.16	73.8	11
Presence of functional ingredients	3.55 ^{def}	1.18	71.1	12
Recommendations from professionals	3.53 ^{def}	1.24	70.6	13
Fat content	3.45 ^{efg}	1.19	69.0	14
Labels (organic, vegan, GMO-free)	3.41 ^{efg}	1.32	68.1	15
Free from trans fats	3.29 ^{gh}	1.30	65.8	16
Alternative to meat-based spreads	3.25 ^{gh}	1.28	65.0	17
Environmental factors	3.20 ^{gh}	1.27	64.0	18
Ethical factors	3.05 ^h	1.30	60.9	19
Advertisements	2.98 ^h	1.32	59.5	20

^a Means followed by different superscript letters are significantly different ($p < 0.05$) according to Friedman's test and Nemenyi's post-hoc test.

over extrinsic claims (such as environmental, ethical, and advertising factors) was statistically significant ($p < 0.05$).

4.1.3. Consumer attitudes towards fish-like vegan spreads

In a landlocked country like Serbia, awareness of fish-like vegan spreads was limited (Supplementary Material 3, Table 2). Over half of the respondents (52%) had not heard of them, 42% were aware, and 6% were unsure. Chi-square analysis confirmed that awareness was significantly influenced by demographic factors, being higher among women ($\chi^2 = 9.075$, $p = 0.011$), middle-aged respondents ($\chi^2 = 29.335$, $p < 0.0001$), and urban consumers ($\chi^2 = 11.174$, $p = 0.004$). Similarly, the vast majority of respondents (71%) had never tried a fish-like vegan spread. While gender did not significantly affect trial rates ($p = 0.500$), actual adoption was significantly higher among urban residents ($\chi^2 = 20.082$, $p < 0.0001$) and specific age groups, particularly the 30–44 cohort ($\chi^2 = 53.408$, $p < 0.0001$). Consumer views on fish-like vegan spreads as direct fish substitutes were mixed: 37% considered them suitable, 38% disagreed, and 25% remained uncertain. The combined 63% of supportive and undecided respondents indicates a receptive market base. This acceptance was significantly shaped by age ($\chi^2 = 44.281$, $p < 0.0001$) and place of residence ($\chi^2 = 19.775$, $p < 0.0001$), with urban and middle-aged consumers showing the highest acceptance, while gender showed a borderline effect ($p = 0.050$). Regarding price sensitivity, consumer expectations were high. Almost a quarter of respondents (23%) expected vegan fish-like spreads to be priced at least 30% lower than conventional fish spreads, while only 13% (combined) were willing to accept premium pricing (+10% or more). Statistical validation confirmed that price flexibility was significantly influenced by gender ($\chi^2 = 25.650$, $p = 0.001$), age ($\chi^2 = 46.517$, $p = 0.001$), and residence ($\chi^2 = 31.869$, $p < 0.0001$). Specifically, women, urban, and middle-aged consumers demonstrated greater price flexibility, whereas men, rural, and older segments strongly preferred discounts.

When asked specifically which product labels would influence their decision to buy a fish-like vegan spread (Table 3), consumer preferences strongly emphasized clean-label attributes. The label claims included in the evaluation were selected to reflect the intended positioning of the

Table 3
Influence of product labels on consumer purchasing decisions for vegan fish-like spreads.

Attribute	Mean ^a	SD	% of max score	Rank
No additives	0.350 ^a	0.477	35.0	1
GMO-free	0.350 ^a	0.477	35.0	1
High protein	0.298 ^b	0.458	29.8	3
Fasting-friendly	0.295 ^{bc}	0.456	29.5	4
Trans fat-free	0.237 ^{cd}	0.425	23.7	5
Gluten-free	0.213 ^{cd}	0.410	21.3	6
Low fat	0.198 ^{cd}	0.399	19.8	7
Organic/Bio	0.197 ^d	0.398	19.7	8
Low salt	0.180 ^d	0.384	18.0	9
Vegan	0.142 ^e	0.349	14.2	10
None	0.126 ^{ef}	0.332	12.6	11
Don't know	0.112 ^{efg}	0.316	11.2	12
Lactose-free	0.098 ^{efg}	0.297	9.8	13
Special diets (e.g., keto, paleo)	0.077 ^{fg}	0.267	7.7	14
Certifications (Kosher/Halal)	0.060 ^g	0.238	6.0	15

^a Means followed by different superscript letters are significantly different ($p < 0.05$) according to Cochran's Q test and McNemar's post-hoc procedure.

**Note: The claims listed in the table represent the set of attributes evaluated in the survey and should not be interpreted as an exhaustive list of possible nutrition, health, sustainability, or clean-label claims.

prototypes and the attributes considered most relevant for early-stage consumer-oriented assessment of plant-based fish-like spreads, including vegan suitability, fasting suitability, clean-label expectations, sustainability, and avoidance of controversial ingredients. They were not intended to represent an exhaustive list of possible nutrition or health claims. Claims such as “source of fibre”, “reduced fat”, or “source of protein” were not included in the evaluated set of label claims. We acknowledge that their inclusion would have provided a more comprehensive and product-relevant assessment, particularly for pulse-based spread formulations. In the context of this study, “fasting-friendly” referred to products suitable for consumption during Orthodox Christian fasting periods, when meat, dairy, eggs are avoided, but fish could be consumed. Within the evaluated set of claims, “no additives” and “GMO-free” were rated highest (both 35%), followed by “high protein content” (30%) and suitability for “fasting” (30%). The GMO-free claim was included as a consumer perception attribute rather than as a formulation-related criterion. Although the cultivation and commercial placing on the market of genetically modified organisms and GMO-containing products are prohibited under the current Serbian regulatory framework, GMO-related concerns may still influence consumer attitudes towards novel and processed plant-based foods. Conversely, organic, religious certifications, and special-diet claims ranked lowest among the evaluated labels. Results confirmed that the consumer preference for clean-label claims (no additives, GMO-free) over sustainability (organic) or niche dietary labels was statistically significant ($p < 0.05$).

4.2. Phase 2: co-creation session

4.2.1. Word association task and consumers perceptions

After workshop introduction, the participants took part in the word-association task which revealed clear consumer perceptions of key ingredients relevant for spread formulation (Fig. 2).

Hummus was mainly associated with ingredients and the product itself, reflecting a clear and well-established consumer understanding. Health- and diet-related associations followed, while sensory and cultural aspects played a secondary role. *Edible oils* were primarily connected with cooking and salads. Health-related perceptions were mixed, while some participants referred to cold-pressed and plant-based oils, others highlighted calorie content and the need for moderate use, reflecting simultaneous health interest and restraint. *Essential oils* were associated with aroma, relaxation, naturalness, and ambience, but were rarely linked to cooking or spreads, indicating limited culinary

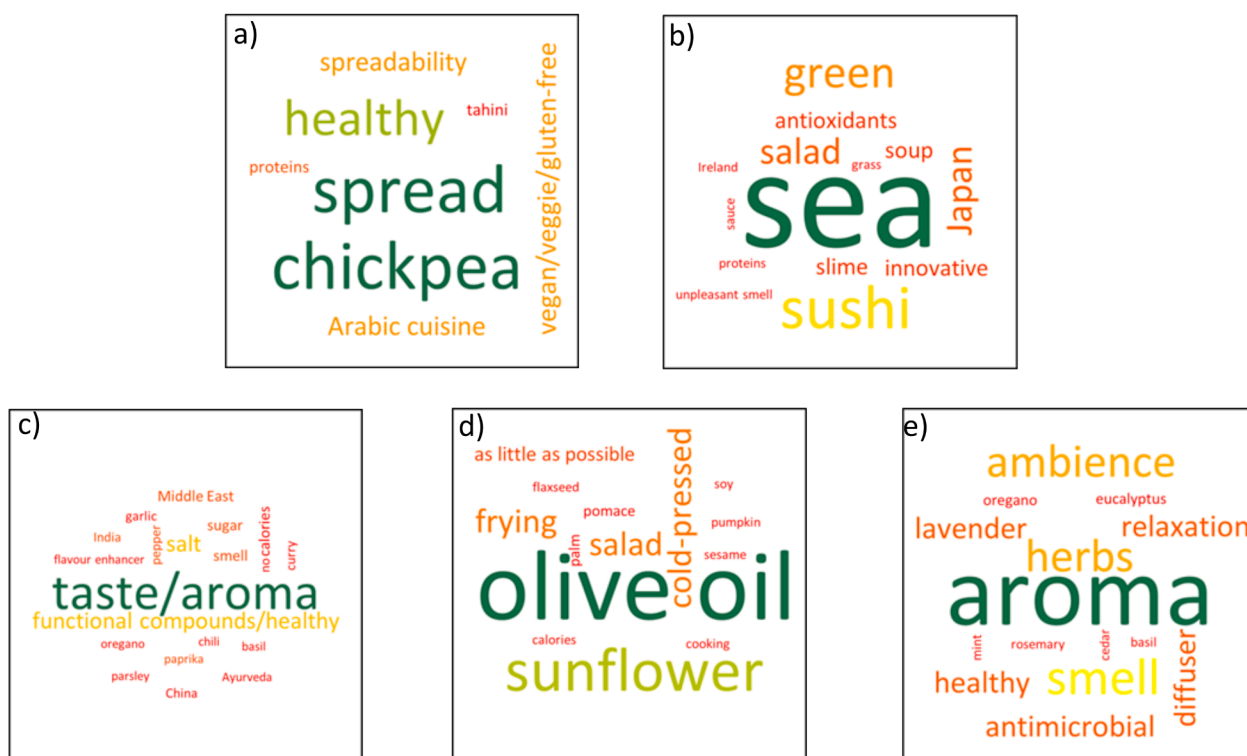


Fig. 2. Word clouds based on word association task (a – Hummus, b – Seaweed, c- Spices, D- Edible oils, e - Essential oils) (approximately here).

familiarity and potential uncertainty about their role in food products. *Spices* generated associations centred on taste, aroma, and culinary enhancement, as well as functional qualities such as antimicrobial effects and the absence of calories; suggesting awareness of their dual

sensory and health-related nature. *Seaweed* generated the most polarised responses. Positive associations included marine origin, sushi, salads, soups, and functional benefits such as antioxidants and proteins. However, participants also expressed negative associations related to slimy

Table 4

Fish-like spread prototypes developed by workshop participants.

Sample	Name	Picture	Base	Spices	Oils	Seaweed
1/2	"Bezkontaktno sočivo"		lentils (89.67%)	salt (1.34%) pepper (0.36%) garlic (0.36%) ginger (0.09%)	olive oil (8.07%)	nori (0.09%)
2/2	"Quatro Nori"		chickpeas (67.61%) fava beans (28.98%)	garlic (0.29%) salt (0.68%) lemon juice (0.39%) hot paprika (0.05%)	olive oil (1.93%)	nori (0.10%)
3/2	"Algamaz"		chickpeas (75.47%)	salt (1.16%) garlic (1.08%) parsley (0.5%)	olive oil (20.01%)	nori (1.08%) wakame (0.7%)
4/2	"Wake Me Up"		lentils (83.8%)	salt (1,5 %) onion (0,7 %) basil (0,3%)	olive oil (12.00%)	wakame (1,7 %)

texture, unpleasant odour, and unfamiliarity, highlighting pronounced sensory and cultural barriers.

4.2.2. Benchmarking of fish-like vegan spreads on the global market

The benchmarking task revealed that the global offer of fish-like vegan spreads is still very limited, and participants struggled to locate commercially available ready-to eat products. Instead, most identified examples encompassed online recipes, such as seaweed-enriched hummus or homemade legume spreads, rather than industrially produced spreads. To compensate this lack of direct benchmarks, other seaweed-based products were also explored to identify relevant sensory and formulation strategies. Across the collected examples, several patterns were identified. Most products and recipes relied on legumes, soy, pea protein, vegetable oils, and seaweed or algae-derived ingredients to achieve marine-like flavours, often supported by smoked notes and spices. Clean-label attributes (GMO-free, no additives, high protein content, omega-3 enrichment) were commonly emphasized, whereby the products were typically marketed within premium or niche segments, highlighting sustainability and overfishing reduction. Sensory attributes described online often included creamy, smoky, umami, or sea-like notes, although some consumer reviews also pointed to undesirable, off-flavours or strong artificial marine tones.

4.2.3. Co-created vegan spreads with fish-like sensory attributes

Based on insights from the benchmarking task, participants developed four pulse-based spread prototypes enriched with seaweeds using familiar spread formats to incorporate marine-derived ingredients (Table 4). The prototypes combined pre-prepared pulse bases, seaweed powder (e.g. nori or wakame), spices, edible oils and essential allowing groups to adjust flavour balance, texture and visual appearance. Although, essential oils were provided and introduced as optional ingredients (Ebrahimzadeh et al., 2023), none of the groups chose to include them in their formulations. Instead, participants relied on familiar spices such as garlic, paprika, parsley, and salt. Across all groups seaweed was incorporated cautiously and in relatively low amounts to avoid dominant marine notes, while essential oils were not incorporated at all, indicating a clear preference for familiar spices and traditional flavour profiles.

4.2.4. Rapid in-situ expert sensory screening and quality assessment

Prior to the Jobs-to-be-Done session, a rapid in-situ screening was conducted by a three-member sensory expert jury to evaluate the viability, overall formulation and sensory direction, and the presence of critical defects in the developed prototypes. The experts assessed each prototype across nine attributes using a 1–5 scale. The individual expert scores are presented in *Supplementary Material 4, Table 3*, while descriptive mean scores by sample are presented in *Supplementary Material 4, Table 4*. Fig. 3 presents descriptive mean scores calculated from the three expert assessments for each prototype and attribute. The figure aims to plot the single value for each of the 4 groups only to visualize the differences between samples, as no statistical differences among prototypes are reported. Descriptively, sample 1/2 received the most favourable evaluations overall, particularly for odour, overall flavour balance, saltiness, acidity, and overall quality. Sample 2/2 obtained the lowest scores across these attributes. Samples 3/2 and 4/2 showed intermediate performances, with sample 4/2 demonstrating slightly higher scores for odour and spreadability.

Based on the outcomes of the rapid expert screening, Sample 1/2 (“Bezkontaktno sočivo”) received the most favourable evaluations overall and emerged as the most promising candidate. Consequently, this specific prototype was selected as the central focal point for the subsequent Jobs-to-be-Done (JTBD) and LEGO® Serious Play® activities. Using a tangible prototype allowed stakeholders to move beyond abstract ideation and practically explore the functional, emotional, and social value propositions of the selected spread.

4.2.5. Jobs-to-be-Done using LEGO® Serious Play®

The four LEGO® Serious Play® models created during the Jobs-to-be-Done part of the session revealed distinct stakeholder interpretations of the roles that plant-based fish-like spreads should fulfil. Although developed independently, the models and accompanying narratives suggested alignment with four stakeholder roles: consumer, food technologist/product developer, marketing expert, and retailer/distributor (Fig. 4).

4.2.5.1. Model 1 – food technologist perspective. This model highlighted formulation-related challenges, including product stability, flavour

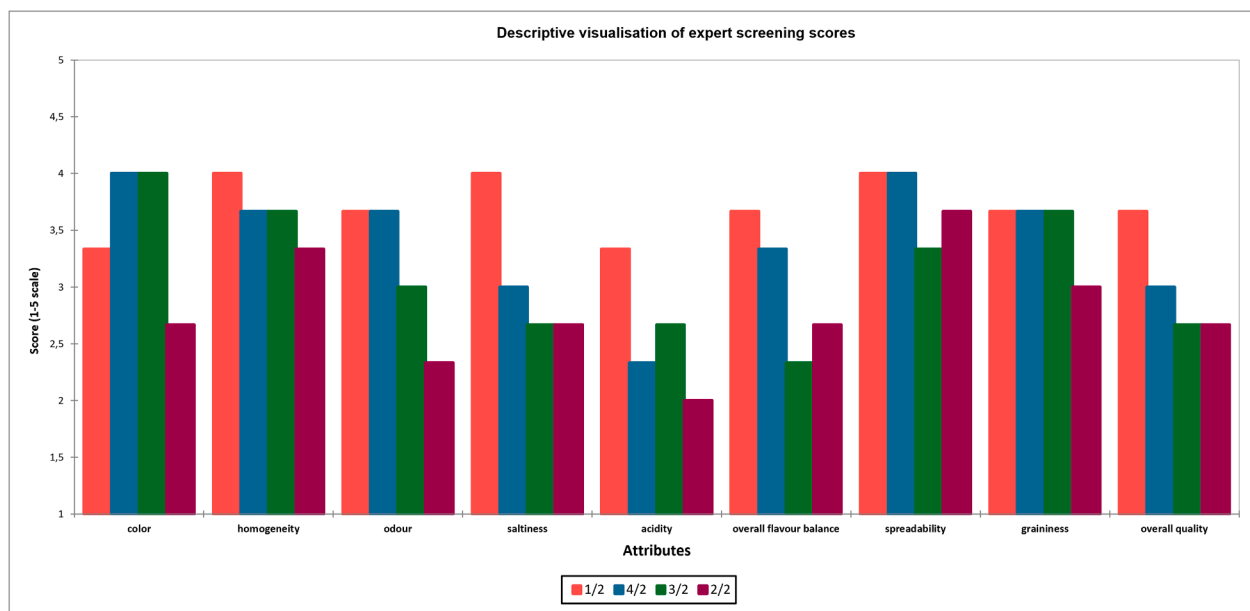


Fig. 3. Descriptive mean scores of the four prototypes using 1–5 scale. (approximately here).

Note: The scale: 1 – Unacceptable: Technologically unfeasible with critical defects; 2 – Slightly unacceptable: Major limitations requiring substantial reformulation; 3 – OK: Technologically viable but with noticeable flaws requiring refinement; 4 – Acceptable: Technologically sound with only minor, non-critical defects; 5 – Extremely acceptable: Optimal technological performance, completely defect-free.

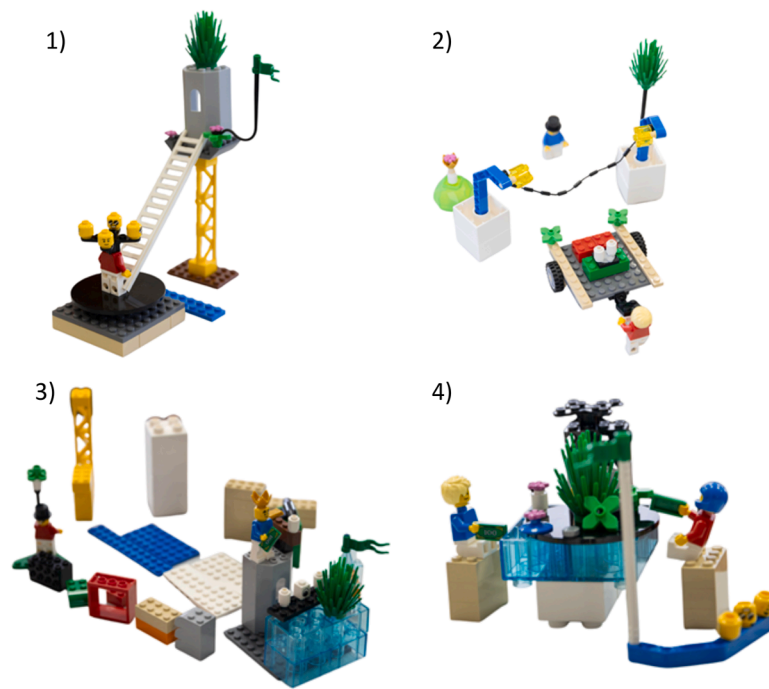


Fig. 4. Jobs-to-be-Done Lego models created by participants (1-food technologist, 2-retailer, 3-marketing expert, 4-consumer) (approximately here).

authenticity, texture optimisation, and clean-label compliance. Participants emphasized challenges in achieving balanced marine-like sensory notes using algae or seaweed while maintaining acceptable colour, texture and nutritional profile. Sustainability considerations were also important. These interpretations were based on key structural elements of the LEGO model (e.g. elevated base, ladder, and functional components symbolising ingredient functionality, formulation stability and process control and the participants' verbal explanations).

4.2.5.2. Model 2 – retailer/distributor perspective. The second model focused on logistics, accessibility, and market feasibility. Structural elements (e.g. modular blocks, wheels, and connected towers) used symbolised distribution flow, shelf placement, and cost-efficient delivery, pointing to the importance of affordability, risk management, and reliable supply chains. The core “job” identified was ensuring that innovative plant-based spreads can be efficiently distributed and made accessible to consumers.

4.2.5.3. Model 3 – marketing expert perspective. This model emphasized product visibility, identity, labelling and differentiation. Bright colours and elevated elements reflected the importance of branding, storytelling and emotional appeal, while marine-related elements symbolised sustainability and novelty. From this perspective, the product's key “job” was to communicate lifestyle values, sustainability, and curiosity through a distinctive and recognisable plant-based alternative.

4.2.5.4. Model 4 – consumer perspective. The consumer model, reflected through Lego figures arranged around a central food element and shared structures, was focused on shared eating, ease of use, familiarity and product versatility. Participants described the spread as a product intended for everyday consumption, social interaction, and integration into existing meal routines.

Taken together, the models confirmed that plant-based fish-like plant-based spreads are perceived as products expected to address multiple stakeholder needs across the value chain. Technologists primarily emphasised formulation performance, marketers focused on identity and differentiation, retailers' highlighted accessibility and logistics, while consumers highlighted sensory pleasure, familiarity, and

social use.

4.3. Phase III: food technologists' expert evaluation

The developed spread prototypes were evaluated by a panel of three experienced food technologists. Each concept was independently rated for originality (novelty and uniqueness), feasibility (clarity and ease of implementation), and effectiveness (ability to meet consumer and market needs) using 5-point scales (Table 5). Concepts with the highest cumulative scores were identified for further refinement in subsequent product development phases. As shown in Table 5, originality scores were uniformly high, with three out of four samples achieving perfect scores (15/15).

Feasibility was evaluated equally across all prototypes (14/15), indicating that all proposed formulations was considered technologically achievable and practical for implementation, regardless of conceptual differences. The most pronounced differences between prototypes emerged in the effectiveness dimension. Sample 2/2 achieved the highest effectiveness score and the highest overall total (44/45), reflecting strong alignment with expert perceptions of consumer relevance and market potential. Samples 1/2 and 4/2 followed closely (43/45), while Sample 3/2 received the lowest overall score (40/45) primarily due to lower effectiveness and originality ratings. Based on the comprehensive expert evaluations, Sample 2/2 emerged as the primary candidate for future commercial development, while Samples 1/2 and 4/2 represent viable alternatives for parallel optimization. Conversely, Sample 3/2 requires substantial conceptual and sensory refinement before advancing to later development stages.

The evaluation process revealed an insightful divergence between rapid in-situ expert sensory screening and quality assessment and long-term commercial viability. While Sample 1/2 achieved the most favourable evaluations in the rapid sensory and quality screening due to its optimal flavour balance and absence of off-flavours, making it the ideal conceptual model for the subsequent JTBD LEGO® session, Sample 2/2 emerged as the most promising candidate during the technological evaluation. This distinction highlights that while Sample 1/2 currently excels in immediate organoleptic appeal; Sample 2/2 demonstrates superior 'effectiveness' in terms of market alignment, scalability, and long-

Table 5
Technological assessment by originality, feasibility and effectiveness.

Sample	Originality 1	Originality 2	Originality 3	Sum Originality	Feasibility 1	Feasibility 2	Feasibility 3	Sum Feasibility	Effectiveness1	Effectiveness 2	Effectiveness 3	Sum Effectiveness	Sum Total
1/2	5	5	5	15	5	5	4	14	5	4	5	14	43
2/2	5	5	5	15	5	5	4	14	5	5	5	15	44
3/2	4	5	4	13	5	5	4	14	5	4	4	13	40
4/2	5	5	5	15	5	5	4	14	5	4	5	14	43

term commercial potential. Such findings underscore the multidimensional nature of food co-creation, demonstrating that sensory optimization (represented by Sample 1/2) and technological viability (represented by Sample 2/2) often require parallel refinement tracks before a final market launch. Finally, sample 1/2 was selected as the boundary object for the JTBD activity because it achieved the highest descriptive scores during the rapid quality assessment screening. However, the subsequent technological assessment identified Sample 2/2 as the concept with the strongest overall commercial-development potential.

5. Discussion

5.1. The power of integrating large-scale consumer insights with co-creation

This study demonstrates how the integration of large-scale consumer insights with participatory co-creation and expert evaluation can support the development of novel, sensory-complex food products such as fish-like vegan spreads. Rather than treating these components as separate research steps, the applied multi-phase approach enabled a continuous translation from market understanding to product design and evaluation. The findings from the consumer survey provided a clear picture of the current market landscape, revealing that fish-based and plant-based spreads remain niche products within a predominantly omnivorous population, which is consistent with national dietary trends (Milešević et al., 2024). The survey identified key market-related barriers and drivers, including limited awareness, low previous exposure, and uncertainty regarding suitability as a fish alternative, price sensitivity, and the importance of ingredient quality, sensory acceptability, and selected label claims (Henn et al., 2022). In contrast, sensory concerns toward unfamiliar marine ingredients, particularly seaweed, emerged during the subsequent word association and co-creation activities.

By introducing the survey-derived findings as strict boundary conditions at the beginning of the co-creation workshop, the multidisciplinary teams were able to focus their ideation on overcoming these specific barriers. This sequential integration aligns with recent frameworks in participatory food design, demonstrating that combining broad quantitative data with deep qualitative co-creation significantly enhances the market relevance of new food products (Vrgović et al., 2022; Nnadiębulam et al., 2025).

5.2. Overcoming sensory barriers through familiar formats and cautious formulation

The survey results highlighted that consumer decision-making in this category is strongly driven by intrinsic product attributes, particularly sensory acceptability, while sustainability and ethical claims play a secondary role. This aligns with previous research demonstrating that sensory characteristics remain the dominant drivers of acceptance for plant-based and seaweed-enriched foods (van Trijp and van Kleef, 2008; Tuorila and Hartmann, 2020; Jönsson et al., 2024). Furthermore, the limited awareness and low prior exposure to fish-like vegan spreads reflect the generally low consumption of seaweed in Western contexts compared to Asian countries (Murai et al., 2021; Fichoux et al., 2022). To mitigate this inherent sensory uncertainty, the choice of a spread-based format was a deliberate product design strategy. Unlike meat or fish analogues that replicate whole-muscle formats (e.g., burgers or fillets), spreads utilize a highly familiar convenience format that effectively lowers the psychological barrier to novel ingredients. The co-creation word association task further confirmed this necessity, revealing polarised responses to seaweed that combined positive health associations with negative sensory expectations regarding odour and texture. Consequently, during the hands-on prototyping phase, participants adopted a risk-mitigation approach: essential oils were avoided,

seaweed was used cautiously, and preference was given to familiar spices (Mani-López et al., 2017). Such findings highlight that co-creation not only generates ideas but also reveals implicit constraints, enabling the translation of abstract consumer attitudes into realistic, market-ready formulation decisions.

5.3. Technological validation and early-stage expert screening

Following the ideation phase, the rapid expert screening provided preliminary guidance for the refinement and prioritisation of co-created concepts based on their technological feasibility and market alignment. The high originality scores across the prototypes reflect the growing relevance of seaweed as a nutritionally rich, sustainable ingredient within the expanding global algae market (Wells et al., 2017; Diaz et al., 2023; Tagliapietra et al., 2023). Furthermore, uniformly high feasibility scores confirmed that legume-based spread formulations represent a highly viable and stable platform for plant-based seafood innovation (Pointke and Pawelzik, 2022). In contrast, the variation observed in the effectiveness scores highlighted the central role of consumer alignment. Successful concepts were those that managed to balance ingredient innovation with familiarity and sensory acceptability. This is consistent with evidence that the acceptance of seaweed-enriched products heavily depends on their ability to seamlessly fit existing consumption habits (Losada-López, 2021; Cappelli, 2022; Govaerts and Olsen, 2023; Stewart-Knox and Mitchell, 2003). By employing a rapid expert screening at this stage, unfeasible formulation attributes were efficiently filtered out prior to further commercial refinement.

5.4. Jobs-to-be-Done and multi-stakeholder value mapping

Although LEGO® Serious Play® has been reported as a hands-on, metaphor-based facilitation method in co-creative workshop settings (Al-Jayyousi and Durugbo, 2020; Zenk et al., 2022), its application in food product development remains relatively limited. Previous studies have demonstrated its potential for generating and refining food product concepts together with consumers (Vrgović et al., 2022). However, co-creation in new food product development has more commonly relied on methods such as focus groups, workshops, surveys, and online platforms to integrate consumer and stakeholder perspectives into the early stages of innovation (McCusker, 2020; Pinesso Ribeiro et al., 2025). The present study extends these earlier applications by embedding LEGO® Serious Play® within a broader multi-phase innovation framework that integrates large-scale consumer survey data, hands-on prototype development, rapid expert screening, and Jobs-to-be-Done analysis. Rather than serving solely as a concept-generation tool, LEGO® Serious Play® was used to explore the functional, emotional, and social value propositions of the most promising prototype identified during the co-creation process. This is particularly relevant for plant-based seafood analogues, where sensory and formulation-related challenges, including flavour, aroma, texture, appearance, and overall consumer acceptance, remain central barriers to successful market adoption (Abotsi et al., 2024; Appiani et al., 2025). Therefore, a key added value of this study lies in the application of the Jobs-to-be-Done (JTBD) framework through LEGO® Serious Play®, which extended the product development of the winning prototype beyond basic formulation toward comprehensive value creation across the food system. The stakeholder-generated models revealed that fish-like vegan spreads are expected to fulfil multiple roles simultaneously, including technological stability, market accessibility, sensory satisfaction, and social usability. These findings align with previous research demonstrating that successful food innovation requires alignment across functional, emotional, and social dimensions (Ulwick, 2017; Kokkorou et al., 2024). Specifically, the JTBD framework enabled the identification of concrete product requirements related to convenience, familiarity, affordability, and clear marketing communication. Taken together, the results confirm that integrating quantitative consumer insights with participatory

co-creation and JTBD-based value mapping represents a highly robust framework for early-stage food innovation. This approach ensures that creativity remains firmly anchored in real market constraints, resulting in solutions that are both technologically innovative and deeply consumer-relevant.

6. Study limitations

This study has several limitations that should be considered when interpreting the findings. First, the sensory evaluation was conducted with a small expert jury ($n = 3$), which limits statistical power and the generalisation of the results. Future research should therefore include a trained sensory panel and an adequate number of assessors, which would provide more robust, reproducible, and objective characterization of sensory attributes through calibrated assessors and standardized descriptive methods. In addition, larger consumer panels should be involved to validate the observed sensory trends in terms of acceptance, preference, and market relevance, thereby ensuring a comprehensive understanding of both product sensory properties and consumer perception. Second, participants in the co-creation workshop were primarily drawn from the regional food innovation ecosystem. Although this is fully aligned with Living Lab principles and early-stage participatory design, broader inclusion of chefs, retailers, and specialised product developers would further enrich concept diversity. The market research was conducted in Serbia, a landlocked country with limited cultural exposure to marine ingredients. This contextual specificity may have influenced certain attitudes towards seaweed or fish-like plant-based spreads. However, the study was designed as a case study aimed at developing and testing a transferable co-creation framework rather than achieving universal generalisability. The questionnaire may serve as a basis for future studies in other countries, but it should be culturally and contextually adapted before use. The label-related findings should be interpreted with caution, as the evaluated claims represented an exploratory and non-exhaustive set. Some relevant nutrition claims for pulse-based products, such as “source of fibre” and “source of protein”, were not included. In addition, “GMO-free” should be understood as a consumer perception and trust-related attribute rather than as a formulation or regulatory requirement in the Serbian context. Future studies should include a more balanced and regulation-aligned set of packaging claims.

Finally, prototype development took place under workshop conditions. Although seaweed and essential oils were introduced as potential ingredients, they were not systematically explored through controlled formulation trials. As a result, the sensory and technological insights reflect early exploratory concepts rather than fully optimised products. These limitations reflect the intentional scope of this study, which focused on developing, piloting, and validating a multi-phase co-creation methodology for early-stage food innovation. The JTBD outputs are qualitative and exploratory in nature and should therefore be interpreted as stakeholder-generated insights rather than validated consumer requirements. The proposed framework can be applied to a wide range of food categories, and its future application through multiple workshops, larger stakeholder groups, and an expanded set of prototypes will enhance robustness while maintaining the methodological foundations established here.

7. Conclusion

This study demonstrated that integrating consumer research, multi-stakeholder co-creation, and expert evaluation offers a powerful approach for early-stage development of innovative plant-based products. Although applied to vegan spreads with fish-like sensory attributes, the proposed framework is modular and transferable across food and non-food product categories. Consumer insights confirmed that sensory quality and clean-label cues are more influential for acceptance than sustainability messaging alone, while psychological barriers such as

food neophobia and limited familiarity with marine ingredients remain critical challenges. The JTBD exercise extended product development beyond formulation by identifying functional, emotional, and social requirements relevant for future refinement and commercialization. Co-created prototypes highlighted a preference for familiar sensory profiles, underscoring the importance of balancing innovation with recognisability. Overall, this work provides both practical guidance for industry and a transferable methodological blueprint for consumer-driven innovation. The findings confirm that early-stage collaborative design can successfully accelerate the development of sustainable, sensory-appelling alternatives aligned with contemporary dietary trends.

Ethical statement

The study protocol was approved by the Ethics Committee of the Institute of Food Technology in Novi Sad by Decision of Approval No 24–49 (13 May 2024) and Decision of Approval No 24–50 (13 May 2024).

Participation was voluntary, and informed consent was obtained from all participants.

CRedit authorship contribution statement

Dragana Ubiparip: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Miloš Županjac:** Writing – original draft, Resources, Investigation, Conceptualization. **Predrag Ikonjić:** Writing – review & editing, Supervision, Investigation. **Branislav Šojić:** Supervision, Investigation, Conceptualization. **Dubravka Škrobot:** Methodology, Investigation, Conceptualization. **Milica Pojić:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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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This manuscript aligns with Sustainable Development Goals 2 (“Zero Hunger”), 9 (“Industry, Innovation and Infrastructure”) 12 (“Responsible Consumption and Production”), 14 (“Life Below Water”) and 17 (“Partnerships for the Goals”) by synthesizing advances in innovative

and scalable processing strategies, sustainable ingredients, circular resource use, and the valorisation of underutilized marine resources in and multi-stakeholder collaboration in innovative spread formulations.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.fufo.2026.101159](https://doi.org/10.1016/j.fufo.2026.101159).

Data availability

Data will be made available on request.

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