Design and assessment of protein-fortified recipes for community-dwelling older adults to prevent the onset of undernutrition

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Alexia Geny[1*], Shiori Koga[2], Rachel Smith[3], Guro Helgesdotter Rognså[2], Céline Brasse[4], Ida Synnøve Grini[2], Isabelle Maître[4], Gilles Feron[1], Miriam Clegg[5], Lisa Methven[3], Øydis Ueland[2], Virginie Van Wymelbeke-Delannoy[1,6], Claire Sulmont-Rossé[1]

[1] Centre des Sciences du Goût et de l'Alimentation, CNRS, INRAE, Institut Agro, Université de Bourgogne Franche-Comté, F-21000 Dijon, France

[2] Nofima AS, Postboks 210, 1431 Ås, Norway

[3] Department of Food and Nutritional Sciences, University of Reading, Whiteknights, Reading, RG6 6AP, UK

[4] GRAPPE, ESA, USC n°1422, INRAE 49007, Angers, France

[5] School of Food and Nutritional Sciences, University College Cork, Ireland

[6] CHU Dijon Bourgogne, Unité de recherche Pôle Personnes Âgées, Dijon, France

[*]Corresponding author: alexia.geny@inrae.fr

Abstract

Introduction. Public health guidelines recommend food fortification (adding ingredients of nutritional importance into commonly consumed foods) to help older adults achieve sufficient protein intake. Despite the nutritional benefits of food fortification, there is a significant gap between nutritional research and sensory acceptance, which can limit older adults' compliance to fortified foods. The present study aimed at developing and testing the feasibility and liking of using "Do it yourself" protein-fortified recipes that could be easily prepared at home in France, Norway and the UK.

Materials and methods. A market review was conducted to identify available high-protein ingredients (n=140). After screening for sensory, nutritional, food technology, and regulatory characteristics, two high-protein ingredients were selected: milk protein powder (isolate) and organic soya mince (extruded). In parallel, common food matrices that could serve as relevant candidates for fortification were identified through 4-day food diaries collected with 65 respondents in France, Norway, and the UK. Eight dishes were selected for recipe fortification and paired with high-protein ingredients (+ 6 to 11g of protein per portion, mean=8.1, SD=2.3). Then, these fortified recipes were assessed for ease-of-use and acceptability in a home-use trial with healthy older adults in the three countries (> 70 years; n=158). Participants made the recipes themselves at home using their own cooking equipment.

Results. Feedback from participants indicated that they found the recipes easy to follow and to prepare themselves. The fortified recipes were liked (mean liking from 5.3 to 5.9 on a 7-point scale) and perceived as being easy to chew, moisten (humidify in mouth) and swallow. More than 50% of the participants were willing to make the recipes again in the future and liked the fortified version equally or more to their usual recipes.

Discussion. Making the recipes by themselves at home removed participants' barriers to using high-protein ingredients. Furthermore, participants modified dishes to their liking by adjusting seasoning and texture to their preference underling the flexibility of the fortification strategy.

Keywords

Aging, enrichment, fortification, malnutrition, protein, older adults, food, liking, feasibility, co-creation

Introduction

As individuals age, ensuring adequate protein intake and quality becomes a critical aspect of maintaining health and preserving autonomy. Protein quality is determined by the presence of all essential amino acids and by the protein's bioavailability. Protein recommendations for older adults are well-established, with the majority of European countries agreeing that protein intake should increase with age, for example to 1.0–1.2 g/kg body weight/day from the 0.70-0.75g/kg body weight/day typically recommended for the general population (Deutz et al. 2014). Yet, a challenge arises in meeting recommended protein intake, often exacerbated by a phenomenon known as the "*anorexia of aging*" (Donini et al., 2003; Giezenaar et al., 2016). This term refers to a multifaceted decline in appetite and food intake among older adults, which can significantly impact their ability to achieve optimal protein intake. Several factors contribute to this phenomenon, including changes in taste perception, diminished olfactory sensitivity, dental issues, diseases and various health conditions, the use of prescription medicines, or decrease of psychological health (Donini et al., 2003; Landi et al., 2016; Schwartz et al., 2018). These physiological changes not only lead to a reduced desire for food but also contribute to inadequate nutrient intake, particularly protein (Giezenaar et al., 2016; Landi et al., 2016; Ter Borg et al., 2015; Van der Meij et al., 2017).

Insufficient protein intake in older adults increases the risk of undernutrition and sarcopenia, a condition marked by the loss of muscle mass and strength (Cruz-Jentoft et al., 2019). In addition, protein undernutrition, leads to consequences such as altered immune function, a decrease in muscle reserve and increased state of frailty (Dent et al., 2023; Ferry, 2012). This dual burden compromises physical function, independence and overall quality of life for older individuals.

To prevent these adverse consequences on health, public health authorities recommend to use enrichment strategies (HAS, 2007; Helsedirektoratet, 2016; National Health Service (NHS), 2017). Among them, food fortification has been identified as an effective strategy to increase protein intake in the older adults (Douglas et al., 2017; Geny et al., 2023; Morilla-Herrera et al., 2016; Sossen et al., 2021). This strategy involves the deliberate addition of essential nutrients - particularly protein - to food items, aiming to improve their nutritional quality. This

strategy offers a flexible approach that aligns well with the dietary habits and preferences of older individuals, allowing fortificants to be seamlessly incorporated into familiar foods (Smith et al., 2022).

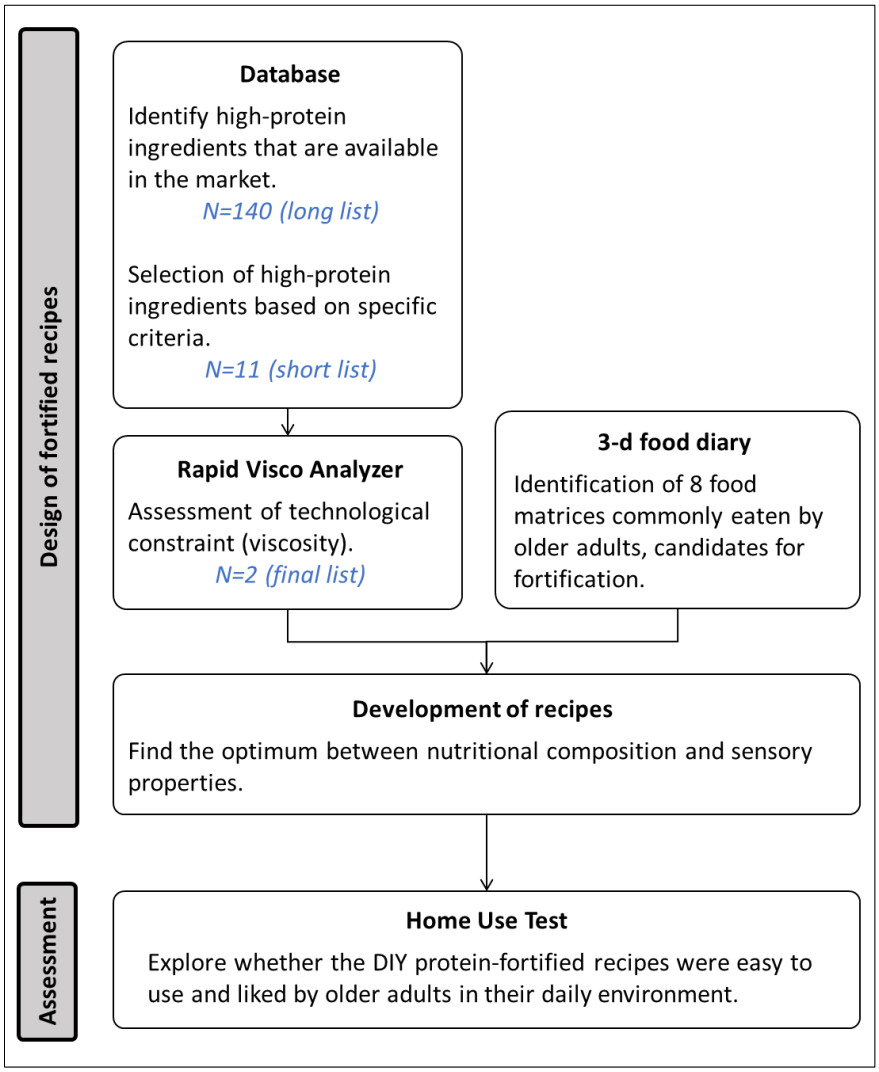
Despite the nutritional benefits of food fortification, there is a significant gap between nutritional research and sensory acceptance, which can limit older adults' compliance to fortified foods. Recent research has highlighted this disparity, showing that very few studies have assessed the acceptability of fortified products in older adults (11 out of 44 papers), underlining the need for a multidisciplinary approach when developing fortified foods targeting older adults (Geny et al., 2023). It is essential to understand the preferences and needs of older adults to design products that they not only consume for nutritional purposes, but also enjoy eating. This is more likely to guarantee widespread and sustained consumption of fortified foods. Therefore, it is important to develop food products targeting older individuals *with* the involvement of older consumers (Sulmont-Rossé et al., 2018; Maitre et al., 2015). Indeed, Van Wymelbeke et al. (2020) demonstrated that enhancing food sensory properties based on older individuals' sensory evaluations resulted in a significant increase in food intake.

Moreover, Geny et al. (2023) illustrated the wide variability in additional energy and protein provided by fortified food across different studies. This additional load varied from 23 to 850 kcal / day for energy (M = 403; SE= 62) and from 4 to 40g / day for protein (M = 19; SE= 2). For practical purposes, it is possible to fortify with regular food ingredients commonly found in a kitchen such as eggs, almonds, grated cheese; however the protein content of such ingredients varies (*e.g.*, egg: 13% protein, almonds: 23% protein, grated cheese: 28% protein from Ciqual French food composition table (ANSES, 2020)). Additionally, these ingredients provide limited amounts of protein. Alternatively, it is possible to fortify by adding high-protein ingredients in the form of concentrated protein powders (> 50% protein). These high-protein ingredients can be either animal-based, such as whey protein isolate, or plant-based, such as soy protein isolate. As high-protein ingredients have a higher protein content, they can be added at a lower level than regular food ingredients to achieve the same extent of fortification, which limits meal portion size. According to our knowledge, there is no documentation that has investigated whether there are available commercial high-protein ingredients that can be used to fortify a large set of recipes.

A qualitative study done within the JPI HDHL project “FORTIPHY” by Smith et al. (2024) explored older adults' attitudes, knowledge, and preferences for “do it yourself” (DIY) protein fortification, including barriers and opportunities. Results from this study revealed a notable lack of awareness among older adults regarding their increased need for protein. Participants were open to learn more about their protein needs and the importance of incorporating more protein into their diets. Additionally, older adults and caregivers preferred to use quick cooking methods when fortifying meals. The study therefore recommended that DIY fortified meals should incorporate ingredients which could be used efficiently. Moreover, there was a consensus that fortificants should be "invisible" meaning they should be integrated during the meal preparation process rather than added directly before eating. Furthermore, the participants emphasized that DIY fortified foods should not negatively compromise the taste and smell of the food, highlighting the importance of maintaining the sensory properties of their meals. From our initial study (Smith et al., 2024), results underscored the importance of developing strategies that incorporate fortificants during cooking into foods older people usually eat, without compromising the sensory aspects of the final meal. As fortifying common recipes may lead to changes in sensory characteristics and usability aspects of dishes (Liu et al., 2022; Norton et al., 2020, 2021; Wendin et al., 2017), there is a need to investigate limits and consequences of such changes.

In this context, it seems important to explore food fortification solutions considering older adults’ insights. The present paper highlights the development process of fortified foods designed for and validated by older adults living at home. The objective was to develop fortified recipes that provided an additional load of 8-14g of protein and 250-300 kcal for one individual food portion, which is approximately the half the average daily deficit observed in older small eaters (Sulmont-Rossé & Van Wymelbeke, 2019). We hypothesise that (i) a review of high-protein ingredients will allow us to select two versatile ingredients that can be incorporated into various food matrices, and (ii) combining technological and sensory tests will enable the development of fortified foods that are accepted by the target population. The present paper is divided in two parts: the design of the fortified recipes (preliminary research) and its assessment among community-dwelling older adults (main research) (**Figure 1**).

Figure 1. Flowchart of development process of fortified foods.



1. Design – Preliminary research

1.1. Development of a database for high-protein ingredients

An online market review was conducted in 2021 to identify high-protein ingredients that are available in the worldwide market for business-to-business (B2B) and business-to-consumer (B2C) purposes. It was conducted by consulting suppliers' websites and using information available on the internet. Each ingredient was then entered into an online database detailing its general characteristics and specific characteristics (regulatory, technological, sensory and nutritional) completed from experience of project experts, technical information from suppliers when available, and internet information. The database has been built on a website, which can be exported in Excel format. The database is available on request.

General characteristics. This section included information about the ingredient's name, the supplier's name, the form (solid, liquid, semi-solid), the price, the packaging, the nutritional composition and additional information available on websites (recipes, recommendations for use).

Regulatory characteristics. This section included information about the size of the market, i.e. business-to-business (B2B; accessible to professionals only) and business-to-consumer (B2C; accessible to consumers). It also helped to identify restrictions related to safety regulations, marketing authorisation and packaging (storage, preservation, shelf life, expiry date…). These factors are crucial in the final selection of the product, within the scope of this project it was not acceptable if only authorised in one specific country and not in other European countries.

Technological characteristics. This section included information about preparation time, temperature of use, solubility, emulsifying and foaming capacity. It allowed an assessment of flexibility of use, solubility in water (and/or oil), textural properties and functionalities (such as thickness, aggregation and foaming) and any associated limitations.

Sensory characteristics. This section includes information about the colour, taste and texture attributes of the ingredient. It also considered whether the ingredient significantly altered the initial colour of the food (e.g. a green ingredient would significantly affect the colour of mashed potatoes) or texture leading to difficulties in oral consumption (chewing, salivation, swallowing).

Nutritional characteristics. This section included information about the protein content, essential amino acid composition (EAA) and protein digestibility (Protein Digestibility Corrected Amino Acid Score, PCDASS, if available on the supplier's website).

The database identified 140 high-protein ingredients or components. Certain data remained unknown as the database relied on information availability. The ingredients were evenly split between animal and plant-based origin, with 49.3% each; and 1.4% of the ingredients were a mixture of animal and plant-based proteins (**Supplementary File A**). The majority of the ingredients (79%) had a protein content of more than 50%, regardless of their origin. On average, the protein content was 67.5 ± 24.7 g/100g ranging from 2g/100g to 100g/100g. The

products were predominantly solids (96%; of which mainly in powder form), while the remaining 4% were in liquid form.

From this database, a shortlist was drawn up by the panel of experts of the project (sensory, nutritional, food technology, regulatory). Three criteria were defined from a priori knowledge: (i) to include products with a protein content of at least 50%, (ii) to include both animal and plant-based products, and (iii) to include well-known protein sources such as whey or soya proteins, as well as more unusual protein sources such as potato or rice proteins. The choice was refined by the experts based on the information gathered for each section. Each section (sensory, nutritional, food technology, regulatory) was evaluated for how suitable it would be to incorporate into the recipes by at least two experts involved in the project, based only on the available information about the ingredient. For each section, the experts gave an overall judgment ("*Yes*"/ "*Some concerns*"/ "*No*") on the feasibility of using the ingredient. If one product led to a "*Some concerns*" or "*No*" judgement whatever the section, it was not retained at the end. **Supplementary File B** displays the 12 ingredients that passed the evaluation for the short list. All ingredients are solid (dry) and protein content was more than 75%, except PrOatein (LANTMÄNNEN) and Organic soya mince (CLEARSPRING).

1.2. Technological assessment

1.2.1. Assessment of the viscosity of high-protein ingredients

The viscosity of 11 high-protein ingredients was measured with a Rapid Visco Analyzer (RVA; PerkinElmer, Massachusetts, US). Organic soya mince (CLEARSPRING) in the shortlist was excluded from the analyses because it was a heat-extruded product rather than a powder and, as such was not expected to cause the same potential textural issues as the protein powders. RVA measurements were carried out with 10 % (w/w) protein for all high-protein ingredients (except for soy protein powder (PURASANA) and Solanic potato protein (AVEBE). Both Soy protein powder (PURASANA) and Solanic potato protein (AVEBE) were difficult to disperse in liquid and gave too high viscosity to measure with RVA at 10 %; therefore, analysis was carried out at 5 % for both high-protein ingredients. All high-protein ingredients were tested into three different liquids: (i) water, (ii) skimmed milk (0.1g/100g fat with 5.9g/100g protein fortified milk from Tine, Norway; pH 6.7) and (iii) tomato juice (Rynkeby, Denmark; pH 4.4).

The method profile of the RVA is detailed in the **Supplementary File C.** Viscosity at 80˚C/5 min and final viscosity at 30˚C/20 min were recorded.

The high-protein ingredients did not increase the viscosity when heated at 80˚C, except PrOatein (LANTMÄNNEN) and Solanic potato protein (AVEBE) (**Supplementary File D-A**). Viscosity was much higher when PrOatein (LANTMÄNNEN) was measured with milk and tomato juice. On the other hand, Solanic potato protein (AVEBE) showed high viscosity with water, while it was much lower with milk and tomato juice. Whey proteins from two different suppliers also demonstrated a slight increase in viscosity when analysed with milk. When the protein mixture was cooled down at the end of the analyses (**Supplementary File D-B**), the viscosity of PrOatein mixtures (LANTMÄNNEN), Solanic potato protein (AVEBE) with water and milk, and whey protein concentrate (PURASANA) with milk further increased.

Whey protein formed relatively large aggregates when compared to Whey protein concentrate (PURASANA), Milk protein powder (DELICAL) and Micellar casein (MY PROTEIN). Such large aggregates can give a poor mouthfeel. The hydrolysed collagen powder (Forteocare, NUTRISENS) was considered to be did not change matrix colour, odourless and tasteless, and did not influence the texture. Such collagen peptides have been found to have protein digestibility-corrected amino acid scores lower than whey, but to maintained nitrogen balance and preserve lean body mass in older women (Hays et al., 2009). Solanic potato proteins (AVEBE) resulted in a dark, unpleasant colour and high viscosity when heated with water and milk. The viscosity was lower when heated with tomato juice; however, large aggregates were formed, which can affect mouthfeel negatively. The essential amino acid (EAA) powder (THE PROTEIN WORKS) had a strong bitter taste, which limited the addition that could be achieved without affecting the taste. Rice protein (PURASANA) and Veggie protein (BIOTONA) were less soluble and did not disperse evenly in the liquids, resulting in a sandy texture; additionally these high-protein ingredients precipitated when the protein mixture was left for some time. Moreover, both Rice protein (PURASANA) and Veggie protein (BIOTONA) had a rancid odour before their best-before dates, even when the products were stored correctly (dry, dark and ambient temperature). This suggested these ingredients may result in an unpleasant taste and odour of the final products. From these assessments, Protein powder (DELICAL), PrOatein (LANTMÄNNEN), Soy protein powder (PURASANA), Micellar

casein (MY PROTEIN), and Whey protein concentrate (PURASANA) were selected for the next stage of testing, measuring viscosity in oatmeal porridge.

1.2.2. Assessment of the technological constraints of high-protein ingredients in oatmeal porridge.

To investigate how the addition of high-protein ingredients influenced the viscosity in food matrices, oatmeal porridge was chosen as a model food matrix and tested with Rapid Visco Analyzer as a pilot study (RVA; PerkinElmer, Massachusetts, US). The method profile for the RVA, detailed in the **Supplementary File E**, was adjusted according to the procedure for making oatmeal porridge. One portion of oatmeal porridge is 290g, consisting of 40g oat flakes and 250g liquid, according to the manufacturer's instructions. The liquid used was whole milk (3.3g/100g protein, 275kJ/100g energy). The addition of 3g or 6g of protein was tested into one oatmeal porridge portion to maintain a good dispersion in liquid for RVA measurements; with the specific high-protein ingredients amount calculated according to its protein content. For the RVA analysis, the formulations were calculated to be 28.5g in total weight (oatmeal and milk with, and without, high-protein ingredients). Moreover, the colour, texture and taste of the protein mixture after RVA measurements were evaluated by project team members.

The viscosity of oatmeal porridge samples, with and without high-protein ingredients, is shown in **Supplementary File F**. The addition of Whey protein concentrate (PURASANA) to oatmeal porridge resulted in the highest viscosity (and noticeably the thickest consistency), indicating an unpleasant porridge texture. Plant-based protein sources (*i.e.,* Soy protein powder - PURASANA and PrOatein - LANTMÄNNEN) gave somewhat higher viscosity compared to Milk protein powder (DELICAL) and Micellar casein (MY PROTEIN). The addition of 3g proteins by Soy protein powder (PURASANA) noticeably influenced the taste (at resulted in a strong soya taste). On the other hand, no dramatic taste change was observed by the addition of PrOatein (LANTMÄNNEN), Micellar casein (MY PROTEIN), and Milk protein powder (DELICAL). Therefore, these high-protein ingredients were tested with an increased amount (6g protein into one oatmeal porridge portion). The viscosity of oatmeal porridge did not increase with the increased addition (6g) amount of the protein powders (**Supplementary File G**). Increased amounts of PrOatein (LANTMÄNNEN) resulted in grainy (coarse) texture, while milk taste was noticeably enhanced when the amount of Micellar casein (MY PROTEIN) and

Protein powder (DELICAL) was increased. The results between Micellar casein (MY PROTEIN) and Milk protein powder (DELICAL) were similar for both viscosity, texture and taste. When the protein content was of the ingredients compared, the Milk protein powder (DELICAL) has a higher protein content (86 %) compared to Micellar casein (MY PROTEIN) (76 %); indicating the addition level would be slightly smaller for Milk protein powder (DELICAL) compared to Micellar casein (MY PROTEIN) to achieve the same protein fortification.

From these assessments, Milk protein powder (DELICAL) was chosen as the candidate for the animal-based high-protein ingredient. Organic soya mince (CLEARSPRING) was chosen as the candidate for the plant-based high-protein ingredient as it offers different texture options that are interesting for recipe development (raw: crispy, crunchy; rehydrated: meaty texture). The additional level of high-protein ingredients needs to be investigated not only for the protein levels to be achieved but also for each food recipe and sensory acceptance (texture and taste) of the dish in order to be accepted by the target population.

1.3. Selection of the dishes

The following criteria were established to select 8 to 10 dishes as a basis for developing DIY protein-fortified recipes:

- They should be commonly consumed by older adults in the majority of the target countries (*i.e.*, France, Norway, UK).

- They should encompass a variety of dishes, including savoury and sweet options as well as solid, semi-liquid, and liquid food matrices to reflect the diverse foods consumed in daily life.

- They should have a high potential for fortification at both the food scale and at a scale of the full scale (*i.e.,* it is simpler to incorporate high-protein ingredients into a carrot soup rather than into whole carrot sticks). Preference was given to dishes with low protein content (*i.e.,* vegetables, potatoes, sweet foods) over protein-rich sources (*i.e.*, meat and fish). Additionally, emphasis was placed on including dishes suitable for breakfast, acknowledging the lower protein intake typically associated with this meal compared to lunch and dinner (Lonnie et al., 2018).

To achieve this, a study was conducted to gather 4-day food diaries from older adults in France, Norway and UK, aimed at identifying commonly consumed dishes among older adults in these countries (Ueland et al., 2023). Participants were required to complete a food diary for 4 days – 3 weekdays and 1 weekend day, with the aim to cover their usual eating habits on these days that they were cooking at home (not including meals that they ate out somewhere else). They were asked to report:

- Time of food/drink consumption
- Description of food/drink (and brand if available)
- Preparation/cooking method
- Estimated amount consumed/portion size (ing or ml)

Participants were provided with a food atlas along with the food diary, including portion pictures (Hercberg et al., 2002) and household measures to assist in estimating portion sizes.

Recruitment of participants and eligibility criteria were the same as the main research (see section *2.1* for more details). Sixty-five participants completed the food diary study in their native language (France: n=21, 11 women, age mean: 77.9, age range: 70-90; Norway: n=24, 20 women, age mean: 76.7, age range: 70-89; UK: n=20, 14 women, age mean: 78.3, age range; 70-90).

All entries in the food diaries were translated into English by the authors and entered into a shared database with the personal participant data anonymised. Word clouds were constructed for each country and meal to identify common food matrices that could serve as good candidates for developing fortified recipes (Ueland et al., 2023). The eight dishes selected are presented in **Table 1**.

Table 1. Presentation of the selected fortified recipes.

Recipe	Form	Taste	Temperature	Targeted time of the day
Bolognese sauce	Solid	Savoury	Hot	Lunch/dinner
Carrot soup	Liquid	Savoury	Hot	Lunch/dinner
Mashed potatoes	Semi-solid	Savoury	Hot	Lunch/dinner
French toast	Solid	Savoury/sweet	Hot/cold	Breakfast/lunch/snacks/dinner/dessert
Granola	Solid	Sweet	Cold	Breakfast/snacks/dessert
Pancakes	Solid	Sweet	Hot/cold	Breakfast/snacks/dessert
Porridge	Semi-solid	Sweet	Hot/cold	Breakfast
Vanilla cake	Solid	Sweet	Hot/cold	Breakfast/snacks/dessert

314 It should be noted that porridge is not commonly consumed in France, but it emerged as a
315 good candidate in the other two countries, particularly for increasing protein intake during
316 breakfast. Therefore, we chose to retain this dish in the list for further consideration.

317 1.4. Development of protein-fortified recipes

318 Fortified recipes were developed by a researcher with extensive product development
319 experience (co-author GHR). Portions sizes were estimated based on commercial
320 recommendations and/or the food diaries described above, to determine typical portion sizes
321 older adults serve themselves. Objectives of additional protein and calorie load are detailed
322 in the introduction. This additional protein and calorie load were reached by using regular
323 food ingredients (*e.g.,* dairy products, nuts, eggs, oil, butter) and/or the high-protein
324 ingredients selected in the previous step (milk protein powder (isolate) - DELICAL© or organic
325 soya mince (extruded) - CLEARSPRING©). Between 14 to 66 % of this additional protein load
326 in each dish was provided by high-protein ingredients. The nutritional composition of fortified
327 recipes is displayed in **Table 2**. Pictures of the fortified recipes are available in **Supplementary**
328 **File H**.

Table 2. Nutritional composition of the fortified recipes (per portion).

Product	kcal*	Protein (g)*	Carbohydrate (g)*	Lipid (g)*	Portion (g)	Additional protein load (g)*	Additional regular protein-rich ingredients	High-protein ingredients
Bolognese sauce	292	18.3	7.4	20.3	180	+ 9.0	Ground almonds	Organic soya mince (CLEARSPRING) [a]
Carrot soup	421	13.0	9.8	36.0	250	+ 11.2	Ground almonds	Milk protein powder (DELICAL) [b]
Mashed potatoes	307	9.4	19.5	22.6	180	+ 6.0	None	Milk protein powder (DELICAL) [b]
French toast	438	17.4	43.8	20.2	210	+ 10.2	Quark or Fromage blanc	None
Granola	237	9.7	16.8	13.5	50	+ 6.2	None	Organic soya mince (CLEARSPRING) [a]
Pancakes	321	13.9	17.8	21.1	130	+ 5.7	Ground almonds Quark or Fromage blanc	Milk protein powder (DELICAL) [b]
Porridge	382	22.7	26.7	19.8	250	+ 10.1	None	Milk protein powder (DELICAL) [b]
Vanilla cake	274	9.8	26.8	21.9	75	+ 6.2	Ground almonds Quark or Fromage blanc	Milk protein powder (DELICAL) [b]

* Additional protein load compared to the standard unfortified recipe (g per portion). [a] Extruded soya mince. [b] Milk protein isolate.

For the mashed potatoes, pancakes and vanilla cake, it was not possible to reach an additional load of 8g of protein per portion as this adversely affected the sensory properties (making the recipe too thick, too different from the original or too dry). Granola was designed to be consumed together with a dairy product (*e.g.,* quark, skyr yoghurt, fromage blanc or high protein milk) which taken together increases total protein content. It was also difficult to increase the energy in the fortified recipes by 250-300 kcal while keeping an equivalent portion size, without substantially degrading the sensory characteristics. Some recipes were further modified with subtle changes in relation to which ingredients were available in each country (*e.g., quark* - a soft cheese with 10% protein -was available in Norway and the UK, buts substituted by *fromage frais (fromage blanc) 0% fat*, 8% protein in France).

2. Assessment – Main research

A home-use trial was designed for older adults to explore whether the DIY protein-fortified recipes were easy to use and liked by older adults in their daily environment.

2.1. Materials and methods

Participants.

Participants were recruited in France, Norway and UK via e-mails using laboratories' participants databases (FR, NO, UK), through local groups, clubs, associations (FR, NO, UK), social media (UK) or snow-balling (NO). Participants were eligible if they were 70 years old or over, lived independently at home and were responsible of cooking most of the meals. Exclusion criteria were suffering from food allergies or intolerances, following a very restrictive diet (such as vegan diet, low salt/sugar) or on an enteral/parenteral diet, or a texture-modified diet, suffering from acute disease, or having not spent the majority of their life in the country concerned (France, Norway, or UK; due to the need to exclude participants who may be unfamiliar with the corresponding culinary culture). Experimental procedure and data collection were approved by national ethic committee (see *ethical statements* section). All participants provided written informed consent to take part. In return for their participation, they received a voucher.

Sample size was calculated to detect a difference of 0.8 point on the 7-point hedonic category scale. Considering an average standard deviation (SD) of 2.26 for liking score in older people (Maitre et al., 2015), a minimum of 51 participants was required for each test (power=0.80; α=0.05).

Products.

Eight fortified recipes were used as described in section *2.2.* Porridge was excluded in France as it is not a commonly consumed food there.

Procedure.

The home use trial (HUT) took place from April 2022 to September 2022. Participants were instructed to prepare protein-fortified recipes themselves in their homes using their own cooking equipment. The participants received a package consisting of: written instructions of the study, eight questionnaires, a final questionnaire, high-protein ingredients clearly marked for each recipe. In addition, a fortification schema was provided to participants to present the fortification process and high-protein ingredients, explaining their benefits and conditions of use (**Supplementary File I**). Each participant was tasked with making each protein-fortified recipe once and completing the corresponding recipe questionnaire (the *recipe questionnaire presentation* section provides more detail). When receiving the study materials, including the two high-protein ingredients, participants had the flexibility to choose when to prepare each recipe but were required to complete all recipes within a month. Subsequently, participants were requested to fill out a final questionnaire developed by the authors, addressing their experience of the fortification process. Participants returned the questionnaires via post. This paper focuses on the findings from the recipes questionnaire, while results from the fortification questionnaire are documented in Smith et al. (2024).

Recipe questionnaire presentation.

The recipe questionnaire was developed by the authors to assess various aspects related the preparation, liking, sensory perception and future use of each protein-fortified recipe (**Appendix A**).

Preparation. Participants were asked about various aspects of the preparation process, such as the need for assistance (2 options: "*yes*", "*no*"), the easiness to understand the instructions and cooking the recipe (5 options: "*very easy*", "*easy*", "*neither easy nor difficult*", "*difficult*", "*very difficult*"), their perception of the preparation time (5 options: "*very short*", "*short*", "*not short, nor long*", "*long*", "*very long*"). They were also asked about any challenges encountered when incorporating high-protein ingredients and any adjustments they made to the recipe. The purpose of these questions was to gather insights into participants' experiences during the preparation process.

Liking. The liking of the sample on a 7-point category scale combining labels and pictograms raging from "*strongly dislike*" on the left to "*strongly like*" on the right. This scale was previously validated for older adults (Maitre et al., 2015).

Sensory perception. The assessment of sensory perception encompassed:

- The ease of chewing, moistening and swallowing the sample (food oral processing questions, FOP) on 5-point category scales. Scales ranged from "*very easy*" to "*very difficult*" (Vandenberghe-Descamps et al., 2018).

- For the Check-All-That-Apply (CATA) evaluation, a generic list of attributes suitable for a broad spectrum of food products (sweet, salty, liquid, solid, etc.) was established, including the attributes frequently associated with fortified foods in previous studies (Liu et al., 2022; Norton et al., 2020, 2021; Tsikritzi et al., 2015; Mingioni, Pirttijärvi, et al. 2016; Wendin et al., 2017) and, as far as possible, their antonyms (Ares & Jaeger, 2015). The CATA evaluation with 23 attributes focused on both texture and taste: moist/juicy, firm/hard, dry (it made my mouth dry), smooth, soft, crunchy/crispy, sticky, liquid, dry (the food was dry), tasty, creamy, floury/powdery, spicy, thick, pasty (like a paste), dense, light, lumpy/grainy, tasteless, oily, mouthcoating (I felt it coat the inside my mouth), pungent, off-flavour. The participants were asked to check all terms that they considered appropriate to describe each sample.

Future use. Two questions were asked with single choice ordinal scales (i) "*Do you plan to make this recipe again in the near future?*" (4 options: *"yes, most definitely", "yes, probably",*

"no, probably not", "no, most definitely not"), and (ii) "*Do you prefer this version of the dish or the version you usually prepare?*" (5 options: *"I prefer this version (fortified)"*, *"I prefer what I was doing before"*, *"I like both equally"*, *"I would usually buy this food pre-made, so I do not usually prepare it myself"*, *"I don't usually eat this food"*).

Throughout questionnaire, free comments were collected for suggestions of recipe improvement. Participants were asked to follow the recipes closely so they could comment on what worked well or needed to be changed in the future, however they were asked to write it down if they did need to change anything.

Data analysis.

Liking scale was converted to scores ranging from 1 (*strongly disliked*) to 7 (*strongly liked*). Scaled responses (FOP – chewing, moistening, swallowing; feasibility – instructions, cooking) were converted into scores ranging from -2 (*very difficult*) to 2 (*very easy*). After checking for normality, one sample Wilcoxon test was done against the reference "0" (*neither difficult nor easy*).

As the continuous data was not normally distributed, analysis of differences between countries needed to be done for each individual product, using Kruskal-Wallis test and *country* as factor. Dunn's procedure was applied as a post hoc test with Bonferroni correction. For qualitative data (dichotomous variables), Chi-squared test or Fisher exact test was done demonstrating pairwise comparisons between countries using Fisher exact test with Bonferroni correction.

Correspondence Analysis (CA). A Correspondence Analysis (CA; Greenacre, 2017) was conducted on the *product x attribute* frequency table in order to visualize the associations between recipes and attributes.

Partial Least Square regression (PLS). In order to identify which attributes were best linked to liking, a Partial Least Square regression (PLS; Tenenhaus et al., 2005) was performed with mean liking of each recipe as target and the attributes' citation frequencies as predictors.

Free comments. Free comments were standardised and analysed according to Symoneaux et al. (2012): translating, typing, spelling and grammatical errors were corrected manually.

Different information written into the same sentence were separated, synonymous were merged into a common term. Thematic analysis was then performed.

Descriptive statistics are shown as median with interquartile range (IQR) for non-parametric data, means with standard deviations (SD) for parametric data or as percentages. Statistical analyses were performed with R software (version 4.3.1) and RStudio interface. The threshold for significance was set at 5%.

2.2. Results

Participants

In total, 158 participants took part in the study (UK n=51, 70-87 years old, 67% female; France n=56, 70-96 years old, 89% female; Norway n=51, 70-93 years old, 75% female). **Table 3** below details the demographics. There were differences between countries in terms of sex, living status and appetite. France had a panel with significantly fewer men, fewer people living with a partner and a lower reported appetite than the Norwegian and UK panels (**Table 3**).

Table 3. Participant characteristics in the home-use trial.

Variable	Total (n=158)	France (n=56)	Norway (n=51)	UK (n=51)	p-value[a]
Age					
Median [IQR]	75 [72-78]	74 [71-78]	75 [72-78]	74 [72-78]	0.209
Mean [Range]	76 [70-96]	76 [70-96]	76 [70-93]	75 [70-87]	
70-79, n (%)	129 (82%)	43 (77%)	41 (80%)	45 (88%)	
80-89, n (%)	23 (14%)	8 (14%)	9 (18%)	6 (12%)	
90-96, n (%)	6 (4%)	5 (9%)	1 (2%)	0 (0%)	
Sex, n (%)					<0.001
Male	36 (23%)	6 (11%) [b]	13 (25%) [a]	17 (33%) [a]	
Female	122 (77%)	50 (89%)	38 (75%)	34 (67%)	
Living status, n (%)					<0.001
Living with a partner	89 (56%)	23 (41%) [b]	33 (65%) [a]	33 (65%) [a]	
Not living with a partner	69 (44%)	33 (59%)	18 (35%)	18 (35%)	
Health status, n (%)					0.297
Better than others my age	65 (41%)	21 (38%)	21 (41%)	23 (45%)	
Same as others my age	87 (55%)	32 (57%)	28 (55%)	27 (53%)	
Worse than others my age	5 (3%)	3 (5%)	1 (2%)	1 (2%)	
NA	1 (1%)	/	1 (2%)	/	
Appetite, n (%)					<0.001
Good	114 (72%)	33 (59%) [b]	43 (84%) [a]	38 (75%) [ab]	
Average	34 (21%)	17 (30%)	5 (10%)	12 (23%)	
Poor	9 (6%)	6 (11%)	2 (4%)	1 (2%)	
NA	1 (1%)	/	1 (2%)	/	

[a] p-value derived from either Kruskal-Wallis or Chi-squared test between countries. Values with different letters were significantly different between countries (Fisher exact test, p≤0.05). IQR = Interquartile range; NA = not answered.

Feasibility of DIY protein-fortified recipes

Over all the recipes, only 18% of the participants required assistance in preparing the fortified recipes, with 16% in France, 10% in Norway, and 25% in the UK (**Appendix B**). The assistance was provided by someone close to them, such as a spouse, child, grandchild, or friend. For a few of them, assistance involved finding ingredients, following instructions, or carrying out culinary operations such as cutting, peeling, crushing, and mixing.

Seventy-three percent of participants did make small adjustments to the fortified recipes (**Table 4**). The percentage was notably high for three dishes: Bolognese sauce (41%), carrot soup (30%), and granola (32%). Participants mainly made adjustments that involved ingredients (95%), such as adding, removing, substituting, or adjusting quantities. These changes were made for reasons of preferences (e.g. removing a disliked ingredient such as celery, adding spices to improve seasoning), because the ingredient could not be found in the shops (e.g. pumpkin or sunflower seeds), to adjust the consistency of the final dish (e.g. adding liquid to liquefy or flour to thicken) or for nutritional reasons (e.g. reducing the amount of fat or salt). In a few cases, these changes to the ingredients increased the calorie and/or protein content of the dish (14%; *e.g.*, increasing the amount of meat or dried fruit), but in general, these changes tended to reduce the calorie and/or protein content (31%; *e.g.*, removing almond powder from the Bolognese sauce; reducing the amount of fat). Some adjustments concerned cooking times (12%), specifically longer cooking times for the carrots in the soup and the bolognese sauce; utensils (8%), particularly the use of microwave or food processors to save time and/or make preparation easier; and preparation stages (9%), particularly the combination of several stages into one to save time (*e.g.,* for the granola, all the ingredients were mixed together in one go and then put in the oven). Thirty-tree percent of participants reported difficulties incorporating the high-protein ingredients, mainly the formation of lumps when incorporating milk protein powder into the milk when preparing mashed potatoes (74%).

Table 4. Feasibility and future use data (%).

Variable	**Bolognese sauce** (%) (n=158)	**Carrot soup** (%) (n=158)	**Mashed potatoes** (%) (n=158)	**French toast** (%) (n=158)	**Granola** (%) (n=158)	**Pancakes** (%) (n=158)	**Porridge** (%) (n=102)	**Vanilla cake** (%) (n=158)
Needed help to prepare recipe	13	11	9	9	12	8	8	9
Adjustment to the recipe	41	30	13	17	32	18	8	15
Issue with protein extract	8	8	28	NA	2	3	2	3
Suggestion to improve the instructions	23	20	11	9	18	20	12	23
Preparation time (min), mean ± SD	45 ± 18	42 ± 19	25 ± 11	16 ± 6	42 ± 24	23 ± 12	11 ± 6	43 ± 43
Perceived preparation time[a], median (IQR)	3 (3-4)	3 (3-4)	3 (3-3)	3 (1-3)	3 (3-4)	3 (2-3)	3 (2-3)	3 (3-3)
mean out of 5 ± SD	3.3 ± 0.6	3.3 ± 0.7	2.8 ± 0.6	2.5 ± 0.7	3.3 ± 0.7	2.7 ± 0.6	2.5 ± 0.8	3.1 ± 0.6
Future use, median (IQR)	2 (1-3)	2 (1-3)	2 (1-3)	2 (1-3)	2 (1-3)	2 (1-3)	3 (1-3)	2 (2-3)
mean out of 4 ± SD	2.1 ± 0.9	2.2 ± 1.0	2.2 ± 1.0	2.1 ± 1.0	2.2 ± 1.0	2.1 ± 0.9	2.5 ± 1.1	2.2 ± 0.9
1=yes, most definitely	28	30	31	34	28	28	26	21
2=yes, probably	41	32	32	32	33	41	21	46
3=no, probably not	23	27	26	24	28	20	30	24
4=no, most definitely not	7	11	10	9	9	9	21	8
NA	0	1	1	1	1	1	2	1
Preferred version								
1=I prefer this version	21	24	16	25	18	18	26	17
2=I prefer what I was doing before	29	25	36	15	4	11	34	21
3=I like both equally	35	21	40	20	9	23	19	27
4=I would usually buy this food pre-made, so I do not usually prepare it myself	6	4	1	0	22	9	2	6
5=I don't usually eat this food	8	22	5	39	44	37	16	25
NA	1	4	2	2	3	1	3	3

Results are presented in percentage, except when stated otherwise.
[a]: score from 1 (very short) to 5 (very long). NA = not answer

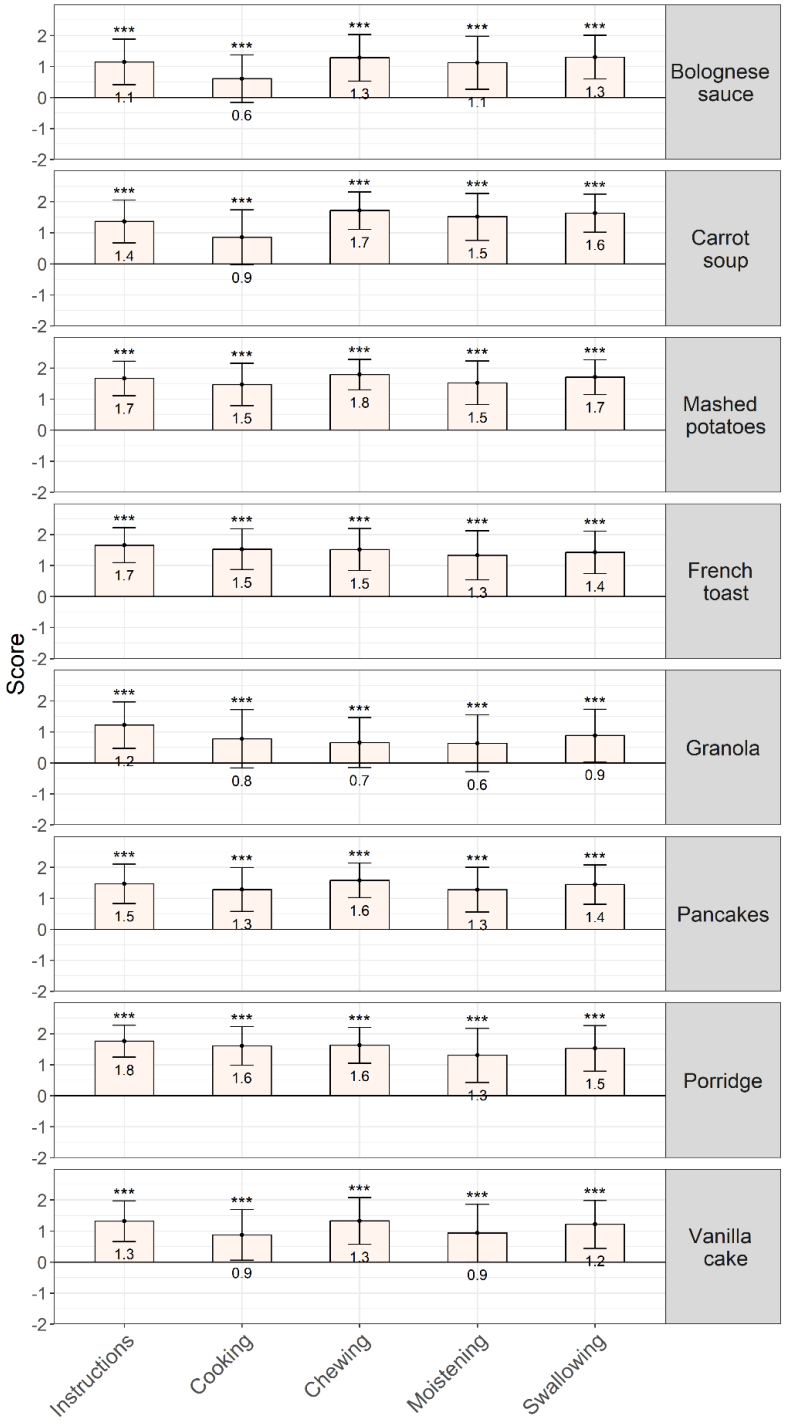
Figure 2 (histograms 1 and 2) shows the mean scores for "*understanding the instructions*" and "*cooking the recipe*" were close to "*1*" ("*easy*") for all recipes, indicating that all instructions were perceived as easy to understand and the cooking easy to undertake. Concerning the clarity of the instructions, no significant differences between countries was found for pancakes and vanilla cake (see **Appendix C**). Norwegian respondents perceived the instructions as more difficult to understand compared to French respondents for the bolognese sauce, carrot soup, mashed potatoes and French toast. Norwegian respondents perceived the instructions as more difficult to understand compare to UK respondents for granola and porridge. Concerning the cooking process, no significant differences between countries were shown for mashed potatoes, French toast, pancakes, and porridge (see **Appendix C**). Norwegian respondents found the cooking more difficult to undertake compared to French respondents for the bolognese sauce and carrot soup. Granola was perceived as more difficult to cook for French and Norwegian respondents, compare to UK respondents. Vanilla cake was perceived as more difficult to cook for UK respondents compare to French respondents.

The participants perceived the preparation time generally as not short, nor long (3 out of 5) with a mean ranging from 2.5 for French toast and porridge to 3.3 for Bolognese sauce, carrot soup and granola (**Table 4**).

Fifty-six percent of participants suggested improvements to the recipes' instructions (**Table 4**). These suggestions included changes to the ingredients (36%), in particular to improve the seasoning or consistency of the final dish, the units of measurement used for quantities (36%), cooking times (23%) and simplifying the recipes / reducing the number of steps (19%). Finally, a few participants asked for details about ingredients, utensils (*e.g.* pan size) and certain culinary terms.

More than 50% of the respondents were willing to make the recipes again in the future (2 out of 4), with a mean ranging from 2.1 for Bolognese sauce, French toast and pancakes to 2.5 for porridge. Most participants liked the fortified version at least as much as usual version of the dish (Bolognese sauce: 66%, carrot soup: 64%, mashed potatoes: 61%, French toast: 75%, granola: 87%, pancakes: 79%, porridge: 57%, vanilla cake: 68%).

Figure 2. Feasibility and food oral processing results compare to "0" ("*neither easy nor difficult*") score. When scores are positive, it is in the "*easy*" part of the scale. When scores are negative, it is the "*difficult*" part of the scale. Mean and standard deviation.



Acceptability and sensory properties of protein-fortified recipes

As shown in **Figure 3**, mean liking scores per country ranged from 4.5 to 5.9 on a 7-point scale, suggesting that the fortified recipes were rather on the "*like*" side of the scale. However, the impact of fortification on liking was dependent on the country. Significant differences between countries were shown for all recipes except the bolognese sauce, mashed potatoes and pancakes. Liking scores for the carrot soup, French toast, porridge and the vanilla cake was lower for the UK compared to other countries, whereas, granola was less well liked by France compared to the other countries.

Figure 3. Liking results of fortified recipes in France (FR), Norway (NO) and the United Kingdom (UK). Results are presented in mean ± SD. Mean values with different letters indicate significant differences between countries (Dunn's procedure, p≤0.05). KW: Kruskal Wallis test.

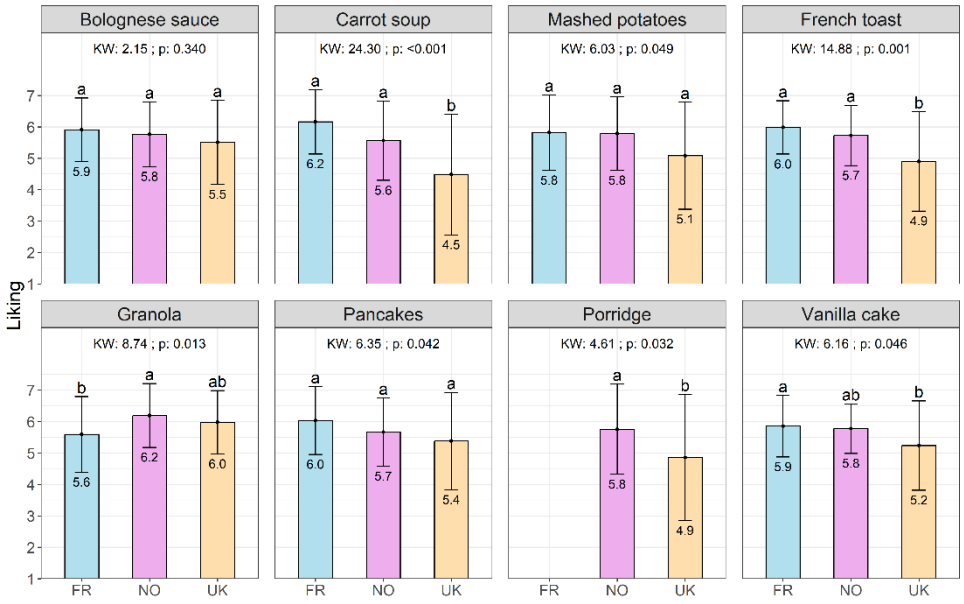


Figure 4 presents the *product by attribute* frequency table from the CATA data in order to visualize the associations between protein-fortified recipes and attributes selected to describe each recipe. Details per country are available in **Appendix D**.

- Bolognaise sauce was perceived as "*lumpy/grainy*", "*moist/juicy*", "*soft*", "*tasty*", and "*thick*".
- Carrot soup was perceived as "*creamy*", "*moist/juicy*", "*smooth*", "*tasteless*", "*tasty*", and "*thick*".

- Mashed potatoes were perceived as "*creamy*", "*moist/juicy*", "*soft*", and "*tasty*".
- French toast was perceived as "*light*", "*moist/juicy*", "*soft*", and "*tasty*".
- Pancakes was perceived as "*light*", "*moist/juicy*", "*smooth*", "*soft*", and "*tasty*"
- Porridge was perceived as "*creamy*", "*moist/juicy*", "*smooth*", "*soft*", "*sticky*", "*tasty*", and "*thick*".
- Vanilla cake was perceived as "*dense*", "*light*", "*moist-juicy*", "*soft*", and "*tasty*".

The same recipe can be perceived differently depending on the culinary habits and preferences of each respondent, as evidenced by the cited contrary attributes. Overall, all recipes were deemed "*tasty*" by over 50% of respondents.

Differences between countries show that French respondents perceived fortified recipes less often "*moist/juicy*" than other countries (**Appendix D**). Norwegian respondents perceived fortified recipes less as being "*mouthcoating*", "*dense*" and "*creamy*" than other countries. UK respondents perceived fortified recipes more as being "*tasteless*", "*soft*", and "*smooth*" than the respondents from other countries.

Figure 4. Frequency table (%).

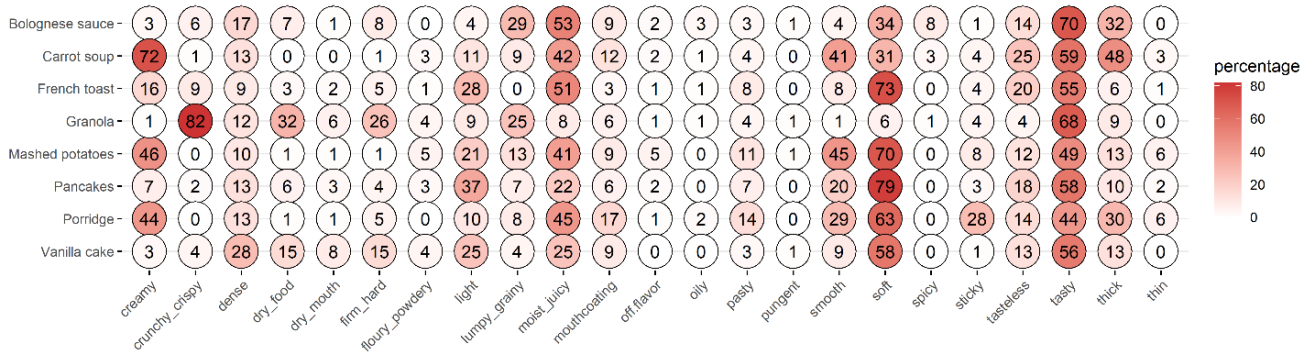
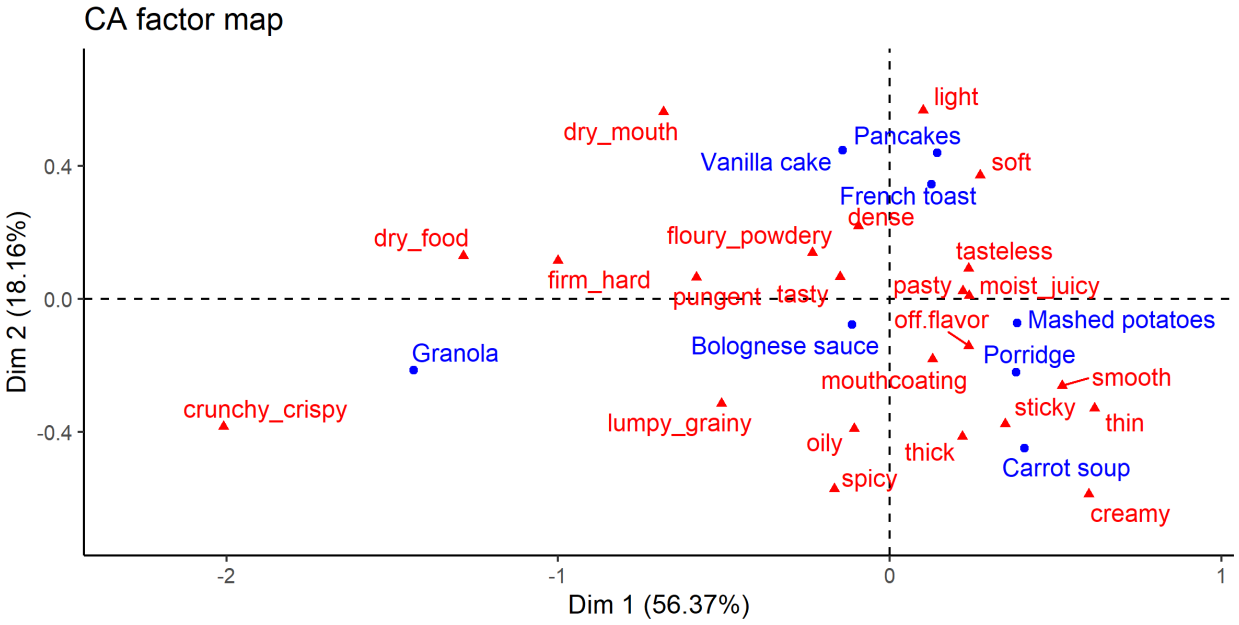


Figure 5 presents the correspondence analysis conducted on the *product x attribute* frequency table. The frequency can be viewed as a "measurement" on a scale from 0 to 100% of respondents who mentioned a particular characteristic for a product. On **Figure 5**, it can be identified the links between the cited attributes and the proximity between products that are positioned using the same sensory space. If a product and an attribute are close on this figure, it means that they were frequently associated (Chi-squared metric). For example, vanilla cake

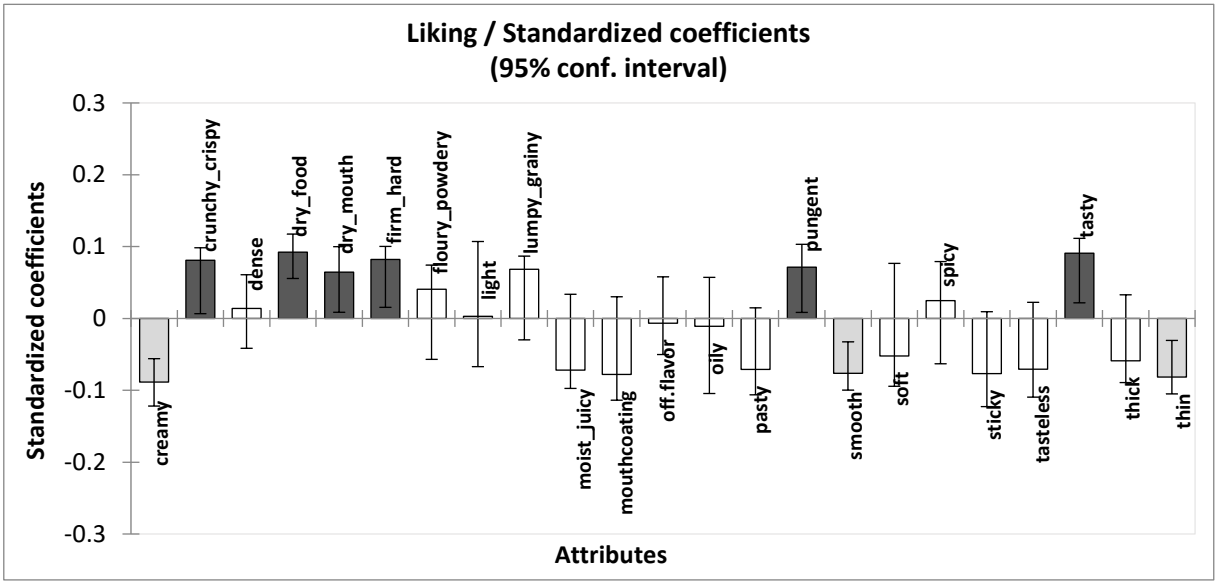
and pancakes are both associated with attributes such as "*light*" and "*soft*", while granola is clearly associated with a "*crunchy*" texture. On this figure, it can be observed that the Dimension 1 appears to oppose foods perceived as having a dry, firm, crunchy texture (e.g., granola, associated with "*crunchy_crispy*") to foods perceived as having a soft, creamy, sticky texture (e.g., pancakes and French toast, associated with "*soft*"). Dimension 1 seems to be associated with the moistness of recipes. The Dimension 2 differentiates perceptions associated with a light or soft texture (e.g., pancakes and French toast, perceived as "*soft*") from those linked to a creamier, thicker texture (e.g., carrot soup, associated with "*creamy*" and "*thick*"). Dimension 2 seems to be associated with the consistency of the recipes.

Figure 5. Correspondence Analysis (CA). Red dots: attributes; Blue dots: samples.



The R^2 of the Partial Least Square regression was 0.87; indicating that 87% of the variance in liking was explained by the citation frequencies (using a generalized linear model). This analysis highlights the attributes *"crunchy, crispy"*, *"dry (food)"*, *"dry (mouth)"*, *"firm, hard"*, *"pungent"* and *"tasty"* were positive drivers of liking; whereas the attributes "creamy", "*smooth"* and *"thin"* were negative drivers of liking over all the tested recipes (**Figure 6**). However, it is worth noting that the attributes "*pungent*" and "*thin*" were rarely chosen (**Figure 4**).

Figure 6. Partial Least Square regression coefficients. PLS performed with mean liking of each product as target and attributes' citation frequencies as predictors (95% confidence interval). Dark grey bars: attributes that contribute significantly positively to consumer liking; Grey striped white bars: positive tendency ($p < 0.10$); Light grey bars: attributes that contribute significantly negatively to consumer liking; White bars: attributes without significant contribution to consumer liking.



Discussion

This paper highlights the process used to involve older adults in the development and validation stages of the design of DIY protein-fortified recipes. Two stages were completed: the first part described the development of recipes, commonly used by older adults, fortified with regular culinary ingredients and high-protein ingredients. In the second part, evaluation of ease-of-use and liking of the fortified recipes were tested by older adults in a home use trial across three countries (France, Norway and the UK).

Development of DIY protein-fortified recipes

Eight fortified recipes were developed with an additional protein load ranging from 5.7g to 11.2g per portion. This additional load was reached by using regular food ingredients (*e.g.,* dairy products, almond, egg, oil, butter) and/or the high-protein ingredients (milk protein powder (isolate) - DELICAL© or organic soya mince (extruded) - CLEARSPRING©). The methodology used in the present paper to review high-protein ingredients allowed us to select

two versatile ingredients that can be incorporated into various food matrices (e.g., Bolognese sauce, carrot soup, mashed potatoes, French toast, granola, pancakes, porridge, vanilla cake), which validate our first hypothesis. However, although high-protein ingredients were employed in the fortification process, it was not always possible to achieve the desired fortification degree due to the sensory changes that occur when high-protein ingredients are added. It is necessary to identify the optimal balance between protein addition and sensory/textural perceptions to ensure the acceptability of fortified foods. This raises the question of whether technological characteristics of high-protein ingredients could be improved to facilitate their incorporation into a wide variety of food matrices (i.e., multi-recipe high-protein ingredients).

Feasibility of DIY protein-fortified recipes

In the present study, participants provided positive feedback regarding the feasibility of preparing fortified recipes. The recipes were easy to understand and cook, consistently receiving high scores on the ease-of-use scale. Participants found the instructions easy to follow and the recipes simple to prepare. The recipes required minimal assistance, common utensils were used, and there were few issues with the high-protein ingredients (except for the mashed potatoes). Adjustments were mainly done on cooking time and weighing unit (*i.e.,* ml instead of cl). In addition, more than 50% of the respondents were willing to make the recipes again in the future and liked the fortified version at least as much as what they usually make. However, a significant proportion of participants (33%) had problems with lump formation when incorporating the milk protein powder. It underscores the need to increase solubility of high-protein ingredients by suppliers, with clear usage instructions.

Moreover, 70% of participants made adjustments involving ingredients, highlighting the flexibility of DIY fortification. They often adapted the recipes to their preferences, aligning with the fortification strategy's goal of catering to individual needs. This positive outcome suggests a potential increase in acceptability of the DIY fortification strategy. However, it is important to raise awareness of the protein and calorie content of certain ingredients to ensure the fortification targets are met. Some substitutions done by the participants may lead to a reduction in protein and calorie content compare to the recommended fortified recipe, even if they are made consciously to reduce fat content (FR: *"I didn't use almond powder*

because in my opinion it adds unnecessary calories"; NO: "*Used cream with less fat instead of heavy cream. Had cream with less fat in the refrigerator and prefer food with as little fat as possible*" or NO: "I omitted 2 tablespoons of butter"; UK: "*Too rich with full cream, milk and butter*"). Indeed, Smith et al. (2024) demonstrated that older individuals in the focus groups were concerned about the correct "balance" of food groups and meal types when choosing what they were eating. They appeared primarily interested in reducing nutrients and food groups as a means of maintaining good health, with comparatively less discussion about the incorporation of essential nutrients or food groups into their diet. This trend is also evident in the present study, as the participants were more concerned about gaining weight (*i.e.,* consciously reducing fat) than about not consuming enough protein. In some cases, substitutions were made out of food habits, such as removing almond powder from Bolognese as it is not a common ingredient in this type of savoury dish. It is of note that almond powder was initially added in the Bolognese sauce recipe to both increase protein content and mask the taste of the high-protein ingredient, soy. Almond powder was not found to give a strange taste to the Bolognese sauce.

Acceptability and sensory properties of protein-fortified recipes

In the current study, liking scores per country suggested that the DIY fortified recipes were rather liked by the participants. Moreover, all fortified recipes consistently received food oral processing scores at the bottom of the scales, positioning them within the "*easy"* range on the FOP scales. The fortified recipes were perceived as being quite easy to chew, moisten and swallow.

Smith et al. (2024) found that focus group participants were suspicious about high-protein ingredients and had many questions about how they could be found, used and the effects they might have on a meal in terms of taste, texture and appearance. They appeared to be more comfortable with using everyday ingredients that they were familiar with. In the present study, participants felt that fortification did not notably affect ease-of-use, taste, or texture, which were concerns they had expressed in the focus groups (Smith et al., 2024). In addition, more than 50% of the respondents were willing to make the recipes again in the future and liked the fortified version at least as much as what their usual version of the dish. The disparity between the results of the focus groups (Smith et al., 2024) and the results of this study is

surprising but encouraging. Making the recipes, cooking by themselves in a realistic context (in their kitchen) can remove the participants' barriers about using high-protein ingredients. Indeed, some studies have investigated the effectiveness of cooking workshops for older adults (Alghamdi et al., 2023; Domper et al., 2024 for reviews). For example, an 8-month cooking intervention study involving men aged ≥65 indicated that cooking lessons could enhance cooking abilities and promote the adoption of new ingredients (Keller et al., 2004). Similarly, a 8-week intervention combining information and culinary skills in adults ≥50 resulted in improvements in nutritional knowledge, dietary habits, and confidence in preparing healthy meals tailored to their needs (Moreau et al., 2015). Participants reported that tasting new foods and recipes during these workshops helped challenge preconceived notions and encouraged dietary diversity. These findings emphasize the potential of being active in the kitchen ("*do-it-yourself*") as a practical approach to overcoming barriers associated with using unknown or specific ingredients, as identified in the present study.

The fortified recipes were predominantly described by participants with soft texture (e.g., "*soft*", "*moist, juicy*", "*light*") compared to attributes referred to in the literature associated with protein fortification (*e.g.*, "*firm*", "*hard*", "*dry*"; Liu et al., 2022; Norton et al., 2020, 2021; Tsikritzi et al., 2015; Wendin et al., 2017). Indeed, in a previous study (Geny et al., 2024), we found that fortification generally leads to a degradation of texture, associated with a granular texture ("*lumpy, grainy*", "*floury, powdery*"), a sticky and compact texture ("*thick*", "*pasty*", "*dense*"). Surprisingly, in the present study a granular and dry texture ("*crunchy, crispy*", "*dry (food)*", "*firm, hard*") was found to be positive drivers of liking. This finding may be attributed to the diverse range of recipes employed in this study, encompassing soup (liquid), vanilla cake (solid, soft), granola (solid, crunchy), and other forms. More specifically, the granola – which has a very distinct texture from other tested recipes as illustrated in **Figure 5** - was given the higher liking scores by the participants, reinforcing the attributes used to describe it ("*crunchy, crispy*", "*dry, food*", "*firm, hard*") in the positive drivers of the PLS. Therefore, it is challenging to generalise the observed results. Interestingly, the attribute "*tasty*" – found as a positive drivers of liking - is more regularly cited than the attribute "*tasteless*", whereas fortification is generally associated with "*tasteless*" in previous studies (Geny et al., 2024; Norton et al., 2020, 2021). There are two possible reasons for these results. Firstly, the present study did not include a comparison with a standard recipe which meant that participants' attention was not

drawn to the differences and possible impact of fortification. Secondly, the participants prepared the fortified recipes themselves (DIY). It allowed participants to understand the fortification procedure and make necessary adjustments to create a dish to their liking by adjusting the seasonings and texture to their preference. The results suggest that this DIY approach increases the likelihood of have a final fortified recipe appreciated.

Last but not least, results of the present study showed that the impact of fortification on liking is dependent on product type and cultural habits (see also Smith et al., 2024). Granola was less appreciated in France as it is not commonly consumed by French older adults. All recipes were commonly consumed in the UK, however some were less liked than the other two countries. It is noteworthy that the UK sample comprises a higher proportion of male participants (approximately one-third) compared to other countries. Given the relatively gendered division of tasks in this generation, this could be a potential explanation for the observed lower liking ratings for the UK population. However, further investigations are necessary to confirm this hypothesis. Subgroup analyses based on gender did not reveal any significant differences due to the limited sample size in each subgroup. An additional hypothesis is that the recipes available may represent a cooking style that is less familiar to the UK than to other countries. There was a potential difference with the texture preference for mashed potato across countries; typically, the French and Norwegian consumers make a more pureed version than the British, and as this recipe was relatively pureed, it was less appealing to those in the UK. This emphasised the necessity of conducting trials of meals with older adults in three different countries in order to demonstrate that preferences can be significantly influenced by cultural factors and that a universal approach would be ineffective. It thus follows that fortification solutions must be adapted to align with cultural preferences.

The combination of preliminary technological research and sensory testing enabled the development of fortified foods that were accepted by the target population (older adults) thereby validating the aforementioned second hypothesis.

Strengths and limitations of the present study

The objective was to provide older individuals with several fortified recipes encompassing sweet and savoury, liquid and solid, hot and cold dishes. The aim was that these recipes were

fortified using only one or two high-protein ingredients, as it is not realistic to offer older people a book of fortified recipes that requires them to use a large number of different high-protein ingredients. The methodology employed has enabled the development of feasible and acceptable DIY fortified recipes. Moreover, it enabled the gathering of valuable feedback to better understand the expectations of older adults. This has led to the identification of ways to improve the recipes, which will be reworked accordingly.

However, this study has a number of limitations. Firstly, the sample recruited for the present study showed certain limitations in representing the population targeted by food fortification. It is likely that we recruited older adults who were more independent and therefore more capable to do food fortification than others. Also, based on self-report questions, 6% of the participants reported having a reduced appetite. The characterization of the participants in the present study was not sufficiently comprehensive to accurately determine the representativeness of the recruited sample in comparison to the target population. Despite efforts to harmonise recruitment, there are some differences between countries. In France, meals are still largely prepared by women, hence the difficulty in recruiting men for this study. Similarly, in the UK older adult males are often less likely to be involved in research studies and many older adults have busy and active lives so do not have the time to participate. In Norway, it is generally very difficult to recruit older adults to studies as many are reticent and do not think they have anything to contribute. When asked, they also say they think it is too exhausting, or they have too much to do/don’t have enough time.

Secondly, it has to be highlighted that there was no direct comparison between the fortified version and the standard ones in the present study. Several studies have highlighted the impact of fortification on the sensory characteristics of fortified food products, particularly flavour and mouthfeel aspects (Norton et al., 2021). For example, solid snacks (such as cakes, biscuits and muffins) fortified with whey protein were perceived as mouthdrying and/or had a dry texture and reduced liking (Norton et al., 2020; Wendin et al., 2017). In fact, the fortification process involved adding dry ingredients (high-protein ingredients) to the standard recipe without increasing the portion size, which impacts texture. However, while fortification systematically led to a change in texture, it did not systematically lead to a significant decrease in liking score (Geny et al., 2024).

Thirdly, the CATA evaluation suffered from several weaknesses. Following the recommendations of Ares & Jaeger (2015), the CATA list was generated from previous consumer studies and from published literature. Because the questionnaire was delivered on paper to make it more accessible for older adults, the attributes' presentation order of the CATA was not randomised, potentially introducing a bias in responses, for example, the first attributes mentioned may have a greater impact on responses than the last ones (Ares & Jaeger, 2013).

Fourthly, although this study developed a diverse range of fortified recipes, including sweet and savoury options, liquid and solid forms, only eight recipes were ultimately designed. To ensure that older adults can incorporate these recipes into their daily lives, it is necessary to develop a greater variety of fortified recipes. In addition, it would be of interest to test fortified recipes with carers. This has been considered, but carers have limited time to put it into practice.

Conclusion

This paper highlights the process used to involve older adults in the development and validation stages of the DIY protein-fortified recipes. Two stages were completed: firstly, the development of fortified recipes; and secondly, the assessment of the feasibility and the acceptability of the DIY fortified recipes through a home use test (HUT).

Sensory changes occurring by adding high-protein ingredients (concentrate or isolates) limit the extent of protein fortification. It is necessary to identify the optimal balance between protein addition and sensory/textural perceptions. Despite these challenges, the DIY protein-fortified recipes were generally perceived as feasible and were liked by the participants. Their ability to freely adjust recipes to their personal preferences highlights the flexibility and adaptability of the DIY fortification strategy, aligning with the goal of catering to individual needs/nutrition. Moreover, the practical experience of making the recipes at home shows that the expected barriers associated with using high-protein ingredients (usage, change in taste, texture, appearance) did not hindered the implementation of recipes by the subjects; indicating the potential effectiveness of this approach in real-life settings. Nevertheless, it is

necessary to provide education on protein intake with age and ingredients containing proteins so older adults can make informed adjustments without reducing protein content.

Significant insights have been gained for the future development and implementation of DIY fortification strategies targeting older adults:

(i) Improving the technological characteristics of high-protein ingredients to facilitate their incorporation into a wide variety of food matrices (*i.e.,* protein extracts for multi-recipe usage).

(ii) Considering sensory perceptions; it is essential to identify the optimal balance between protein addition and sensory perception.

(iii) Providing educational support to increase knowledge on proteins and the fortification strategy.

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Appendix

Appendix A - Recipe questionnaire

Please complete this questionnaire every-time you make a new recipe. This is your opportunity to provide feedback on the recipe development so please read the questions carefully and give your answers honestly. To ensure we can capture your thoughts in the moment, please try to complete this questionnaire within 1 hour after eating the meal. When answering questions, please think about the recipe on its own, regardless of whether you added any toppings at the end (*e.g* for the porridge, pancakes). Thank you!

Recipes

1) Recipe tested:

- ☐ Oat porridge [UK/NOR only]
- ☐ Sweet French toast
- ☐ Pancakes
- ☐ Muffins/Loaf cake
- ☐ Granola
- ☐ Carrot soup
- ☐ Mashed potatoes
- ☐ Bolognese

Preparation

2) Did you have help preparing this recipe?

- ☐ No
- ☐ Yes; please specify: ……

3) Overall, this recipe was…

- ☐ Very easy to make
- ☐ Easy to make
- ☐ OK (neither easy nor difficult)
- ☐ Difficult to make
- ☐ Very difficult to make

4) Did you have all the utensils and appliances needed to prepare this recipe?

☐ Yes

☐ No; please specify what you were missing and what you replaced it with:.....

.....

.....

5) The instructions for making this recipe were:

☐ Very easy to understand

☐ Easy to understand

☐ OK (neither easy nor difficult)

☐ Difficult to understand

☐ Very difficult to understand

6) When making this recipe…

☐ I follow the recipe instructions exactly as they were written.

☐ I did not do some steps exactly as they were written; please specify which ones, why and what you had to do instead: .....

.....

7) Do you have any suggestions for improving the understanding of these instructions?

.....

.....

8) Approximately how long did you take to prepare this recipe? .....

9) This preparation time seemed...

☐ Very short

☐ Short

☐ Not short, nor long

☐ Long

☐ Very long

Ingredients

13) Did you follow the recipe using the specified ingredients?

☐ I used the same ingredients as listed in the recipe

☐ It was not possible use some ingredients; please specify which ones, why and what you used instead:.....

14) Did you encounter some issues when using/incorporating the milk protein powder or the soya protein in the recipe?

☐ The recipe did not require the use of milk protein powder or soya protein

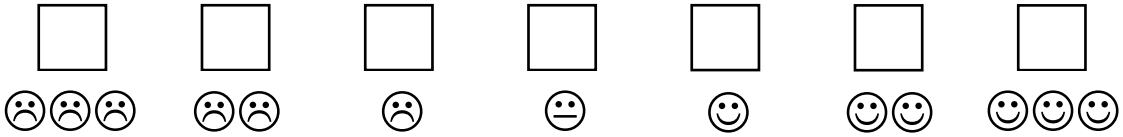
☐ No

☐ Yes, please specify what: .....

.....

Tasting

15) Overall, how much did you like this dish?



Strongly dislike — Neutral, I neither like nor dislike — Strongly like

16) For you, **chewing** this dish was…

☐ Very Easy

☐ Easy

☐ OK (neither easy or difficult to chew)

☐ Difficult

☐ Very Difficult

17) For you, how easy was this food to **hydrate with saliva** once it was in your mouth

☐ Very Easy

☐ Easy

☐ OK (neither easy or difficult to moist)

☐ Difficult

☐ Very Difficult

18) For you, **swallowing** this dish was…

☐ Very Easy

☐ Easy

☐ OK (neither easy or difficult to swallow)

☐ Difficult

☐ Very Difficult

19) Please, check all words that you associate with the dish you've just eaten:

- ☐ Moist / juicy
- ☐ Dry (it made my mouth dry)
- ☐ Dry (the food was dry)
- ☐ Firm / hard
- ☐ Soft
- ☐ Crunchy / crispy
- ☐ Sticky
- ☐ Thin
- ☐ Smooth
- ☐ Lumpy / grainy
- ☐ Creamy
- ☐ Floury / powdery
- ☐ Mouthcoating (I felt it coat the inside my mouth)
- ☐ Thick
- ☐ Pasty (like a paste)
- ☐ Dense
- ☐ Light
- ☐ Tasty
- ☐ Tasteless
- ☐ Oily
- ☐ Spicy
- ☐ Pungent
- ☐ Off-flavor

20) Do you have any comments (positive or negative) or suggestions regarding the seasoning, appearance, taste or texture of the dish?

.....

.....

.....

Future use

21) Do you plan to make this recipe again in the near future?

- ☐ Yes, most definitely
- ☐ Yes, probably
- ☐ No, probably not
- ☐ No, most definitely not

22) Do you prefer this version of the dish or the version you usually prepare?

- ☐ I prefer this version
- ☐ I prefer what I was doing before
- ☐ I like both equally
- ☐ I would usually buy this food pre-made, so I do not usually prepare it myself
- ☐ I don't usually eat this food

THANK YOU FOR YOUR TIME!

Appendix B – Feasibility and future use data (%) per countries

Results are presented in percentage except when stated otherwise.

Bolognese sauce						
Variable (%)	**Total (n=158)**	**France (n=56)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	13	5[b]	8[b]	25[a]	21.45	<0.001
Adjustment to the recipe	41	57[a]	33[b]	31[b]	16.50	<0.001
Issue with protein extract	8	13	4	6	5.87	0.053
Suggestion to improve the instructions	23	21	22	25	0.75	0.686
Preparation time (min), mean ± SD	45 ± 18	48 ± 17	44 ± 19	42 ± 17	2.45	0.294
Perceived preparation time[a], median (IQR)	3 (3-4)	3 (3-4)	3 (3-4)	3 (3-4)	2.79	0.248
mean out of 5 ± SD	3.3 ± 0.6	3.4 ± 0.8	3.2 ± 0.5	3.3 ± 0.5		
Future use, median (IQR)	2 (1-3)	2 (1-2)[b]	2 (1-3)[b]	2 (2-3)[a]	13.95	0.001
mean out of 4 ± SD	2.1 ± 0.9	1.8 ± 0.8	2.0 ± 0.9	2.5 ± 0.9		
1=yes, most definitely	28	38	33	14		
2=yes, probably	41	43	41	39		
3=no, probably not	23	18	20	33		
4=no, most definitely not	7	2	6	14		
NA	0	0	0	0		
Prefered_version						
1=I prefer this version	21	25	29	8		
2=I prefer what I was doing before	29	18	29	41		
3=I like both equally	35	32	31	43		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	6	14	4	0		
5=I don't usually eat this food	8	11	4	8		
NA	1	0	2	0		

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

Carrot soup						
Variable (%)	**Total (n=158)**	**France (n=56)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	11	5[b]	10[ab]	20[a]	10.38	0.006
Adjustment to the recipe	30	30	37	24	4.89	0.087
Issue with protein extract	8	7	4	12	4.42	0.110
Suggestion to improve the instructions	20	20	20	20	0.01	0.997
Preparation time (min), mean ± SD	42 ± 19	41 ± 16	45 ± 22	40 ± 17	0.43	0.807
Perceived preparation time[a], median (IQR)	3 (3-4)	3 (3-4)	3 (3-4)	3 (3-4)	3.28	0.194
mean out of 5 ± SD	3.3 ± 0.7	3.2 ± 0.6	3.4 ± 0.7	3.4 ± 0.7		
Future use, median (IQR)	2 (1-3)	2 (1-2)[b]	2 (1-3)[b]	3 (2-3)[a]	23.17	<0.001
mean out of 4 ± SD	2.2 ± 1.0	1.8 ± 0.9	2.0 ± 0.9	2.7 ± 1.0		
1=yes, most definitely	30	41	29	18		
2=yes, probably	32	41	39	16		
3=no, probably not	27	13	25	43		
4=no, most definitely not	11	5	4	24		
NA	1	0	2	0		
Prefered_version						
1=I prefer this version	24	29	31	12		
2=I prefer what I was doing before	25	14	20	43		
3=I like both equally	21	32	18	12		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	4	0	8	4		
5=I don't usually eat this food	22	23	14	27		
NA	4	2	10	2		

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

Mashed potatoes						
Variable (%)	**Total (n=158)**	**France (n=56)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	9	4[b]	4[b]	20[a]	20.42	<0.001
Adjustment to the recipe	13	9	14	16	2.46	0.292
Issue with protein extract	28	32[a]	18[b]	33[a]	7.62	0.022
Suggestion to improve the instructions	11	7	12	16	4.01	0.135
Preparation time (min), mean ± SD	25 ± 11	28 ± 12	25 ± 12	23 ± 9	3.09	0.213
Perceived preparation time[a], median (IQR)	3 (3-3)	3 (3-3)[ab]	3 (2-3)[a]	3 (3-3)[b]	7.80	0.020
mean out of 5 ± SD	2.8 ± 0.6	2.8 ± 0.7	2.6 ± 0.6	2.9 ± 0.6		
Future use, median (IQR)	2 (1-3)	2 (1-2)[b]	1 (1-2)[b]	3 (2-3)[a]	36.96	<0.001
mean out of 4 ± SD	2.2 ± 1.0	2.0 ± 0.9	1.7 ± 0.8	2.8 ± 0.9		
1=yes, most definitely	31	30	51	12		
2=yes, probably	32	45	31	18		
3=no, probably not	26	18	14	47		
4=no, most definitely not	10	7	2	22		
NA	1	0	2	2		
Prefered_version						
1=I prefer this version	16	14	18	16		
2=I prefer what I was doing before	36	27	35	47		
3=I like both equally	40	55	39	24		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	1	2	2	0		
5=I don't usually eat this food	5	0	4	12		
NA	2	2	2	2		

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

French toast						
Variable (%)	**Total (n=158)**	**France (n=56)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	9	2[b]	6[b]	20[a]	21.08	<0.001
Adjustment to the recipe	17	16	16	20	0.54	0.764
Issue with protein extract	NA*	NA*	NA*	NA*	NA*	NA*
Suggestion to improve the instructions	9	9	6	14	3.34	0.188
Preparation time (min), mean ± SD	16 ± 6	17 ± 7[a]	16 ± 6[ab]	14 ± 6[b]	7.01	0.030
Perceived preparation time[a], median (IQR)	3 (1-3)	3 (2-3)[ab]	2 (2-3)[b]	3 (3-3)[a]	13.00	0.001
mean out of 5 ± SD	2.5 ± 0.7	2.5 ± 0.7	2.3 ± 0.7	2.7 ± 0.6		
Future use, median (IQR)	2 (1-3)	2 (1-2)[b]	2 (1-2)[b]	3 (2-3)[a]	30.37	<0.001
mean out of 4 ± SD	2.1 ± 1.0	1.8 ± 0.9	1.8 ± 0.8	2.7 ± 0.9		
1=yes, most definitely	34	46	41	12		
2=yes, probably	32	34	37	25		
3=no, probably not	24	14	18	41		
4=no, most definitely not	9	5	2	22		
NA	1	0	2	0		
Prefered_version						
1=I prefer this version	25	18	41	16		
2=I prefer what I was doing before	15	20	8	18		
3=I like both equally	20	36	20	2		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	0	0	0	0		
5=I don't usually eat this food	39	27	25	65		
NA	2	0	6	0		

*French toast did not contain high-protein ingredients

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

Granola						
Variable (%)	**Total (n=158)**	**France (n=56)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	12	11[ab]	6[b]	20[a]	9.14	0.010
Adjustment to the recipe	32	45[a]	29[b]	20[b]	16.51	<0.001
Issue with protein extract	2	2	2	2	0.01	0.995
Suggestion to improve the instructions	18	12	25	18	5.18	0.075
Preparation time (min), mean ± SD	42 ± 24	48 ± 24[a]	47 ± 24[a]	32 ± 19[b]	20.64	<0.001
Perceived preparation time[a], median (IQR)	3 (3-4)	3 (3-4)[a]	3 (3-4)[b]	3 (3-3)[ab]	4.87	0.087
mean out of 5 ± SD	3.3 ± 0.7	3.4 ± 0.8	3.3 ± 0.5	3.1 ± 0.8		
Future use, median (IQR)	2 (1-3)	2 (2-3)	2 (1-2)	2 (2-3)	8.71	0.013
mean out of 4 ± SD	2.2 ± 1.0	2.4 ± 1.0	1.9 ± 0.9	2.3 ± 0.9		
1=yes, most definitely	28	21	41	22		
2=yes, probably	33	30	35	33		
3=no, probably not	28	30	18	37		
4=no, most definitely not	9	14	6	8		
NA	1	4	0	0		
Prefered_version						
1=I prefer this version	18	5	35	14		
2=I prefer what I was doing before	4	2	10	2		
3=I like both equally	9	0	12	18		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	22	14	25	27		
5=I don't usually eat this food	44	71	18	39		
NA	3	7	0	0		

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

Pancakes						
Variable (%)	**Total (n=158)**	**France (n=56)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	8	5[b]	2[b]	18[a]	17.85	<0.001
Adjustment to the recipe	18	21	12	22	4.23	0.120
Issue with protein extract	3	2	0	6	7.30	0.026
Suggestion to improve the instructions	20	9[b]	22[ab]	31[a]	15.47	<0.001
Preparation time (min), mean ± SD	23 ± 12	29 ± 11[a]	21 ± 11[b]	18 ± 9[b]	22.47	<0.001
Perceived preparation time[a], median (IQR)	3 (2-3)	3 (2-3)	3 (2-3)	3 (3-3)	4.24	0.120
mean out of 5 ± SD	2.7 ± 0.6	2.6 ± 0.6	2.7 ± 0.7	2.9 ± 0.5		
Future use, median (IQR)	2 (1-3)	2 (1-2)[b]	2 (2-3)[a]	2 (2-3)[a]	17.32	<0.001
mean out of 4 ± SD	2.1 ± 0.9	1.7 ± 0.8	2.2 ± 0.9	2.5 ± 1.0		
1=yes, most definitely	28	45	24	16		
2=yes, probably	41	39	45	39		
3=no, probably not	20	13	24	25		
4=no, most definitely not	9	2	8	18		
NA	1	2	0	2		
Prefered_version						
1=I prefer this version	18	14	33	8		
2=I prefer what I was doing before	11	2	22	12		
3=I like both equally	23	21	24	25		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	9	5	2	20		
5=I don't usually eat this food	37	55	18	35		
NA	1	2	2	0		

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

Porridge						
Variable (%)	**Total (n=102)**	**France (n=0)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	8	/	2[b]	14[a]	8.02	0.005
Adjustment to the recipe	8	/	12	4	2.96	0.086
Issue with protein extract	2	/	0	4	2.22	0.136
Suggestion to improve the instructions	12	/	10	14	0.55	0.456
Preparation time (min), mean ± SD	11 ± 6	/	12 ± 6[a]	10 ± 5[b]	5.47	0.019
Perceived preparation time[a], median (IQR)	3 (2-3)	/	2 (2-3)	3 (2-3)	1.91	0.167
mean out of 5 ± SD	2.5 ± 0.8	/	2.4 ± 0.7	2.6 ± 0.8		
Future use, median (IQR)	3 (1-3)	/	2 (1-3)[b]	3 (2-4)[a]	15.07	<0.001
mean out of 4 ± SD	2.5 ± 1.1	/	2.0 ± 1.0	2.9 ± 1.0		
1=yes, most definitely	26	/	41	12		
2=yes, probably	21	/	24	18		
3=no, probably not	30	/	25	35		
4=no, most definitely not	21	/	10	31		
NA	2	/	0	4		
Prefered_version						
1=I prefer this version	26	/	29	24		
2=I prefer what I was doing before	34	/	27	41		
3=I like both equally	19	/	22	16		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	2	/	2	2		
5=I don't usually eat this food	16	/	20	12		
NA	3	/	0	6		

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

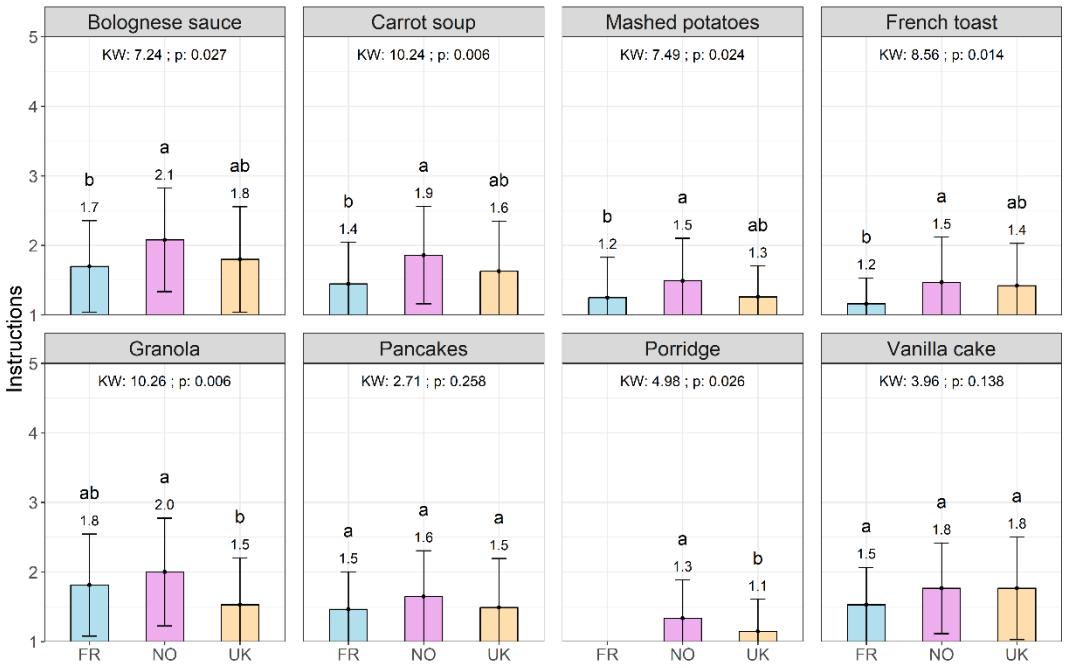
Vanilla cake						
Variable (%)	**Total (n=158)**	**France (n=56)**	**Norway (n=51)**	**UK (n=51)**	**X2 or KW**	**p-value**
Needed help to prepare recipe	9	7	8	14	3.02	0.221
Adjustment to the recipe	15	16	10	20	3.86	0.145
Issue with protein extract	3	2	2	4	1.13	0.569
Suggestion to improve the instructions	23	20[ab]	18[b]	33[a]	7.91	0.019
Preparation time (min), mean ± SD	43 ± 43	38 ± 18	55 ± 72	36 ± 20	2.64	0.268
Perceived preparation time[a], median (IQR)	3 (3-3)	3 (3-3)	3 (3-3)	3 (3-3)	1.12	0.572
mean out of 5 ± SD	3.1 ± 0.6	3.1 ± 0.6	3.0 ± 0.5	3.2 ± 0.5		
Future use, median (IQR)	2 (2-3)	2 (1-2)[b]	2 (2-2)[b]	3 (2-3)[a]	26.85	<0.001
mean out of 4 ± SD	2.2 ± 0.9	1.9 ± 0.8	2.0 ± 0.8	2.7 ± 0.8		
1=yes, most definitely	21	30	25	6		
2=yes, probably	46	52	51	35		
3=no, probably not	24	13	20	41		
4=no, most definitely not	8	4	4	18		
NA	1	2	0	0		
Prefered_version						
1=I prefer this version	17	9	31	12		
2=I prefer what I was doing before	21	18	18	27		
3=I like both equally	27	34	29	18		
4=I would usually buy this food pre-made, so I do not usually prepare it myself	6	2	4	14		
5=I don't usually eat this food	25	36	10	29		
NA	3	2	8	0		

Values with different letters were significantly different between countries (Dunn's procedure or Fisher exact test, p≤0.05). [a]: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

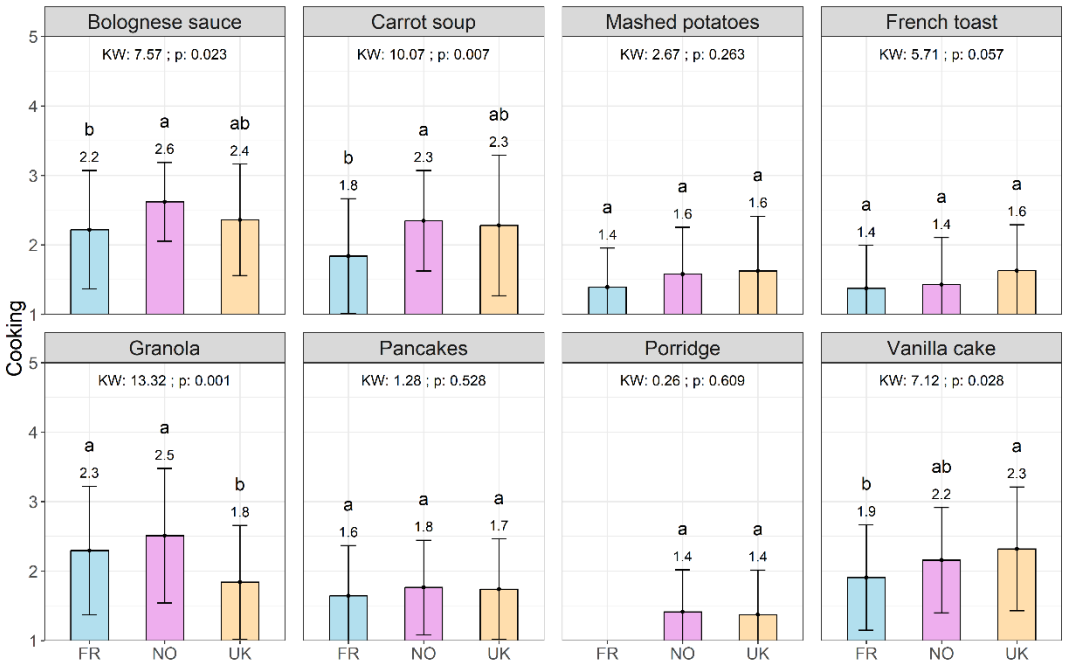
Appendix C – Differences between countries

The following variables were based on a 5-point scale: 1 = "*very easy*"; 2 = "*easy*"; 3 = "*ok*"; 4 = "*difficult*"; 5 = "*very difficult*". Results are presented in mean ± SD. Values with different letters were significantly different between countries (Dunn's procedure, p≤0.05). KW: Kruskal-Wallis test.

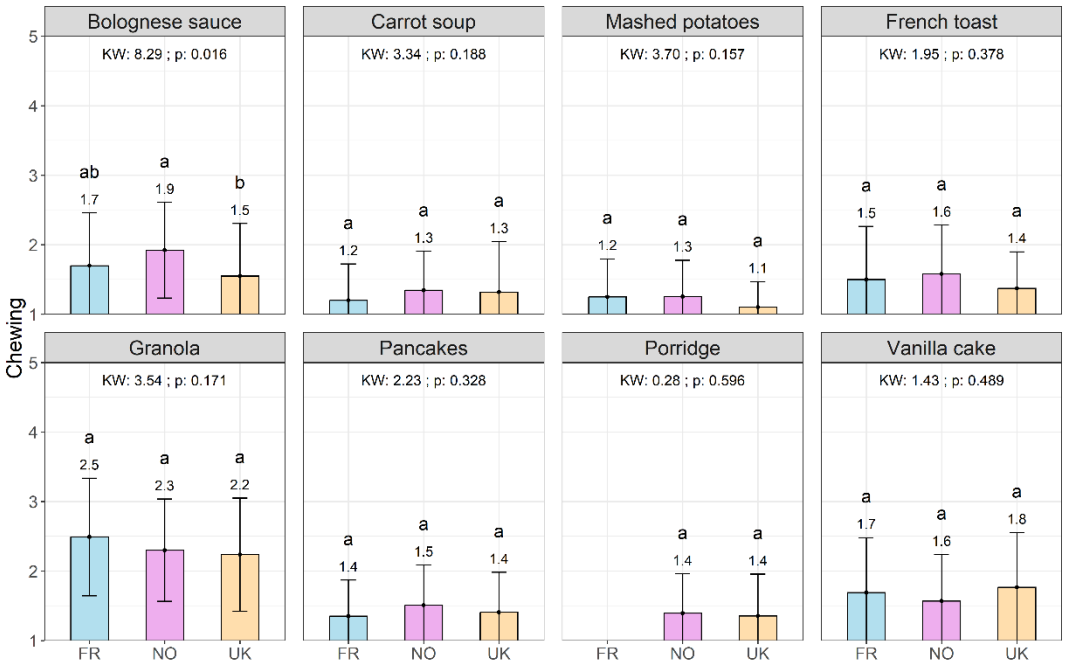
A. Instructions



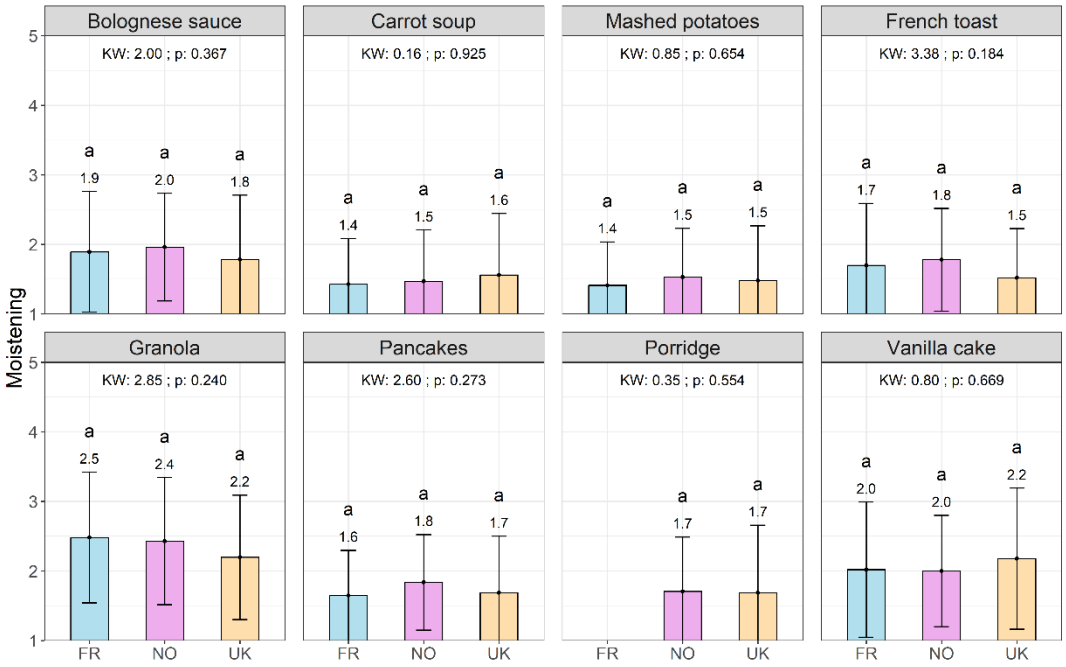
B. Cooking



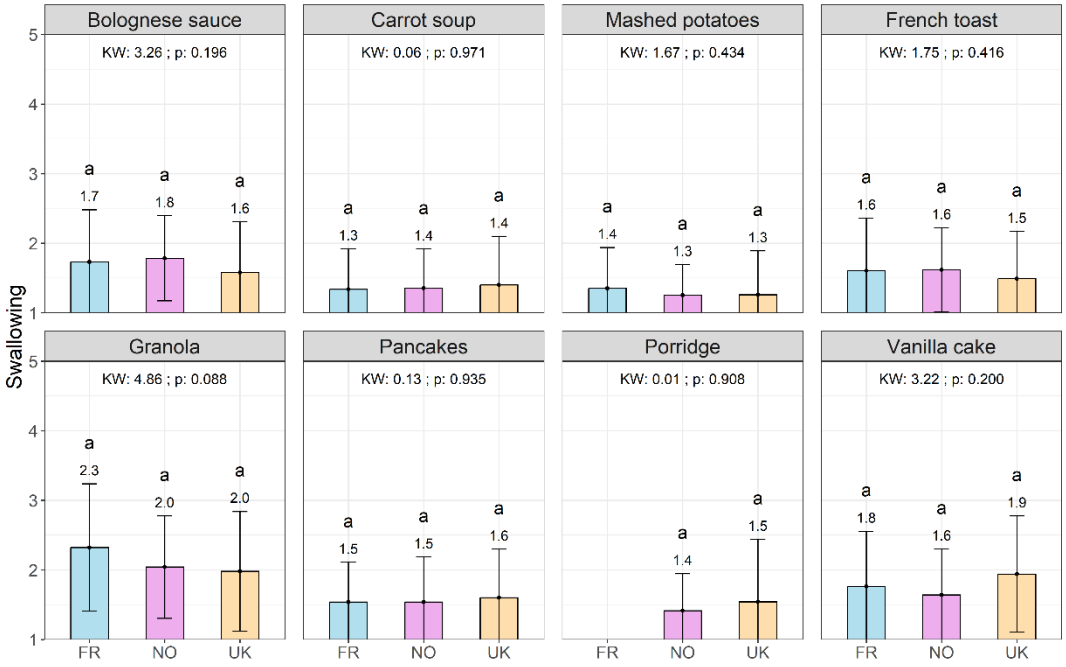
C. Chewing



D. Moistening



E. Swallowing



Appendix D – Frequency table of attributes selected for each dish per country

Values with different letters were significantly different between countries (Fishers exact test, p≤0.05).