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

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16

17 Abstract

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

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

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

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

43 **Keywords**

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

45 creation

46 Introduction

47 As individuals age, ensuring adequate protein intake and quality becomes a critical aspect of
48 maintaining health and preserving autonomy. Protein quality is determined by the presence
49 of all essential amino acids and by the protein's bioavailability. Protein recommendations for
50 older adults are well-established, with the majority of European countries agreeing that
51 protein intake should increase with age, for example to 1.0–1.2 g/kg body weight/day from
52 the 0.70-0.75g/kg body weight/day typically recommended for the general population (Deutz
53 et al. 2014). Yet, a challenge arises in meeting recommended protein intake, often
54 exacerbated by a phenomenon known as the “*anorexia of aging*” (Donini et al., 2003;
55 Giezenaar et al., 2016). This term refers to a multifaceted decline in appetite and food intake
56 among older adults, which can significantly impact their ability to achieve optimal protein
57 intake. Several factors contribute to this phenomenon, including changes in taste perception,
58 diminished olfactory sensitivity, dental issues, diseases and various health conditions, the use
59 of prescription medicines, or decrease of psychological health (Donini et al., 2003; Landi et al.,
60 2016; Schwartz et al., 2018). These physiological changes not only lead to a reduced desire for
61 food but also contribute to inadequate nutrient intake, particularly protein (Giezenaar et al.,
62 2016; Landi et al., 2016; Ter Borg et al., 2015; Van der Meij et al., 2017).

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

69 To prevent these adverse consequences on health, public health authorities recommend to
70 use enrichment strategies (HAS, 2007; Helsedirektoratet, 2016; National Health Service (NHS),
71 2017). Among them, food fortification has been identified as an effective strategy to increase
72 protein intake in the older adults (Douglas et al., 2017; Geny et al., 2023; Morilla-Herrera et
73 al., 2016; Sossen et al., 2021). This strategy involves the deliberate addition of essential
74 nutrients - particularly protein - to food items, aiming to improve their nutritional quality. This

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

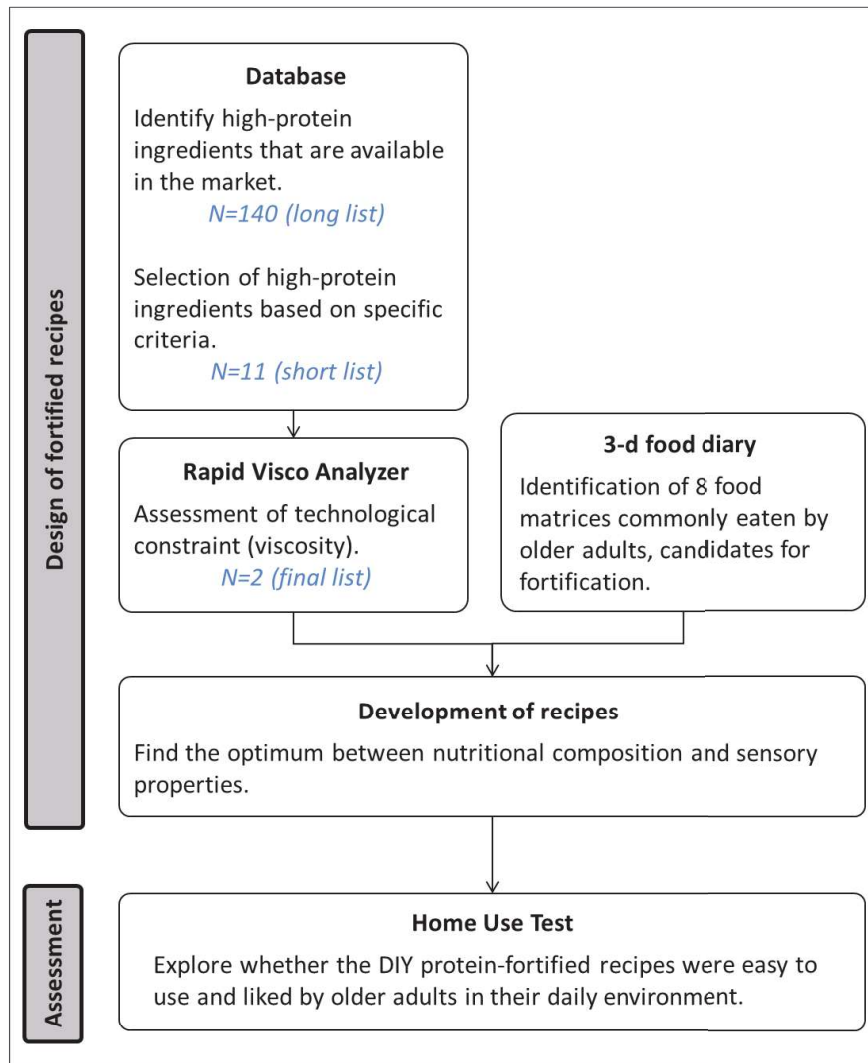
78 Despite the nutritional benefits of food fortification, there is a significant gap between
79 nutritional research and sensory acceptance, which can limit older adults' compliance to
80 fortified foods. Recent research has highlighted this disparity, showing that very few studies
81 have assessed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

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

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

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

Figure 1. Flowchart of development process of fortified foods.



136 1. Design – Preliminary research

137 1.1. Development of a database for high-protein ingredients

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

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

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

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

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

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

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

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

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

190 **1.2. Technological assessment**

191 **1.2.1. Assessment of the viscosity of high-protein ingredients**

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

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

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

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

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

235 **1.2.2. Assessment of the technological constraints of high-protein ingredients in oatmeal** 236 **porridge.**

237 To investigate how the addition of high-protein ingredients influenced the viscosity in food
238 matrices, oatmeal porridge was chosen as a model food matrix and tested with Rapid Visco
239 Analyzer as a pilot study (RVA; PerkinElmer, Massachusetts, US). The method profile for the
240 RVA, detailed in the **Supplementary File E**, was adjusted according to the procedure for
241 making oatmeal porridge. One portion of oatmeal porridge is 290g, consisting of 40g oat flakes
242 and 250g liquid, according to the manufacturer's instructions. The liquid used was whole milk
243 (3.3g/100g protein, 275kJ/100g energy). The addition of 3g or 6g of protein was tested into
244 one oatmeal porridge portion to maintain a good dispersion in liquid for RVA measurements;
245 with the specific high-protein ingredients amount calculated according to its protein content.
246 For the RVA analysis, the formulations were calculated to be 28.5g in total weight (oatmeal
247 and milk with, and without, high-protein ingredients). Moreover, the colour, texture and taste
248 of the protein mixture after RVA measurements were evaluated by project team members.

249 The viscosity of oatmeal porridge samples, with and without high-protein ingredients, is
250 shown in **Supplementary File F**. The addition of Whey protein concentrate (PURASANA) to
251 oatmeal porridge resulted in the highest viscosity (and noticeably the thickest consistency),
252 indicating an unpleasant porridge texture. Plant-based protein sources (*i.e.*, Soy protein
253 powder - PURASANA and PrOatein - LANTMÄNNEN) gave somewhat higher viscosity
254 compared to Milk protein powder (DELICAL) and Micellar casein (MY PROTEIN). The addition
255 of 3g proteins by Soy protein powder (PURASANA) noticeably influenced the taste (at resulted
256 in a strong soya taste). On the other hand, no dramatic taste change was observed by the
257 addition of PrOatein (LANTMÄNNEN), Micellar casein (MY PROTEIN), and Milk protein powder
258 (DELICAL). Therefore, these high-protein ingredients were tested with an increased amount
259 (6g protein into one oatmeal porridge portion). The viscosity of oatmeal porridge did not
260 increase with the increased addition (6g) amount of the protein powders (**Supplementary File**
261 **G**). Increased amounts of PrOatein (LANTMÄNNEN) resulted in grainy (coarse) texture, while
262 milk taste was noticeably enhanced when the amount of Micellar casein (MY PROTEIN) and

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

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

276 **1.3. Selection of the dishes**

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

- 279 - They should be commonly consumed by older adults in the majority of the target
280 countries (*i.e.*, France, Norway, UK).
- 281 - They should encompass a variety of dishes, including savoury and sweet options as
282 well as solid, semi-liquid, and liquid food matrices to reflect the diverse foods
283 consumed in daily life.
- 284 - They should have a high potential for fortification at both the food scale and at a scale
285 of the full scale (*i.e.*, it is simpler to incorporate high-protein ingredients into a carrot
286 soup rather than into whole carrot sticks). Preference was given to dishes with low
287 protein content (*i.e.*, vegetables, potatoes, sweet foods) over protein-rich sources (*i.e.*,
288 meat and fish). Additionally, emphasis was placed on including dishes suitable for
289 breakfast, acknowledging the lower protein intake typically associated with this meal
290 compared to lunch and dinner (Lonnie et al., 2018).

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

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

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

303 Recruitment of participants and eligibility criteria were the same as the main research (see
 304 **section 2.1** for more details). Sixty-five participants completed the food diary study in their
 305 native language (France: n=21, 11 women, age mean: 77.9, age range: 70-90; Norway: n=24,
 306 20 women, age mean: 76.7, age range: 70-89; UK: n=20, 14 women, age mean: 78.3, age
 307 range; 70-90).

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

313 **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.

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

341 2. Assessment – Main research

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

344 2.1. Materials and methods

345 *Participants.*

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

358 Sample size was calculated to detect a difference of 0.8 point on the 7-point hedonic category
359 scale. Considering an average standard deviation (SD) of 2.26 for liking score in older people
360 (Maitre et al., 2015), a minimum of 51 participants was required for each test (power=0.80;
361 $\alpha=0.05$).

362 *Products.*

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

365 *Procedure.*

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

381 *Recipe questionnaire presentation.*

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

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

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

396 **Sensory perception.** The assessment of sensory perception encompassed:

- 397 - The ease of chewing, moistening and swallowing the sample (food oral processing
398 questions, FOP) on 5-point category scales. Scales ranged from “very easy” to “very
399 difficult” (Vandenberghe-Descamps et al., 2018).
- 400 - For the Check-All-That-Apply (CATA) evaluation, a generic list of attributes suitable for
401 a broad spectrum of food products (sweet, salty, liquid, solid, etc.) was established,
402 including the attributes frequently associated with fortified foods in previous studies
403 (Liu et al., 2022; Norton et al., 2020, 2021; Tsikritzi et al., 2015; Mingioni, Pirttijärvi, et
404 al. 2016; Wendin et al., 2017) and, as far as possible, their antonyms (Ares & Jaeger,
405 2015). The CATA evaluation with 23 attributes focused on both texture and taste:
406 moist/juicy, firm/hard, dry (it made my mouth dry), smooth, soft, crunchy/crispy,
407 sticky, liquid, dry (the food was dry), tasty, creamy, floury/powdery, spicy, thick, pasty
408 (like a paste), dense, light, lumpy/grainy, tasteless, oily, mouthcoating (I felt it coat the
409 inside my mouth), pungent, off-flavour. The participants were asked to check all terms
410 that they considered appropriate to describe each sample.

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

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

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

421 **Data analysis.**

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

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

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

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

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

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

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

447 **2.2. Results**

448 *Participants*

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

454 **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 (%)					
Male	36 (23%)	6 (11%) ^b	13 (25%) ^a	17 (33%) ^a	<0.001
Female	122 (77%)	50 (89%)	38 (75%)	34 (67%)	
Living status, n (%)					
Living with a partner	89 (56%)	23 (41%) ^b	33 (65%) ^a	33 (65%) ^a	<0.001
Not living with a partner	69 (44%)	33 (59%)	18 (35%)	18 (35%)	
Health status, n (%)					
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 (%)					
Good	114 (72%)	33 (59%) ^b	43 (84%) ^a	38 (75%) ^{ab}	<0.001
Average	34 (21%)	17 (30%)	5 (10%)	12 (23%)	
Poor	9 (6%)	6 (11%)	2 (4%)	1 (2%)	
NA	1 (1%)	/	1 (2%)	/	

455 ^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 =
456 Interquartile range; NA = not answered.

457

458

459 *Feasibility of DIY protein-fortified recipes*

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

465 Seventy-three percent of participants did make small adjustments to the fortified recipes
466 (**Table 4**). The percentage was notably high for three dishes: Bolognese sauce (41%), carrot
467 soup (30%), and granola (32%). Participants mainly made adjustments that involved
468 ingredients (95%), such as adding, removing, substituting, or adjusting quantities. These
469 changes were made for reasons of preferences (e.g. removing a disliked ingredient such as
470 celery, adding spices to improve seasoning), because the ingredient could not be found in the
471 shops (e.g. pumpkin or sunflower seeds), to adjust the consistency of the final dish (e.g. adding
472 liquid to liquefy or flour to thicken) or for nutritional reasons (e.g. reducing the amount of fat
473 or salt). In a few cases, these changes to the ingredients increased the calorie and/or protein
474 content of the dish (14%; *e.g.*, increasing the amount of meat or dried fruit), but in general,
475 these changes tended to reduce the calorie and/or protein content (31%; *e.g.*, removing
476 almond powder from the Bolognese sauce; reducing the amount of fat). Some adjustments
477 concerned cooking times (12%), specifically longer cooking times for the carrots in the soup
478 and the bolognese sauce; utensils (8%), particularly the use of microwave or food processors
479 to save time and/or make preparation easier; and preparation stages (9%), particularly the
480 combination of several stages into one to save time (*e.g.*, for the granola, all the ingredients
481 were mixed together in one go and then put in the oven). Thirty-three percent of participants
482 reported difficulties incorporating the high-protein ingredients, mainly the formation of lumps
483 when incorporating milk protein powder into the milk when preparing mashed potatoes
484 (74%).

485

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

486
487

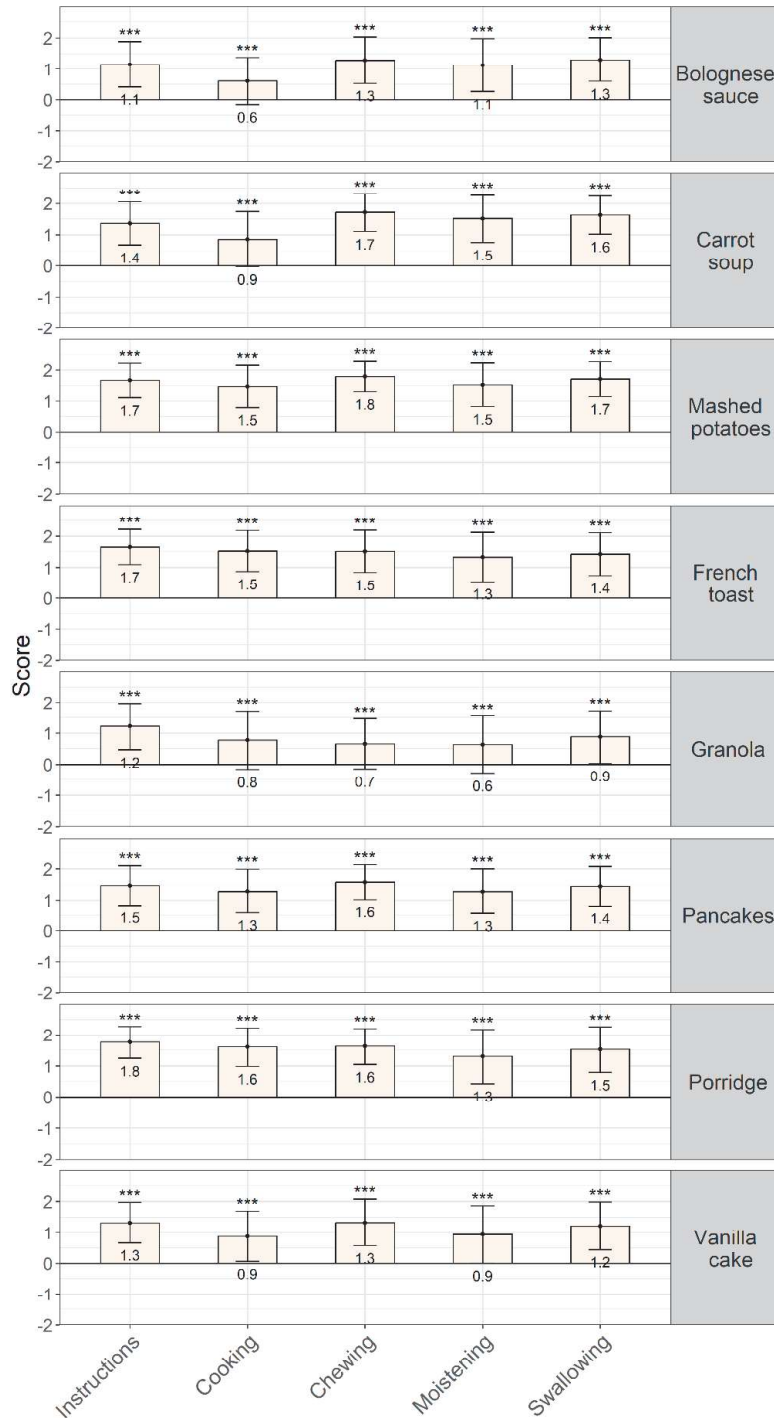
488 **Figure 2** (histograms 1 and 2) shows the mean scores for “*understanding the instructions*” and
489 “*cooking the recipe*” were close to “1” (“*easy*”) for all recipes, indicating that all instructions
490 were perceived as easy to understand and the cooking easy to undertake. Concerning the
491 clarity of the instructions, no significant differences between countries was found for
492 pancakes and vanilla cake (see **Appendix C**). Norwegian respondents perceived the
493 instructions as more difficult to understand compared to French respondents for the
494 bolognese sauce, carrot soup, mashed potatoes and French toast. Norwegian respondents
495 perceived the instructions as more difficult to understand compare to UK respondents for
496 granola and porridge. Concerning the cooking process, no significant differences between
497 countries were shown for mashed potatoes, French toast, pancakes, and porridge (see
498 **Appendix C**). Norwegian respondents found the cooking more difficult to undertake
499 compared to French respondents for the bolognese sauce and carrot soup. Granola was
500 perceived as more difficult to cook for French and Norwegian respondents, compare to UK
501 respondents. Vanilla cake was perceived as more difficult to cook for UK respondents compare
502 to French respondents.

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

506 Fifty-six percent of participants suggested improvements to the recipes’ instructions (**Table**
507 **4**). These suggestions included changes to the ingredients (36%), in particular to improve the
508 seasoning or consistency of the final dish, the units of measurement used for quantities (36%),
509 cooking times (23%) and simplifying the recipes / reducing the number of steps (19%). Finally,
510 a few participants asked for details about ingredients, utensils (*e.g.* pan size) and certain
511 culinary terms.

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

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

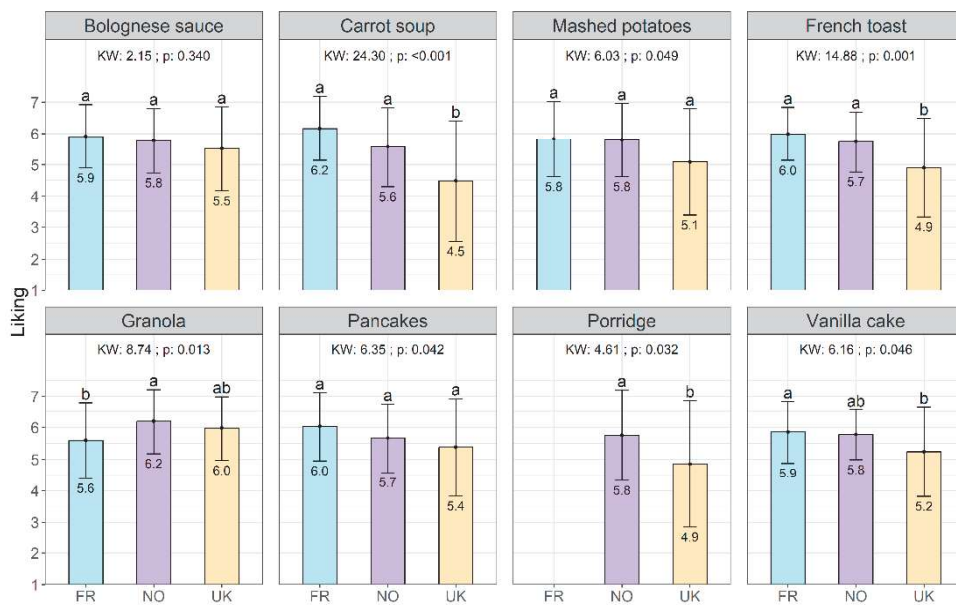


520

521 **Acceptability and sensory properties of protein-fortified recipes**

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

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



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

- 535 - Bolognese sauce was perceived as “lumpy/grainy”, “moist/juicy”, “soft”, “tasty”, and
 536 “thick”.
- 537 - Carrot soup was perceived as “creamy”, “moist/juicy”, “smooth”, “tasteless”, “tasty”,
 538 and “thick”.

- 539 - Mashed potatoes were perceived as “creamy”, “moist/juicy”, “soft”, and “tasty”.
 - 540 - French toast was perceived as “light”, “moist/juicy”, “soft”, and “tasty”.
 - 541 - Pancakes was perceived as “light”, “moist/juicy”, “smooth”, “soft”, and “tasty”
 - 542 - Porridge was perceived as “creamy”, “moist/juicy”, “smooth”, “soft”, “sticky”, “tasty”,
 - 543 and “thick”.
 - 544 - Vanilla cake was perceived as “dense”, “light”, “moist-juicy”, “soft”, and “tasty”.
- 545 The same recipe can be perceived differently depending on the culinary habits and
- 546 preferences of each respondent, as evidenced by the cited contrary attributes. Overall, all
- 547 recipes were deemed “tasty” by over 50% of respondents.

548 Differences between countries show that French respondents perceived fortified recipes less

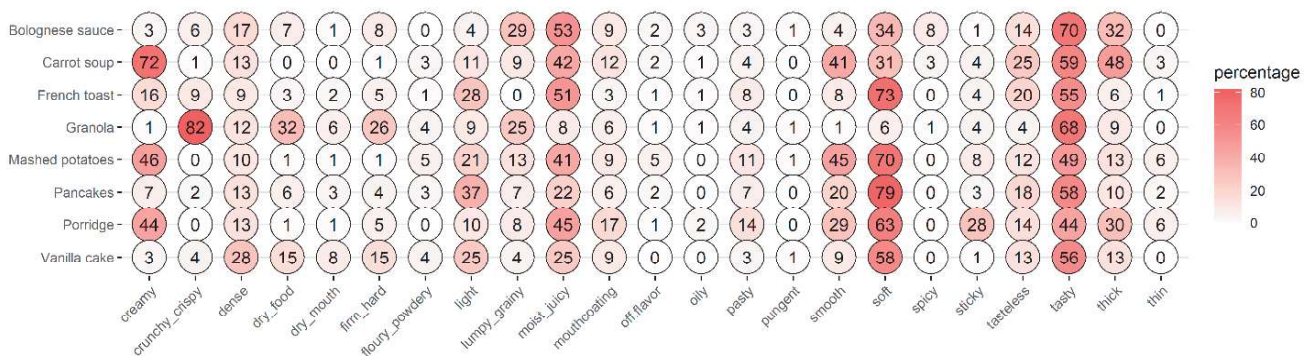
549 often “moist/juicy” than other countries (Appendix D). Norwegian respondents perceived

550 fortified recipes less as being “mouthcoating”, “dense” and “creamy” than other countries. UK

551 respondents perceived fortified recipes more as being “tasteless”, “soft”, and “smooth” than

552 the respondents from other countries.

553 **Figure 4. Frequency table (%).**



554

555 **Figure 5** presents the correspondence analysis conducted on the *product x attribute* frequency

556 table. The frequency can be viewed as a “measurement” on a scale from 0 to 100% of

557 respondents who mentioned a particular characteristic for a product. On **Figure 5**, it can be

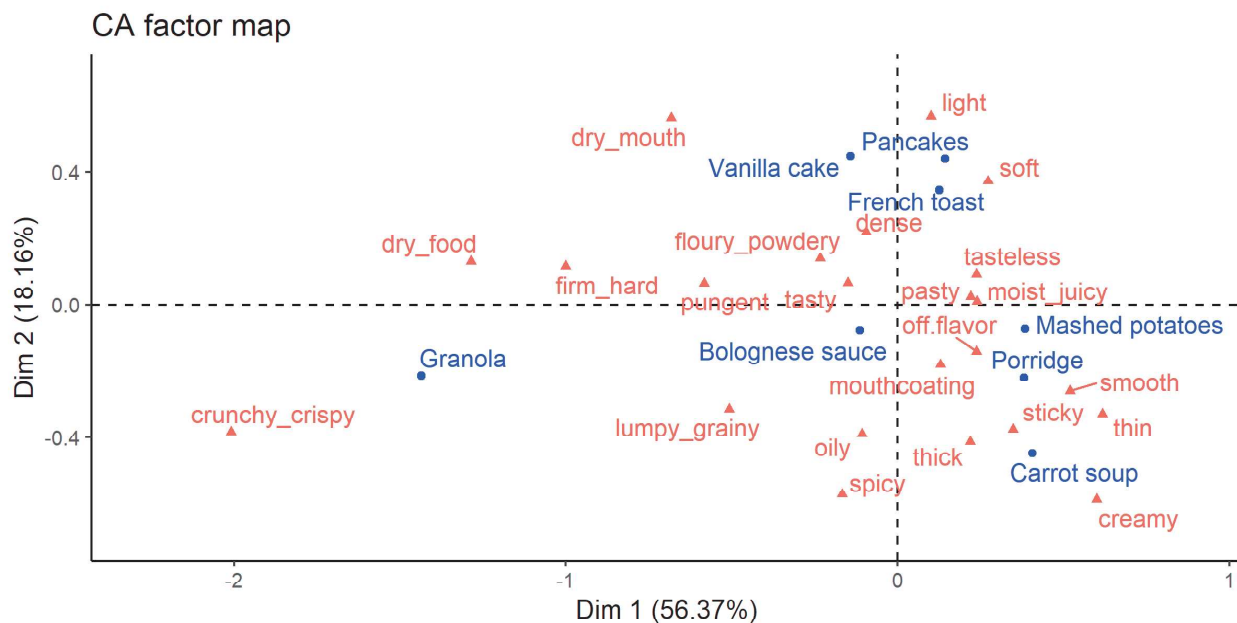
558 identified the links between the cited attributes and the proximity between products that are

559 positioned using the same sensory space. If a product and an attribute are close on this figure,

560 it means that they were frequently associated (Chi-squared metric). For example, vanilla cake

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

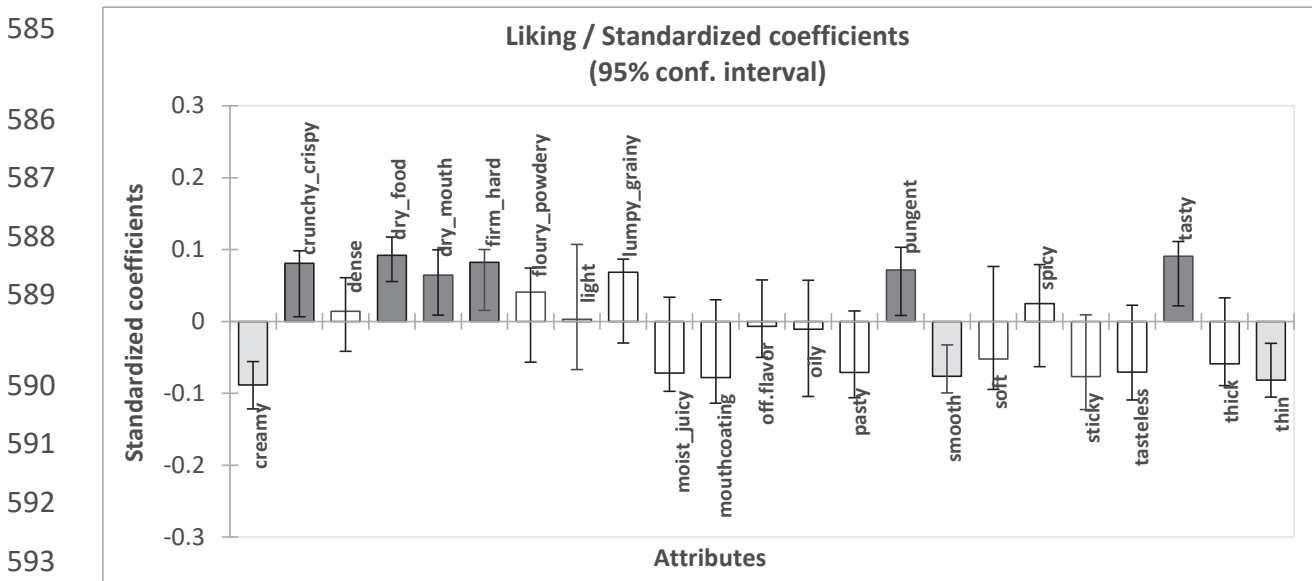
570 **Figure 5. Correspondence Analysis (CA).** Red dots: attributes; Blue dots: samples.



571

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

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



594 **Discussion**

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

601 ***Development of DIY protein-fortified recipes***

602 Eight fortified recipes were developed with an additional protein load ranging from 5.7g to
 603 11.2g per portion. This additional load was reached by using regular food ingredients (e.g.,
 604 dairy products, almond, egg, oil, butter) and/or the high-protein ingredients (milk protein
 605 powder (isolate) - DELICAL© or organic soya mince (extruded) - CLEARSPRING©). The
 606 methodology used in the present paper to review high-protein ingredients allowed us to select

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

617 *Feasibility of DIY protein-fortified recipes*

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

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

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

652 ***Acceptability and sensory properties of protein-fortified recipes***

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

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

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

680 The fortified recipes were predominantly described by participants with soft texture (e.g.,
681 *"soft", "moist, juicy", "light"*) compared to attributes referred to in the literature associated
682 with protein fortification (e.g., *"firm", "hard", "dry"*; Liu et al., 2022; Norton et al., 2020, 2021;
683 Tsikritzi et al., 2015; Wendin et al., 2017). Indeed, in a previous study (Geny et al., 2024), we
684 found that fortification generally leads to a degradation of texture, associated with a granular
685 texture (*"lumpy, grainy", "floury, powdery"*), a sticky and compact texture (*"thick", "pasty",*
686 *"dense"*). Surprisingly, in the present study a granular and dry texture (*"crunchy, crispy", "dry*
687 *(food)", "firm, hard"*) was found to be positive drivers of liking. This finding may be attributed
688 to the diverse range of recipes employed in this study, encompassing soup (liquid), vanilla cake
689 (solid, soft), granola (solid, crunchy), and other forms. More specifically, the granola – which
690 has a very distinct texture from other tested recipes as illustrated in **Figure 5** - was given the
691 higher liking scores by the participants, reinforcing the attributes used to describe it (*"crunchy,*
692 *crispy", "dry, food", "firm, hard"*) in the positive drivers of the PLS. Therefore, it is challenging
693 to generalise the observed results. Interestingly, the attribute *"tasty"* – found as a positive
694 drivers of liking - is more regularly cited than the attribute *"tasteless"*, whereas fortification is
695 generally associated with *"tasteless"* in previous studies (Geny et al., 2024; Norton et al., 2020,
696 2021). There are two possible reasons for these results. Firstly, the present study did not
697 include a comparison with a standard recipe which meant that participants' attention was not

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

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

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

724 **Strengths and limitations of the present study**

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

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

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

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

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

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

770 **Conclusion**

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

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

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

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

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

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

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

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- 965

966 **Appendix**

967 **Appendix A - Recipe questionnaire**

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

974
 975

976 **Recipes**

977 1) Recipe tested:

- | | |
|---|--|
| <input type="checkbox"/> Oat porridge [UK/NOR only] | <input type="checkbox"/> Granola |
| <input type="checkbox"/> Sweet French toast | <input type="checkbox"/> Carrot soup |
| <input type="checkbox"/> Pancakes | <input type="checkbox"/> Mashed potatoes |
| <input type="checkbox"/> Muffins/Loaf cake | <input type="checkbox"/> 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?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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:

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

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		
Preferred 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, $p \leq 0.05$). ^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		
Preferred_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, $p \leq 0.05$). ^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		
Preferred_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, $p \leq 0.05$). ^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		
Preferred 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, $p \leq 0.05$). ^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, $p \leq 0.05$). ^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		
Preferred_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, $p \leq 0.05$). ^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		
Preferred_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, $p \leq 0.05$). ^a: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

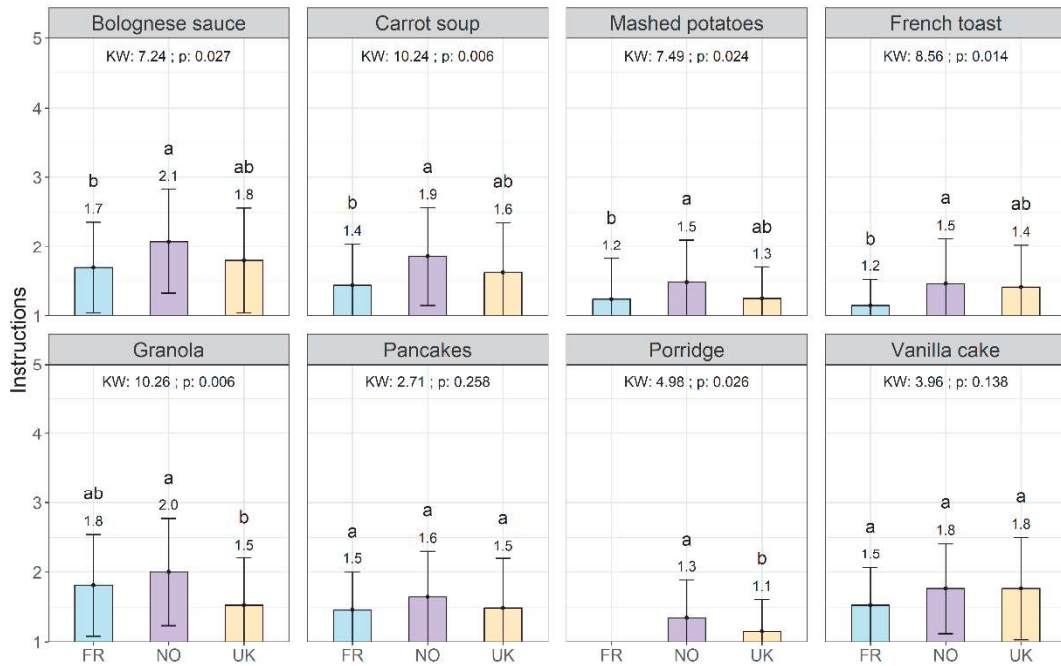
Vanilla cake						
Variable (%)	Total (n=158)	France (n=56)	Norway (n=51)	UK (n=51)	X2 or KW	p-value
Needed help to prepare recipe	9	7	8	14	3.02	0.221
Adjustment to the recipe	15	16	10	20	3.86	0.145
Issue with protein extract	3	2	2	4	1.13	0.569
Suggestion to improve the instructions	23	20 ^{ab}	18 ^b	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, $p \leq 0.05$). ^a: score from 1 (very short) to 5 (very long). X2: chi-square test. KW: Kruskal-Wallis test.

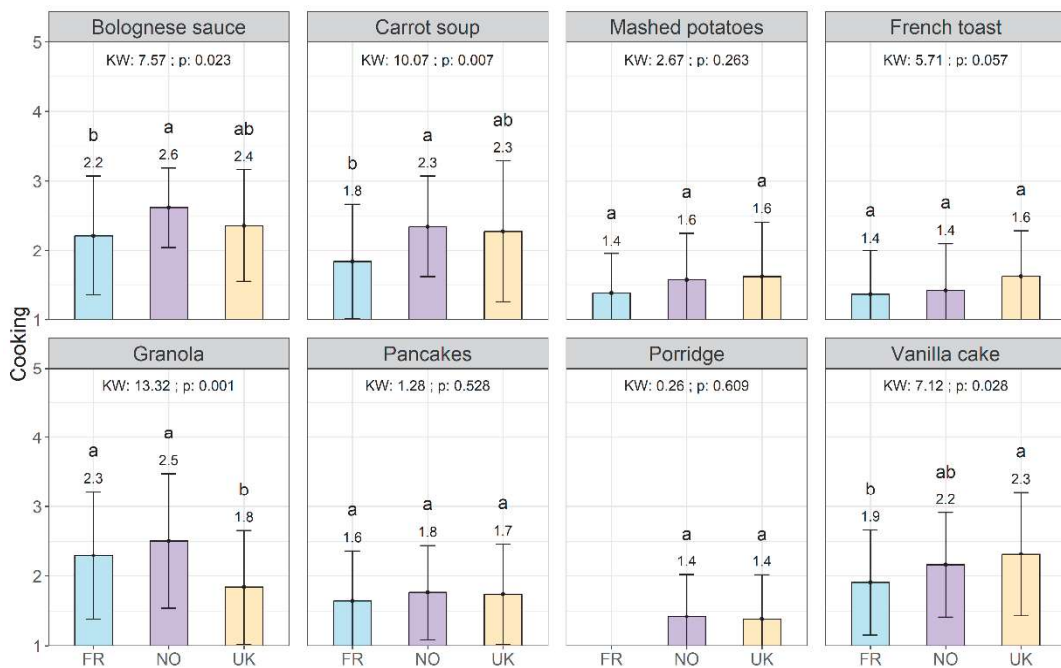
Appendix C – Differences between countries

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, $p \leq 0.05$). KW: Kruskal-Wallis test.

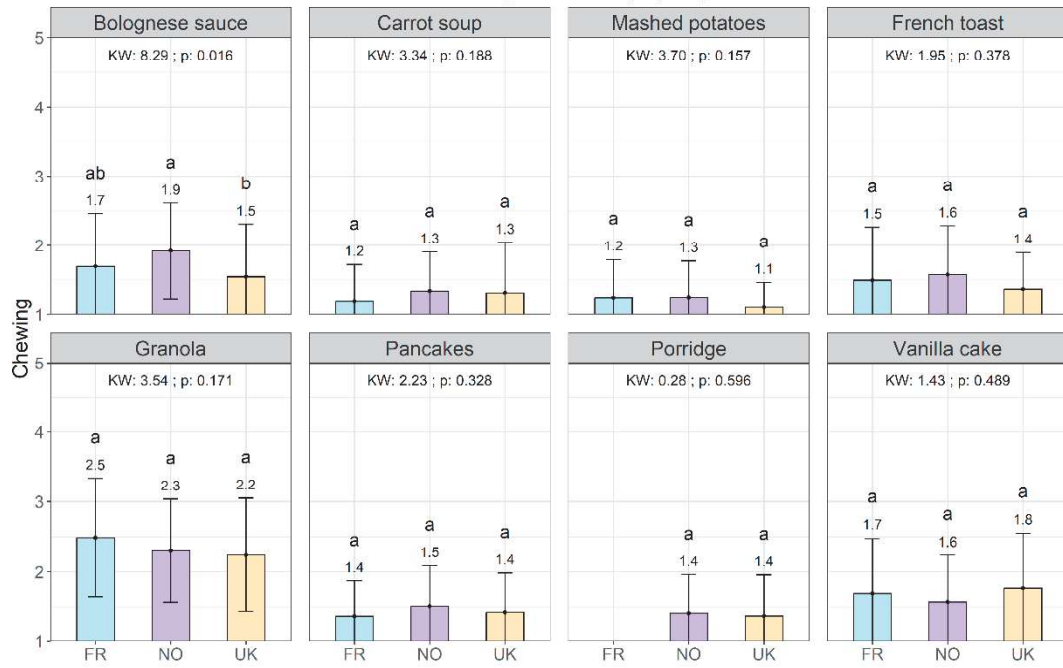
A. Instructions



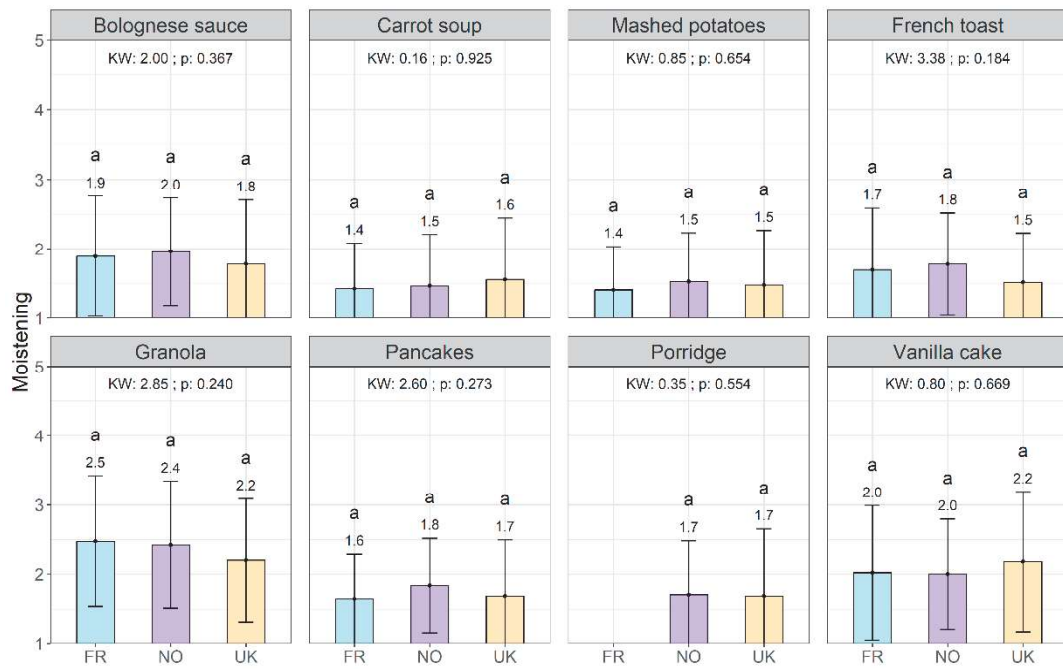
B. Cooking



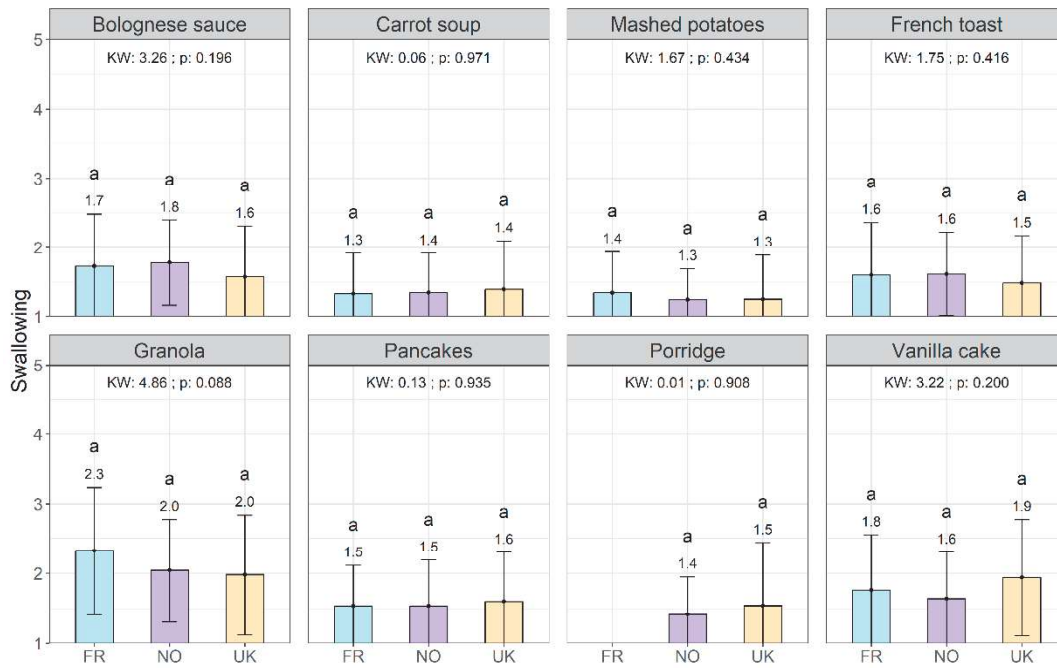
C. Chewing



D. Moistening

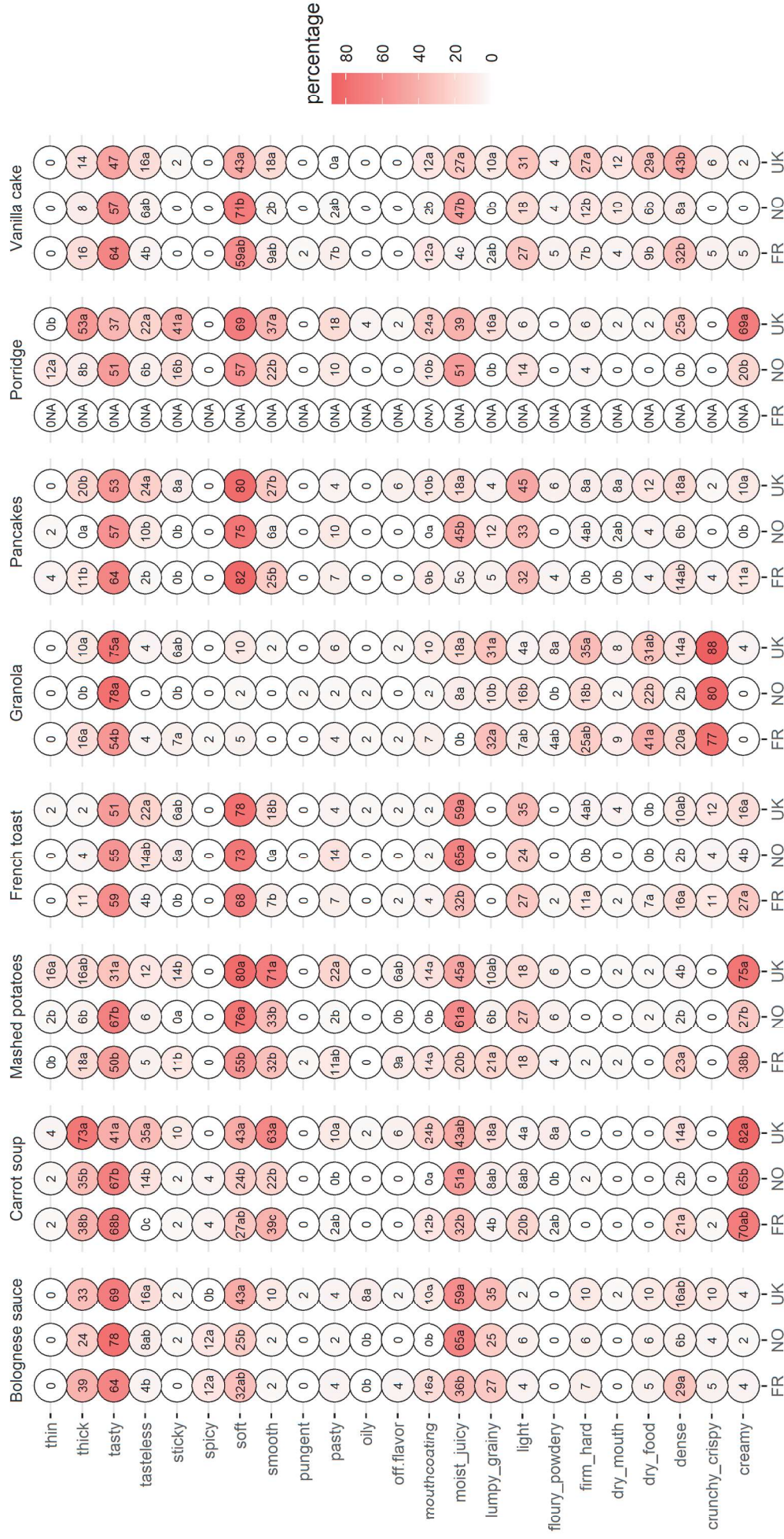


E. Swallowing



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

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



Supplementary files

This supplementary file is a part of the original submission and has been peer reviewed.

Supplement to: Geny, et al. Design and assessment of protein-fortified recipes for community-dwelling older adults to prevent the onset of undernutrition

SF-A. Characterization of the 140 high-protein ingredients (summary of the database)	2
SF-B. Characterization of the 12 high-protein ingredients (short list).....	3
SF-C. Test profile for analyses of protein-rich ingredients with RVA.....	4
SF-D. Viscosity (cP) of protein mixtures	5
SF-E. Test profile for analyses of oatmeal porridge with protein-rich ingredients with RVA....	6
SF-F. Viscosity of oatmeal porridge with the addition of 3 g proteins.....	7
SF-G. Viscosity of oatmeal porridge with (3 and 6 g protein) and without protein-rich ingredients (0 g protein).....	8
SF-H. Pictures of the fortified recipes	9
SF-I. Fortification schema presentation	10

SF-A. Characterization of the 140 high-protein ingredients (summary of the database)

	TOTAL (100%)	Animal (49.3%)	Plant-based (49.3%)	Mix (1.4%)
N	140	69	69	2
Form, n (%)				
Liquid	6 (4%)	6 (9 %)	0 (0%)	0 (0%)
Solid	134 (96%)	63 (91 %)	69.0 (100%)	2.0 (100%)
Protein level, n (%)				
< 50 %	22 (16%)	13 (19%)	9 (13%)	0 (0%)
≥ 50 %	110 (78%)	49 (71%)	60 (87%)	1 (50%)
No information	8.0 (6%)	7 (10%)	0 (0%)	1 (50%)
Mean (SD)	67.46 (24.7)	70.06 (31.34)	65.28 (16.81)	57 (0)

Animal proteins were from milk (73%), collagen (7%), beef (5%), chicken (5%), egg (3%), essential amino acid powder (2%) and pork (2%). Plant-based proteins were from pea (30%), soy (22%), bean (12%), rice (12%), hemp (10%), wheat (9%), pumpkin (6%), seaweed (6%), sunflower (6%), lentil (4%), moringa (3%), oat (3%), chia (1%), corn (1%), kale (1%), lupin (1%), potato (1%) and rapeseed (1%). Different plant proteins are often combined together into a single product to improve its nutritional profile.

SF-B. Characterization of the 12 high-protein ingredients (short list)

Origin	Product name	Description	Protein (%)	Form	Supplier	Country	Market
Animal	EAA powder	100% essential amino acids	100	Solid (powder)	THE PROTEIN WORKS	United Kingdom	B to C
Animal	Fortecare	Collagen peptides	90	Solid (powder)	NUTRISENS	France	B to C
Animal	Milk protein powder	Milk protein isolate and calcium caseinate (milk)	86	Solid (powder)	DELICAL	France	B to C
Animal	Pure whey isolate	Whey protein isolate (milk)	87	Solid (powder)	BULK	United Kingdom	B to C
Animal	Micellar casein	Casein (milk)	76	Solid (powder)	MY PROTEIN	United Kingdom	B to C
Animal	Whey protein	Whey protein concentrate (milk)	80	Solid (powder)	PURASANA	Belgium	B to C
Plant	PROatein	Oat protein	60	Solid (powder)	LANTMÄNNEN	Sweden	B to B
Plant	Rice protein powder	Sprouted brown rice grains extract	80	Solid (powder)	PURASANA	Belgium	B to C
Plant	Solanic potato protein	Potato protein concentrate	80	Solid (powder)	AVEBE	Netherlands	B to B
Plant	Soy protein powder	Soy protein isolate	90	Solid (powder)	PURASANA	Belgium	B to C
Plant	Organic soya mince	Organic partially defatted whole soya beans (extruded)	52	Solid (mince)	CLEARSPRING	United Kingdom	B to C
Plant	Veggie protein	Pea, whole grain rice and hemp protein	80	Solid (powder)	BIOTONA	Belgium	B to C

SF-C. Test profile for analyses of protein-rich ingredients with RVA

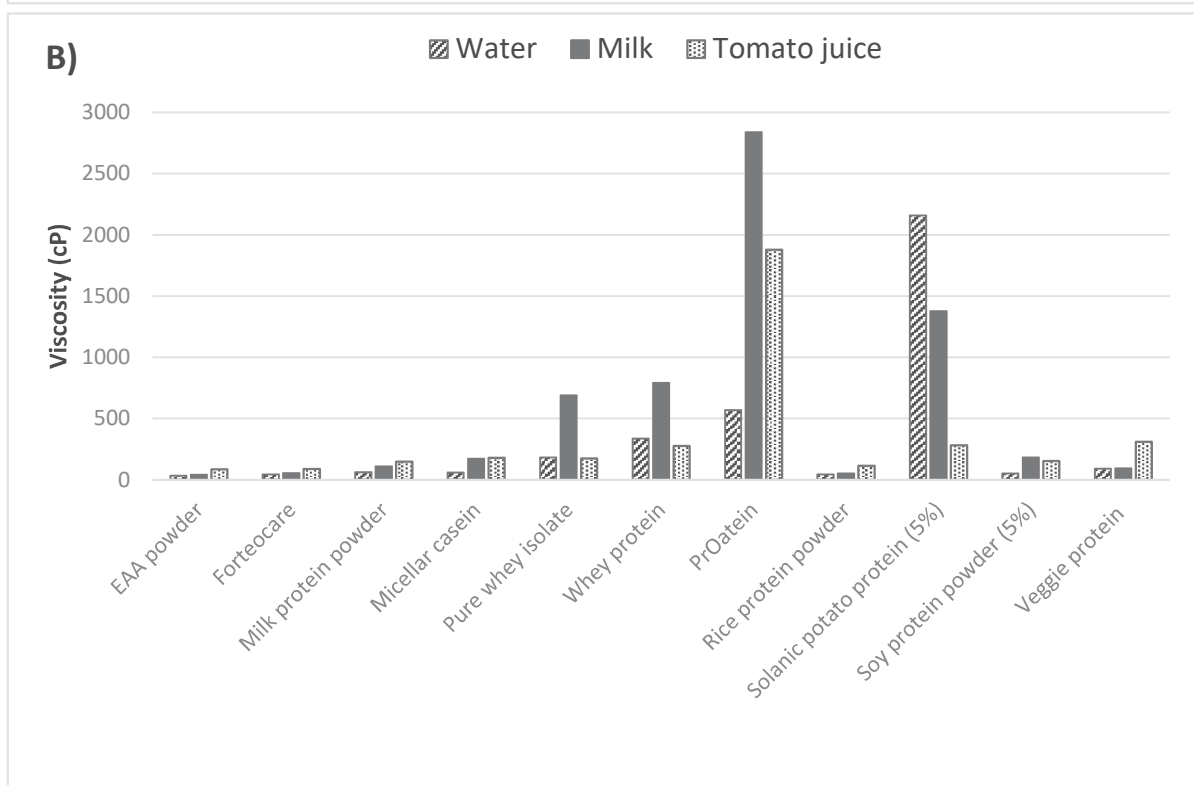
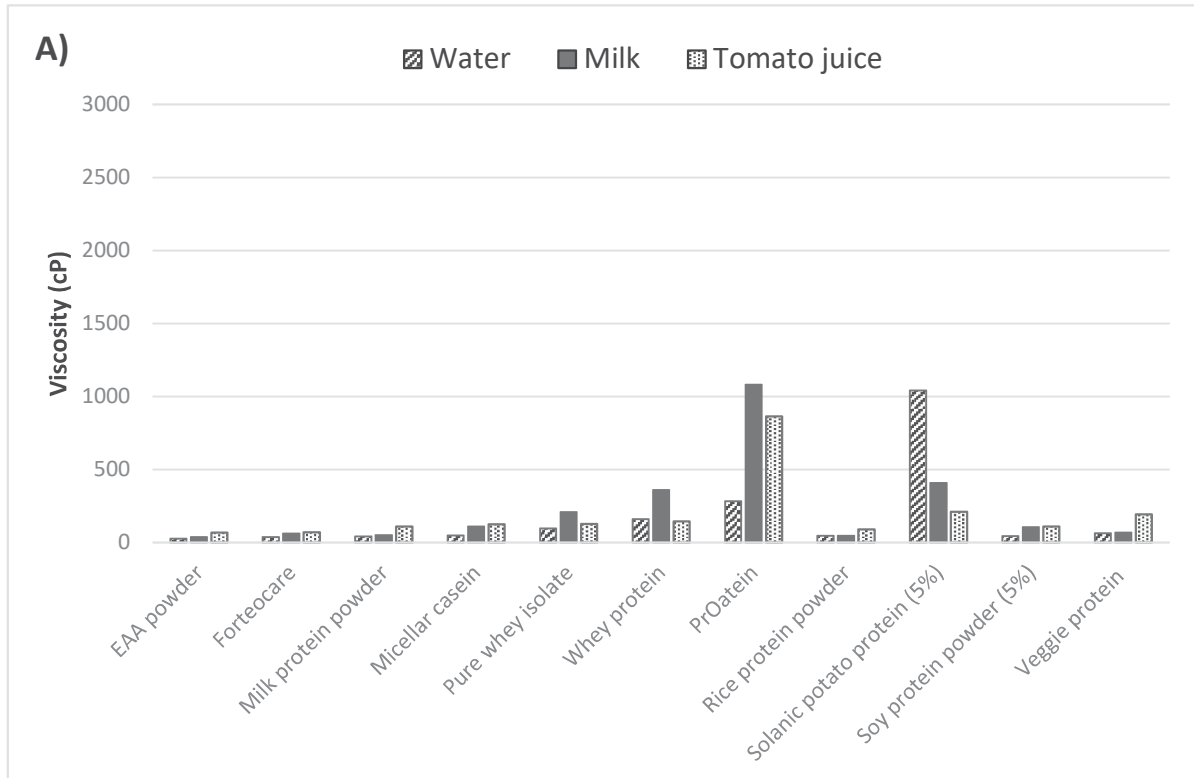
Time	Type	Value
00:00	Temp	50 °C
00:00	Speed	960 rpm
00:10	Speed	300 rpm
01:00	Temp	50 °C
04:30	Temp	80 °C
09:30	Temp	80 °C
15:00	Temp	30 °C
20:00	End	

The temperature profile was 50°C from 0 to 1 min, and it was increased to 80°C from 1 to 4.5 min and kept constant until 9.5 min. Temperature was thereafter decreased from 80 to 30°C from 9.5 to 15 min and kept constant until the end of the analysis (20 min). The solid protein powders were combined with each liquid by initially stirring at 960 rpm for 10 sec, and the mixture was stirred at 300 rpm during the analysis.

RVA: Rapid Visco Analyzer

SF-D. Viscosity (cP) of protein mixtures

with water (striped bar), skimmed milk (solid bar) and tomato juice (dotted bar) at 80°C, 5 min (A) and at 30°C, 20 min (B) measured by RVA (Rapid Visco Analyzer).



SF-E. Test profile for analyses of oatmeal porridge with protein-rich ingredients with RVA

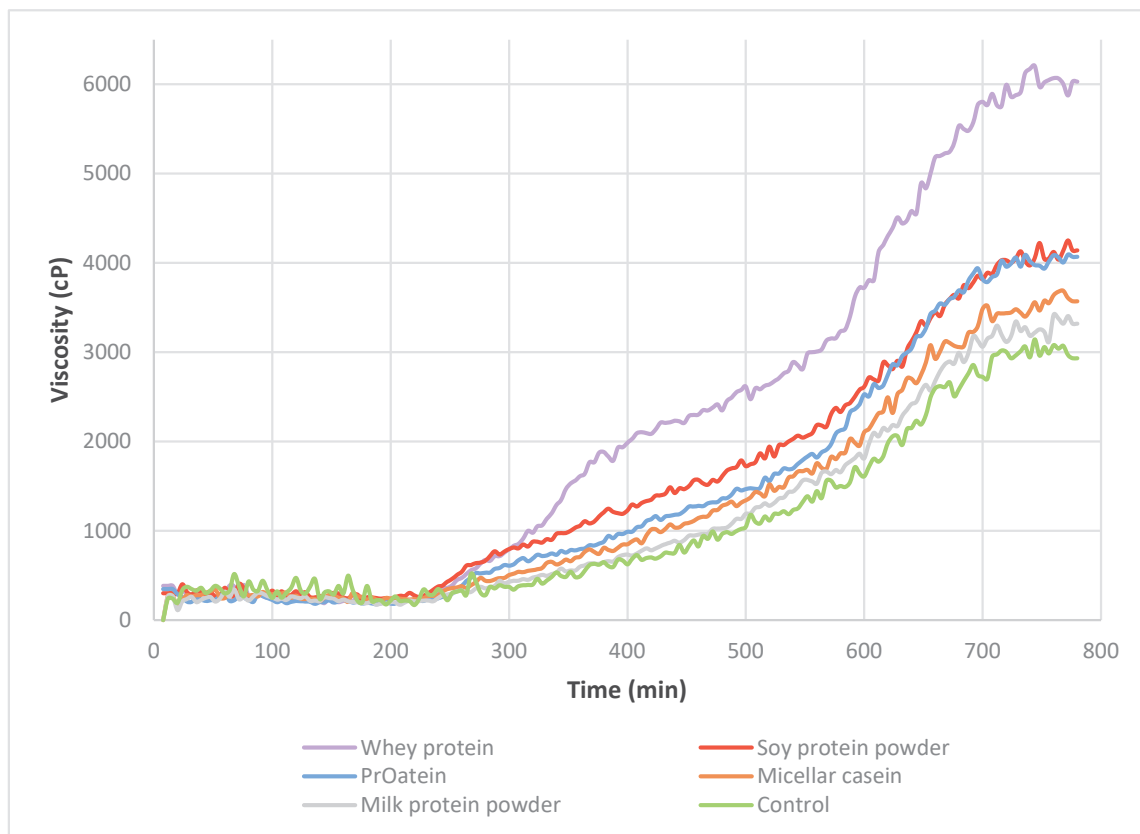
Time	Type	Value
00:00	Temp	50 °C
00:00	Speed	960 rpm
00:10	Speed	160 rpm
01:00	Temp	50 °C
04:30	Temp	95 °C
07:30	Temp	95 °C
11:00	Temp	50 °C
13:00	End	

The temperature profile was 50°C from 0 to 1 min, and it was increased to 95°C from 1 to 4.5 min and kept constant until 7.5 min. Temperature was thereafter decreased from 95°C to 50°C from 7.5 to 11 min and kept constant until the end of the analysis (13 min). Liquid and solid (oatmeal and protein powder) were combined by stirring at 960 rpm for 10 sec at the beginning, and oatmeal porridge was stirred at 300 rpm during the analysis.

RVA: Rapid Visco Analyzer

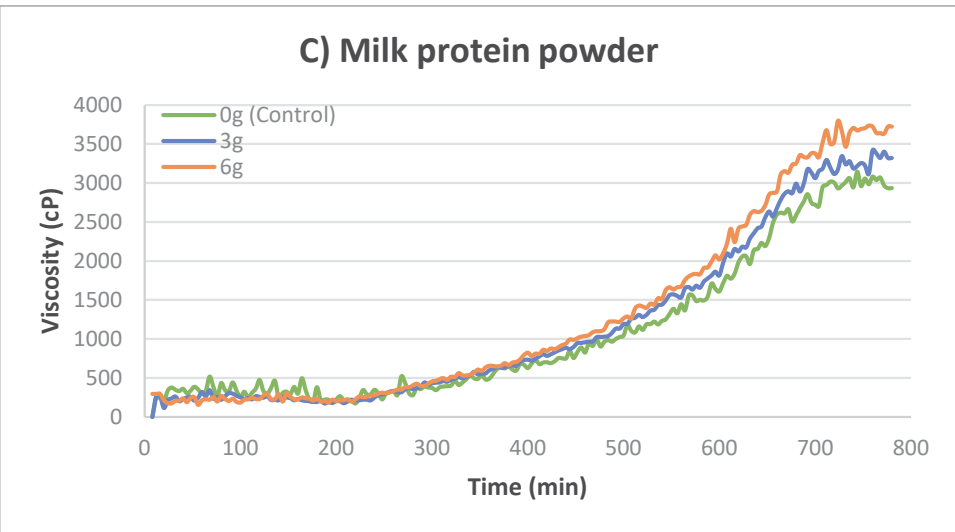
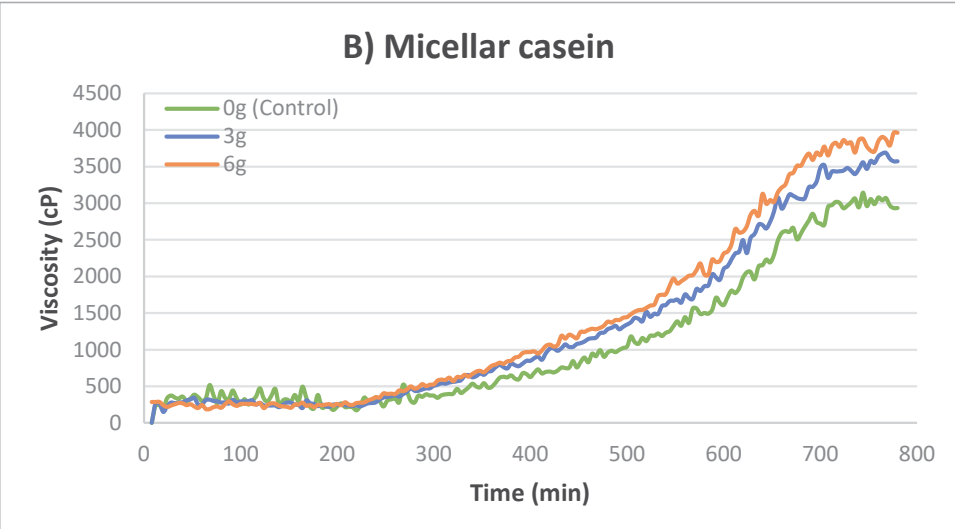
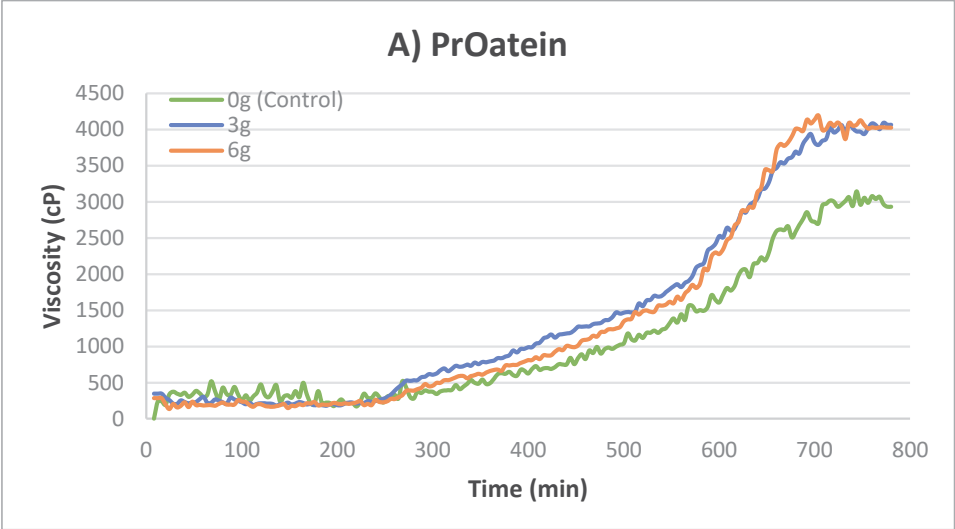
SF-F. Viscosity of oatmeal porridge with the addition of 3 g proteins

Whey protein (PURASANA; purple), Soy protein powder (PURASANA; red), PrOatein (LANTMÄNNEN; blue), Micellar casein (MY PROTEIN; orange), Milk protein powder (DELICAL; grey), and without high -protein ingredient (Control; green) analysed with RVA (Rapid Visco Analyzer).



SF-G. Viscosity of oatmeal porridge with (3 and 6 g protein) and without protein-rich ingredients (0 g protein)

PrOatein (A), Micellar Casein (B) and Milk protein powder (C) measured by RVA (Rapid Visco Analyzer).



SF-H. Pictures of the fortified recipes

Bolognese sauce



Carrot soup



Mashed potatoes



French toast



Granola



Pancakes



Porridge



Vanilla cake



SF-I. Fortification schema presentation

Presentation of the project

For older adults, eating well is a key factor in preserving their health capital and preventing the onset of age-related diseases. "Eating well" means having a suitable diet in terms of quality and quantity, allowing the older adults person to meet their nutritional needs. In fact, several studies (including work carried out in our laboratory) have shown that a certain number of older people have an insufficient consumption of proteins and/or calories, which may have serious adverse effects such as muscle loss or impaired immune functions and predisposes the person to undernutrition (see the scheme).

Presentation of the study

We are currently developing recipes to allow older people meeting their protein needs and we want them to be tested. The objective of this study is to evaluate recipes in terms of feasibility and pleasantness, taste and texture.

For this study, we will ask you to cook and taste 8 recipes at home. These recipes will correspond to common dishes (soup, cake, bolognaise sauce...) but they will have a higher level of protein than the standard dish (+8-12 g). For each recipe, you will be asked to complete a questionnaire on any difficulties encountered when preparing the recipes and, on your perception, and appreciation of the final dish. We will also ask you to complete a final questionnaire on your food habits and preferences.

Presentation of the protein extracts

Some well-known ingredients are rich in proteins (meat, fish, eggs, pulses, dairy products, nuts...). Aside from these ingredients, **protein extracts** with a higher protein content can be found on specific markets (sport market, vegan market). There are in powder form and composed of proteins extracted from natural foods. They are either from animal origin (*e.g.* milk, meat) or from vegetal origin (*e.g.* soya, pea, rice, potato). The ingredient went under several processes to be concentrated in order to have only its protein.

All protein extracts available in the European market were inventory and screened by a panel of experts on nutritional, sensory and technological aspects to select the most appropriate ones. We have finally selected 2 types of protein powders to fortify the recipes: **milk protein extract** and **soya protein extract**.

Protein content

On this table is presented several high-protein ingredients and their protein content.

Ingredients	Protein content (g/100 g)
Milk protein extract	85.7 g
Soya protein extract	52.0 g
Beef steak, grilled	27.6 g
Emmental, grated	27.5 g
Salmon, steamed	23.0 g
Nuts, dry	15.7 g
Egg, hard-boiled	13.5 g
Green lentils, cooked	10.1 g
Pasta, cooked	4.4 g
White rice, cooked	3.1 g

Usage recommendations

Protein powders should be stored in a cupboard away from heat, moisture and light. The shelf life of these extracts will be indicated on each sachet - please consume the powders within 6 weeks of opening the sachet and respect the doses indicated in the recipes.

MEAL FORTIFICATION

