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1 **The effect of nutrient fortification of sauces on product stability, sensory properties and**
2 **subsequent liking by older adults**

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28 **Abstract**

29 There are potential nutritional and sensory benefits of adding sauces to hospital meals. The
30 aim of this study was to develop nutrient fortified sauces with acceptable sensory properties
31 suitable for older people at risk of under-nutrition. Tomato, gravy and white sauce were
32 fortified with macro and micro-nutrients using food ingredients rich in energy and protein as
33 well as vitamin and mineral premixes. Sensory profile was assessed by a trained panel.
34 Hedonic liking of fortified compared with standard sauces was evaluated by healthy older
35 volunteers. The fortified sauces had higher nutritional value than the conventional ones, for
36 example the energy content of the fortified tomato, white sauce and gravy formulations were
37 increased between 2.5 and 4 fold compared to their control formulations. Healthy older
38 consumers preferred the fortified tomato sauce compared with unfortified. There were no
39 significant differences in liking between the fortified and standard option for gravy. There
40 were limitations in the extent of fortification with protein, potassium and magnesium, as
41 excessive inclusion resulted in bitterness, undesired flavours or textural issues. This was
42 particularly marked in the white sauce to the extent that their sensory characteristics were not
43 sufficiently optimised for hedonic testing. It is proposed that the development of fortified
44 sauces is a simple approach to improving energy intake for hospitalised older people, both
45 through the nutrient composition of the sauce itself and due to the benefits of increasing
46 sensorial taste and lubrication in the mouth.

47

48 **Keywords:** malnutrition, micronutrient, macronutrient, fortification, older people

49 **Practical Applications:**

50 This study developed macro- and micro- nutrient fortified sauces where the intended use is
51 for older adults at risk of under-nutrition. The energy content was increased between 2.5 and
52 4 fold compared to control formulations. Whey protein was successfully added to tomato and

53 white sauces. We note that excessive protein addition leads to textural issues and excessive
54 potassium or magnesium inclusion results in undesired flavours. We propose that fortified
55 sauces are a simple approach to improving energy intake for hospitalised older people.

56

57 **1. Introduction**

58 Older people (>65 years) often do not consume enough energy and / or nutrients to support
59 their minimum requirements. Current estimates suggest that undernutrition affects 1.3million
60 of people over 65 years of age in the UK (BAPEN 2011). This under-nutrition has been well
61 documented to be associated with increased incidence of complications, longer hospital stays,
62 reduced mobility, increased social isolation and reduced quality of life, and affects not only
63 the older person, but also impacts on community and health service resources (Cowan and
64 others 2004).

65 Maximising food intake is important for prevention and treatment of malnutrition, and this is
66 sometimes difficult due to small appetite. One way of overcoming a small appetite is to
67 fortify foods. Nutrient fortification can refer to the addition of either macronutrients or
68 micronutrients to foods; or merely the addition of suitable condiments, such as a sauce, to
69 foods. Previous studies have reported that the addition of sauces to a meal increased energy
70 intake in older adults without affecting pre-meal hunger, desire to eat, or post-meal
71 pleasantness (Appleton 2009). The increased energy consumption was mainly from fat and
72 protein.

73 Within hospitalised older adults, it has been reported that meal macronutrient
74 fortification can improve energy (+26%) and protein (+23%) intake (Gall 1998). When
75 considering how to increase protein levels in foods for older people, both protein level and
76 protein quality should be considered. Recent studies of individuals with sarcopenia have

77 found that whey protein stimulates muscle protein synthesis more effectively than casein or
78 vegetable protein (Pennings and others 2011) .
79 Best and Appleton (2011) found that the addition of both seasoning and sauce to an older
80 person's meal resulted in comparable increases in energy, protein and fat intake, thus
81 supporting a role for flavour enhancement in increasing the food intake of older people, as
82 well as the role of the sauce itself. However, sauces may be more beneficial than dry
83 seasonings when promoting food intake in older people due to the semi-solid nature of the
84 sauce. In older individuals, where gastro-intestinal secretions and motility are known to be
85 reduced or impaired (Cowan 2004), semi-solid foods may facilitate chewing and swallowing
86 and aid the passage of foods through the digestive system (Appleton 2009).

87 *1.1 Micronutrient fortification*

88 Older hospital patients may be at risk of micronutrient deficiency due to low food intake,
89 chronic diseases or medication (Bates and others 1999). Moreover, eating micronutrient-dense
90 foods becomes increasingly important where appetite is small but vitamin and mineral needs
91 remain high.

92 Considering the development of micronutrient fortified foods for older hospital patients, two
93 approaches could be taken. One approach would be to provide a "full" nutrient supplement,
94 the principle taken by oral nutritional supplement (ONS) beverages. An alternative approach,
95 and the one taken in this study, is to fortify products with micronutrients for which there is
96 substantial evidence within the older adult institutionalised community.

97 Evidence from the UK National Diet and Nutrition Survey (NDNS) indicates that the
98 micronutrients that institutionalised older people are most likely to be at risk of deficiency of
99 are iron, vitamin D, riboflavin, folate and vitamin C (Bates and others 1999). The study by
100 Bates and others (1999) considered micronutrients where intake was low (more than 25 % of
101 institutionalised participants with intakes below the RNI) or where more than 25 % of

102 institutionalised participants had biochemical indices low enough to be associated with
103 deficiency. More recently the Food Standards Agency (FSA) guidelines for food provision
104 for older adults in residential care (Food Standards Agency 2007) recommend levels five
105 minerals (sodium, potassium, magnesium, iron and zinc) and three vitamins (riboflavin,
106 vitamin D and folate). It should also be noted that the Department of Health recommended
107 nutrient intake (RNI) values for minerals and vitamins give guidelines for the 50+ age group,
108 but there are no such guidelines in place for an older age group. The most recent UK NDNS
109 report from May 2014 (Public Health England 2014) summarises intake and deficiency of
110 nutrients in adults over 65 years of age, but not in an institutionalised cohort. It concludes that
111 in the over 65 age group mean intake of all vitamins met the RNI, except for vitamin D which
112 only met 33% of the RNI. Regarding minerals, mean intakes of potassium, magnesium and
113 selenium were below the RNI, although this was the case in all age groups. It was reported
114 that mean intake of iron, calcium, vitamin C and folate were higher in the over 65 age group
115 than reported in previous surveys. Although this is good news, there is no evidence to suggest
116 that institutionalised older adults are meeting their RNI for these nutrients.

117 *1.2 Sauce Types*

118 Tomato based sauce, white sauce and gravy are three commonly used sauces in the UK
119 (CookinInfo 2014), aside from the bottled sauces applied at the table (e.g. Ketchup). Tomato
120 sauces are typically served on pasta or with meat or fish, with the tomatoes being an
121 important source of carotenoids. White sauces are produced using fat, a thickener and milk.
122 They are widely used in the UK within fish recipes and, to a lesser extent, within pasta.
123 Gravy is typically applied to meat dishes as well as to vegetable and potato side dishes.
124 Although traditionally produced using meat stock, meat fat and thickener, gravy is widely
125 available as a commercial dried product containing stock, yeast extract and thickeners to
126 which water is added before serving. Typically neither tomato sauce nor commercial

127 “instant” gravy, would be particularly energy or protein dense, while white sauces are
128 generally more energy and protein dense.

129 In view of the potential for sauces to increase nutrient provision in older hospital patients the
130 aim of this study was to develop a range of savoury sauces fortified with energy, protein and
131 micronutrients, delivering high taste impact and acceptable sensory profiles for older adults.

132 **2. Materials and methods**

133 *2.1 Materials for Tomato Sauce*

134 A tomato base was prepared using chopped tomatoes (Napolina Ltd., UK), extra virgin olive
135 oil (Filippo Berio Ltd., UK), garlic granules and onion granules (McCormick UK Ltd.), salt
136 basil, parsley, oregano and lemon juice (local retailer). Fortified formulations (Table 1)
137 contained combinations of sunflower oil, double cream, unsalted butter (local retailer),
138 double concentrated tomato puree (Napolina Ltd., UK), whey protein isolate (WPI) (protein
139 content minimum 94%, fat 0.2%) (Volac International Ltd., UK), maltodextrin (C* dry,
140 Cargill PLC, UK), and a de-oiled soybean lecithin (Emulpur IP, Cargill PLC, UK). Tomato
141 puree was used to restore the red colour where ingredients resulted in a pale coloured sauce.
142 The lecithin prevented separation of the sauces when extra lipid was added.

143 *2.2 Materials for White Sauce:*

144 White sauce (Table 2) was prepared using semi-skimmed (1.7% fat) or whole pasteurised
145 milk (4% fat), salted butter, white flour, salt, nutmeg, white pepper and bay leaves (local
146 retailer). Mineral water was used to compensate for the losses during cooking (Harrogate
147 Spring Water Ltd., UK). Double cream (local retailer) or WPI (as above, Volac, UK) were
148 added to increase energy and protein content.

149 *2.3 Materials for Gravy:*

150 Gravy (Table 3) was produced using commercial gravy granules (Bisto, or Bisto reduced salt
151 gravy granules, Premier Foods, UK) and water (Harrogate Spring Water Ltd., UK).
152 Fortification utilised unsalted butter or double cream (local retailer) soy sauce (Pearl River,
153 sodium content 5.8g per 100ml, Guangdong PRB Bio-tech co, Ltd., China), Kikkoman low
154 salt soy sauce (sodium 3.6g per 100ml, Kikkoman Foods Europe B.V., Netherlands) and de-
155 oiled soybean lecithin (Emulpor IP, Cargill PLC, UK).
156 Taste enhancement was achieved through the use of soy sauce and a commercial flavour
157 enhancer (sodium 3g/100g, glutamate 16g/100g; Givaudan Schweiz AG, Switzerland).

158 *2.4 Micronutrient addition to Sauce:*

159 A micronutrient blend (Lycored, Kent, UK) (an orange-yellow coloured powder) was used at
160 0.1% (w/w). The premix (100 mg) contained iron (6 mg), zinc (6.4 mg), riboflavin (0.8 mg),
161 vitamin B6 (0.86 mg), folic acid (134 µg), vitamin C (26.6 mg) and vitamin D (6.6 µg). In
162 addition, the sauces were enriched with potassium and magnesium. Initially dipotassium
163 hydrogen phosphate (K_2HPO_4) (45% K by weight) (5.16% (w/w) addition), and magnesium
164 oxide (MgO) (60% Mg by weight) (0.34% (w/w) addition) were used to provide one-third of
165 the RNI of potassium and magnesium in 50g of sauce. However, due to excessive bitter and
166 metallic taste these concentrations were lowered to 1.2% and 0.08% (w/w) for K_2HPO_4 and
167 MgO respectively following tasting trials. These percentages corresponded to 18.4% and
168 14.2% of RNI for potassium and magnesium respectively in a portion of sauce (50g). The
169 potassium salt was later replaced with 1.5% (ww) tri-potassium citrate monohydrate
170 ($C_6H_5K_3O_7 \cdot H_2O$) (36% K by weight) aiming to improve taste acceptability.

171 *2.5 Tomato Sauce preparation*

172 Chopped tomatoes were blended (laboratory microniser), all other ingredients were added
173 and the sauce blend was cooked (20 min, low heat, stirred at 10 min).

174 *2.6 White Sauce preparation*

175 Butter and bay leaves were heated (low heat) until butter melted. White flour added, stirred
176 and heated (2 min). Milk added gradually, continuous stirred until the sauce reached boiling
177 point (ca. 10 min). Other ingredients (double cream, WPI, micronutrients) then added, heated
178 for a further 2 minutes, stirring occasionally. Sauce seasoned with salt, white pepper and
179 nutmeg. Bay leaves removed and the sauce was re-diluted with water to account for 15%
180 weight loss due to evaporation.

181 *2.7 Gravy preparation*

182 Boiling water was added to the commercial gravy granules, all additional ingredients were
183 added, continuously stirring until dissolved and blended (electric hand blender, 1 min).

184 *2.8 Nutritional Profile*

185 Calculations were made in order to define the nutritional profile of sauces using the software
186 Dietplan 6 (Forestfield Software Ltd., Horsham, UK).

187 *2.9 Sensory profile analysis*

188 All samples were frozen post manufacture (-18°C). For sensory analysis, samples were
189 defrosted at ambient temperature for 2 hours, heated in a microwave (5 min, stirred at 2.5
190 min) to a temperature of 75°C, and held in a heated trolley for up to 20 min.

191 Sensory profiling of sauces was conducted by a trained panel (n= 8 to 11; average age 48
192 years). The panel developed a consensus vocabulary for all samples. Attribute scoring was on
193 140 mm unstructured line-scales (scaled 0-100) using Compusense® software (Version 5.0,
194 Canada). Panellists were seated in individual testing booths under artificial daylight, except
195 for white sauce samples which were evaluated under red light. Samples were presented in a
196 balanced order, coded with random 3 digit numbers. Scoring was carried out in duplicate on
197 separate days.

198 *2.9.1 Sensory profiling of fortified tomato sauces*

199 Macronutrient fortified samples were initially compared to control tomato sauce (Table 1).
200 The cream and WPI plus maltodextrin fortified sauces were further fortified with
201 micronutrients and profiled.

202 *2.9.2 Sensory profiling of fortified white sauces*

203 Four samples were evaluated: Control, Energy Fortified, Energy, Protein and Micronutrient
204 fortified and maximum nutrient fortified (Table 2).

205 *2.9.3 Sensory profiling of fortified gravies*

206 Macronutrient fortified gravy was initially compared to control gravy (Table 3). Energy
207 enhancers were used (vegetable oil, butter, double cream) with soy sauce (Pearl River
208 Bridge) to darken the colour. The macronutrient fortified gravy was then compared to options
209 further fortified with micronutrients and / or flavour enhancement.

210 *2.10 Hedonic liking evaluation*

211 The part of the study to test the hedonic liking was given a favourable ethical opinion for
212 conduct by the University of Reading Research Ethics Committee (study number 0830).
213 Healthy older volunteers (n=31 for tomato sauce; n= 36 for gravy), age 62-87 years (mean
214 age 71 years), rated their liking for tomato sauce and gravy samples on a hedonic category
215 scale ranging from 1 (dislike extremely) to 9 (like extremely). The consumer tests were
216 carried out in a central location where the tables were laid out to form a restaurant-like
217 environment. All samples were presented monadically in a balanced order and labelled with 3
218 digit random codes.

219 The tomato sauce samples initially rated were the control and the three macronutrient
220 fortified samples (Table 1). Samples (30g) were served at 75 ± 5 °C in paper cups (100ml). In
221 a separate assessment, the control tomato sauce was compared to the double cream plus

222 micronutrient fortified sample, where sauce (40+/-5g) and pasta (40+/-5g) were served in
223 paper cups (100ml) with a plastic fork.

224 Two gravies were rated, the control and the macronutrient fortified option (table 3). Samples
225 (20g) were served at 75±5 °C, poured over mashed potato (30 g) in transparent plastic dishes
226 (200ml). Hedonic testing of the white sauces was not carried out (see discussion section 3.3).

227 *2.11 Data analysis:*

228 Statistical analysis of sensory profiling data was performed using two-way analysis of
229 variance, with main effects tested against the sample by assessor interaction, and Fisher's
230 LSD test for multiple comparisons, using Senpaq (SenPaq, v4.2; Qi Statistics Ltd; Reading,
231 UK). The 9-point hedonic liking data was analysed using the Wilcoxon Signed Rank Test
232 using XLStat (XLStat version 2009, Addinsoft, France).

233

234 **3. Results and Discussion**

235 *3.1 Nutritional Information*

236 *3.1.1 Tomato sauce*

237 The nutritional profile of the tomato sauces is shown in Table 5. The energy content of the
238 fortified formulations was increased 3 to 4 fold compared with the control, predominantly
239 through the use of high lipid ingredients; butter, vegetable oils and/or cream (Table 1).

240 Protein and carbohydrate levels were increased 1.9 and 1.5 fold respectively when WPI and
241 maltodextrin were used. Table 4 compares the double cream plus micronutrients sauce
242 variant (the variant selected for hedonic testing, section 3.2) to the dietary reference values
243 (DRV) for macronutrients and reference nutrient intake (RNI) values for micronutrient, for
244 older people (Department of Health 1991). Assuming a 50 g portion size of sauce, the
245 maximum energy and protein provided was rather limited, 4% and 2% of the DRV

246 respectively. However it is expected from previous authors (Appleton, 2009) that the use of
247 sauce would not only provide macronutrients itself, but also lead to a greater intake of
248 nutrients from the meal to which it was applied. A portion size of 50 g is conservative, if used
249 as a pasta sauce for example the portion size could be 2 to 4 fold higher, providing up to 16%
250 and 8% of DRV for energy and protein respectively. Micronutrient addition enriched the
251 sauces with vitamins and minerals. However, the ingredients used to achieve the
252 macronutrient fortification also contributed to the micronutrient content of the sauce; all
253 fortified sauces were higher in potassium and vitamin E, and to a lesser extent thiamine,
254 riboflavin, niacin, pantothenic acid and biotin. The sauce fortified with double cream was
255 higher in copper, iodine, retinol and vitamin D. The sauce fortified with WPI was higher in
256 carotene and folate. A 50g portion of the double cream plus micronutrient sauce would
257 provide 33% to 40% of vitamins D, B₆,C, riboflavin, folate, iron and zinc as well as 13% and
258 10% of potassium and magnesium requirements respectively.

259 *3.1.2 White sauce*

260 The energy content of fortified white sauces (Table 6) was 2.5 fold higher than the control,
261 primarily due to whole milk and double cream (Table 2), which also increased the fat content
262 more than three fold. Although WPI was used to increase the protein content, the overall
263 increase was small, from 3.8 to 4.5 % (w/w). Whole milk and double cream increased the
264 levels of retinol, carotene and vitamin E delivered, as they are fat soluble vitamins. The
265 major contribution to micronutrients was through the addition of the vitamin and mineral
266 premix (Table 6). It was noted however, that the macronutrient fortification led to a decrease
267 in calcium delivered compared with the control, this was not intentional and could be
268 rectified through the mineral premix addition in future developments. A 50 g portion of the
269 maximum nutrient fortified would provide 35% to 43% of the vitamins (D, riboflavin, B₆,
270 folate and C), iron and zinc as well as 10 % of both potassium and magnesium RNI for older

271 people (DH 1991) (Table 4), however it should be noted that this sauce did not have an
272 optimised sensory profile (section 3.3) and required further development. The 50g of portion
273 of sauce would provide a limited amount of energy and protein, 6% and 4% of the DRV
274 respectively. It was noted that as a dairy sauce it is relatively high in fat and provides 30 % of
275 the DRV for saturated fats. However, it is also noted that the sauces were developed
276 primarily for provision to undernourished older hospital patients where increasing energy
277 intake is paramount. DRVs were predominantly used as a guide for the micronutrient
278 fortification.

279 *3.1.3 Gravy*

280 The nutrient profile of the fortified gravies (Table 7) showed a 2.8 fold energy increase
281 compared with the control, achieved predominantly through the increase in fat (over 5 fold),
282 through the addition of cream, oil and butter (Table 3). The maximum fortification that was
283 practically possible did not have a significant impact on overall protein level. The
284 micronutrient content of the gravies changed substantially after the incorporation of the
285 vitamin and mineral premix (Table 8). The maximum fortified gravy (the final variant tested,
286 Table 3) was compared to daily recommendations based on the FSA (2007) guidelines for
287 nutrients for food provided to older people in residential care in Table 4. A 50 g portion of
288 this gravy would provide 33% to 34% of the vitamins (D, riboflavin, B₆, folate and C) iron
289 and zinc as well as 8% of both potassium and magnesium RNI for older people in residential
290 care (Food Standards Agency 2007). The 50g of portion of sauce would provide only 3%
291 energy and 1% protein of the DRV.

292 Across all three sauce types the macronutrient enhancement was partly achieved through the
293 addition of high fat ingredients. The UK FSA recommendations (Food Standards Agency
294 2007) for food provision to older adults in long term residential care recommend restricting
295 fat intake to a maximum of 76 g per day, with a maximum of 24 g saturated fat per day. So,

296 certainly in long term care and in the community, routinely increasing fat content should not
297 be recommended without taking into account the persons baseline nutritional and medical
298 status. However, within acute hospital care setting that the sauces were designed for, the
299 energy intake of older patients is of primary importance as opposed to fat intake restriction.

300 *3.2 Sensory and hedonic evaluation of tomato sauces*

301 Between the four tomato sauce samples initially tested (control and three macronutrient
302 fortified samples) there were significant differences between 25 of the 32 consensus attributes
303 (data not shown). In appearance and mouthfeel the control was thicker, darker, lumpier,
304 grainier, more gelatinous and fuller bodied than the macronutrient fortified samples, due to its
305 increased content of chopped tomato. Unsurprisingly, samples which had the oiliest
306 appearance and mouthfeel were the ones which contained both oil and either butter or cream.
307 The sample containing WPI and maltodextrin was not oilier than the control, despite oil
308 addition. In terms of orthonasal smell and retronasal flavour, the control was less creamy and
309 buttery; more herby and pungent, but had a significantly weaker tomato smell (mean values
310 29 compared to 38- 44, $p=0.006$), implying successful utilisation of tomato puree in place of
311 chopped tomatoes in the fortified sauces. With regard to taste, the control was less sweet,
312 more bitter and sour than the macronutrient fortified products. It was also significantly more
313 salty than the WPI plus maltodextrin and the butter products. The control had the most
314 astringent and burning after effect. When the four tomato sauce samples were presented to
315 older volunteers, significant differences in mean hedonic liking were found ($p< 0.0001$). Two
316 of the macronutrient fortified options, those containing double cream and WPI plus
317 maltodextrin, were liked more than the control (mean liking scores of 5.9 and 5.7 compared
318 to 4.5). The sample containing butter was not significantly different in liking score (mean
319 4.9) from the control.

320 The two preferred macronutrient options were progressed to micronutrient fortification. It
321 was important to study the effect of mineral addition to sauce containing WPI to examine
322 possible textural issues (coagulation, flocculation, viscous appearance) or taste issues (bitter,
323 metallic). The resulting four samples were directly compared through sensory profiling.
324 There were significant differences in 18 of the 46 consensus attributes (Table 8). The nutrient
325 premix had a yellowish-orange colour due to the iron inclusion. The iron undergoes oxidation
326 when in contact with air, forming iron (III) oxide which has a red-brown colour, explaining
327 the darker colour of the sauce.

328 The addition of micronutrients appeared to reduce the viscosity and lumpy texture of the
329 samples; although this was only significant in the cream variant. This may be attributed to the
330 stabilising action of the citrate salt on dairy ingredients. It has been shown that the addition of
331 chelating agents, such as tri potassium citrate, in optimum concentration, can improve heat
332 stability and texture in dairy systems by reducing the concentrations of ionic calcium
333 (Mekmene and Gaucheron 2011).

334 In terms of orthonasal smell and retronasal flavour the addition of micronutrients tended to
335 lower sweet smell and, in the case of the cream sample, tomato smell, whereas meaty, fried
336 onion and smoky flavours were enhanced. Of greater concern, the addition of micronutrients
337 led to significantly higher bitter taste, which was more substantial in the WPI plus
338 maltodextrin sample. Potassium and magnesium are known to have bitter taste at relatively
339 low taste thresholds of 340 – 680mg and 100mg per litre respectively in pure solutions
340 (Lawless and others 2003; Schiffman and others 1995), and they were present in the
341 micronutrient enhanced formulation at 8840 and 730 mg per litre respectively. Bitter taste
342 and meaty flavour remained higher in the micronutrient fortified samples as aftertaste effects.

343 With regards to mouthfeel, micronutrient addition tended to reduce grainy mouthfeel and the
344 WPI plus maltodextrin variants were grainier than the cream ones. This may be due to the

345 powder form of both WPI and maltodextrin compared to the liquid form of double cream.
346 Oily and gelatinous mouthfeel were highest in the micronutrient enhanced cream sample.
347 As the cream variant with micronutrients tended to be less bitter, starchy and grainy than the
348 WPI option, it was progressed to consumer testing. Two tomato sauce samples (control and
349 double cream + micronutrients) were presented to older volunteers (n=31), however, the
350 differences in mean hedonic liking did not reach significance ($p=0.096$). The control sample
351 received a lower mean liking score (5.3) than the fortified product (6.0). The potentially
352 negative attributes associated with micronutrient fortification, and detected by the sensory
353 panel do not, therefore, appear to have reduced liking by the older consumers.

354 *3.3 Sensory evaluation of white sauces*

355 The four white sauce variants were described by 38 consensus attributes, of which 29 were
356 significantly different between samples (Table 9). Although the micronutrient enhanced
357 white sauces had a more yellow colour, this difference was not rated; red lights were used to
358 avoid biasing panel scores of other attributes. Concerning appearance and mouthfeel, the
359 control white sauce was significantly thicker, lumpier, more glutinous, more mouthcoating
360 and less smooth than the modified formulations. This was attributed to the higher amount of
361 flour used in the control. All sauces were frozen post manufacture, thawed and reheated for
362 sensory profiling. Although the native starch in flour is cooked during sauce preparation, any
363 remaining native starches would be extensively damaged after a freeze/thaw cycle (Arocas
364 and others 2009). In future, a combination of native starches and hydrocolloids could be used
365 to improve stability. In the present study the sauce was more stable with higher fat (cream and
366 whole milk) and less flour.

367 Concerning orthonasal smell and retronasal flavour, the main significant differences were
368 caused by the addition of micronutrients which led to higher ratings of fish, metallic and
369 chemical aroma. The fish aroma was very high in the maximum fortified sample and was

370 attributed to the addition of K-citrate. Fishy aromas are typically caused by lipid oxidation
371 and it is likely that this was catalysed by potassium. The chemical aroma occurred in both of
372 the micronutrient fortified samples, hence is likely to be attributed to the inclusion of the
373 vitamin and mineral premix and / or the magnesium oxide. Concerning taste, the maximum
374 nutrient fortified sample was less sweet, and more salty, sour and bitter. The salty taste was
375 attributed to micronutrient addition and not due to sodium which was virtually constant
376 between samples (117-123mg Na/100g of sauce). Similarly, the minor difference in total
377 sugars content (Table 6) does not explain the differences in sweetness, implying the tastes
378 associated with the use of K-citrate (bitter, sour and salty) suppressed sample sweetness. Milk
379 flavour was also lower where K-citrate, MgO and the vitamin/mineral premix were added.
380 Creamy flavour was, as expected, higher following the addition of cream in the macronutrient
381 fortified options, but suppressed where K-citrate was added. The control sample had a more
382 starchy flavour, explained by the slightly higher level of added flour. Nutmeg and pepper
383 flavour were suppressed by both the macro- and micro-nutrient fortification. The maximum
384 fortified sample was most mouthdrying. This might be explained by the high levels of
385 potassium salt, by the higher levels of protein (4.5%) in this sample, or a combination of the
386 two factors. Previous studies have shown whey proteins to cause mouthdrying (Ye and others
387 2012). The control sauce led to the most burning after effect, perhaps attributed to its lower
388 concentration of fat (5.8%). Results of previous research indicated that increased fat content,
389 up to approximately 20%, increases lubrication and decreases sensations of roughness and
390 dryness in semi-solid foods (Wijk and Prinz 2005).

391 Summarising the results, macronutrient fortification led to a smoother sauce with, not
392 surprisingly, a creamier flavour. Addition of micronutrients (vitamin and mineral premix plus
393 MgO) did not substantially change the sauce attributes. However the addition of K-citrate at
394 (1.6%; 698mg K per 100g sauce) led to fish and chemical off-flavours. Hedonic liking on the

395 white sauce formulations was not carried out as the micronutrient fortification remained sub-
396 optimal.

397 *3.4 Sensory and hedonic evaluation of gravies*

398 Of 38 sensory attributes used to describe the profile of the control and macronutrient
399 enhanced gravies, only 7 were significantly different between samples (data not shown). The
400 macronutrient enhanced options was equally as brown as the control, through the use of soy
401 sauce (Pearl River); whereas initial samples developed were too pale once ingredients such as
402 cream, butter and oil were added. Although this particular soy sauce was high in sodium, the
403 macronutrient fortified gravy used reduced salt gravy granules to equalise the salt content of
404 the two samples. The fortified option was thinner and less oily than the control in appearance,
405 with a richer mouthfeel. It was less savoury and starchy in smell, with more buttery and dairy
406 flavour.

407 Hedonic liking of the control gravy and the macronutrient fortified gravy found no significant
408 difference ($p=0.57$) with mean liking scores of 6.5 and 6.3 respectively.

409 The macronutrient fortified gravy was further modified by flavour enhancement (using a low
410 salt soy sauce, rich in glutamate, plus a commercial flavour enhancer) and micronutrient
411 fortification. The presence of micronutrients caused several changes to the sensory profile of
412 the gravies (Table 10). Of 42 consensus attributes, 24 were significantly different between
413 samples. The addition of micronutrients led to a lower brown appearance. When the
414 commercial flavour enhancer was used, the addition of micronutrients suppressed aroma
415 attributes such as savoury, onion, beef stock, red wine and acidic. Considering taste,
416 bitterness was significantly higher with the incorporation of the flavour enhancer, but the
417 differences were not substantial. Concerning flavour, the addition of micronutrients led to
418 suppression of beef and red wine flavour, but caused mushroom and nutty flavours. The

419 addition of the powdered micronutrient premix caused a less smooth mouthfeel. Where the
420 flavour enhancer was present, addition of micronutrients caused a less rich mouthfeel. In
421 terms of after effects, both gravy types had stronger mushroom flavour after-effect where
422 micronutrients were added. Overall the use of flavour enhancer significantly led to higher
423 ratings of umami (savoury) taste and beef flavour, which might benefit the acceptability by
424 older adults (Dermiki and others 2013). The incorporation of micronutrients only led to
425 higher levels of potentially negative attributes (eg bitter), but to a relatively small extent.

426 *3.5 Limitations in the fortification of Whey Protein and Micronutrients*

427 The addition of WPI and the combination of WPI and micronutrients can lead to sauce
428 instability. The macronutrient enhanced sauces developed in this study can be characterised
429 as oil-in-water emulsions after the incorporation of high fat ingredients. Many food
430 emulsions consist of droplets of fat or oil suspended in an aqueous medium. The interface
431 between the oil and the water at the droplet surface must be occupied by surfactant molecules
432 to prevent immediate aggregation or coalescence. Surfactants can be either small amphiphilic
433 molecules (such as lecithin used in this study), and large surface active molecules, such as
434 proteins (Biesalski and others 2003). Aggregation occurs where the surfactant layer cannot
435 prevent the droplets from approaching one another. The net charge of a protein, and hence an
436 adsorbed protein layer, is highly dependent on pH. If the pH is close to the isoelectric point of
437 the protein, its net charge approaches zero, which favours aggregation. Emulsions containing
438 whey proteins are generally unstable at pH values close to 5, especially if the emulsion is
439 heated (Biesalski and others 2003). The presence of calcium ions is inversely related to the
440 pH (Geerts and others 1983) and therefore affects the stability of the emulsions. This is
441 explained by binding of the calcium ions to the phosphoserine residues of the caseins, which
442 reduces the negative charge on the protein, and so reduces stability. In our case, emulsion
443 instability occurred in all three types of sauce when a certain concentration of whey protein

444 isolate was exceeded. The addition of micronutrients in combination with WPI resulted in
445 coagulation of the sauces and this phenomenon was observed during the freezing/thawing
446 procedure. It has been reported that the casein micelles of milk are destabilised by slow
447 freezing (cryodestabilisation) and storage at a temperature in the range -10 to -20°C. This
448 causes a decrease in pH and an increase in the calcium ion concentration in the unfrozen
449 phase of milk (Fox and Brodkorb 2008). The most unstable sauce was the white sauce and
450 this might be due to its high concentration of milk constituents and their sensitivity to the
451 presence of minerals. The samples that were unstable were unacceptable for sensory
452 evaluation, therefore were not assessed. The maximum limit of WPI addition in each type of
453 sauce was established in the presence of other energy fortifying ingredients. Above this
454 maximum level, not only the texture and consistency of the sauce were affected but several
455 sensory properties as well such as smell, flavour and after effects.

456

457 **4. Conclusion**

458 This study demonstrated that a substantial increase in the energy and macronutrient content
459 could be achieved in conventional sauces. This increase was implemented by the addition of
460 ingredients such as double cream (all sauces), butter (tomato sauce and gravy), vegetable oil
461 (tomato sauce and gravy), maltodextrin (tomato sauce), whole milk (white sauce), soy sauce
462 (gravy) and WPI (tomato and white sauces), which are rich in macronutrients such as fat,
463 carbohydrates and protein. This macronutrient fortification is considered suitable for the
464 needs of many older adults at risk of malnutrition in an acute care setting. However, it is
465 recognised that further development of such fortified sauces is needed to meet the needs of
466 older adults with chronic conditions such as renal or cardio-vascular disease.

467 Micronutrient fortification appropriate to the needs of older adults was achieved in tomato
468 sauce and gravy through the use of vitamin and mineral premixes, however the micronutrient
469 fortification of the white sauce required further optimisation.

470 For all micronutrient enhanced sauces, matching 1/3 of RNI could not be achieved for
471 potassium and magnesium (Table 4) due to unacceptability taste, flavour and after effects.
472 Therefore, the concentration of these minerals had to be adjusted to a desired level in terms of
473 acceptable sensory properties, in order to minimise bitter and metallic taste and after effects
474 and to avoid any texture and instability problems. For the micronutrient fortified tomato
475 sauce, the addition of 33-40% of RNI for some vitamins (riboflavin, B₆, folate and C), Fe and
476 Zn, plus 10-13% of RNI for K and Mg in a 50 g sauce portion (Table 4), resulted in a sauce
477 that was higher in meaty flavour and more bitter. However, this did not reduce the liking of
478 the sauce as rated by older volunteers. For the micronutrient fortified white sauce, the
479 addition of 35-43% of RNI for vitamins, Fe and Zn, plus 10% of RNI for K and Mg in a 50 g
480 sauce portion (Table 4), resulted in a sauce that was higher in fishy and chemical flavour as
481 well as more bitter and metallic. However, when the K-citrate was excluded the fishy flavour
482 and metallic taste were significantly lower. For the micronutrient fortified gravy, the addition
483 of 33-34% of RNI for some vitamins, Fe and Zn, plus 8% of RNI for K and Mg in a 50 g
484 gravy portion (Table 4), resulted in a sauce that was higher in mushroom and nutty flavour.
485 Further studies of the hedonic liking of the fortified sauces with the target community of
486 older hospital patients should be carried out, and in particular the sauces needed to be tested
487 within real meals. It is recommended that this is done with the fortified options of sauces
488 developed in this study, but also with an option excluding potassium. Potassium was found to
489 contribute substantially to negative flavour and taste, cause issues of sauce instability, and is
490 not recommended for older patients with renal disease (Sinha and Agarwal 2013).

491 Older patients with a diminished sense of taste and flavour perception could benefit from
492 flavour enhancement of the sauces. In this study, flavour enhancement of the nutrient
493 fortified gravy was carried out successfully using a commercial natural flavour enhancer as
494 well as yeast extracts. Further development needs to include optimisation of flavour
495 enhancers.

496 Finally, evaluating the effects of nutrient enhanced sauces on satiety post meal and appetite at
497 next meal, as well evaluating of the effects on overall food and nutrient consumption is
498 essential.

499 It is proposed that the development of fortified sauces is a simple approach to improving
500 energy intake for hospitalised older people, both through the nutrient composition of the
501 sauce itself and due to the benefits of increasing sensorial taste and lubrication in the mouth.

502

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510

511 **Author Contributions:**

512 LM, YM, PM, OK and MG designed the research; RT, JW, VC and VA conducted the
513 research; RT and LM analysed the data; RT and LM wrote the manuscript; RT, LM, PM and
514 OK had primary responsibility for the final content.

515

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576 human buccal cells on the perception of astringency in whey protein beverages.
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580 **Table 1 Tomato sauce formulations**

	Control (g/kg)	Butter formulation (g/kg)	Double cream formulation^a (g/kg)	WPI + Maltodextrin formulation^a (g/kg)
Chopped tomatoes	723	581	515	524
Unsalted butter	-	64	-	-
Olive oil	16	13	12	12
Sunflower oil	-	64	114	116
Tomato puree	-	64	114	116
Double cream	-	-	57	-
Maltodextrin	-	-	-	29
Whey Protein Isolate (WPI)	-	-	-	10
Onion granules	43	35	31	31
Garlic granules	16	13	12	12
Emulsifier	-	3	3	3
Salt	8	6	6	6
Basil (dried)	2	2	1	1
Oregano (dried)	2	2	1	1
Parsley (dried)	2	2	1	1
Lemon juice	8	8	6	6
Mineral water	180	145	129	131

581 ^aFormulations progressed to micronutrient fortification through addition of 1g/kg of vitamin and
582 mineral premix, 15g/kg tri-potassium citrate monohydrate and 0.8g/kg magnesium oxide.

	Control (g/kg)	Energy Fortified (g/kg)	Energy, Protein and micronutrient fortified (g/kg)	Maximum Nutrient Fortified (g/kg)
Semi-skimmed pasteurised milk	897	-	-	-
Whole pasteurised milk	-	610	603	592
Salted butter	51	41	40	40
Plain white flour	50	41	40	40
Double cream	-	305	301	296
WPI	-	-	10	15
Salt	1.0	1.0	1	1
Nutmeg	0.1	0.1	0.1	0.1
White pepper	0.4	0.4	0.4	0.4
Bay leaves	0.4	0.4	0.4	0.4
Vitamin and mineral premix	-	-	1	1
Magnesium oxide	-	-	0.8	0.8
Tri-potassium citrate monohydrate	-	-	-	15

586 **Table 3 Gravy formulations**

	Control (g/kg)	Macronutrient fortified (g/kg)	Macronutrient & Flavour Enhancer (g/kg)	Macronutrient & Micronutrient (g/kg)	Macronutrient & Micronutrient & Flavour Enhancer (g/kg)
Bisto gravy granules	86.3	76.8	0	0	0
Bisto reduced salt gravy granules	-	-	73.6	75.7	72.6
Double cream	-	34.7	33.2	34.1	32.7
Vegetable oil	-	23.1	22.1	22.8	21.8
Unsalted butter	-	46.2	44.3	45.5	43.7
Water	909	809	775	797	764
Pearl River Bridge Soy Sauce	-	5.8	5.8	5.7	5.7
Lecithin	5.1	5.0	4.9	5.0	4.8
Kikkoman low salt soy sauce	-	-	33.2	-	32.7
Flavour enhancer	-	-	7.8	-	7.6
Vitamin and mineral premix	-	-	-	1	1
Dipotassium hydrogen phosphate	-	-	-	12.8	12.6
Magnesium Oxide	-	-	-	0.8	0.8

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Table 4 Nutrients provided by the sauces compared to average daily requirements

Nutrient	Average Daily Requirements ^a	Nutrients per 50 g portion			% of Daily Requirement		
		Tomato Sauce : Double cream plus Micronutrients Formulation	White Sauce : Maximum Nutrient Fortified Formulation	Gravy : Macro- and Micro-nutrient fortified with flavour enhancer	Tomato Sauce : Double cream plus Micronutrients Formulation	White Sauce : Maximum Nutrient Fortified Formulation	Gravy : Macro- and Micro-nutrient fortified with flavour enhancer
Vitamin D (µg)	> 10 µg	3.3	3.5	3.3	33	35	33
Riboflavin (B ₂) (mg)	> 1.2mg	0.42	0.52	0.40	35	43	33
Vitamin B ₆ (mg)	nr (> 1.3mg) ^b	0.46	0.47	0.43	35	36	33
Folate (B ₉) (µg)	> 200 µg	71	74	67	36	37	34
Vitamin C (mg)	nr (> 40 mg) ^b	16	15	14	40	36	34
Potassium (mg)	> 3500 mg ^c	440	349	293	13	10	8
Magnesium (mg)	> 300 mg	30	30	26	10	10	9
Iron (mg)	> 9 mg	3.3	3.2	3.0	37	36	34
Zinc (mg)	> 9.5 mg	3.3	3.5	3.2	35	37	34
Energy (kcal)	> 1955 kcal	87	123	54	4	6	3
Protein (g)	> 50 g	0.9	2.3	0.5	2	5	1
Fat (g)	<74.5 g	8.0	11	4.5	11	15	6
SFA (g)	<23.5 g	1.8	7.2	2.3	17	30	10

591 ^aFood Standards Agency (2007) guidelines for nutrients for food provided to older people in residential care (Department of Health 1991 values)

592 ^bnr = no recommendation specified; but highlighted as low intake and/or deficient in older adults (Bates and others, 1999, Russell & Suter 1993)

593 ^cexcept in cases of renal disease where daily RNI < 274mg

	Control (/100g)	Butter formulation (/100g)	Double cream formulation (/100g)	WPI +Maltodextrin formulation (/100g)	WPI + Maltodextrin + Micronutrients Formulation (/100g)	Double cream + Micronutrients formulation (/100g)
Energy (kcal)	45	149	174	164	164	174
Protein (g)	1.5	1.6	1.8	2.8	2.8	1.8
Carbohydrates (g)	5.6	5.4	5.6	8.4	8.4	5.6
Of which sugars (g)	4	4.2	4.5	7.4	7.4	4.5
Fat (g)	1.8	13.4	15.9	13.1	13.1	15.9
Of which saturated (g)	0.3	4.5	3.5	1.6	1.6	3.5
Fibre (g)	1.7	1.6	1.6	1.6	1.6	1.6
Sodium (g)	0.4	0.3	0.3	0.3	0.3	0.3
Salt (g)	0.9	0.7	0.7	0.7	0.7	0.7
Minerals						
Sodium (Na) (mg)	351	281	290	292	291	290
Potassium (K) (mg)	282	311	343	346	884 ^a	879 ^a
Calcium (Ca) (mg)	30	28	26	29	29	26
Magnesium (Mg) (mg)	13	12	12	13	73 ^a	60 ^a
Phosphorus (P) (mg)	31	31	35	35	35	34
Iron (Fe) (mg)	0.73	0.74	0.65	0.68	6.66 ^a	6.65 ^a
Copper (Cu) (mg)	0.08	0.1	0.39	0.18	0.17	0.38
Zinc (Zn) (mg)	0.22	0.21	0.22	0.27	6.65 ^a	6.61 ^a
Chloride (Cl) (mg)	561	483	482	483	480	481
Manganese (Mn) (mg)	0.14	0.14	0.12	0.14	0.14	0.12
Selenium (Se) (ug)	0.5	0.4	0.5	0.4	0.4	0.5
Iodine (I) (ug)	3.6	2.9	4.6	2.6	2.6	4.5
Vitamins						
Retinol (ug)	-	-	44	-	-	44
Carotene (ug)	328	391	322	430	424	318
Vitamin D (ug)	-	-	0.02	-	6.59 ^a	6.62 ^a
Vitamin E (mg)	1.1	4.38	7.1	7.12	7	6.98
Thiamin (mg)	0.03	0.05	0.05	0.07	0.07	0.05
Riboflavin (mg)	0.01	0.02	0.04	0.03	0.82 ^a	0.83 ^a
Niacin (mg)	0.43	0.61	0.62	0.77	0.75	0.61
Tryptophan (mg)	0.252	0.251	0.277	0.262	0.26	0.268
Vitamin B6 (mg)	0.06	0.06	0.05	0.06	0.92 ^a	0.91 ^a
Vitamin B12 (ug)	-	-	Trace	-	-	Trace
Total Folate(ug)	8	9	8	11	145 ^a	142 ^a
Pantothenic acid, Pantothenate (mg)	0.18	0.21	0.25	0.24	0.24	0.25
Biotin (ug)	1.1	1.3	1.5	1.5	1.5	1.5
Vitamin C (mg)	6	5	5	6	32 ^a	32 ^a

595 ^aMicronutrients added directly as a premix

596

597

	Control (/100g)	Energy Fortified (/100g)	Energy, Protein and micronutrient fortified (/100g)	Maximum Nutrient Fortified (/100g)
Energy (kcal)	98	248	249	246
Protein (g)	3.8	3.1	4	4.5
Carbohydrates (g)	8.5	6.9	6.8	6.7
Of which sugars (g)	4.6	3.6	3.6	3.5
Fat (g)	5.8	23.3	23	22.6
Of which saturated (g)	3.9	14.8	14.6	14.3
Fibre (g)	0.2	0.2	0.2	0.2
Sodium (g)	0.12	0.12	0.12	0.12
Salt (g)	0.31	0.3	0.3	0.29
Minerals				
Sodium (Na) (mg)	123	118	119	117
Potassium (K) (mg)	156	127	128	698 ^a
Calcium (Ca) (mg)	122	98	102	102
Magnesium (Mg) (mg)	12	10	58a	59a
Phosphorus (P) (mg)	95	81	83	82
Iron (Fe) (mg)	0.15	0.15	6.51a	6.39a
Copper (Cu) (mg)	0.01	0.01	0.06	0.09
Zinc (Zn) (mg)	0.41	0.35	7.17a	7.05a
Chloride (Cl) (mg)	150	147	146	143
Manganese (Mn) (mg)	0.04	0.03	0.04	0.05
Selenium (Se) (ug)	1.1	1.7	1.7	1.7
Iodine (I) (ug)	29	31.7	31.3	30.7
Vitamins				
Retinol (ug)	18	270	267	261
Carotene (ug)	10	169	167	164
Vitamin D (ug)	-	0.1	7.09a	6.94a
Vitamin E (mg)	0.05	0.59	0.58	0.57
Thiamin (mg)	0.04	0.04	0.04	0.04
Riboflavin (mg)	0.23	0.21	1.05a	1.03a
Niacin (mg)	0.18	0.2	0.2	0.2
Tryptophan (mg)	0.667	0.565	0.558	0.547
Vitamin B6 (mg)	0.06	0.05	0.96a	0.94a
Vitamin B12 (ug)	0.9	0.8	0.8	0.7
Total Folate (ug)	10	8	150a	147a
Pantothenic acid, Pantothenate (mg)	0.66	0.46	0.45	0.45
Biotin (ug)	2.9	1.9	1.9	1.9
Vitamin C (mg)	2	2	30a	29a

^aMicronutrients added directly as a premix

Table 7 Nutritional profile of gravies

	Control (/100g)	Macronutrient fortified (/100g)	Macronutrient & Flavour Enhancer (/100g)	Macronutrient & Micronutrient (/100g)	Macronutrient & Micronutrient & Flavour Enhancer (/100g)
Energy (kcal)	38	107	109	106	107
Protein (g)	0.2	0.3	0.9	0.3	0.9
Carbohydrates (g)	5.6	5.2	5.6	5.1	5.5
Of which sugars (g)	1.4	1.3	1.6	1.4	1.5
Fat (g)	1.7	9.5	9.1	9.3	8.9
Of which saturated (g)	1	4.8	4.6	4.8	4.6
Fibre (g)	-	-	Trace	-	Trace
Sodium (g)	0.48	0.46	0.49	0.35	0.48
Salt (g)	1.2	1.16	1.23	0.86	1.2
<u>Minerals^a</u>					
Sodium (Na) (mg)	482	462	490	347	482
Potassium (K) (mg)	19	20	19	594	585
Calcium (Ca) (mg)	7	8	7	8	7
Magnesium (Mg) (mg)	3	3	3	51	51
Phosphorus (P) (mg)	6	7	7	7	7
Iron (Fe) (mg)	0.06	0.06	0.06	0.02	6.06
Copper (Cu) (mg)	0.02	0.02	0.02	-	0.02
Zinc (Zn) (mg)	0.03	0.03	0.03	6.42	6.42
Manganese (Mn) (mg)	0.03	0.03	0.03	0.03	0.03
Selenium (Se) (ug)	-	0.1	0.1	0.1	0.1
Iodine (I) (ug)	-	1.5	1.4	1.4	1.4
<u>Vitamins^a</u>					
Retinol (ug)	-	27	26	27	25
Carotene (ug)	-	17	16	16	16
Vitamin D (ug)	-	0.01	0.01	6.61	6.61
Vitamin E (mg)	-	0.06	0.05	0.06	0.05
Thiamin (mg)	-	Trace	Trace	Trace	Trace
Riboflavin (mg)	-	0.01	0.01	0.8	0.8
Niacin (mg)	-	-	-	-	-
Tryptophan (mg)	0.07	0.07	0.07	0.07	0.07
Vitamin B6 (mg)	-	Trace	Trace	0.86	0.86
Vitamin B12 (ug)	-	Trace	Trace	Trace	Trace
Total Folate (ug)	-	Trace	Trace	134	134
Pantothenic acid, Pantothenate (mg)	-	0.01	0.01	0.01	0.01
Biotin (ug)	-	Trace	Trace	Trace	Trace
Vitamin C (mg)	-	Trace	Trace	27	27

^a Nutrient information for commercial gravy granules combined from pack declaration (macronutrient) and McCance & Widdowson food tables (micronutrient)

606 **Table 8 Sensory profile of the micronutrient enhanced tomato sauces (rated on 0-100 scale)**

Modality	Attribute	Double cream	Double cream + Micronutrients	WPI + Maltodextrin	WPI + Maltodextrin + Micronutrients	
Appearance	Lightness of Brown Colour	59.8 ^b	69.5 ^a	54.8 ^b	56.1 ^b	
	Thickness	63.1 ^a	49.1 ^b	64.3 ^a	57 ^{ab}	
	Lumpy	28.7 ^a	21.7 ^b	31.6 ^a	27.5 ^{ab}	
	Green bits*	20.8 ^b	25.6 ^{ab}	28.8 ^a	23 ^{ab}	
Odour	Oily	20.8 ^b	31.2 ^a	23 ^b	22.8 ^b	
	Tomato	57.1 ^a	45.8 ^b	50 ^{ab}	52.2 ^{ab}	
Taste	Sweet	38.1 ^a	30.1 ^b	37 ^{ab}	32.5 ^{ab}	
	Bitter	27.2 ^b	37.5 ^{ab}	28.2 ^b	43.5 ^a	
Flavour	Starchy	20.1 ^b	26.4 ^{ab}	24.1 ^{ab}	31.6 ^a	
	Meaty (intense seafood type)	11.1 ^b	25 ^a	7.1 ^b	28.2 ^a	
	Fried onions	16.8 ^b	32.8 ^a	19.8 ^b	24 ^{ab}	
	Smoky	10.2 ^{ab}	13.9 ^{ab}	8.4 ^b	16.6 ^a	
	Grainy	29.6 ^{ab}	22 ^b	35.1 ^a	29.6 ^{ab}	
	Mouthfeel	Oily (mouthfeel)	20.6 ^c	37.8 ^a	29.2 ^b	29.6 ^{ab}
		Gelatinous	4.5 ^b	13 ^a	7.2 ^{ab}	7.8 ^{ab}
Pieces		14.7 ^b	14 ^b	25.6 ^a	16.3 ^b	
After effects	Meaty (intense seafood type)	9.8 ^b	20.5 ^a	8.3 ^c	19 ^{ab}	
	Bitter	20.6 ^b	35.6 ^{ab}	21.1 ^b	37.5 ^a	

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608 ^{abc} Mean values with the same letter within the same row are not significantly different at p < 0.05

609 *Green bits were due to herb addition, differences are expected to be due to minor batch to batch
610 variation

611 Attributes were no significant differences were found between products were appearance: black
612 bits, separated, watery; smell : herbs, onion, butter, chicken stock, cheesy, savoury, burnt; taste :
613 salty, sour , sweet, umami, metallic; flavour : creamy, buttery, ripe tomato, cooked tomato, herbs,
614 cheesy, burnt; mouthfeel : full body ; aftereffect : astringent (mouthdrying), burning, oily lips,
615 mouth coating, metallic

616

617

618

619 **Table 9 Sensory profile of fortified white sauces (rated on 0-100 scale)**

		Control	Energy Fortified	Energy, Protein and micronutrient fortified	Maximum Nutrient Fortified
Appearance	Thick	79.6 ^a	39.1 ^c	54.5 ^b	40.2 ^c
	Lumpy	61.2 ^a	17.7 ^c	23.0 ^b	19.2 ^b
	Whisked	7.1 ^b	20.7 ^a	17.2 ^a	19.1 ^a
Smell	Milk	49.5 ^a	48.8 ^{ab}	45.5 ^{ab}	39.5 ^b
	Fish	10.0 ^b	10.2 ^b	19.5 ^b	42.9 ^a
	Vegetable soup (dry pack)	5.8 ^b	6.9 ^{ab}	11.5 ^a	8.1 ^{ab}
	Chemical	8.0 ^{bc}	5.1 ^c	14.8 ^{ab}	19.8 ^a
	Savoury	26.4 ^a	17.3 ^b	26.1 ^a	27.5 ^a
	Taste	Salty	12.8 ^b	9.6 ^b	10.9 ^b
Sweet		23.0 ^a	24.1 ^a	17.9 ^{ab}	12.1 ^b
Sour		10.5 ^{bc}	6.4 ^c	12.8 ^{ab}	17.6 ^a
Bitter		13.9 ^{ab}	9.9 ^b	14.8 ^{ab}	20.7 ^a
Flavour	Milk	53.2 ^a	48.8 ^{ab}	40.1 ^{bc}	33.8 ^c
	Cream	26.4 ^{ab}	38.3 ^a	32.9 ^a	20.0 ^b
	Starchy	38.3 ^a	18.4 ^c	29.2 ^b	31.1 ^b
	Nutmeg	37.3 ^a	28.7 ^{ab}	21.9 ^b	19.5 ^b
	Pepper	23.6 ^a	13.6 ^b	15.5 ^b	15.8 ^b
	Chemical	7.5 ^b	6.3 ^b	10.6 ^b	18.1 ^a
	Metallic	10.6 ^b	9.8 ^b	11.7 ^b	17.4 ^a
Mouthfeel	Fish	7.8 ^b	7.0 ^b	13.3 ^b	34.8 ^a
	Thick	73.8 ^a	32.5 ^c	50.6 ^b	38.3 ^c
	Smooth	22.2 ^b	52.5 ^a	43.0 ^a	45.1 ^a
	Glutenous	48.4 ^a	18.3 ^c	28.3 ^b	27.1 ^{bc}
	Mouthcoating	43.3 ^a	30.4 ^b	37.2 ^{ab}	37.3 ^{ab}
After effects	Mouthdrying	27.6 ^{ab}	21.5 ^b	27.2 ^{ab}	32.4 ^a
	Salty	10.5 ^{ab}	8.0 ^b	9.1 ^b	12.6 ^a
	Metallic	9.2 ^{ab}	5.7 ^b	8.4 ^b	13.6 ^a
	Salivating	18.1 ^{ab}	13.9 ^b	17.4 ^{ab}	19.8 ^a
	Burning	24.4 ^a	10.4 ^b	10.6 ^b	8.5 ^b

620 ^{abc} Mean values with the same letter within the same row are not significantly different at p <0.05621 Attributes were no significant differences were found between products were smell : mushroom, chicken, egg, cheese;
622 flavour : butter, egg, cheese; mouthfeel : greasy ; aftereffect : umami

623

624 **Table 10 Sensory profile of micronutrient enhanced gravies (rated on 0-100 scale)**

		Macronutrient fortified	Macronutrient & Flavour Enhancer	Macronutrient & Micronutrient	Macronutrient & Micronutrient & Flavour Enhancer
Appearance	Brown	55.4 ^b	41.5 ^c	66.3 ^a	49.8 ^b
	Oily	21.5 ^{ab}	28.9 ^a	20.3 ^b	27.4 ^{ab}
Smell	Caramel	14.3 ^a	5.3 ^b	7.2 ^b	7.7 ^b
	Savoury	29.3 ^b	31.0 ^b	40.7 ^a	30.8 ^b
	Mushroom	23.1 ^{ab}	31.8 ^a	17.0 ^b	25.5 ^{ab}
	Onion	12.6 ^b	10.1 ^b	20.3 ^a	12.7 ^b
	Chicken	12.4 ^{ab}	15.5 ^a	7.7 ^b	13.5 ^{ab}
	Beef stock	16.7 ^{ab}	10.1 ^b	26.3 ^a	13.4 ^b
	Red wine	4.4 ^b	0.8 ^b	26.7 ^a	6.6 ^b
	Buttery	21.2 ^a	14.5 ^{ab}	12.1 ^b	11.3 ^b
	Acidic	8.0 ^b	8.1 ^b	16.3 ^a	9.7 ^b
Taste	Acidic	12.3 ^{bc}	10.4 ^c	26.0 ^a	18.4 ^b
	Bitter	13.4 ^b	20.1 ^{ab}	24.4 ^a	26.7 ^a
	Salty	22.1 ^b	23.0 ^b	31.0 ^a	30.5 ^a
	Umami	29.3 ^b	29.3 ^b	37.0 ^a	33.4 ^{ab}
Flavour	Creamy	17.8 ^a	14.7 ^{ab}	10.8 ^b	12.5 ^b
	Buttery	25.5 ^a	18.1 ^{ab}	18.5 ^{ab}	16.1 ^b
	Beef	17.6 ^b	11.1 ^b	29.2 ^a	17.4 ^b
	Mushroom	17.8 ^b	32.6 ^a	15.7 ^b	32.8 ^a
	Nutty	5.2 ^{ab}	11.6 ^a	1.8 ^b	10.9 ^a
	Red wine	4.9 ^b	2.1 ^b	26.5 ^a	8.7 ^b
Mouthfeel	Greasy	30.1 ^a	33.5 ^a	23.0 ^b	28.5 ^{ab}
	Smooth	52.2 ^a	40.8 ^b	55.2 ^a	41.8 ^b
	Rich	28.9 ^b	25.6 ^b	40.6 ^a	30.8 ^b
	Starchy	12.2 ^{ab}	14.4 ^a	10.5 ^b	11.8 ^{ab}
After effects	Salty	15.8 ^b	19.6 ^b	30.5 ^a	33.9 ^a
	Sweet	19.8 ^{ab}	13.5 ^b	21.4 ^a	17.1 ^{ab}
	Sour	4.8 ^b	9.3 ^{ab}	12.6 ^a	10.3 ^{ab}
	Mushroom	14.5 ^b	26.3 ^a	13.6 ^b	27.7 ^a

625 ^{abc} Mean values with the same letter within the same row are not significantly different at p < 0.05

626 Attributes where no significant differences were found between products were appearance: thick, opaque, bits; smell :
627 fatty, starchy, boiled vegetables, nutty; taste: sweet; flavour: acidic, meat, burnt caramel; mouthfeel: mouthcoating,
628 gritty, dry

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