The Effect of Nutrient Fortification of Sauces on Product Stability, Sensory Properties, and Subsequent Liking by Older Adults

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

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

Practical Application: This study developed macro- and micronutrient fortified sauces where the intended use is for older adults at risk of undernutrition. The energy content was increased between 2.5- and 4-fold compared to control formulations. Whey protein was successfully added to tomato and white sauces. We note that excessive protein addition leads to textural issues and excessive potassium or magnesium inclusion results in undesired flavors. We propose that fortified sauces are a simple approach to improving energy intake for hospitalized older people.

Introduction

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

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

Within hospitalized older adults, it has been reported that meal macronutrient fortification can improve energy (+26%) and protein (+23%) intake (Gall and others 1998). When considering how to increase protein levels in foods for older people, both protein level and protein quality should be considered. Recent studies of individuals with sarcopenia have found that whey protein stimulates muscle protein synthesis more effectively than casein or vegetable protein (Pennings and others 2011) .

Best and Appleton (2011) found that the addition of both seasoning and sauce to an older person's meal resulted in comparable increases in energy, protein and fat intake, thus supporting a role for flavor enhancement in increasing the food intake of older people, as well as the role of the sauce itself. However, sauces may be more beneficial than dry seasonings when promoting food intake in older people due to the semisolid nature of the sauce. In older individuals, where gastrointestinal secretions and motility

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are known to be reduced or impaired (Cowan and others 2004), semisolid foods may facilitate chewing and swallowing, and aid the passage of foods through the digestive system (Appleton 2009).

Micronutrient fortification

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

Considering the development of micronutrient fortified foods for older hospital patients, 2 approaches could be taken. One approach would be to provide a "full" nutrient supplement, the principle taken by oral nutritional supplement beverages. An alternative approach, and the one taken in this study, is to fortify products with micronutrients for which there is substantial evidence within the older adult institutionalized community.

Evidence from the U.K. Natl. Diet and Nutrition Survey (NDNS) indicates that the micronutrients that institutionalized older people are most likely to be at risk of deficiency of are iron, vitamin D, riboflavin, folate, and vitamin C (Bates and others 1999). The study by Bates and others (1999) considered micronutrients where intake was low (more than 25% of institutionalized participants with intakes below the recommended nutrient intake [RNI]) or where more than 25% of institutionalized participants had biochemical indices low enough to be associated with deficiency. More recently the Food Standards Agency (FSA) guidelines for food provision for older adults in residential care (Food Standards Agency 2007) recommend levels 5 minerals (sodium, potassium, magnesium, iron, and zinc) and 3 vitamins (riboflavin, vitamin D, and folate). It should also be noted that the Dept. of Health RNI values for minerals and vitamins give guidelines for the 50+ age group, but there are no such guidelines in place for an older age group. The most recent U.K. NDNS report from May 2014 (Bates and others 2014) summarizes intake and deficiency of nutrients in adults over 65 y of age, but not in an institutionalized cohort. It concludes that in the over 65 age group mean intake of all vitamins met the RNI, except for vitamin D, which only met 33% of the RNI. Regarding minerals, mean intakes of potassium, magnesium, and selenium were below the RNI, although this was the case in all age groups. It was reported that mean intake of iron, calcium, vitamin C, and folate were higher in the over 65 age group than reported in previous surveys. Although this is good news, there is no evidence to suggest that institutionalized older adults are meeting their RNI for these nutrients.

Sauce types

Tomato based sauce, white sauce and gravy are 3 commonly used sauces in the United Kingdom (Cook's Info 2015), aside from the bottled sauces applied at the table (for example, Ketchup). Tomato sauces are typically served on pasta or with meat or fish, with the tomatoes being an important source of carotenoids. White sauces are produced using fat, a thickener, and milk. They are widely used in the United Kingdom within fish recipes and, to a lesser extent, within pasta. Gravy is typically applied to meat dishes as well as to vegetable and potato side dishes. Although traditionally produced using meat stock, meat fat, and thickener, gravy is widely available as a commercial dried product containing stock, yeast extract, and thickeners to which water is added before serving. Typically, neither tomato sauce nor commercial "instant" gravy, would be particularly energy or protein dense, whereas white sauces are generally more energy and protein dense.

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

Materials and Methods

Materials for tomato sauce

A tomato base was prepared using chopped tomatoes (Napolina Ltd., U.K.), extra virgin olive oil (Filippo Berio Ltd., U.K.), garlic granules, and onion granules (McCormick U.K. Ltd.), salt basil, parsley, oregano, and lemon juice (local retailer). Fortified formulations (Table 1) contained combinations of sunflower oil, double cream, unsalted butter (local retailer), double concentrated tomato puree (Napolina Ltd.), whey protein isolate (WPI; protein content minimum 94%, fat 0.2%; Volac Intl. Ltd., U.K.), maltodextrin (C∗ dry, Cargill PLC, U.K.), and a deoiled soybean lecithin (Emulpur IP, Cargill PLC). Tomato puree was used to restore the red color, where ingredients resulted in a pale colored sauce. The lecithin prevented separation of the sauces when extra lipid was added.

Materials for white sauce

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

Materials for gravy

Gravy (Table 3) was produced using commercial gravy granules (Bisto, or Bisto reduced salt gravy granules, Premier Foods, U.K.) and water (Harrogate Spring Water Ltd.). Fortification utilized unsalted butter or double cream (local retailer) soy sauce (Pearl River, sodium content 5.8 g per 100 mL, Guangdong PRB Biotech co, Ltd., China), Kikkoman low salt soy sauce (sodium 3.6 g per 100 mL, Kikkoman Foods Europe B.V., the Netherlands), and deoiled soybean lecithin (Emulpur IP, Cargill PLC).

Taste enhancement was achieved through the use of soy sauce and a commercial flavor enhancer (sodium 3 g/100 g, glutamate 16 g/100 g; Givaudan Schweiz AG, Switzerland).

Micronutrient addition to sauce

A micronutrient blend (Lycored, Kent, U.K.; an orange-yellow colored powder) was used at 0.1% (w/w). The premix (100 mg) contained iron (6 mg), zinc (6.4 mg), riboflavin (0.8 mg), vitamin B6 (0.86 mg), folic acid (134 μg), vitamin C (26.6 mg), and vitamin D (6.6 μg). In addition, the sauces were enriched with potassium and magnesium. Initially, dipotassium hydrogen phosphate (K_2HPO_4; 45% K by weight; 5.16% [w/w] addition), and magnesium oxide (MgO; 60% mg by weight; 0.34% [w/w] addition) were used to provide one-third of the RNI of potassium and magnesium in 50 g of sauce. However, due to excessive bitter and metallic taste these concentrations were lowered to 1.2% and 0.08% (w/w) for K_2HPO_4 and MgO, respectively following tasting trials. These percentages corresponded to 18.4% and 14.2% of RNI for potassium and magnesium respectively in a portion of sauce (50 g). The potassium salt was later replaced with 1.5%

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Table 1–Tomato sauce formulations.

	Control Control (g/kg)	Butter formulation (g/kg) 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

[a]Formulations progressed to micronutrient fortification through addition of 1 g/kg of vitamin and mineral premix, 15 g/kg tripotassium citrate monohydrate, and 0.8 g/kg magnesium oxide.

Table 2–White sauce formulations.

	Control (g/kg)	Energy fortified (g/kg)	Energy, protein and micronutrient fortified (g/kg)	Maximum nutrient fortified (g/kg)
Semiskimmed pasteurized milk	897	–	–	–
Whole pasteurized 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
Tripotassium citrate monohydrate	–	–	–	15

Table 3–Gravy formulations.

	Control (g/kg)	Macronutrient fortified (g/kg)	Macronutrient and flavor flavor Enhancer (g/kg)	Macronutrient and micronutrient (g/kg)	Macronutrient and micronutrient and flavor 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
Flavor enhancer	–	–	7.8	–	7.6
Vitamin and mineral premix	–	–	–	1	1
Dipotassium hydrogen phosphate	–	–	–	12.8	12.6
Magnesium oxide	–	–	–	0.8	0.8

(w/w) tripotassium citrate monohydrate ($C_6H_5K_3O_7{\cdot}H_2O$; 36% K by weight) aiming to improve taste acceptability.

Tomato sauce preparation

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

White sauce preparation

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

Gravy preparation

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

Nutritional profile

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

Sensory profile analysis

All samples were frozen postmanufacture (–18 °C). For sensory analysis, samples were defrosted at ambient temperature for 2 h, heated in a microwave (5 min, stirred at 2.5 min) to a temperature of 75 °C, and held in a heated trolley for up to 20 min.

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

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

Sensory profiling of fortified white sauces. Four samples were evaluated: control, energy fortified, energy, protein and micronutrient fortified, and maximum nutrient fortified (Table 2).

Sensory profiling of fortified gravies. Macronutrient fortified gravy was initially compared to control gravy (Table 3). Energy enhancers were used (vegetable oil, butter, double cream) with soy sauce (Pearl River Bridge) to darken the color. The macronutrient fortified gravy was then compared to options further fortified with micronutrients and/or flavor enhancement.

Hedonic liking evaluation

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

The tomato sauce samples initially rated were the control and the 3 macronutrient fortified samples (Table 1). Samples (30 g) were served at 75 ± 5 °C in paper cups (100 mL). In a separate assessment, the control tomato sauce was compared to the double cream plus micronutrient fortified sample, where sauce (40 ± 5 g) and pasta (40 ± 5 g) were served in paper cups (100 mL) with a plastic fork.

Two gravies were rated, the control and the macronutrient fortified option (Table 3). Samples (20 g) were served at 75 ± 5 °C, poured over mashed potato (30 g) in transparent plastic dishes (200 mL). Hedonic testing of the white sauces was not carried out (see section "Results and Discussion").

Data analysis

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

Results and Discussion

Nutritional information

Tomato sauce. The nutritional profile of the tomato sauces is shown in Table 4. The energy content of the fortified formulations was increased 3- to 4-fold compared with the control, predominantly through the use of high lipid ingredients; butter, vegetable oils, and/or cream (Table 1). Protein and carbohydrate levels were increased 1.9- and 1.5-fold, respectively when WPI and maltodextrin were used. Table 5 compares the double cream plus micronutrients sauce variant (the variant selected for hedonic testing, section "Sensory and hedonic evaluation of tomato sauces") to the dietary reference values (DRV) for macronutrients and reference nutrient intake (RNI) values for micronutrient, for older people (Department of Health 1991). Assuming a 50 g portion size of sauce, the maximum energy and protein provided was rather limited, 4% and 2% of the DRV, respectively. However, it is expected from previous authors (Appleton 2009) that the use of sauce would not only provide macronutrients itself, but also lead to a greater intake of nutrients from the meal to which it was applied. A portion size of 50 g is conservative, if used as a pasta sauce, for example the portion size could be 2- to 4-fold higher, providing up to 16% and 8% of DRV for energy and protein, respectively. Micronutrient addition enriched the sauces with vitamins and minerals. However, the ingredients used to achieve the macronutrient fortification also contributed to the micronutrient content of the sauce; all fortified sauces were higher in potassium and vitamin E, and to a lesser extent thiamine, riboflavin, niacin, pantothenic acid, and biotin. The sauce fortified with double cream was higher in copper, iodine, retinol, and vitamin D. The sauce fortified with WPI was higher in carotene and folate. A 50 g portion of the double cream plus micronutrient sauce would provide 33% to 40% of vitamins D, B_6, C, riboflavin, folate, iron, and zinc as well as 13% and 10% of potassium and magnesium requirements, respectively.

White sauce. The energy content of fortified white sauces (Table 6) was 2.5-fold higher than the control, primarily due to whole milk and double cream (Table 2), which also increased the fat content more than 3-fold. Although WPI was used to increase the protein content, the overall increase was small, from 3.8% to 4.5% (w/w). Whole milk and double cream increased the levels of retinol, carotene, and vitamin E delivered, as they are fat soluble vitamins. The major contribution to micronutrients was through the addition of the vitamin and mineral premix (Table 6). It was noted however, that the macronutrient fortification led to a decrease in calcium delivered compared with the control, this was not intentional and could be rectified through the mineral premix addition in future developments. A 50 g portion of the maximum nutrient fortified would provide 35% to 43% of the

Table 4–Nutritional profile of tomato sauces.

	Control (/100 g)	Butter formulation (/100 g)	Double cream formulation (/100 g)	WPI + maltodextrin formulation (/100 g)	WPI + maltodextrin + micronutrients formulation (/100 g)	Double cream + micronutrients formulation (/100 g)
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
Fiber (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) (μg)	0.5	0.4	0.5	0.4	0.4	0.5
Iodine (I) (μg)	3.6	2.9	4.6	2.6	2.6	4.5
Vitamins						
Retinol (μg)	–	–	44	–	–	44
Carotene (μg)	328	391	322	430	424	318
Vitamin D (μg)	–	–	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 (μg)	–	–	Trace	–	–	Trace
Total Folate (μg)	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 (μg)	1.1	1.3	1.5	1.5	1.5	1.5
Vitamin C (mg)	6	5	5	6	32[a]	32[a]

[a]Micronutrients added directly as a premix.

vitamins (D, riboflavin, B_6, folate, and C), iron, and zinc as well as 10% of both potassium and magnesium RNI for older people (DH 1991; Table 5), however it should be noted that this sauce did not have an optimized sensory profile (section "Sensory evaluation of white sauces") and required further development. The 50 g of portion of sauce would provide a limited amount of energy and protein, 6% and 4% of the DRV, respectively. It was noted that as a dairy sauce it is relatively high in fat and provides 30% of the DRV for saturated fats. However, it is also noted that the sauces were developed primarily for provision to undernourished older hospital patients where increasing energy intake is paramount. DRVs were predominantly used as a guide for the micronutrient fortification.

Gravy. The nutrient (D, riboflavin, B_6, folate, and C) iron, and zinc as well as 8% of both potassium and magnesium profile of the fortified gravies (Table 7) showed a 2.8-fold energy increase compared with the control, achieved predominantly through the increase in fat (over 5-fold), through the addition of cream, oil, and butter (Table 3). The maximum fortification that was practically possible did not have a significant impact on overall protein level. The micronutrient content of the gravies changed substantially after the incorporation of the vitamin and mineral premix (Table 8). The maximum fortified gravy (the final variant tested, Table 3) was compared to daily recommendations based on the FSA (2007) guidelines for nutrients for food provided to older people in residential care in Table 5. A 50 g portion of this gravy would provide 33% to 34% of the vitamins RNI for older people in residential care (Food Standards Agency 2007). The 50 g of portion of sauce would provide only 3% energy and 1% protein of the DRV.

Across all 3 sauce types the macronutrient enhancement was partly achieved through the addition of high fat ingredients. The U.K. FSA recommendations (Food Standards Agency 2007) for food provision to older adults in long-term residential care recommend restricting fat intake to a maximum of 76 g per day, with a maximum of 24 g saturated fat per day. So, certainly in long-term care and in the community, routinely increasing fat content should not be recommended without taking into account the persons baseline nutritional and medical status. However, within acute hospital care setting that the sauces were designed for, the energy intake of older patients is of primary importance as opposed to fat intake restriction.

Sensory and hedonic evaluation of tomato sauces

Between the 4 tomato sauce samples initially tested (control and 3 macronutrient fortified samples) there were significant

Table 5–Nutrients provided by the sauces compared to average daily requirements.

Nutrient	Average daily requirements[a]	Nutrients per 50 g portion: Tomato sauce: double cream plus micronutrients micronutrients formulation	Nutrients per 50 g portion: White sauce: maximum nutrient fortified formulation	Nutrients per 50 g portion: Gravy: macro- and micronutrient fortified with flavor enhancer	% of daily requirement: Tomato sauce: double cream plus micronutrients formulation	% of daily requirement: White sauce: maximum nutrient fortified formulation	% of daily requirement: Gravy: macro- and micronutrient fortified with flavor enhancer
Vitamin D (μg)	>10 μg	3.3	3.5	3.3	33	35	33
Riboflavin (B_2) (mg)	>1.2 mg	0.42	0.52	0.40	35	43	33
Vitamin B_6 (mg)	nr (>1.3 mg)[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

[a]Food Standards Agency (2007) guidelines for nutrients for food provided to older people in residential care (Department of Health 1991 values).
[b]nr = no recommendation specified; but highlighted as low intake and/or deficient in older adults (Bates and others, 1999, Russell & Suter 1993).
[c]except in cases of renal disease where daily RNI < 274 mg.

differences between 25 of the 32 consensus attributes (data not shown). In appearance and mouthfeel, the control was thicker, darker, lumpier, grainier, more gelatinous, and fuller bodied than the macronutrient fortified samples, due to its increased content of chopped tomato. Unsurprisingly, samples which had the oiliest appearance and mouthfeel were the ones which contained both oil and either butter or cream. The sample containing WPI and maltodextrin was not oilier than the control, despite oil addition. In terms of orthonasal smell and retronasal flavor, the control was less creamy and buttery; more herby and pungent, but had a significantly weaker tomato smell (mean values 29 compared to 38 to 44, $P = 0.006$), implying successful utilization of tomato puree in place of chopped tomatoes in the fortified sauces. With regard to taste, the control was less sweet, more bitter, and sour than the macronutrient fortified products. It was also significantly more salty than the WPI plus maltodextrin and the butter products. The control had the most astringent and burning after effect. When the 4 tomato sauce samples were presented to older volunteers, significant differences in mean hedonic liking were found ($P < 0.0001$). Two of the macronutrient fortified options, those containing double cream and WPI plus maltodextrin, were liked more than the control (mean liking scores of 5.9 and 5.7 compared to 4.5). The sample containing butter was not significantly different in liking score (mean 4.9) from the control.

The 2 preferred macronutrient options were progressed to micronutrient fortification. It was important to study the effect of mineral addition to sauce containing WPI to examine possible textural issues (coagulation, flocculation, and viscous appearance) or taste issues (bitter, metallic). The resulting 4 samples were directly compared through sensory profiling. There were significant differences in 18 of the 46 consensus attributes (Table 8). The nutrient premix had a yellowish-orange color due to the iron inclusion. The iron undergoes oxidation when in contact with air, forming iron (III) oxide, which has a red-brown color, explaining the darker color of the sauce.

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

In terms of orthonasal smell and retronasal flavor the addition of micronutrients tended to lower sweet smell and, in the case of the cream sample, tomato smell, whereas meaty, fried onion and smoky flavors were enhanced. Of greater concern, the addition of micronutrients led to significantly higher bitter taste, which was more substantial in the WPI plus maltodextrin sample. Potassium and magnesium are known to have bitter taste at relatively low taste thresholds of 340 to 680 mg and 100 mg per liter, respectively in pure solutions (Schiffman and others 1995; Lawless and others 2003), and they were present in the micronutrient enhanced formulation at 8840 and 730 mg/L, respectively. Bitter taste and meaty flavor remained higher in the micronutrient fortified samples as aftertaste effects. With regards to mouthfeel, micronutrient addition tended to reduce grainy mouthfeel and the WPI plus maltodextrin variants were grainier than the cream ones. This may be due to the powder form of both WPI and maltodextrin compared to the liquid form of double cream. Oily and gelatinous mouthfeel were highest in the micronutrient enhanced cream sample.

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Table 6–Nutritional profile of white sauces.

	Control (/100 g)	Energy fortified (/100 g) (/100 g)	Energy, protein, and micronutrient fortified (/100 g)	Maximum nutrient fortified (/100 g)
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
Fiber (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	58[a]	59[a]
Phosphorus (P) (mg)	95	81	83	82
Iron (Fe) (mg)	0.15	0.15	6.51[a]	6.39[a]
Copper (Cu) (mg)	0.01	0.01	0.06	0.09
Zinc (Zn) (mg)	0.41	0.35	7.17[a]	7.05[a]
Chloride (Cl) (mg)	150	147	146	143
Manganese (Mn) (mg)	0.04	0.03	0.04	0.05
Selenium (Se) (μg)	1.1	1.7	1.7	1.7
Iodine (I) (μg)	29	31.7	31.3	30.7
Vitamins				
Retinol (μg)	18	270	267	261
Carotene (μg)	10	169	167	164
Vitamin D (μg)	–	0.1	7.09[a]	6.94[a]
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	1.05[a]	1.03[a]
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	0.96[a]	0.94[a]
Vitamin B12 (μg)	0.9	0.8	0.8	0.7
Total Folate (μg)	10	8	150[a]	147[a]
Pantothenic acid, Pantothenate (mg)	0.66	0.46	0.45	0.45
Biotin (μg)	2.9	1.9	1.9	1.9
Vitamin C (mg)	2	2	30[a]	29[a]

[a]Micronutrients added directly as a premix.

As the cream variant with micronutrients tended to be less bitter, starchy, and grainy that the WPI option, it was progressed to consumer testing. Two tomato sauce samples (control and double cream + micronutrients) were presented to older volunteers ($n = 31$); however, the differences in mean hedonic liking did not reach significance ($P = 0.096$). The control sample received a lower mean liking score (5.3) than the fortified product (6.0). The potentially negative attributes associated with micronutrient fortification, and detected by the sensory panel do not, therefore, appear to have reduced liking by the older consumers.

Sensory evaluation of white sauces

The 4 white sauce variants were described by 38 consensus attributes, of which 29 were significantly different between samples (Table 9). Although the micronutrient enhanced white sauces had a more yellow color, this difference was not rated, red lights were used to avoid biasing panel scores of other attributes. Concerning appearance and mouthfeel, the control white sauce was significantly thicker, lumpier, more glutinous, more mouthcoating, and less smooth than the modified formulations. This was attributed to the higher amount of flour used in the control. All sauces were frozen postmanufacture, thawed, and reheated for sensory profiling. Although the native starch in flour is cooked during sauce preparation, any remaining native starches would be extensively damaged after a freeze/thaw cycle (Arocas and others 2009). In future, a combination of native starches and hydrocolloids could be used to improve stability. In the present study the sauce was more stable with higher fat (cream and whole milk) and less flour.

Concerning orthonasal smell and retronasal flavor, the main significant differences were caused by the addition of micronutrients which led to higher ratings of fish, metallic and chemical aroma. The fish aroma was very high in the maximum fortified sample and was attributed to the addition of K-citrate. Fishy aromas are typically caused by lipid oxidation and it is likely that this was catalyzed by potassium. The chemical aroma occurred in both of the micronutrient fortified samples, hence is likely to be attributed to the inclusion of the vitamin and mineral premix and/or the magnesium oxide. Concerning taste, the maximum nutrient fortified sample was less sweet, and more salty, sour, and bitter. The salty taste was attributed to micronutrient addition and not due to sodium which was virtually constant between samples (117 to 123 mg Na/100 g of sauce). Similarly, the minor difference in total sugars content (Table 6) does not explain the differences in sweetness, implying the tastes associated with the use of K-citrate (bitter, sour, and salty) suppressed sample sweetness. Milk flavor was also lower where K-citrate, MgO, and the vitamin/mineral premix were added. Creamy flavor was, as expected, higher following the addition of cream in the macronutrient fortified options, but

Table 7–Nutritional profile of gravies.

	Control Control (/100 g)	fortified (/100 g)	Macronutrient and flavor enhancer (/100 g)	Macronutrient and micronutrient (/100 g)	Macronutrient and flavor enhancer (/100 g)
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
Fiber (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
Minerals[a]					
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) (μg)	–	0.1	0.1	0.1	0.1
Iodine (I) (μg)	–	1.5	1.4	1.4	1.4
Vitamins[a]					
Retinol (μg)	–	27	26	27	25
Carotene (μg)	–	17	16	16	16
Vitamin D (μg)	–	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 (μg)	–	Trace	Trace	Trace	Trace
Total folate (μg)	–	Trace	Trace	134	134
Pantothenic acid, pantothenate (mg)	–	0.01	0.01	0.01	0.01
Biotin (μg)	–	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).

suppressed where K-citrate was added. The control sample had a starchier flavor, explained by the slightly higher level of added flour. Nutmeg and pepper flavor were suppressed by both the macro- and micronutrient fortification. The maximum fortified sample was most mouthdrying. This might be explained by the high levels of potassium salt, by the higher levels of protein (4.5%) in this sample, or a combination of the 2 factors. Previous studies have shown whey proteins to cause mouthdrying (Ye and others 2012). The control sauce led to the most burning after effect, perhaps attributed to its lower concentration of fat (5.8%). Results of previous research indicated that increased fat content, up to approximately 20%, increases lubrication and decreases sensations of roughness and dryness in semisolid foods (Wijk and Prinz 2005).

Summarizing the results, macronutrient fortification led to a smoother sauce with, not surprisingly, a creamier flavor. Addition of micronutrients (vitamin and mineral premix plus MgO) did not substantially change the sauce attributes. However, the addition of K-citrate at (1.6%; 698 mg K per 100 g sauce) led to fish and chemical off-flavors. Hedonic liking on the white sauce formulations was not carried out as the micronutrient fortification remained suboptimal.

Sensory and hedonic evaluation of gravies

Of 38 sensory attributes used to describe the profile of the control and macronutrient enhanced gravies, only 7 were significantly different between samples (data not shown). The macronutrient enhanced options was equally as brown as the control, through the use of soy sauce (Pearl River), whereas initial samples developed were too pale once ingredients such as cream, butter, and oil were added. Although this particular soy sauce was high in sodium, the macronutrient fortified gravy used reduced salt gravy granules to equalize the salt content of the 2 samples. The fortified option was thinner and less oily than the control in appearance, with a richer mouthfeel. It was less savory and starchy in smell, with more buttery and dairy flavor.

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

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

Table 8–Sensory profile of the micronutrient enhanced tomato sauces (rated on 0 to 100 scale).

Modality	Attribute	Double cream	Double cream + micronutrients	WPI + maltodextrin	WPI + maltodextrin + micronutrients
Appearance	Lightness of brown color	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[a]	20.8[b]	25.6[ab]	28.8[a]	23[ab]
	Oily	20.8[b]	31.2[a]	23[b]	22.8[b]
Odor	Tomato	57.1[a]	45.8[b]	50[ab]	52.2[ab]
	Sweet	38.1[a]	30.1[b]	37[ab]	32.5[ab]
Taste	Bitter	27.2[b]	37.5[ab]	28.2[b]	43.5[a]
Flavor	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]
Mouthfeel	Grainy	29.6[ab]	22[b]	35.1[a]	29.6[ab]
	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[bc]	20.5[a]	8.3[c]	19[ab]
	Bitter	20.6[b]	35.6[ab]	21.1[b]	37.5[a]

Mean values with the same letter (a, b, and c) within the same row are not significantly different at $P < 0.05$.
Attributes were no significant differences were found between products were appearance: black bits, separated, watery; smell: herbs, onion, butter, chicken stock, cheesy, savory, burnt; taste: salty, sour, sweet, umami, metallic; flavor: creamy, buttery, ripe tomato, cooked tomato, herbs, cheesy, burnt; mouthfeel: full body; aftereffect : astringent (mouthdrying), burning, oily lips, mouth coating, metallic.
[a]Green bits were due to herb addition, differences are expected to be due to minor batch to batch variation.

Table 9–Sensory profile of fortified white sauces (rated on 0 to 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]
	Savory	26.4[a]	17.3[b]	26.1[a]	27.5[a]
Taste	Salty	12.8[b]	9.6[b]	10.9[b]	20.4[a]
	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]
Flavor	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]
	Fish	7.8[b]	7.0[b]	13.3[b]	34.8[a]
Mouthfeel	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]
	Mouthdrying	27.6[ab]	21.5[b]	27.2[ab]	32.4[a]
After effects	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]

Mean values with the same letter (a, b, and c) within the same row are not significantly different at $P < 0.05$.
Attributes were no significant differences were found between products were smell: mushroom, chicken, egg, cheese; flavor: butter, egg, cheese; mouthfeel: greasy; after effect: umami.

addition of micronutrients led to suppression of beef and red wine flavor, but caused mushroom and nutty flavors. The addition of the powdered micronutrient premix caused a less smooth mouthfeel. Where the flavor enhancer was present, addition of micronutrients caused a less rich mouthfeel. In terms of after effects, both gravy types had stronger mushroom flavor after-effect where micronutrients were added. Overall, the use of flavor enhancer significantly led to higher ratings of umami (savory) taste and beef flavor, which might benefit the acceptability by older adults (Dermiki and others 2013). The incorporation of micronutrients only led to higher levels of potentially negative attributes (for example, bitter), but to a relatively small extent.

Table 10–Sensory profile of micronutrient enhanced gravies (rated on 0 to 100 scale).

		Macronutrient fortified	Macronutrient and flavor enhancer	Macronutrient and micronutrient	Macronutrient and micronutrient and flavor 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]
	Savory	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]
	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]
Flavor	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]

Mean values with the same letter (a, b, and c) within the same row are not significantly different at $P < 0.05$.
Attributes where no significant differences were found between products were appearance: thick, opaque, bits; smell: fatty, starchy, boiled vegetables, nutty; taste: sweet; flavor: acidic, meat, burnt caramel; mouthfeel: mouthcoating, gritty, dry.

Limitations in the fortification of whey protein and micronutrients

The addition of WPI and the combination of WPI and micronutrients can lead to sauce instability. The macronutrient enhanced sauces developed in this study can be characterized as oil-in-water emulsions after the incorporation of high fat ingredients. Many food emulsions consist of droplets of fat or oil suspended in an aqueous medium. The interface between the oil and the water at the droplet surface must be occupied by surfactant molecules to prevent immediate aggregation or coalescence. Surfactants can be either small amphiphilic molecules (such as lecithin used in this study), and large surface active molecules, such as proteins (Biesalski and others 2003). Aggregation occurs where the surfactant layer cannot prevent the droplets from approaching one another. The net charge of a protein, and hence an adsorbed protein layer, is highly dependent on pH. If the pH is close to the isoelectric point of the protein, its net charge approaches zero, which favors aggregation. Emulsions containing whey proteins are generally unstable at pH values close to 5, especially if the emulsion is heated (Biesalski and others 2003). The presence of calcium ions is inversely related to the pH (Geerts and others 1983) and, therefore, affects the stability of the emulsions. This is explained by binding of the calcium ions to the phosphoserine residues of the caseins, which reduces the negative charge on the protein, and so reduces stability. In our case, emulsion instability occurred in all 3 types of sauce when a certain concentration of WPI was exceeded. The addition of micronutrients in combination with WPI resulted in coagulation of the sauces and this phenomenon was observed during the freezing/thawing procedure. It has been reported that the casein micelles of milk are destabilized by slow freezing (cryodestabilization) and storage at a temperature in the range −10 to −20°C. This causes a decrease in pH and an increase in the calcium ion concentration in the unfrozen phase of milk (Fox and Brodkorb 2008). The most unstable sauce was the white sauce and this might be due to its high concentration of milk constituents and their sensitivity to the presence of minerals. The samples that were unstable were unacceptable for sensory evaluation, therefore were not assessed. The maximum limit of WPI addition in each type of sauce was established in the presence of other energy fortifying ingredients. Above this maximum level, not only the texture and consistency of the sauce were affected but several sensory properties as well such as smell, flavor, and after effects.

Conclusion

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

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

For all micronutrient enhanced sauces, matching one-third of RNI could not be achieved for potassium and magnesium (Table 5) due to unacceptability taste, flavor and after effects. Therefore, the concentration of these minerals had to be adjusted to a desired level in terms of acceptable sensory properties, in order to minimize bitter and metallic taste and after effects and to avoid any texture and instability problems. For the micronutrient fortified tomato sauce, the addition of 33% to 40% of RNI for some vitamins (riboflavin, B_6, folate, and C), Fe and Zn, plus 10% to 13% of RNI for K and Mg in a 50 g sauce portion (Table 5), resulted in a sauce that was higher in meaty flavor and more bitter. However, this did not reduce the liking of the sauce as rated by older volunteers. For the micronutrient fortified white sauce, the addition of 35% to 43% of RNI for vitamins, Fe, and Zn, plus 10% of RNI for K and Mg in a 50 g sauce portion (Table 5), resulted in a sauce that was higher in fishy and chemical flavor as well as more bitter and metallic. However, when the K-citrate was excluded the fishy flavor and metallic taste were significantly lower. For the micronutrient fortified gravy, the addition of 33% to 34% of RNI for some vitamins, Fe, and Zn, plus 8% of RNI for K and Mg in a 50 g gravy portion (Table 5), resulted in a sauce that was higher in mushroom and nutty flavor.

Further studies of the hedonic liking of the fortified sauces with the target community of older hospital patients should be carried out, and in particular the sauces needed to be tested within real meals. It is recommended that this is done with the fortified options of sauces developed in this study, but also with an option excluding potassium. Potassium was found to contribute substantially to negative flavor and taste, cause issues of sauce instability, and is not recommended for older patients with renal disease (Sinha and Agarwal 2013).

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

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

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

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Author Contributions

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

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