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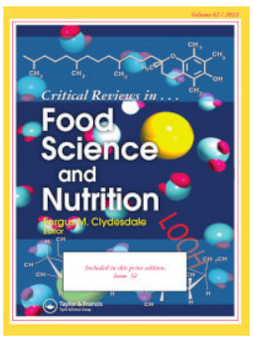

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REVIEW

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Review of protein intake and suitability of foods for protein-fortification in older adults in the UK

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ABSTRACT

Protein is a vital dietary component for combating negative health outcomes associated with malnutrition in older adults, including sarcopenia, functional decline and reduced quality of life. Yet, recommended daily protein intake is consistently unmet, as evidenced in the literature and reaffirmed in this review. Poor appetite is recognized as a major determinant of protein-energy undernutrition and thus fortification of regular food or drinks provides a flexible and relevant approach for older adults with reduced appetite. To increase the likelihood of fortified products being successfully incorporated into the diets of older adults, they must be adaptable to older adults eating patterns, cater for their preferences and take the specific age-related problems that complicate food intake into account. This paper aims to highlight older adults' current sources of protein, shopping habits, typical eating patterns and commonly consumed foods, and hence consider appropriate carriers for protein enrichment. Data were reanalyzed from a combination of freely available UK datasets, including the National Dietary and Nutrition Survey and the Food and You Survey, alongside data purchased from market research consultancy, Kantar. These insights draw attention to the potential suitability of foods for fortification purposes, with the ultimate objective to promote eating pleasure and prevent malnutrition.

KEYWORDS

Older adults; protein; malnutrition; dietary behaviors; fortification; new product development

Introduction

The UK national population trajectory highlights an aging population, forecasting that by 2050, one in four people will be aged 65 years and over (Office for National Statistics 2021a). The prevalence of this trend globally has led medical professionals to advocate the concept of "adding life to years," which aims to look beyond simply extending life years, but promotes better wellbeing and quality of life during these later years (World Health Organization 2020). This has been acknowledged in the "Decade of Healthy Aging" plan (World Health Organization 2020), which encourages healthy behaviors in older adults, including appropriate dietary choices and maintaining healthy dietary patterns.

A nutritious diet is essential for healthy aging in older adults and reducing the risk of chronic diseases and rate of functional decline (Dorrington et al. 2020). Thus, emphasis is frequently placed on the synergistic effects of nutritious food combinations (Granic et al. 2015). Additionally, evidence also indicates that increasing individual macronutrients, in particular protein, has prominent beneficial health outcomes for the risk of frailty (Mendonça et al. 2020), fracture risk (Groenendijk et al. 2019), cognition (Fernando et al. 2018), and immune function (Li et al. 2007), which can themselves have further consequences. For example, susceptibility to sarcopenia, a progressive and generalized loss of muscle mass and strength, increases with age (Cruz-Jentoft et al. 2010) and a decreased quality of life (Hunter et al. 2019). Sarcopenia can result in an increased risk of falls and fractures, as well as reduced independence and exercise ability, which in turn is associated with the increased risk of metabolic diseases, such as type 2 diabetes (Hunter et al. 2019).

Still, consuming protein at a safe level is essential, as excessive protein intake can be detrimental. For example, excess protein intake can cause negative alterations in renal function which can cause damage to kidneys and lead to an accumulation of toxic protein metabolites (Ko et al. 2017). Moreover, long term high intake of undigested protein can encourage pathogens and protein-fermenting bacteria which release toxic metabolites into the colon and subsequently increase disease risk (Ma et al. 2017; Cai et al. 2022). As such, dietary source of protein, protein content and factors effecting protein digestibility are important for managing the composition of gut microbiota (Wu et al. 2022).

With the above in mind, it is suspected that most of the population are not at risk at consuming excess protein. Evidence suggests that protein requirements in adult humans have been underestimated in Dietary Reference

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Intake recommendations, as concluded by a joint consultation from the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the United Nations University (UNU) (FAO/WHO/UNU 2007) as well as by the re-analysis of data by Elango et al. (2010; Elango et al. 2010). These papers argue that the traditional nitrogen balance method tends to underestimate requirements because it relies on accurate quantification of intake and losses; however, losses are often underestimated leading to intake being overestimated. The use of an indicator amino acid technique using stable isotopes to measure amino acid oxidation is considered to be more accurate (Elango et al. 2010; Arentson-Lantz et al. 2015). It has been concluded that intakes of twice the safe level (0.83 g per kg of body weight) are unlikely to be associated with any risk (FAO/WHO/UNU 2007; Elango et al. 2010). Additionally, current guidelines do not provide tailored recommendations for older adults, whom require comparatively more protein per day than younger adults in order to maintain, or minimize loss of, muscle mass and strength (Dorrington et al. 2020; Coelho-Junior et al. 2020). Older muscle is susceptible to anabolic resistance and so requires greater amounts of amino acids to stimulate muscle anabolism (Coelho-Junior et al. 2020). Older adults also have decreased postprandial availability of amino acids, reduced perfusion of muscle postprandially, decreased uptake of dietary amino acids into the muscle, reduced anabolic signaling for protein synthesis, and reduced digestive capacity all of which compound the need to increase protein intake with age (Bauer et al. 2013; Koopman et al. 2009; Burd, Gorissen, and Van Loon 2013). The current UK population protein recommendation is 0.75 g per kg of body weight, yet evidence suggests that increasing this in adults aged 65 and over may be necessary (Dorrington et al. 2020; Bauer et al. 2013; Deutz et al. 2014). Healthcare professionals from the European Society for Clinical Nutrition and Metabolism (ESPEN) and the PROT-AGE Study Group have advised that a healthy older adult's daily protein intake should be increased to 1–1.2 g per kg of body weight, per day, compared to 0.75 g per kg in younger adults respectively (Bauer et al. 2013; Deutz et al. 2014). This is elevated for frail older adults who should consume 1.2–1.5g of protein per kg of body weight per day (Bauer et al. 2013).

Yet, the evidence assessing older adults intake, including older adults in the UK, consistently suggests their protein intake targets are not being met (Roberts et al. 2018; Morris et al. 2020; Lonnie et al. 2018; Mendonça et al. 2018). For example, the Newcastle 85+ study, which focused on community-living adults aged 85 and over, found a median protein intake of 0.97 (0.77–1.24) g/kg of body weight per day (Mendonça et al. 2018). Moreover, this study highlighted a large cohort of 75% of older adults with a protein intake of less than 1.2 g/kg of body weight per day who may be vulnerable to protein-energy malnutrition and the associated negative health ramifications (Mendonça et al. 2018).

Numerous risk factors exist for malnutrition, including social, physical, medical and psychological changes in the aging process (Norton, Lignou, and Methven 2021). Poor appetite is recognized as a major determinant of protein-energy undernutrition (van der Pols-Vijlbrief et al. 2014), as reduced intake ultimately provides fewer opportunities to consume the necessary nutrients. Swallowing difficulties (dysphagia) and the texture of foods which can increase processing time in the mouth, can lead to increased feelings of satiety (Chambers 2016) and influence appetite regulation (Norton, Lignou, and Methven 2021). Protein can also be more satiating than fat and carbohydrates, and this can lead to reduced intake at subsequent meals, though the evidence for this in older adults is mixed (Appleton 2018; Veldhorst et al. 2008). Recent evidence suggests that once significant weight loss has occurred, aggressive nutritional support may not result in improved outcomes, hence maintenance of appetite and food intake is of considerable importance in aging (Dent, Hoogendijk, and Wright 2019).

In addition, the majority of protein is commonly consumed in one main meal, typically at dinnertime, and as such protein intake at breakfast and lunch can be inadequate (<30 g/meal) (Gaytán-González et al. 2020). Whilst there is conflicting evidence that has shown no effect of feeding pattern (Kim et al. 2015), some research suggests that optimal muscle protein synthesis is best obtained in a pulse-feeding pattern, which involves a higher intake of protein (above a 25 g threshold) three times a day (Arnal et al. 1999; Morris et al. 2020). Therefore, identifying methods to balance the consumption of protein throughout the day might represent an important opportunity for nutritional intervention.

To increase protein intake there are two predominant approaches: supplementation and fortification (Moloney and Jarrett 2021). Oral nutritional supplements (ONS) are a blend of macro- and micronutrients, often presented as a liquid, to complement nutritional intake (BAPEN 2016). Fortification, which typically consists of adding high-energy-high protein ingredients to regular food or drinks, is recognized as a flexible and appropriate approach to increase protein in older adults with reduced appetite (Norton, Lignou, and Methven 2021). More research intervention trials have been published on supplements compared to fortification (Moloney and Jarrett 2021). For example, randomized double blind clinical trials with older adults have tested the efficacy of long-term nutritional supplementation combined with physical activity and found protein supplementation significantly increased muscle density (Englund et al. 2017) and strength and lean mass (Bell et al. 2017) more than the placebo groups. There are randomized controlled trials that have tested fortified foods for both protein intake and physical outcome measures. Protein fortified foods and drinks were tested in a 12 week post-hospital intervention with older patients and found to increase protein intake but not physical performance (Beelen, de Roos, and de Groot 2017). Another study using fortified snacks with older adults receiving home care found mini-nutritional assessment (MNA) scores improved in the intervention group, while plasma albumin concentration and handgrip strength decreased in the control group but not in the intervention group over the 3-month study (Nykänen, Törrönen, and Schwab 2018). One study across eight nursing homes found to a protein and energy fortified brioche to improve nutritional status to a greater extent than an ONS (Van

Wymelbeke et al. 2016). This is promising; however, successful real-world application of fortification requires more than assessing their efficacy. Food products and supplements must also be relevant and desirable to consumers for increased purchasing and consumption to occur and their potential benefits to be seen. Previous research with older adults has indicated that they prefer products from their current diet to be used as carriers for protein-enrichment (van der Zanden et al. 2014). Therefore, this suggests the most appropriate carriers must be identified from commonly consumed foods in older adults' diets.

To source the appropriate information to create protein-fortified products, made specifically for the older adult population, the purpose of this review is to 1) provide the latest evidence on protein and energy intake in the diet of UK older adults and their typical dietary sources; 2) explore older adult's food purchasing behaviors; 3) highlight commonly consumed foods in the diet of UK older adults; and 4) discuss the suitability of commonly consumed foods for protein fortification.

Methods

To achieve these aims, we will draw on freely accessible national data which includes two datasets from the National Diet and Nutrition Survey (Public Health England 2020; Public Health England 2019), and data from Wave 5 of the Food and You Survey (Food Standards Agency 2020). We will also draw on food purchase data, from the Office for National Statistics (2021b) and market research consultancy, Kantar. The combination of insights from these datasets should provide a rich and contemporary view on the food consumption behaviors of older adults. Table 1 provides detail on each data set we have used and sample sizes for each age group analyzed are listed throughout the review. In this review, the frame of reference for "older adults" is 65 years and over, and as such, the data analyzed will primarily focus on the responses from adults aged 65 years and over. We will also make comparisons with older (75 years and above) and younger (64 years and below) groups where data are available.

Older adult's daily intakes in the UK

Daily energy intake and contribution of food groups

To understand the average daily energy intake and contribution of food groups, data were reanalyzed from the latest National Diet and Nutrition Survey (NDNS) Rolling Programme Years 9–11 (Public Health England 2020). In recent years, the NDNS has facilitated comparisons between older age groups by introducing a ≥75 years band, revealing the nuances in intakes within older populations. Unfortunately, this data was not available in previous reviews of protein intake in UK older adults (Lonnie et al. 2018). Table 2 shows the average daily energy intake for men and women across three age groups (Public Health England 2020) alongside the average energy requirements for the general population (with an average physical activity level), for comparison (Scientific Advisory Committee on Nutrition 2012). It indicates that energy intake recommendations are either not currently being met by any age group, or that under-reporting of daily energy intake is common in all age groups.

Figure 1 shows which food groups contribute the most to daily energy intake across different age groups (sample size: 19–64 years $n = 1{,}392$; 65–74 years $n = 262$; and ≥75 years $n = 190$). It reveals that cereal and cereal products, meat and meat products, and milk and milk products have the largest share in nearly all age groups, with vegetables and potatoes being slightly higher than milk and milk products in the 19–64- and 65–74-year-old age groups. Cereals and cereal

Table 1. UK Datasets included in review.

Source	Dataset title	Years
National Diet and Nutrition Survey (https://www.gov.uk/government/collections/national-diet-and-nutrition-survey)	NDNS Years 9–11 Descriptive Statistics Tables; Protein intake (g/day, % total energy and % food energy) by NDNS RP survey years, age and sex	2008/9–2018/19
	NDNS Years 9–11 Descriptive Statistics Tables; Percentage contribution of food groups to average daily protein intake by NDNS RP survey years and age	2008/9–2018/19
	NDNS Years 9–11 Descriptive Statistics Tables; Total energy intake (MJ/day and kcal/day) and food energy intake (MJ/day and kcal/day) by survey years, age and sex	2008/9–2018/19
	NDNS UK Y1_9 Descriptive statistics and tables of plots; Total quantities of food consumed (grams) per day: all consumers, by age	2012/13–2016/17
Food and You Survey (https://www.food.gov.uk/research/food-and-you)	Food and You Survey Wave 5; Responsibility for food or grocery shopping	2018
	Food and You Survey Wave 5; Where households shop for food	2018
Office for National Statistics (https://www.ons.gov.uk/)	Family Spending Workbook 2 – Expenditure by Income; Household expenditure by gross income quintile group where the household reference person is aged 30 to 49	2018–2020
	Family Spending Workbook 2 – Expenditure by Income; Household expenditure by gross income quintile group where the household reference person is aged 50 to 64	2018–2020
	Family Spending Workbook 2 – Expenditure by Income; Household expenditure by gross income quintile group where the household reference person is aged 65 to 74	2018–2020
	Family Spending Workbook 2 – Expenditure by Income; Household expenditure by gross income quintile group where the household reference person is aged 75 or over	2018–2020
KANTAR	Market data of food purchases from the Kantar panel which comprises approximately 30,000 households in Great Britain collected over 13 periods per year. The regional and demographic profile of the panel aims to represent the profile of the population of GB. The purchased data set consisted of 22 elected food categories, 19 of which were utilized for this analysis (as outlined in Table S1b – supplementary) to ensure all major dietary components were included.	2018–2020

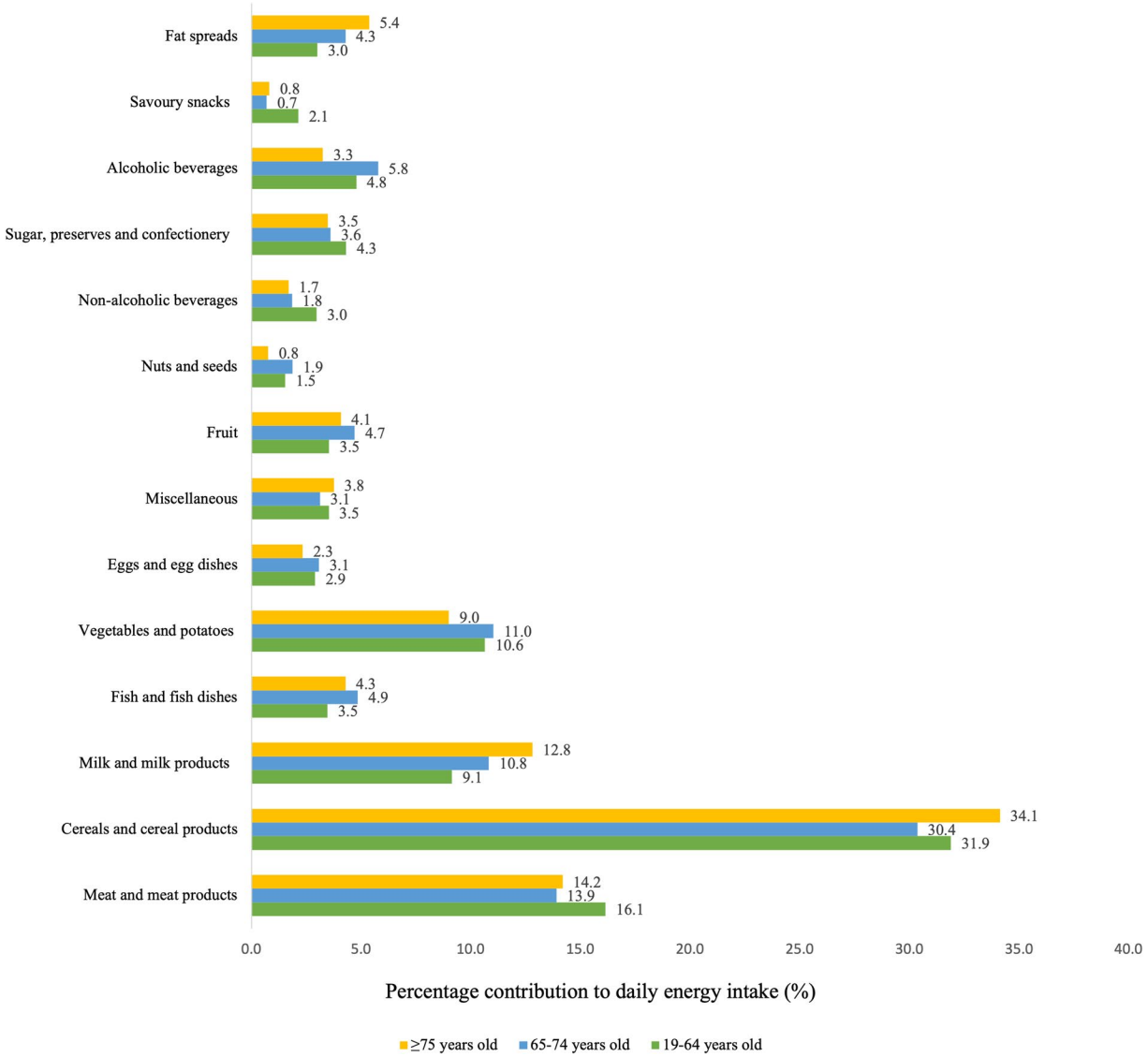

Figure 1. Percentage contribution (%) of food groups to average daily energy intake in the UK in 2016/2019: adults aged 19–64, 65–74 and ≥75 years old. Source: reanalyzed data from the National Diet and Nutrition Survey Rolling Programme Years 9–11.

Table 2. Average daily energy intake and requirements (kcals).

	Average daily energy intake (kcals)			Average energy requirements (kcals)		
	19–64 years	65–74 years	75 + years	19–64 years	65–74 years	75 + years
Male	2,053	1,978	1,763	2,662	2,342	2,294
Female	1,605	1,490	1,458	2,127	1,912	1,840

products may be the largest source of energy intake because the foods in this group are particularly energy-dense (including cakes, puddings and pizza), however, it could also be a result of food preferences contributing to these figures. Notably, older adults aged 75 years and over obtain a substantial amount of their energy from cereal products, meat products and milk products.

Daily protein intake and contribution of food groups

Daily protein intake and percentage contribution from food groups were also reanalyzed from NDNS data (Public Health England 2020) and are shown in Table 3. Despite a required elevation in protein intake for older adults, this daily intake is notably less than adults aged 19–64 who consume 76 g/day (Public Health England 2020). Taking the suggested amount of protein per day for older adults, as recommended by experts (1.2–1.5g per kg of body weight) (Bauer et al. 2013; Deutz et al. 2014) and the UK average weights for age (Scientific Advisory Committee on Nutrition 2012), Table 3 shows the recommended range of protein per day for older adults. It highlights a potential protein deficit of 5.22–23.85g protein per day for adults aged 65–74 years and

Table 3. Average daily protein intake and recommendations (grams per day).

	Average protein intake (grams per day)		Recommended protein intake (grams per day)	
	65–74 years	75 + years	65–74 years	75 + years
Male	74.5	68.8	80.4–100.5	78.12–97.65
Female	60.6	59.2	68.64–85.8	65.16–81.45
Combined	69.3	63.4	74.52–93.15	71.64–89.55

8.24–26.15g protein per day for adults aged 75+. This indicates that older adults aged 65+ years in the UK population may be more vulnerable to frailty (Mendonça et al. 2020), functional decline (Fernando et al. 2018), and increased morbidity and mortality (Schlenker 1993).

In line with previous trends (Lonnie et al. 2018; Hengeveld et al. 2019), Figure 2 indicates that meat and meat products (32%) are the largest contributor of protein to diets in the UK, followed by cereals (23%) and milk products (15%). By contrast, snacks and beverages provide very little protein. This is similar to the findings in Figure 1, suggesting some food groups contribute comparably to protein and energy intakes, however vegetables and potatoes contribute less to protein intakes than they contribute to energy intakes. Figure 2 shows the percentage contribution of different food groups to daily protein intake across different age groups. It illustrates that whilst older adults consume less protein than younger adults from meat and meat products, fish and fish dishes contribute more protein to the diets of adults aged 65 years and over compared to younger adults, as do the milk and milk products for the ≥75 years group.

As meat is the greatest contributor to protein intake, Figure 3 aims to understand how different meat sources account for daily protein intake across different age groups. It shows that white meat is evidently responsible for most of the daily protein contribution from meat and meat products. There is little variation between the two oldest age groups, showing that chicken and turkey dishes contributes 10–11% of older adult's daily protein intake. As this meat contributes noticeably more protein to the diets of older adults than processed meats such as sausages (1–2%), bacon and ham (4%), and burgers and kebabs (0%), it suggests that the older adults are getting most of their protein from lean sources of meat.

On the other hand, Figure 4 which shows the contribution to daily protein intake from the foods within the cereal category for different age groups and indicates that the contributions are relatively homogenous between food types. The main contributors to protein from cereal products in the diets of older adults are high fiber breakfast cereals (4%) and white bread (5%). There is a marked 6% decrease in the protein contribution from pasta, rice, pizza and other miscellaneous cereals as age increases (a decline from 8% in adults aged 19–64 to 2% in adults aged ≥75). Overall older adults obtain more protein from brown, granary, wheatgerm and whole meal bread than the younger age

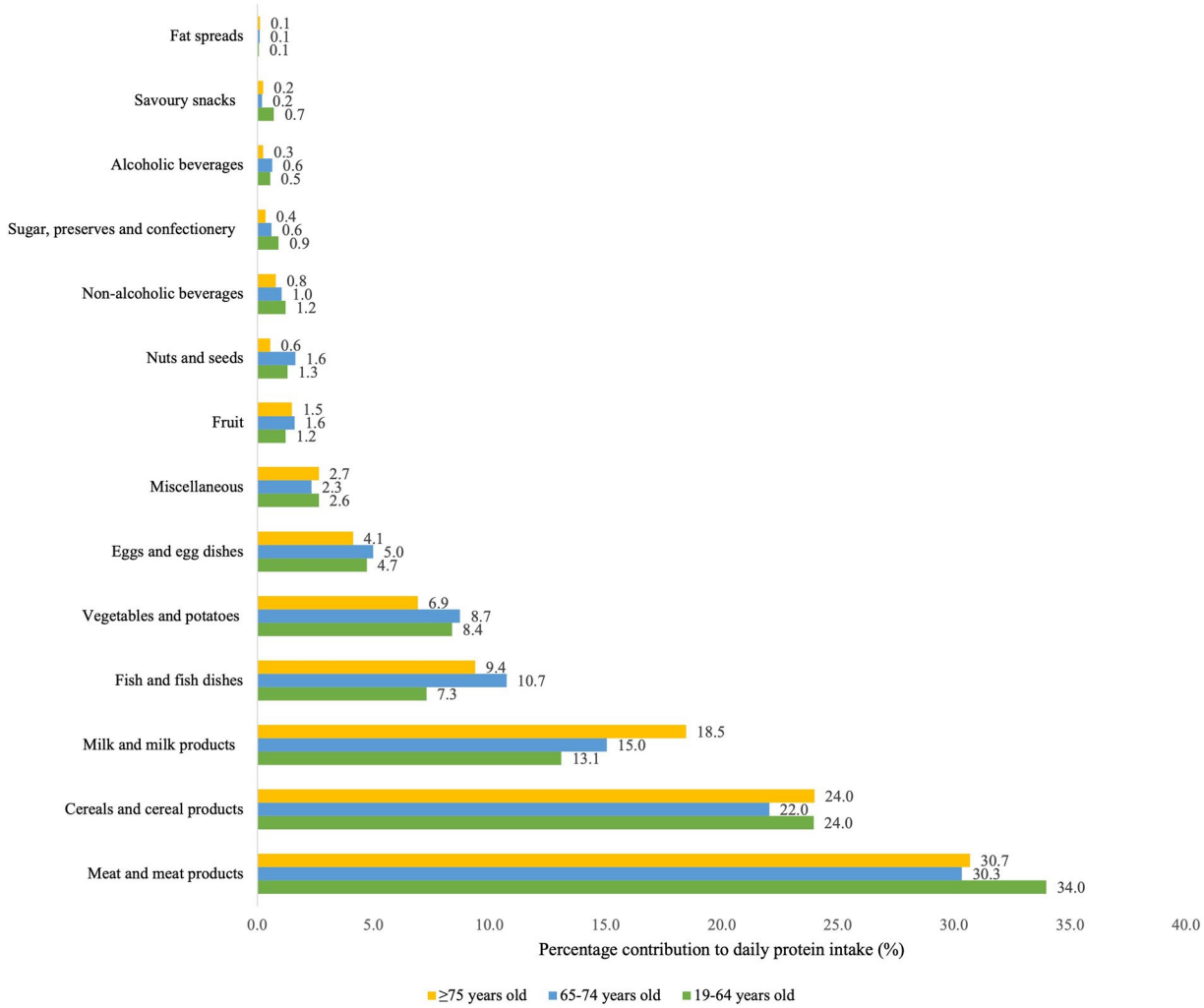

Figure 2. Percentage contribution (%) of food groups to average daily protein intake in the UK in 2016/2019: adults aged 19–64, 65–74 and ≥75 years. Source: reanalyzed data from the National Diet and Nutrition Survey Rolling Programme Years 9–11.

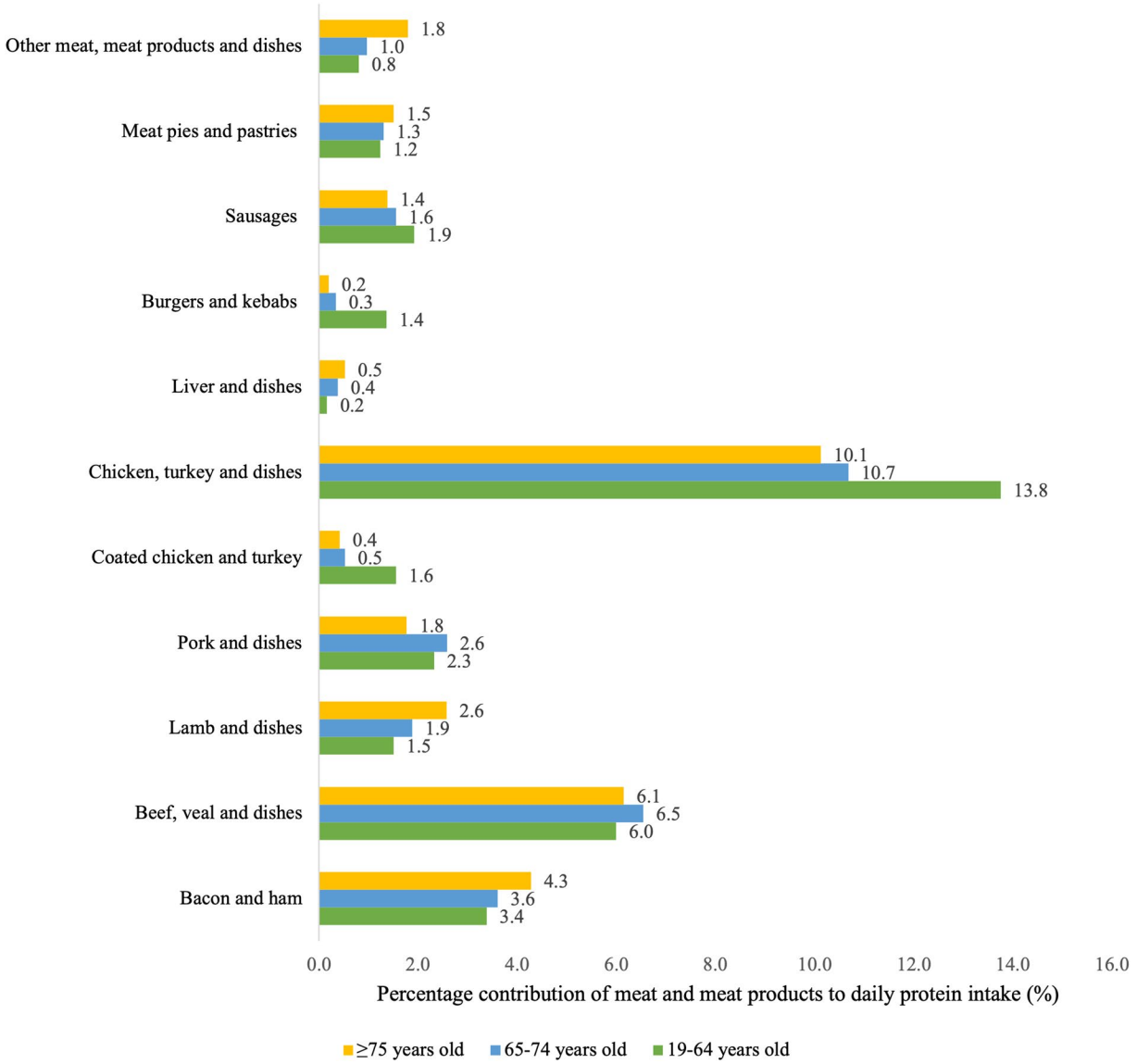

Figure 3. Percentage contribution (%) of meat and meat products to average daily protein intake in the UK in 2016/2019: adults aged 19–64, 65–74 and ≥75 years. Source: reanalyzed data from the National Diet and Nutrition Survey Rolling Programme Years 9–11.

group, suggesting that some older adults are less inclined to consume refined carbohydrates; however white bread remains the most popular of the three bread types.

Figure 5 presents the contributions to protein intake from the milk and milk products category across different age groups, which was the third largest contributor to daily protein intake overall. This data shows that semi-skimmed milk makes the biggest contribution to protein intake amongst the three milk types and is also the largest contributor in the entire milk and milks category (4–8%). This is particularly evident for the ≥75 years group who get 8% of their protein from semi-skimmed milk. This may elucidate why protein contribution from milk and milk products was highest in the ≥75 years group (18%) (Figure 2).

Older adult's food purchasing behavior

As a means to explore the food purchasing behaviors of older adults, data were reanalyzed from the Food and You Survey Wave 5 (2018) (Food Standards Agency 2020) and market research consultancy firm, Kantar (2021a).

Responsibility for food and grocery shopping

Figure 6 illustrates the level of responsibility for food and grocery shopping in older adults (sample size: 55–64 years $n = 376$ (218 female); 65–74 years $n = 361$ (205 female) and ≥75 years $n = 303$ (175 female)). Noticeably there are stark gender differences; the percentage of females who are responsible for all or most of the shopping is nearly double that of the males, across all three age groups. This figure (up to 79% of women) is slightly higher than previous findings in a global trends survey seven years ago which indicated that on average 70% of British women were primarily responsible for the food shopping (Ipsos MORI 2014). It also reveals that up to a fifth of males (20%) have no responsibility at all for the food and grocery shopping. Diet quality has previously been found to be better

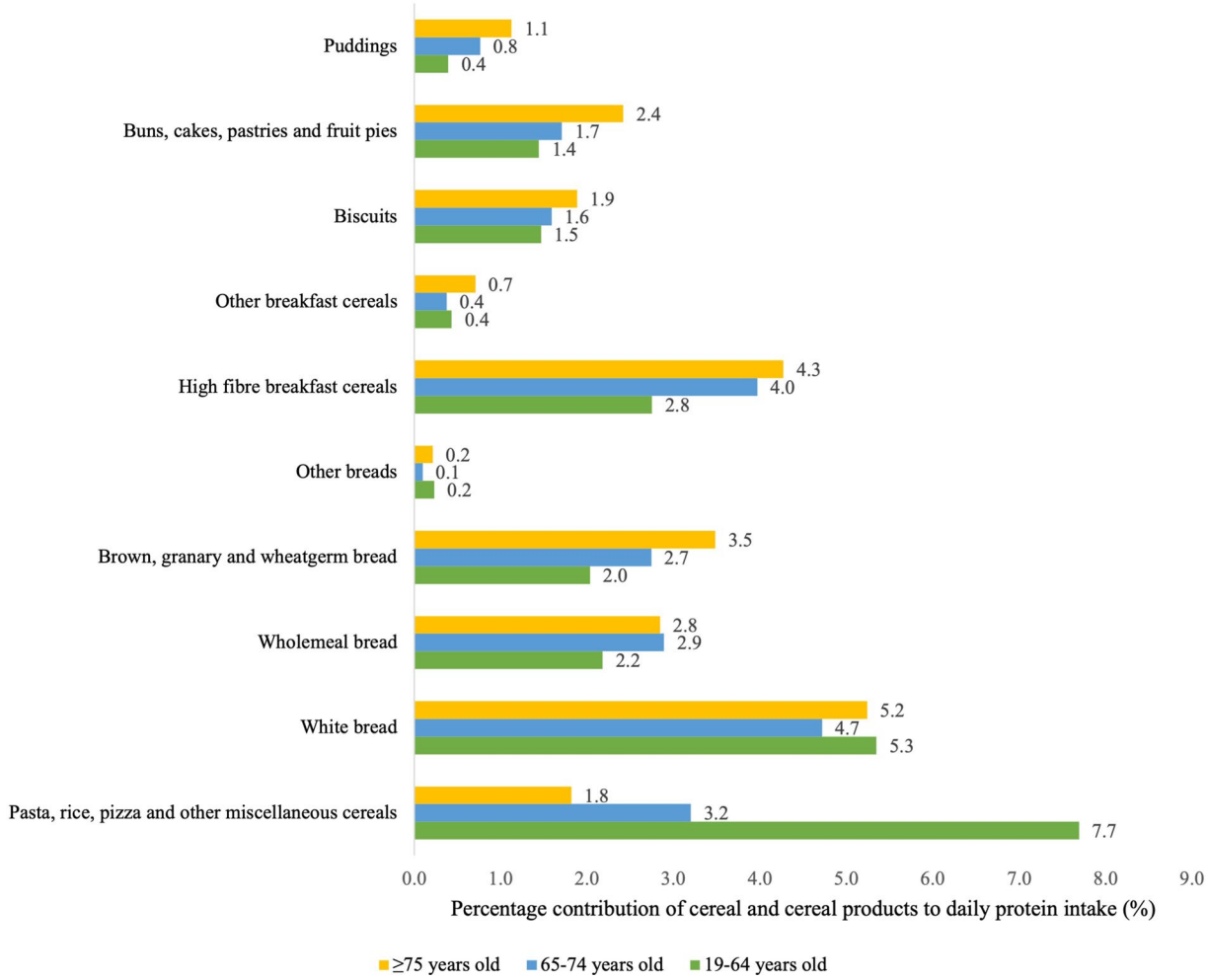

Figure 4. Percentage contribution (%) of cereal and cereal products to average daily protein intake in the UK in 2016/2019: adults aged 19–64, 65–74 and ≥75 years. Source: reanalyzed data from the National Diet and Nutrition Survey Rolling Programme Years 9–11.

in British men who are married and not living alone (Atkins et al. 2015). This suggests that women are the main gateway to food and drink entering the home and perhaps also take responsibility for the quality and types of foods.

Location of food and grocery shopping

Figure 7 shows the locations where older adults do their food and grocery shopping. The location does not appear to differ greatly within the older age groups (55–64, 65–74 and ≥75 years). The vast majority (up to 97%) of older adults do their food and grocery shopping at a large supermarket, which is distinctly higher than the number of older adults who frequent mini supermarkets (up to 41%), the second most common location. In terms of specialist independent grocers, older adults are more likely to shop at an independent butcher, than a greengrocer, baker or fishmonger. The data also indicates that older adults are less likely to utilize home delivery services. However, it is possible that this figure has increased, since the Covid-19 pandemic has led to a dramatic 229% growth in online grocery spending in retired households (Kantar 2021b).

Expenditure on food and drink

UK data for average weekly expenditure on food and non-alcoholic drinks is reported from Living Costs and Food Survey (LCFS) for which recent data was reported to the end of the 2020 financial year (Office for National Statistics 2021b). Comparing older adults (age 75+ and 65–74) to younger adults (50–64 and 30–49), average weekly food expenditure is less per household (£59.80 and £46.80, compared to £68.30 and £68.60 respectively), however this is influenced by household size, which is smaller, on average, in the older age groups (1.5, 1.8, 2.3 and 3.0 people respectively). Considering this, average weekly food expenditure per person is lower at age 75+ compared to age 65–74 (£31.20 compared £33.22). A lower average weekly expenditure per person in the 75+ group may reflect the likelihood of older adults eating less. In addition, retired adults medium yearly income (£25,434) is less than that of non-retired adults (£32,141) (Office for National Statistics 2020), which highlights that the foods developed must be affordable for older adults to have maximum reach and impact.

Data purchased from Kantar provided the total expenditure per month for various food categories by households

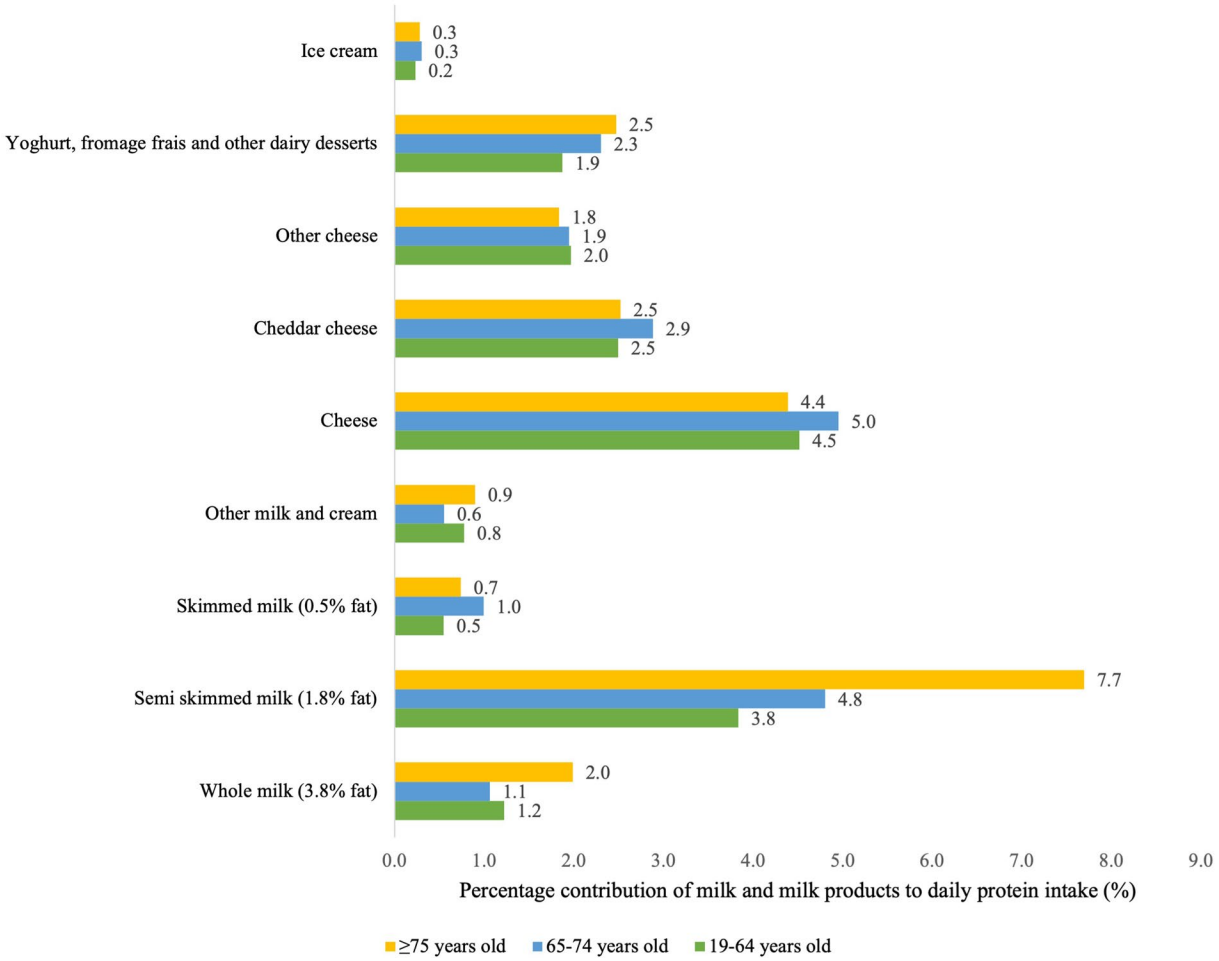

Figure 5. Percentage contribution (%) of milk and milk products to average daily protein intake in the UK in 2016/2019: adults aged 19–64, 65–74 and ≥75 years. Source: reanalyzed data from the National Diet and Nutrition Survey Rolling Programme Years 9–11.

in the UK for the years 2018 to 2020. However, when analyzed by age it did not distinguish between the number of people in a household. Thus, to provide insight on which foods older adults buy more or less of, data was reanalyzed to show the percentage that different food categories contributed to the overall basket spend for each age group (shown in Figure 8). Most of the food category names can be taken at face value however, some categories represent several food types under one umbrella term, as detailed in supplementary Table S1b.

The findings indicated that overall adults across all age ranges purchased items which contributed to their overall basket spend in a similar way (Figure 8). For example, meat fish and poultry contributed the most to overall basket spend for everyone, and wholemeal bread contributed the least. Research suggests the prohibitive cost of meat is a key factor for consumption and can prevent older adults from consuming meat (Best and Appleton 2013; Font-i-Furnols and Guerrero 2014), which could directly influence their protein intake. However, spend as a percentage of the shopping basket was significantly affected by food type ($F[18, 4284] = 18716$, $p < 0.0001$), age ($F[5,4284] = 250$, $p < 0.0001$) and year ($F[2,4284] = 14.5$, $p < 0.0001$) as well as significant interactions of food by age ($F[90, 4284] = 39.9$, $p < 0.001$) and food by year ($F[26, 4284] = 3.6$, $p < 0.001$) but not age by year ($F[10, 4284] = 0.79$, $p = 0.64$).

Of the 19 food categories, there were 15 where spend as a proportion of the total basket varied significantly by age; only frozen vegetables, sweet home cooking, white bread and wholemeal bread did not differ by age.

The only category where older adults spent proportionally more than all age groups was chilled convenience (age 65+ spent 9.6% which was significantly more than all adults under 55 at 8.2–8.8%, $p < 0.05$). As this food category refers to items such as chilled soup, pasta sauces and ready meals, it is possible that older adults have more of a preference for foods which require less preparation.

Food and drinks commonly consumed by older adults

Consumption data from the National Diet and Nutrition Survey (NDNS) Years 5–9 of the Rolling Programme (2012/2017) was reanalyzed to gain insight on the foods that are more or less commonplace in a typical older adult's diet (Public Health England 2019). This older dataset only categorizes older adults into adults aged 65 and older so the nuances within the older age groups are unavailable.

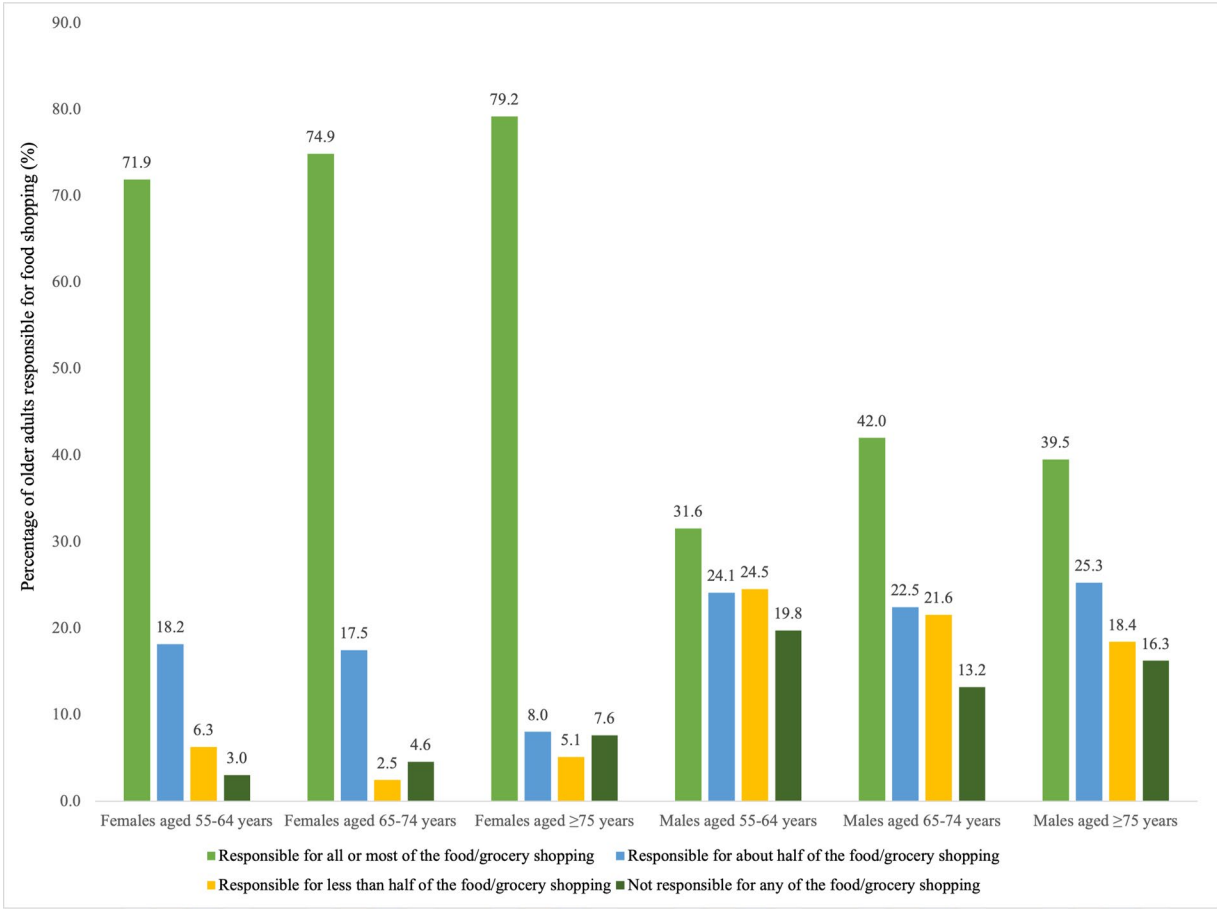

Figure 6. Responsibility for food/grocery shopping: percentage of adults aged 55–64, 65–74 and ≥75 years. Source: reanalyzed data from the Food and You Survey Wave 5 2018 (Food Standards Agency).

Age and gender differences in consumed food

Figure 9 reveals the change in percentage of male and female consumers aged 65 and older ($n = 826$) versus the males and females in 19–64-year-old age group ($n = 2526$) who consume particular foods. Importantly, a negative percentage does not indicate that those foods are not common in older adults, only that they are more common in the diet of the younger age group. It shows a clear distinction between foods that are more commonly consumed in the older age versus younger age groups. The data indicates that there are more adults aged 65 and older who consume foods such as puddings, potato dishes, and oily fish than adults aged 19–64. Figure 9 also highlights some gender differences. For example, there is a greater increase in consumption of puddings and wine with age in male respondents compared to female respondents, whereas the relative increase in consumption of butter, semi-skimmed milk and wholemeal bread is more prominent in older female respondents. This information can infer which foods are more likely to be consumed by older adults and thus which foods may be suitable candidates for protein-fortification.

Amount of food and drinks most commonly consumed

Data was reanalyzed from the NDNS Years 5–9 of the Rolling Programme to determine the average quantity of foods (grams of food or milliliters of milk and soup) older adults typically consume per day and how this varies by gender (males $n = 338$, females $n = 488$). This analysis (shown in Figure 10) excludes beverages except milk. The foods that the overall sample consumed the most of per day were soups, fruit and vegetables and milk.

This figure suggests that there are some foods that would not be worthwhile enriching with protein due to the very small amounts of them that would be consumed (such as fats and sugar confectionary), limiting their effectiveness at a population level. It would be more appropriate to consider food products that older adults eat a substantial amount of already in their diets, such as milk, soups, high fiber breakfast cereals and yoghurts. It is also more effective to enrich products that older adults consume more of and can be consumed throughout the day to achieve a pulsing protein feeding pattern (Arnal et al. 1999; Morris et al. 2020), therefore milk or yoghurt may be particularly appropriate foods as they can be mixed into sweet and savory meals, as well as being consumed as a snack (yoghurt) or consumed with hot beverages (milk).

Suitability of commonly consumed foods by older adults for protein fortification

As it is very difficult for older adults to consume more protein by simply increasing the quantity of food they eat

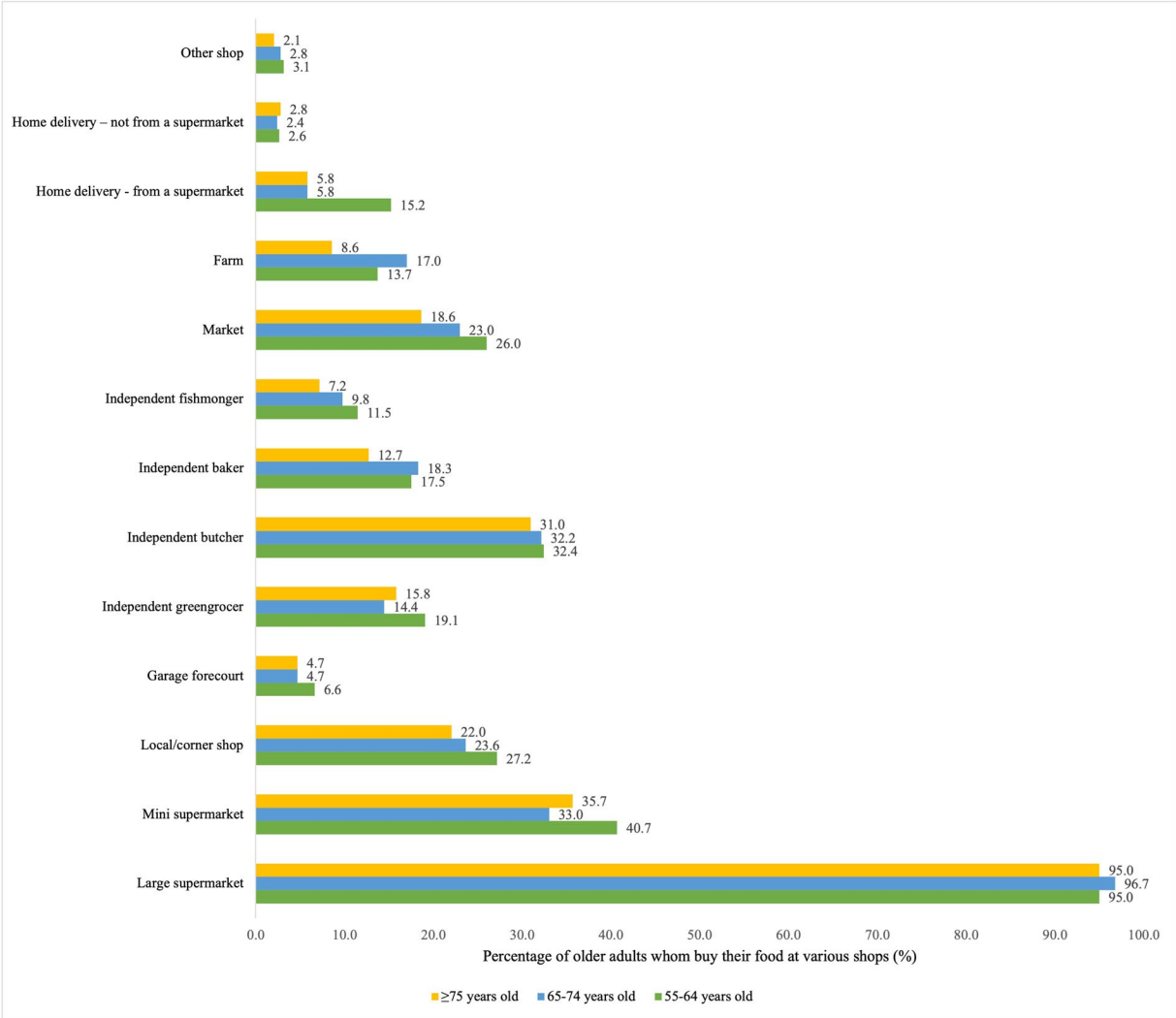

Figure 7. Location of food/grocery shopping: percentage of adults aged 55–64, 65–74 and ≥75 years. Source: reanalyzed data from the Food and You Survey Wave 5 2018 (Food Standards Agency).

(Nieuwenhuizen et al. 2010), fortification provides the opportunity to enrich commonly eaten food products with protein. Protein-enriched foods, such as sauces, bread and yoghurt have been found to be successful at increasing protein intake in healthy free-living older adults (Appleton 2018) and the hospitalized older adult population (Stelten et al. 2015). However, it is vital to understand which protein-fortified products will be successfully accepted and enjoyed by an older adult population on a routine basis. Below we discuss some factors that will greatly influence the acceptability and effectiveness of the fortified products.

Fortifying foods that older adults commonly eat

In order for protein-fortified products to benefit older adults, protein must be added to the foods which older adults will most frequently consume, as older adults tend to keep the same foods on rotation in their diets and rarely stray from these (Whitelock and Ensaff 2018). Research shows that older adults' preferred carriers for protein would be the products in their current diet (van der Zanden et al. 2014) suggesting that any new products must comply with their usual habits. This is in part because older adults do not want to change their grocery habits, but also that they also believe the quickest way to replenish a protein deficiency is to incorporate it into frequently consumed foods (van der Zanden et al. 2014). Research indicates that older adults are most willing to try healthy carriers of protein and that the majority of adults (79%) would be likely to prefer meal-type carriers, rather than a fortified snack (van der Zanden et al. 2015).

The findings in the current review provide a comprehensive account of the foods most commonly consumed by older adults and also highlight the foods that do not contribute a sufficient amount of dietary protein. Notably, soup is more prevalent in the diets of older adults than the younger population and consumed similarly by both men and women (127 ml–131ml of soup per day). Previous research has indicated that hospitalized older adults who were on a diet of fortified soup and sauces for twelve weeks showed a significantly higher protein intake than those on a standard diet

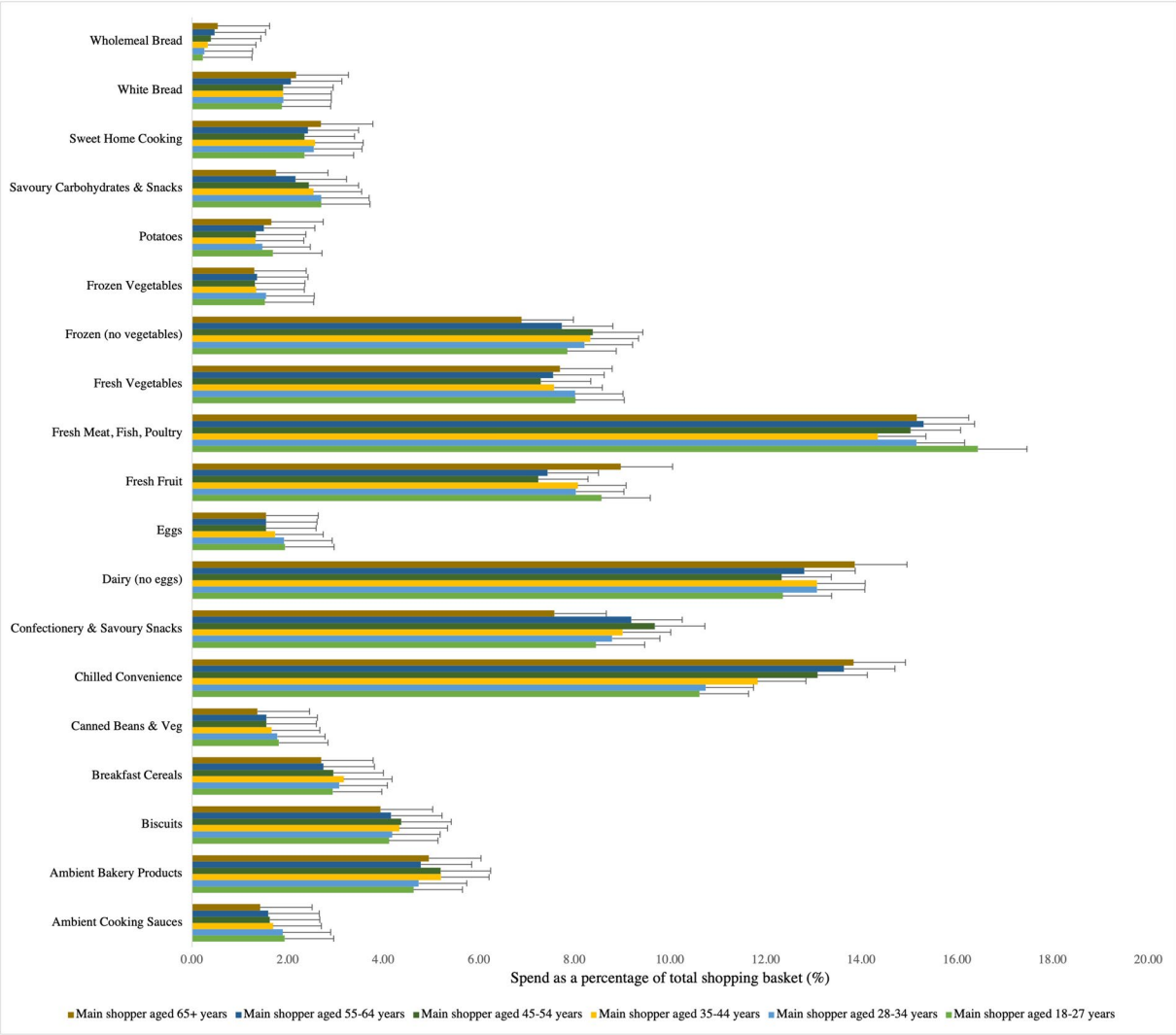

Figure 8. Food type as a percentage of overall basket spend per age group in UK: over 36 months in 2018–2020. Source: reanalyzed data purchased from market research consultancy, Kantar. Shopper age *N* calculated as a mean across the time period (18–27, $n = 563$; 28–34, $n = 2{,}615$; 35–44, $n = 6{,}180$; 45–54, $n = 6{,}761$; 55–64, $n = 5{,}590$; 65+, $n = 7{,}042$).

(Smoliner et al. 2008). In addition, research has shown that older adults preferred soups that were enriched with protein compared to their standard counterparts, suggesting that protein enriched soups have potential to improve dietary provision in older adults without compromising sensory experience (Donahue, Crowe, and Lawrence 2014). A reason for this could be is that older adults are shown to perceive soups to be less creamy than younger adults (Kremer, Mojet, and Kroeze 2005), thus fortifying soup with a whey protein could contribute to the creamy taste, making it more perceptible and rounded in flavor.

With regards to older adults cognitive perception of fortified foods, older adults have previously indicated that in their opinion, dairy, bread and cheese would "fit well" for protein-fortification purposes (van der Zanden et al. 2014). Some also felt that adding protein to something that already contained protein was appealing (van der Zanden et al. 2014). This review revealed that dairy and cheese currently provide a good source of dietary protein for older adults and the food that older adults consume the most of is milk. Thus, dairy and cheese products may be two strong contenders for successful fortification because they are commonly consumed but are also perceived to be congruent with protein fortification. There are also a variety of foods and meals which can be made from dairy sources which would facilitate the opportunity for enriching a range of foods with protein, as one protein enriched food would have a limited impact on diet.

Opportunities to incorporate protein-fortified products throughout the day

Optimal muscle protein synthesis requires a higher protein intake and a distribution of protein intake above a 25 g threshold, three times a day (Morris et al. 2020). Older adults suffer from anabolic resistance and so there is a need for effective intervention strategies to compensate (Pennings et al. 2012), including higher protein intake and resistance exercises (Breen and Phillips 2011). Therefore, it is important that the protein-fortified products are suitable for

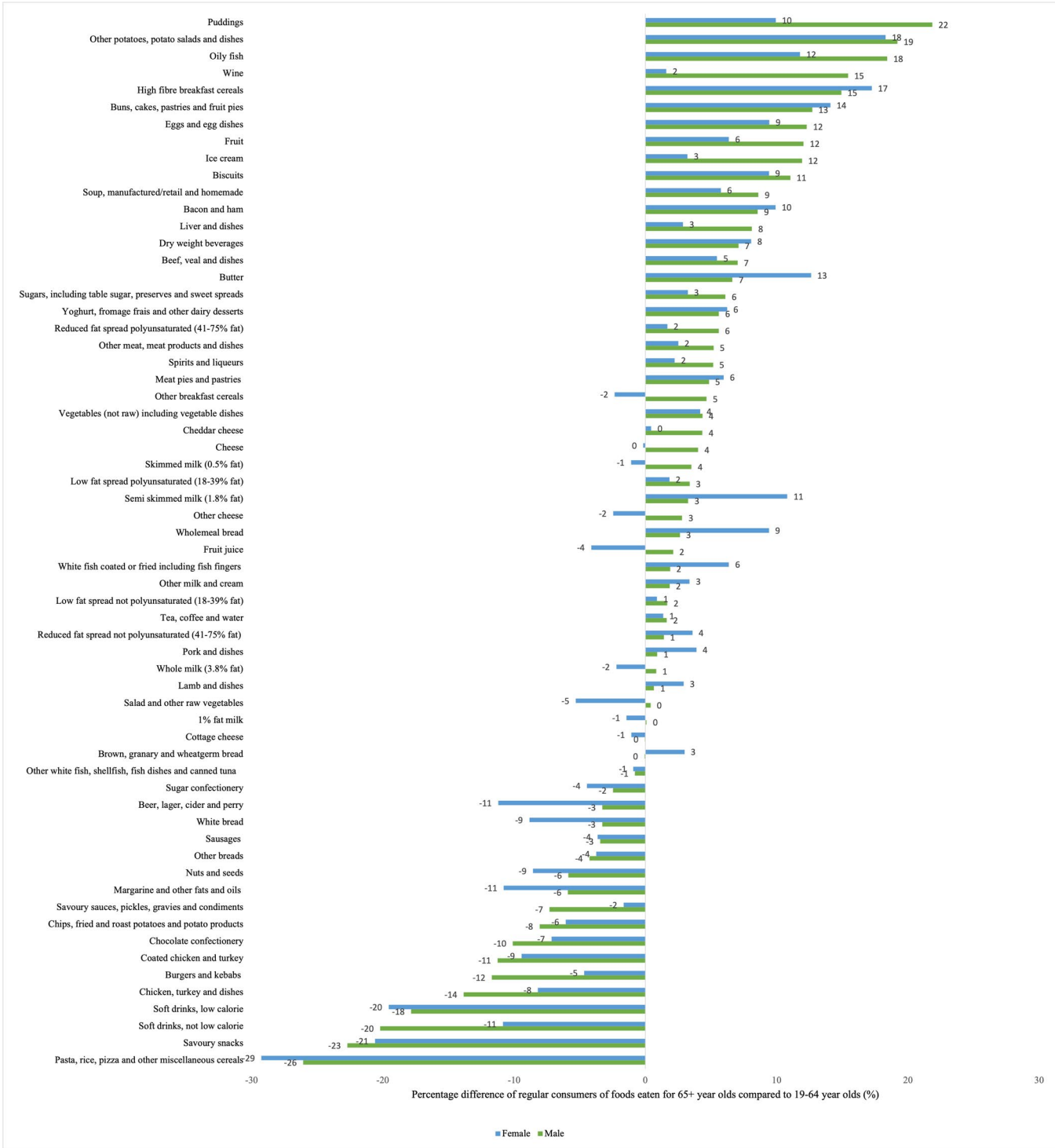

Figure 9. Change in percentage of males and females aged 65 and older versus the males and females in 19–64-year-old age group who consume particular foods (2012/2017). Source: reanalyzed data from the National Diet and Nutrition Survey Years 5–9 of the Rolling Programme.

incorporation into a wide variety of meals and snacks throughout the day. A dairy product such as milk, for example, could be fortified for regular use by older adults, to be used alongside a cereal, hot drinks throughout the day, and be used as the base of a white sauce in other meals.

Understanding meal patterns, including the number and timing of eating occasions and their relation to protein intake is critical for nutritional interventions (Engelheart, Brummer, and Forslund 2020; Lonnie et al. 2018). Twenty-four-hour recalls and food diary studies have shown that the majority of older adults have four to five eating occasions throughout the day (Engelheart, Brummer, and Forslund 2020). The majority of energy and protein is consumed in three peaks across the day, which correspond to breakfast, lunch and dinner time. The literature shows that the majority of older adults consume the majority of their

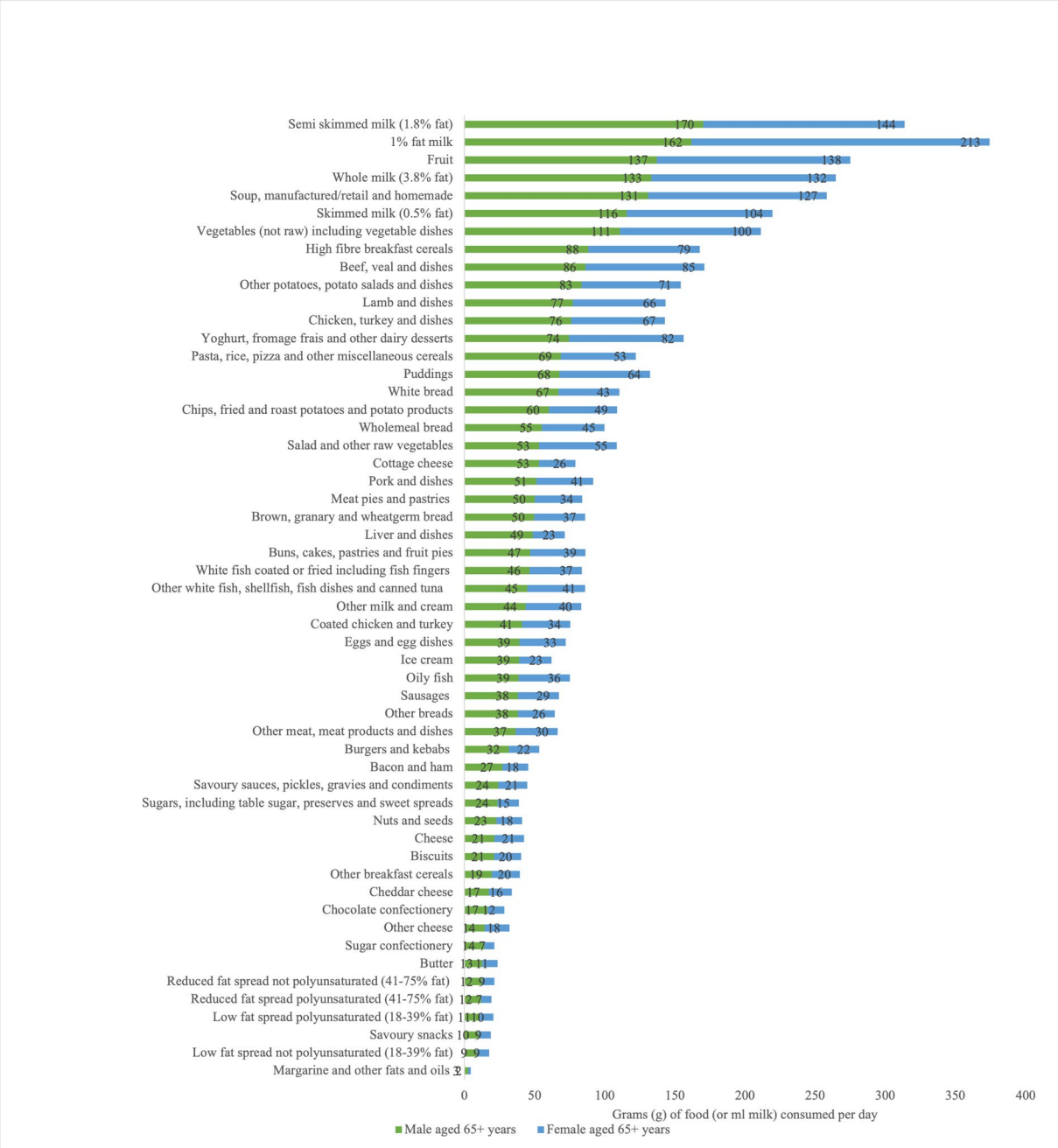

Figure 10. Grams of food (or ml) consumed per day in UK (2012/2017): female and male consumers aged 65+ years. Source: reanalyzed data from the National Diet and Nutrition Survey Years 5–9 of the Rolling Programme.

daily protein (>20 g) at mid-day, which is also when they have their largest energy intake of the day (Engelheart, Brummer, and Forslund 2020). It also highlights several eating occasions which have the lowest protein intake (under 10 g), such as an afternoon snack, (Engelheart, Brummer, and Forslund 2020), or the morning time (Morris et al. 2020).

Importantly, the protein distribution in older adults is a higher priority than the total daily amount per se (Bollwein et al. 2013; Lonnie et al. 2018). Therefore, to successfully improve protein intake and reduce sarcopenia, products should be appropriate for increasing a high protein intake at eating occasions beyond the main midday meal. For example, ingestion of a high protein meal at dinner time should be sustained as it has been shown to increase overnight muscle protein synthesis (Lonnie et al. 2018; Kouw et al. 2017).

Problems that complicate food intake in older adults

There are a range of challenges associated with older age that can complicate food intake in older adults. For example taste and aroma perception can decline with age (Doty and Kamath 2014; Methven et al. 2012), hence reducing the flavor of food for older adults. In addition, texture perception can alter (Hall and Wendin 2008; Kremer et al. 2007;

Rothenberg and Wendin 2015), appetite is reduced (Pilgrim et al. 2015) and up to 33% of older adults have swallowing difficulties (dysphagia) (Thiyagalingam et al. 2021).

Thus, solutions which aim to address protein deficiency in older adults must consider these needs, in addition to identifying the foods that older adults are most likely to consume. For example, although there is evidence in Figure 8 and 9 that eggs make up a smaller percentage of the total spend of older adults' shopping baskets and they eat less eggs and egg dishes per day than younger age groups (in grams), Figure 9 conversely showed eggs are more likely to be consumed by older adults than younger adults. Previous research has shown that older adults who regularly consume eggs believe they are a convenient, not easily wasted, and affordable protein source (Appleton 2016; Van den Heuvel, Murphy, and Appleton 2015). They are also soft in texture and so are more comfortable to eat for those with limited physical abilities or who wear dentures, which is positively correlated with the hindrance of food purchasing, preparation or consumption (Appleton 2016). Therefore, fortification using eggs has potential under this criterion.

Problems that complicate fortification of foods

In addition to personal eating complications and taste alterations, protein fortification can further affect the flavor, taste and texture of foods, though protein type will affect products differently (Norton et al. 2020; Tsikritzi et al. 2014; Wendin et al. 2017; Withers et al. 2014). For example, this review indicates that dairy is a commonly consumed food group by the older adults and has been previously considered a good fit for fortification by older adults themselves (van der Zanden et al. 2014). Dairy products are suitable carriers for fortification as, in addition to the regular consumption, they already comprise of readily digestible milk proteins, casein and whey. Indeed milk proteins, or more specifically whey proteins, can by fortified into dairy products, from standard commercial milks on the one hand (e.g., Arla "Best of Both") (Arla Foods 2021) through to oral nutritional supplements (ONS) that are usually accessed via prescription. There are positives and negatives to adding whey protein, which must be considered to ensure products are simultaneously nutritionally beneficial and likeable, which influences the compliance in consuming such foods. From a nutritional perspective, whey protein has a higher leucine content, leading to greater muscle protein synthesis than other proteins (Wall, Cermak, and van Loon 2014; Pennings et al. 2011). However, whey protein supplementation can cause the resultant product to be drier, harder, and increase "off" flavors (Norton et al. 2020). It can also cause sensory impediments such as astringency or mouth drying attributes (Bull et al. 2017; Carter, Foegeding, and Drake 2020; Norton, Lignou, and Methven 2021; Pires et al. 2020) which limits consumption and product enjoyment (Norton, Lignou, and Methven 2021). Therefore, fortified products must be optimized and undergo rigorous sensory testing with the end-user, to develop foods that are appetizing and easy to consume. To this end, there are alternatives to whey, including soy and pea protein, which may be more appealing to consumers wanting to consume vegetarian and vegan foods. Whilst more research is needed, a recent review of clinical trials suggest that provided a high amount of total protein is consumed, the muscle response to animal and plant based proteins might not differ substantially (Putra et al. 2021), therefore fortified products should ensure to cater for consumers with varying dietary preferences.

Discussion

In recognition that successful protein-fortified products must be compatible with older adults' diets and food preferences, this review has explored older adults' normal sources of protein and energy intake, their food purchasing behaviors, and commonly consumed foods in their diet. The findings are corroborative with previous protein intake reviews (Lonnie et al. 2018), indicating that older adults in the UK continue consume too few calories and too little protein in their diets. The review highlights the large contribution of meat, cereals, and milk products to protein intake in the UK and reveals the nuances between adults aged 65–74 and 75+ which had been unavailable in earlier NDNS datasets. This review has also elaborated on these findings by exploring the protein contribution of specific foods under each food category for an enhanced understanding of protein sources. The Food and You Survey, and Kantar data added knowledge on purchasing behaviors, such as gender differences in responsibility for shopping and how different food groups contributed to overall shopping expenditure. Finally, the analysis of NDNS data revealed the foods commonly consumed by older adults and the amount at which they were consumed. These findings, combined with existing literature additionally suggest several foods that may be most suitable for protein-fortification purposes.

There are some limitations in this review which must be acknowledged. For example, this review included data from national datasets which relied on self-reported food intake estimates, food expenditure, and shopping behavior. This can lead to two types of self-reporting biases; social desirability bias and recall bias, one where individuals may want to present themselves differently, perhaps as healthier than in reality, and the other where it is simply difficult to evaluate ones behaviors retrospectively (Althubaiti 2016). The consequence is that this review may make conclusions based on data that is subject to these biases and it is therefore difficult to determine confidence in its accuracy. However, the benefit of these national datasets using self-report is generally the potential to reach a much wider sample size, thus this contributes to the confidence that the patterns seen are widespread and common amongst a large population. In addition, we have supplemented this data with Kantar shopping expenditure data which is an objective measure. Another point, which has been noted throughout this review, is that successful fortification of foods relies not only on objectively pairing seemingly appropriate ingredients together based on the data, but by hearing the first-hand opinion of the target

audiences and conducting practical research, perhaps in a real-life home environment, to determine which ideas "sink or float." Until complementary research such as this is included to form the bigger picture, recommendations may be subject to change and improvements.

The foods identified in this review (such as dairy products and chilled convenience foods like soup) appear to be particularly suitable due to the large role they play in older adults' diets. This is because if protein-fortified products are to be beneficial for older adult health, enough of the product must be consumed (Norton, Lignou, and Methven 2021). As the review has highlighted, sufficient consumption levels are best achieved by targeting several key factors; the solutions must be adaptable to older adult's eating habits, they should be incorporated into the foods present in their current diet and purchasing habits, and the recipes should account for consumption complications in older age.

Considering the benefits of "pulse-feeding" through consumption of 25 g of protein three times a day (Arnal et al. 1999; Morris et al. 2020), and the fact that some meals during the day are naturally lower in protein than others (for example breakfast and lunch), it is particularly relevant to be able to fortify a range of meals with a range of different protein ingredients to make 25 g three times a day an achievable goal.

Ultimately, food product specifications and consumer needs are best met when they are co-created with the consumer (Raffaele 2013). Yet, prior to that, an exploration of relevant data on the eating behaviors of older adults such as this can provide a useful starting point for new product development routes.

Declaration of interest statement

The authors report there are no competing interests to declare.

Data access statement

No new data were generated or analysed during this study.

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