# Plant Food Sources of Protein for Optimum Health, Muscle Status and Sustainability - the Evidence and the Practice

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## Summary

- The consumption of plant food sources of protein, including soya, offers broad health and environmental benefits. This has been credited in part, to the more rounded macronutrient composition of plant foods such as grains, legumes, nuts and seeds and products thereof - for instance, their lower saturated and higher unsaturated fatty acid profiles and higher fibre content.
- Plant foods can provide all the essential amino acids and a varied plant-based diet can meet all nutritional requirements, including minerals such as calcium and iron.
- Protein requirements for pregnancy, lactation, in older age and for athletes are higher than for the general population.
- To optimise muscle protein synthesis, protein intake should be balanced across the day, taking into consideration:
  - Muscle protein synthesis plateaus at intakes of 0.25 - 0.30g/kg bodyweight of high quality protein in healthy young adults per meal. This equates to about 20g protein (~10g essential amino acids) for an 80kg individual, with any surplus protein being oxidised and/or excreted.
  - Consuming a variety and larger portions of plant food sources of protein offsets their generally lower protein and essential amino acid content.
- A key barrier to including more plant foods in the diet is a lack of knowledge of how to prepare and incorporate them into usual day-to-day patterns.


In the latest release of dietary guidelines from Public Health England, plant food sources of protein were listed ahead of animal food sources of protein for the first time. The protein food group is now called **'beans, pulses, fish, eggs, meat and other proteins'**[1]. This change in emphasis follows an increasing recognition of the health benefits of plant-based diets, and plant foods being more environmentally sustainable and thus preferable dietary choices to mitigate climate change[2].

## Health and Sustainability Benefits of Plant Foods

Direct comparison of plant to animal food sources of protein in terms of ascribing health effects is problematic because they differ so significantly in terms of nutritional content[3]. In particular, plant food sources of protein have a more rounded macronutrient profile than animal food sources of protein – generally including some carbohydrates, fibre and unsaturated fats, while saturated fat content is often low[4].

Pointedly, it is the more balanced macronutrient profile that is largely attributed with the health benefits of including more plants in the diet. For example, the higher fibre content of plant-based diets is often accompanied by lower fat intakes, reducing the energy density of the diet, which in turn reduces energy intake[5,6]. This has flow-on effects to other weight-related co-morbidities. Indeed, the World Cancer Research Fund also recommends the consumption of foods 'mostly of plant origin' and more specifically inclusion of relatively unprocessed grains and/or legumes at every meal, because of this[7].

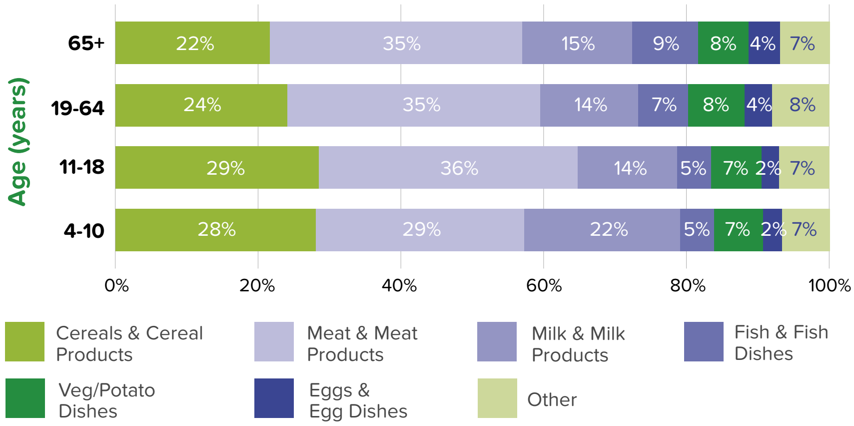
Another pertinent example would be the impact on cardiovascular health, where research has shown for a long time that vegetarian and vegan populations tend to have lower blood pressure, cholesterol levels and rates of cardiovascular disease than their omnivorous counterparts[8]. This may in part be attributed to the cardio-protective effect of lower levels of saturated fats and higher levels of polyunsaturated fats in plant foods, as well the presence of other cardio-protective components[8,9]. For instance, the cholesterol-lowering effect of soya food is partly due to the 'displacement' of higher saturated fat foods, in addition to the intrinsic cholesterol-lowering properties of soya protein itself[10].

Added to the health benefits is the fact that animal foods generally have higher greenhouse gas (GHG) emissions than plant foods per unit weight – this is because they are resource-intensive (energy, land and water) and are a primary source of the potent GHGs – methane and nitrous oxide[2]. As such, given food consumption is responsible for one-fifth of all GHG emissions in the UK, modelling work has shown that reducing the amount of animal foods in the diet will make a critical contribution to climate change mitigation[11].

## Protein Consumption

Mean protein intakes in the UK are well above the Reference Nutrient Intake (7%-10% energy) for all groups, providing 14.9% - 15.2% energy for children and 16.4% - 17.1% for adults, equating to a mean protein intake per day of 54.1g - 74.4g[12]. The majority of this comes from animal foods, with meat, dairy and fish contributing over half (55% - 60%).

**Figure 1. Main food contributors to dietary protein intakes[12]**




## Plant Protein Content, Quality and Mineral Bioavailability

The main plant foods that contain protein are legumes (beans, lentils and peas), nuts, seeds, grains and products thereof. Of these, legumes generally contain the most protein on a dry weight basis ranging from 22% - 24% in red kidney beans and red split lentils respectively, to as much as 36% in soya beans[4].

Seeds also contain significant amounts of protein, albeit they are consumed in smaller portions than legumes. Protein content ranges from 18% in sesame seeds to up to 25% and 30% in hempseeds and linseeds respectively[4,13,14]. The inclusion of seeds into the diet can provide appreciable amounts of protein; for example, 1 tablespoon (15g) of pumpkin seeds provides over 3g protein.

The protein content of grains is lower than that in legumes and seeds, ranging from 6% in white rice, 11% in oats to above 13% in wheat, quinoa, amaranth, buckwheat on a dry weight basis (the latter three of which are technically classed as 'pseudo-grains')[15]. However, due to grains being consumed in larger portions and with greater frequency, they are the main provider of plant protein in UK diets (Figure 1).

The protein content of nuts generally ranges from 9% in macadamia nuts to 20% in pistachios and 21% in almonds meaning that a handful (30g) provides approximately between 3g - 6g protein.

On a weight-by-weight basis, plant foods are generally lower in protein than animal foods. This is due to a more rounded macronutrient profile, providing substantial amounts of other macronutrients such as fats, most of which are unsaturated, carbohydrates and fibre[4]. Moreover, plant foods are also relatively lower in essential amino acids (EAAs) than animal foods, meaning that they get lower scores of protein quality, such as the Protein Digestibility-Corrected Amino Acid Score (PDCAAS) or the more recently proposed, but not yet used, Digestible Indispensable Amino Acid Score (DIAAS)[17-20]. Soya is a key exception, having a PDCAAS score of 0.9 out of 1, which is on a par with meat[10]. Crucially however, as all plant food sources of protein contain all EAAs, it has been repeatedly argued that a varied diet that meets energy needs, even one based entirely on plants, can meet all EAA requirements[21-24].

The presence of anti-nutrients in plant food sources of protein such as trypsin inhibitors, tannins and phytic acid can contribute to lower protein quality and furthermore reduce mineral absorption such as calcium, iron and zinc in single meal studies[25]. However, importantly, the way that food is prepared such as milling, soaking, sprouting, fermenting and cooking can affect the level and impact of anti-nutritional factors[26,27]. What is more, the presence of vitamin C, widely available in plant foods, can offset some of the effect of phytic acid when consumed at the same time[28,29].

As such, single food measures of protein quality and anti-nutrient content do not reflect the scale of impact across the total diet and there are no apparent functional consequences of reduced mineral bioavailability in plant foods in Western diets.

Looking at iron as a case in point, the body regulates levels by controlling uptake and can absorb more when it is needed[27,28,30]. Indeed, there appears to be no greater incidence of iron deficiency among vegetarians, suggesting adaption to potentially lower intakes[28,31]. Similarly, plenty of plant foods naturally have good calcium bioavailability despite the presence of anti-nutrients such as soya, almonds and tahini[32,33]. Fortified plant-based products such as in soya drink and calcium-set tofu also show very good calcium bioavailability[33].

## Protein Requirements

| Population Group | Protein Requirements (g/kg) |
|---|---|
| Young Adults[34,35] | 0.8 |
| Older Adults[36] | 1.0 - 1.2 |
| Athletes[37] | 1.0 - 2.0 |

## Young Adults

General population dietary requirements are set on the basis of providing sufficient amino acids to support normal tissue growth, maintenance and muscle protein synthesis (MPS)[34]. Healthy young adults consuming a mixed diet require 0.8g/kg bodyweight/day, while growth stages, pregnancy, lactation, athletes and older adults require proportionately more.

## Athletes

Higher protein intakes are needed in this group to support the reparation of exercise-induced muscle damage, maintain muscle mass and offset the oxidation of protein during exercise (typically 1% - 5% of energy cost)[37-39]. Muscle protein accretion is also an often sought-after goal of athletes and extra substrate is needed to support this. Though it should be noted that muscle strength is not synonymous with MPS, but rather MPS in conjunction with resistance training.

The International Society of Sports Nutrition recommends that exercising individuals (participating in more than two hours of exercise at least five times a week) require between 1.0g - 2.0g protein/kg bodyweight/day depending on the type and intensity of exercise, the quality of protein ingested and the energy and carbohydrate intake[37]. With regards to the latter, it should be noted that MPS is optimised when the overall diet provides sufficient energy to offset exercise costs, particularly in the body's preferred fuel of carbohydrates[37,39].

- Endurance exercise = 1.0g - 1.6g protein/kg bodyweight/day
- Strength/power exercise = 1.6g - 2.0g protein/kg bodyweight/day
- Intermittent exercise = 1.4g - 1.7g protein/kg bodyweight/day

## Older Adults

Muscle mass naturally declines with age and adults can lose 30 - 50% of muscle mass between 40 - 80 years of age[36,40]. Ensuring adequate protein intake and exercise is critical to prevent excessive losses in muscle mass and thus offset the morbidities associated with sarcopenia, such as an increased risk of falls, hip fractures, reduced mobility, loss of independence and increased mortality[41-43].

Protein requirements are higher in older adults to counter the "anabolic resistance" that occurs with advancing age – that is, the reduced responsiveness of MPS to amino acid ingestion[44,45]. The PROT-AGE recommendations advise that older adults (≥ 65 years of age) should consume 1.0g - 1.2g/kg bodyweight/day[36]. The latest National Diet and Nutrition Survey data indicates an average daily protein intake of 64.3g by women to 74.4g by men in this age group, equating to approximately 1.0g/kg bodyweight/day[12].

# Optimising Muscle Protein Synthesis

Skeletal muscle plays an important role in overall health including weight management, heart health and bone health[45,46]. Moreover, protein ingestion can stimulate MPS both at rest and after exercise, thus optimising MPS is relevant for all population groups[45,46]. However, doing so is more complex than simply ensuring total protein requirements are met – attention should be paid to the leucine content, amount of the protein offered and the pattern and timing of consumption as well as physical activity.

## Protein Amount and Leucine Content

Experimental data suggests that MPS plateaus at around 0.25g - 0.30g/kg bodyweight of high quality protein per meal in healthy young adults at rest[45]. This equates to about 20g protein (~10g EAAs) for an 80kg individual, with any surplus protein being oxidised and/or excreted[46-50]. However, the quantity of protein and leucine intake at which MPS plateaus will vary depending on age, type and intensity of physical activity and timing of consumption. The limited data for older adults suggests intakes of 20g - 30g protein while, more recent evidence suggests that for young athletes participating in whole-body resistance training, MPS plateau is reached at higher protein intakes of 40g[45,51]. Unfortunately, there is sparse work looking at a corresponding optimal dose for plant protein, in older adults or for exercise recovery[45,48]. However, we would expect that proportionately more plant protein or a combination of plant and animal proteins would be needed to provide optimal amounts of EAAs[47].

A specific trio of EAAs known as Branched Chain Amino Acids (BCAAs) – leucine, isoleucine and valine, constitute approximately a third of skeletal muscle protein. It has been argued that leucine is independently responsible for the postprandial stimulation of MPS – a concept known as '*the leucine trigger hypothesis*' or '*the leucine threshold*'[37,39,45,47,52]. Consequently, the ingestion of meals and snacks rich in leucine are believed to be the most effective at triggering MPS[45,47,52].

In order to ensure adequate EAAs, including leucine, are obtained from plant foods, the following can be undertaken[47]:

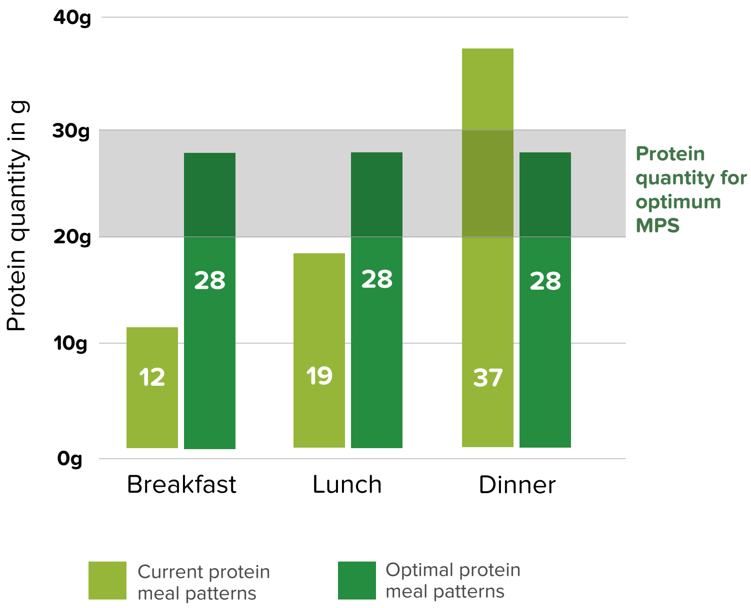
- Ensuring that greater portion sizes of plant food sources of protein are consumed.
- Combining plant and animal food sources of protein at meal times.
- Supplementing plant-based meals with an additional ~3g of free leucine for athletes and older adults with poor appetites.

## Pattern and Timing

Given the evidence for a plateau in MPS following protein consumption, it is desirable to encourage regular, balanced 20g - 30g protein portions throughout the day (Figure 2). This also applies to athletes because although a 1-hour "anabolic window of opportunity" post-exercise is often referred to, evidence suggests that this effect may stretch for as much as 24 hours[45,47,49,51,52]. For strength training athletes, evidence indicates protein consumption prior to sleep could also be beneficial[37].

**Figure 2. Comparing current protein intake patterns of adults aged 65 years and over with the ideal protein pattern for optimum MPS**

(Adapted from reference 49)




## Driving Change

Perceptually, there is a high awareness of the potential health benefits of including more plant foods in the diet[53]. Possible attitudinal barriers to consuming more plant proteins include a perceived lack of knowledge about how to prepare and cook them; a refusal to change eating habits, as well as meat being highly appreciated and perceived as being tasty, as well as easy to buy and prepare[53,54].

Thus, health professionals need to be mindful of promoting easy, tasty and cost-effective ways that more plant sources of protein can be incorporated.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