Plant-based proteins in sports nutrition

This information sheet focuses on sports nutrition for athletes and physically active individuals. It explains the role of protein intake and physical activity in supporting muscle health, with particular attention to the potential of plant-based proteins to maintain and build muscle mass.

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Key messages

- Regular physical activity or exercise combined with adequate dietary protein intake helps to maintain or grow muscle mass and strength.
- Sports nutrition is nutrition that helps athletes, physically active individuals, and those who want to build or maintain muscle mass to perform well, recover faster, and support muscle growth.
- Plant-based proteins are generally a more sustainable option compared to animal-based proteins.
- Although plant-based proteins generally have a lower protein quality compared to animal-based proteins, they can effectively support muscle health and performance.
- Nutritional strategies to maximise the anabolic properties of plant-based proteins include increasing protein intake, combining different protein sources, and/or fortification with specific amino acids.

Plant-based proteins are gaining popularity due to their lower environmental impact compared to animal-based proteins. They require less water, land, and energy to produce, mainly because converting plant protein into animal protein is inefficient[1-3]. For example, producing one kilogram of animal protein requires about six kilograms of plant-based protein, of which around three kilograms are suitable for direct human consumption[4, 5].

Consumer interest in sustainable food choices is also driving the increased use of plant-based proteins in sports nutrition. This field focuses on supporting physical performance, recovery, and the maintenance or growth of muscle mass in athletes and physically active individuals. It is therefore relevant to look at the role of plant-based proteins within the field of sports nutrition.

Protein intake and physical activity to support muscle health

Muscle maintenance

Maintaining muscle mass is crucial for overall health and well-being. Healthy muscles help reduce frailty and improve movement, strength and the ability to stay active, factors that all play a significant role in daily life.

Skeletal muscle tissue (referred to as muscle tissue) contains muscle proteins that are constantly being built (synthesised) and broken down[6]. This process, known as muscle protein turnover, occurs at a rate of around 1 - 2 % per day (0.04 – 0.14 %/h^{-1}). This means that over a period of 2 to 3 months the muscle tissue is completely renewed. This ongoing process allows muscle tissue to stay healthy and adapt to various physical activities, such as running and climbing stairs.

Muscle loss

Muscle protein turnover can also result in muscle loss. Muscle loss (deconditioning) occurs when the rate of muscle breakdown exceeds the rate of muscle regeneration. Conditions such as immobilisation, ageing, cancer-related cachexia, COPD, type 2 diabetes, and cardiovascular diseases can contribute to the deterioration of muscle mass. This loss of muscle tissue can impact strength and increase the risk of physical complications such as frailty, weakness, and reduced mobility. Therefore, it is essential to stimulate the muscles daily, particularly after (disease-related) muscle loss, to preserve and rebuild muscle mass.

Muscle recovery and growth

Rebuilding muscle (reconditioning) is particularly important after physical activity, as it helps muscles recover and become stronger. Intense exercise causes small amounts of muscle damage, which stimulates the body to repair the tissue. This repair process, known as muscle protein synthesis involves building new proteins to replace the damaged ones[7, 8].

In addition to repair, muscle growth occurs because of this process. The muscles adapt to the type of physical activity performed. For example, endurance exercise improves the ability of muscles to use oxygen, while resistance training increases muscle size and strength.

Studying muscle protein synthesis

To understand how dietary protein supports muscle growth, researchers use advanced techniques like stable isotope tracer infusion[9]. In these studies, amino acids are labelled and tracked in the body to measure how much ends up in muscle tissue. This can be done via direct infusion or by using intrinsically labelled foods, such as milk from cows fed with labelled amino acids.

Most of our understanding of protein metabolism in humans comes from a combination of clinical studies (for example in older adults) and intervention studies in healthy individuals. These models are essential for investigating how different protein sources, such as plant-based proteins, are digested, absorbed, and used by the body to support muscle protein synthesis.

Synergy between protein intake and physical activity

To maintain muscle health and function, the body requires anabolic stimuli. These stimuli trigger a natural process aimed at growing and repairing tissues. In muscle tissue, anabolic stimuli promote the production of muscle proteins.

To stimulate muscle protein synthesis, the two most important anabolic stimuli are proper nutrition and physical activity[6].

Nutrition, particularly protein intake, provides the essential building blocks for muscle protein synthesis. After consumption, proteins are broken down into amino acids via the (microbial) proteolytic pathways in the gut and then absorbed into the bloodstream (**Figure 1**). These amino acids are transported via the blood to various tissues, including muscle, where they are used to build new muscle proteins. Additionally, some amino acids such as leucine act as signalling molecules that directly trigger an anabolic response, enhancing muscle protein synthesis. In this way, the consumed protein from food is ultimately used to synthesise muscle proteins[10].

The other key anabolic stimulus for muscle protein synthesis is physical activity. When combined with adequate nutrition, physical activity creates a synergistic effect. After exercise, protein intake stimulates muscle protein synthesis more strongly, and this effect lasts longer[11]. Exercise enhances the muscle's ability to utilise amino acids from protein intake as building blocks for new muscle protein. This is why athletes and physically active individuals benefit from consuming protein during recovery: it aids in building and repairing muscle tissue. These synergistic effects of protein intake and physical activity are also relevant in older adults and clinical populations, where they contribute significantly to the maintenance of muscle mass and the promotion of recovery.

Factors influencing post-prandial protein synthesis

Following ingestion of protein, various dietary and physiological factors can affect muscle protein synthesis. These include the type and amount of protein, the composition of the meal, the timing of intake, how the food is prepared, and even body position while eating. Individual differences also play a role. For example, the body's ability to process protein can decline with age due to reduced digestive efficiency, changes in enzyme activity, and a lower sensitivity of muscle tissue to dietary protein.

Protein source and quality

Protein sources can broadly be divided into animal-based and plant-based foods. These sources differ from each other in several ways that influence their quality and effectiveness in supporting muscle recovery and growth.

The protein quality of food depends on a number of criteria[12]:

1. The amount of protein in the food.
2. The extent to which the protein is digested in the gut and the absorption of the released amino acids by the body.
3. The composition of essential amino acids in the protein.

Protein content

Animal-based foods such as meat, eggs, and dairy products typically have a high digestible protein content. Many plant-based foods, such as legumes, seeds, and certain grains, are also good sources of protein. However, compared to animal products, plant-based whole foods generally contain lower amounts of protein per 100 grams.

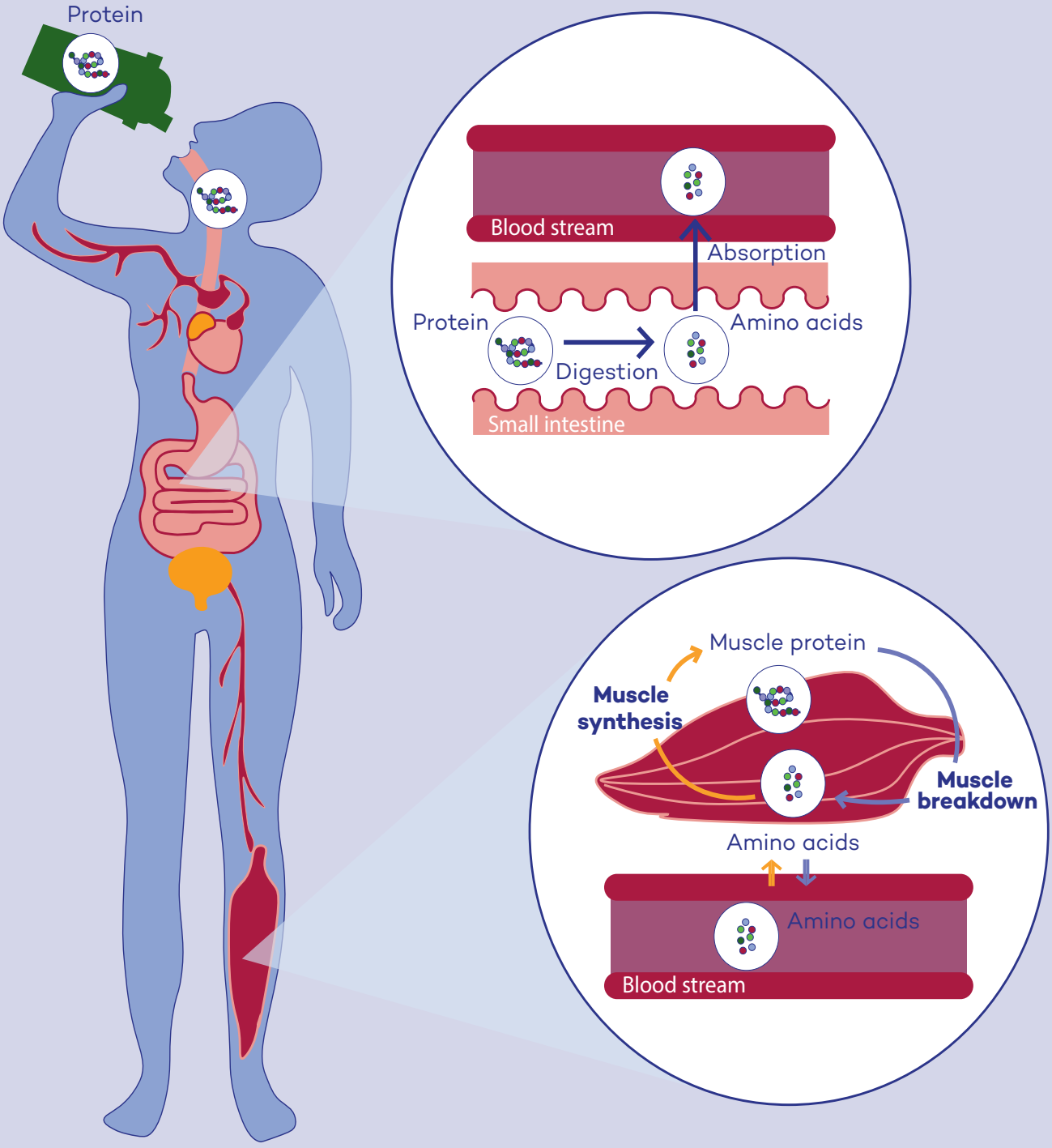

Figure 1. Schematic overview of the process from protein digestion to muscle protein turnover. Dietary proteins are broken down into amino acids in the small intestine, absorbed into the bloodstream, and delivered to the skeletal muscle tissue, where they contribute to both synthesis and breakdown of muscle proteins.

To achieve the same protein intake from plant-based foods, individuals may need to consume larger portions or include a variety of protein-rich plant foods in their diet. In sports nutrition, plant-based protein concentrates, isolates and hydrolysates are often used for convenience and to provide higher protein intake without excessive food volume.

Digestion and absorption

Plant-based and animal-based protein sources differ in how efficiently the body digests and absorbs them. In general, animal-based protein sources are more efficiently digested and absorbed than plant-based sources, delivering amino acids into the bloodstream more quickly. This is due to the structure of plant cells and the presence of antinutritional compounds, which can limit protein availability. However, food preparation methods, such as heating and cooking, as well as processing techniques like protein extraction, can help break down plant cell walls and improve protein digestibility. This is especially relevant in sports nutrition such as protein isolates and hydrolysates.

Essential amino acids

Amino acid composition plays an important role in protein quality and its ability to stimulate muscle recovery. Proteins consist of essential amino acids, which must be obtained through diet, and non-essential amino acids, which the body can produce itself. The balance and quantity of essential amino acids largely influence protein quality. Animal-based proteins, like meat, eggs, and dairy, typically provide all essential amino acids in the right amounts, making them high-quality sources. Plant-based proteins, however, may lack one or more essential amino acids, potentially reducing their quality. Combining different plant protein sources can help create a complete amino acid profile and improve protein quality.

Protein concentrates, isolates, & hydrolysates

Concentrates

Contain 60 - 80 % protein, with the remaining content consisting of fats and carbohydrates. They are commonly used in protein supplements, meal replacements, and certain functional foods.

Isolates

Processed to contain 90 % or more protein, with minimal fats and carbohydrates. They are typically found in high-protein supplements, protein shakes, and sports nutrition products.

Hydrolysates

Proteins that have been partially broken down into smaller peptides through hydrolysis, improving digestibility and absorption. Hydrolysates are often included in recovery supplements and formulations designed for rapid muscle repair.

Protein hydrolysates

Protein hydrolysates are proteins that have been partially broken down into smaller peptides and free amino acids. While cooking or processing can help release proteins from the food matrix, hydrolysis goes a step further by 'pre-digesting' the protein itself using enzymes or acids. This may result in making proteins easier to absorb, leading to a faster increase in available amino acids in the blood circulation. This could be beneficial for muscle recovery and growth after exercise[13].

While hydrolysates from dairy proteins like whey have been widely studied, more research is needed on plant-based protein hydrolysates. Exploring how processing techniques can enhance the nutrient quality of plant proteins is a promising area for future research[13].

Leucine

Studies on the effects of protein intake on the anabolic response are mostly performed with milk proteins, whey and casein, used as protein source[6]. From this research it is known that whey protein has a higher content of the essential amino acid leucine compared to casein protein. Leucine is an essential amino acid that plays a key role as a signalling molecule in stimulating the anabolic response[14]. Whey protein therefore has a higher anabolic response due to its higher digestibility and higher leucine content compared to casein[6]. Thus, protein sources with a higher leucine content have a higher stimulation of muscle protein synthesis.

Among plant-based proteins leucine content varies, ranging from higher values such as corn (13.5 % of total protein)[15], potato (8.3 %)[15], and fava bean (5.08 – 7.21 %)[16], to lower levels found in hemp (5.1 %)[15] and lupin (5.2 %)[15]. On average, plant-based proteins contain approximately 7.1 % leucine, compared to 8.8 % in animal-based proteins[15].

Although some plant proteins are lower in leucine or lack one or more essential amino acids, they can be complementary. For example, combining grains and legumes (such as rice and beans) can provide a complete amino acid profile, supporting a nutritionally balanced plant-based diet.

More information on plant-based protein and protein quality is provided in the ***Factsheet Plant-based proteins***.

Amount and timing of protein intake

The amount and timing of protein intake influences the digestion, absorption and thereby the availability of amino acids for muscle protein synthesis. After exercise the elevated sensitivity to amino acids can last for up to 24 hours[17]. This means that the body is in an optimal state for muscle recovery and growth long after exercise.

Research shows that consuming 20 – 25 grams of protein after exercise is sufficient to maximise muscle repair and growth for 4 – 6 hours in healthy, young adults. Consuming more protein during this period does not seem to result in a greater rate of muscle protein synthesis. That is why the current advice is to spread protein intake evenly throughout the day, with each main meal containing 20 – 25 grams of protein[9, 18].

Recent studies, however, suggest that consuming a larger amount of protein in a single meal can increase the muscle-building response over a longer period of time[9]. When more than 20 grams of protein was consumed at once, the body effectively utilised the additional protein for building muscle protein rather than burning the excess for energy. This demonstrates the body's ability to sustain muscle-building processes over a longer time, even with higher protein intakes in a single meal. However, this is an area of active research, and more studies are needed to fully understand the optimal timing and amount of protein intake for optimal muscle protein synthesis.

Strategies to improve the anabolic properties of plant-based proteins

While plant-based proteins may have a different protein quality compared to animal-based proteins, there are opportunities to enhance their anabolic response through various nutritional strategies[10] (**Figure 2**):

1. Consuming a larger amount of plant-based protein to compensate for the lesser quality (i.e. lesser content of essential amino acids).
2. Using blends of plant-based proteins to create a more balanced amino acid profile.
3. Fortifying plant-based protein with specific amino acid(s) that are too low.

1. Increasing protein intake

Lower protein quality can be compensated by consuming a higher quantity of plant-based protein[6, 10]. In general, plant-based proteins can contain lower amounts of specific essential amino acids compared to animal-based proteins[15]. By increasing the total plant-based protein intake, there are enough essential amino acids available to effectively stimulate muscle protein synthesis. The amino acid profile varies however for each protein source. Some plant-based proteins such as derived from pea, corn and potato contain a comparable amount of total essential amino acid content to animal-based proteins[15].

Studies have shown that a higher quantity of plant-based protein intake can stimulate muscle protein synthesis to the same extent as a similar intake of animal-based protein. In a clinical study in healthy young males, muscle protein synthesis stimulation was found to be similar following intake of 30 grams of pea, potato, corn or wheat-derived protein compared to an equivalent amount of milk-derived protein[19-22].

These findings highlight the potential of plant-based protein isolates, commonly used in sports nutrition, to support muscle repair and growth[19-22]. While larger amounts of plant-based protein can help meet protein needs, this may not always be feasible when relying on protein intake from whole foods. In sports nutrition, protein is often provided in the form of isolates and hydrolysates. These concentrated forms of protein are more easily digested and provide a higher intake of (essential) amino acids per gram compared to whole plant-based foods. High protein products therefore provide a feasible way for active individuals to effectively support muscle recovery and performance with plant-based protein.

2. Protein blends

Combining different plant-based protein sources can create a more balanced amino acid profile[10]. Key essential amino acids for muscle protein synthesis such as leucine, lysine, and/or methionine are often present in lower amounts in plant-based proteins[15]. This varies between different protein sources. For example, pulses are generally rich in leucine[23]. By combining complementary protein sources, such as fava beans that are rich in leucine with brown rice, which is rich in methionine, the overall amino acid profile can become more complete. This strategy enhances the anabolic response of plant-based proteins, making them more effective in stimulating muscle protein synthesis[10].

3. Fortification with amino acids

Another way to enhance the quality of plant-based proteins is by adding specific essential amino acids[10]. Since some plant-based proteins contain lower amounts of leucine, lysine and/or methionine, and fortifying them with these amino acids can help stimulate muscle protein synthesis. However, more human intervention studies on the efficacy of this approach for improving anabolic properties are needed.

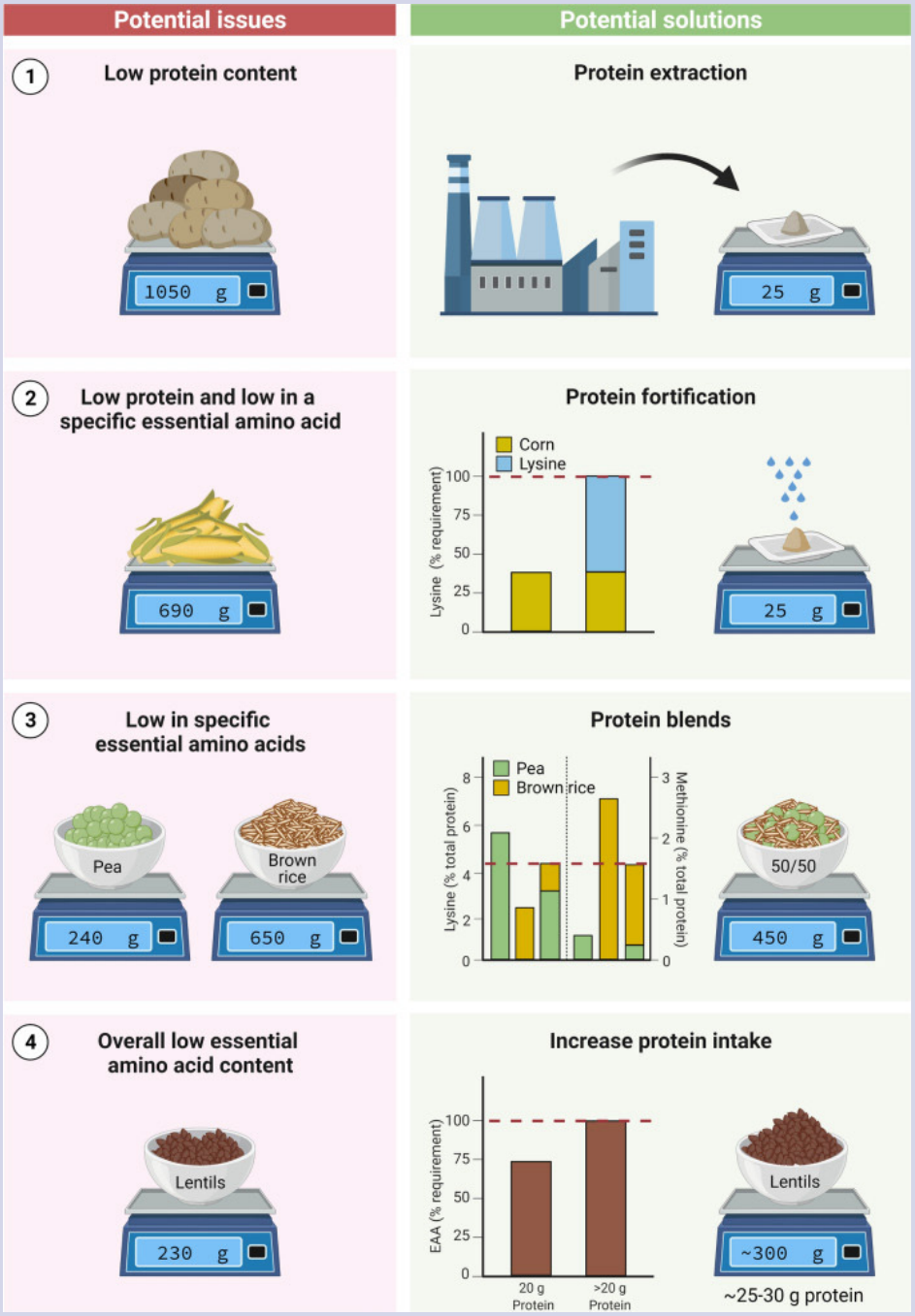

Figure 2. Overview of potential issues and solutions to optimise the anabolic response following plant-based protein consumption. (1) For plant-based foods with a high protein quality, but low protein content (e.g. potato), extraction of high-quality protein isolates forms an effective method to allow ingestion of a desired amount of protein. (2) For plant-based food sources with deficiencies in specific amino acids (e.g. corn: low in lysine), a protein isolate or concentrate can be fortified with the deficient free amino acid(s) to improve the amino acid content profile. (3) Plant-based food sources with deficiencies in specific essential amino acids can be combined to improve the overall amino acid profile of the protein blend. For example, peas are low in methionine but high in lysine; in contrast, brown rice is high in methionine but low in lysine. A blend combining pea and brown rice would meet overall amino acid requirements. (4) When plant-based food sources (or protein isolates) are deficient in one or more amino acids (e.g. lentils, wheat), this may be compensated for by simply ingesting a greater amount of the plant-based protein source. Illustrations: the scale balance represents the amount of food to be consumed to provide 20 g protein, unless otherwise indicated. Weight for brown rice and lentils represent cooked amounts. Dashed horizontal line in graphs represents the amino acid requirements for adults (WHO/FAO/UNU Expert Consultation 2007[24]).

Source: Pinckaers, P.J., Trommelen, J., Snijders, T., & van Loon, L.J. (2021)[10].

General knowledge gaps

While plant-based proteins are increasingly recognised for their role in muscle repair and growth, more research is needed to directly compare their anabolic properties to animal-based proteins. Human intervention studies are essential to explore how efficiently different plant-based proteins can stimulate muscle protein synthesis.

Current studies mainly focus on protein isolates and individual amino acids, which can easily enter the blood circulation and be incorporated into the muscle tissue. However, intake of protein from whole foods involves additional influencing factors, such as meal composition, antinutritional compounds and food processing that may affect protein digestion and absorption. Clinical research is needed to better understand these dynamics and how they influence the anabolic properties of plant-based proteins.

Understanding the relationship between protein quality and quantity will help optimise nutritional strategies to improve the anabolic properties of plant-based proteins.

Conclusions

Plant-based proteins are potentially an attractive, sustainable and effective source for sports nutrition. With sufficient intake, they can provide the necessary protein to effectively support muscle growth and recovery. Their anabolic properties can be optimised through three key strategies: increasing the total protein intake, combining different plant-based protein sources to create complementary amino acid profiles, and fortifying with specific amino acids when needed. Protein isolates and blends offer convenient ways to achieve these goals in sports nutrition. By applying these strategies, plant-based proteins can fully meet the needs of active individuals, supporting muscle health and function while contributing to a more sustainable food system.

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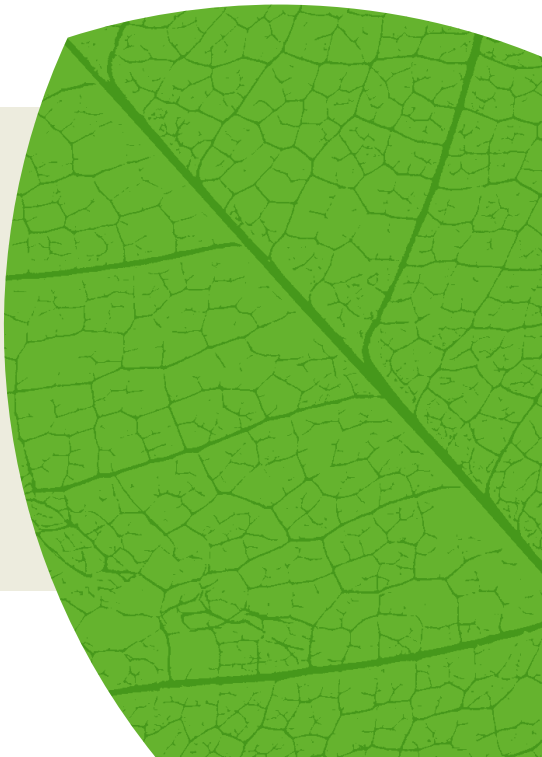

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