The anabolic properties of plant-derived proteins

IMPACT

The main aim of this dissertation was to investigate the anabolic properties of plant-derived proteins, and to evaluate how they compare with animal-derived proteins in their capacity to stimulate muscle protein synthesis. This thesis extends on previous work reporting on the inferior anabolic properties of soy protein isolate ingestion when compared with animal-derived protein in humans [1-3]. This dissertation evaluated the plasma amino acid profiles and muscle protein synthesis rates following ingestion of wheat, corn, pea, and potato derived protein in comparison to animal-derived milk protein in healthy, young men. The amino acid profiles following ingestion of 30 g of the selected plant-derived proteins showed lower plasma essential amino acid availability, when compared to the ingestion of the same amount of milk-derived protein, especially for leucine, lysine, and methionine. Despite a lower essential amino acid provision, muscle protein synthesis rates were strongly increased following ingestion of the selected plant-derived protein sources. Importantly, this muscle protein synthetic response did not differ when compared to the ingestion of the same amount of milk protein. Similar results were observed when potato protein isolate was ingested during recovery from exercise. Furthermore, we presented data on the anabolic properties of protein blends, in which different plant-derived proteins are combined, with or without animal-derived protein. We showed that despite lower plasma essential amino acid availability, the ingestion of the selected protein blends increased muscle protein synthesis rates, which was not different from the increase observed following ingestion of milk protein. Lastly, we reported that ingestion of a lysine enriched plant-based meat substitute, consisting of wheat- and chickpea-derived protein, increases muscle protein synthesis rates to an extent not different from chicken breast filet, when both provide 40 g protein. Collectively, we can conclude, that ingestion of an ample amount of plant-derived protein (i.e. ≥30 g) stimulates muscle protein synthesis to an extent not different from ingesting the same amount of animal-derived protein in healthy, young men.

Stimulating muscle protein synthesis is fundamental for maintaining muscle health and support the exercise induced muscle reconditioning response [4]. When protein is ingested in close proximity to physical activity or exercise, the increased muscle protein synthetic response is greater and prolonged, when compared with the stimulation observed following exercise or protein ingestion only [5-8]. However, it is important to note that not all proteins are the same and do not have the same potential to stimulate muscle protein synthesis rates [9, 10]. Therefore, this thesis provides valuable information outlining the anabolic properties of various plant-derived proteins, their protein blends, and a plant-based meat substitute. The impact of this dissertation, as well as the implications for translation into practice will be discussed below.

Scientific relevance

This thesis broadens our understanding of the anabolic properties of plant-derived proteins. We have made substantial contributions to the scientific field, to better understand the important factors impacting the anabolic response following protein ingestion. Early studies on protein quality identified three main factors that would determine protein quality, and the subsequent anabolic response: 1) essential amino acid composition, 2) leucine content,

and 3) protein digestion and amino acid absorption of the specific protein or protein source [10]. Given that on all these factors plant-derived proteins are subpar when compared to animal-derived proteins, plant-derived proteins have traditionally been considered to exhibit a lower capacity to increase muscle protein synthesis rates [11]. This assumption was primarily based on earlier studies evaluating the anabolic properties following ingestion of soy protein isolates [1-3, 12]. Several, of these studies showed that soy protein ingestion stimulates muscle protein synthesis to a lower extent when compared to the ingestion of dairy-derived proteins, both at rest and during post-exercise recovery [1-3]. There are, however, many different plant protein sources with each holding their own unique properties [9, 10]. This thesis expands our knowledge by investigating the anabolic properties of wheat, corn, pea, and potato protein, protein blends, and a plant-based meat substitute *in vivo* in humans. The current work clearly shows that low essential amino acids contents of plant-derived proteins do not necessarily compromise the acute anabolic response when a sufficient amount of protein (i.e. ≥30 g) is ingested in healthy, young men. Therefore, neither protein characteristics, such as essential amino acid composition, nor the availability of essential amino acids in the circulation following ingestion, predict the muscle protein synthetic response following protein ingestion. Hence, statements on the anabolic properties of a specific protein can only be sustained when muscle protein synthesis rates have been assessed directly following the ingestion of that specific protein *in vivo* in humans.

With the work presented in this thesis we have substantially contributed to the current knowledge on the anabolic properties of plant-derived proteins and have provided many new directions for future research. It would be of interest to evaluate the muscle protein synthetic response of the selected proteins in older individuals. Given that older individuals suffer from anabolic resistance [13], it is of substantial interest to determine how plant-derived proteins compare with animal-derived proteins in stimulating muscle protein synthesis rates in this population. Secondly, the amount of protein ingested is of key importance to consider when evaluating plant-derived protein sources, particularly in older adults [14, 15]. A key question that should be addressed is whether older individuals need to ingest more plant-derived protein to elicit a similar anabolic response when compared with the ingestion of animal-derived protein. Furthermore, as discussed in chapter 9, there is a need to transition towards assessing the anabolic response following ingestion of whole foods and more complex meals, to take into account all interactions between foods and nutrients on protein digestion, amino acid absorption, and anabolic signaling originating from all other foods components besides protein.

Target groups and societal relevance

There is a global transition towards the consumption of more plant-derived proteins, which will become more important to attain future global protein needs [16-18]. Plant-derived proteins are considered to be a more sustainable protein source as production requires less water, land, and energy resources when compared to animal-derivedproteins [19]. Given the essential role of dietary protein in the maintenance of muscle health, it is key to understand the anabolic properties of plant-derived proteins.

The work in this thesis shows that wheat, corn, pea, and potato-derived protein isolates may potentially be used as effective alternative protein sources when transitioning towards more plant-based protein consumption in young, healthy individuals. In addition, we show that plant-derived protein blends, and plant-based meat substitutes, may also be considered as alternative protein sources when transitioning towards the consumption of more plant-derived proteins. This provides direction and opportunities for industry for the development of plant-derived protein rich products and meat substitutes, i.e. the type and amount of protein to be used to ensure an anabolic response similar to the ingestion of an equivalent amount of animal-derived products. We identified potato protein concentrate as an effective protein source to stimulate muscle protein synthesis rates at rest and during recovery from exercise. This is of special interest, since potato protein concentrate is produced from the waste product of potato starch extraction. Hence, this not only shows that plant-derived proteins can support the transition towards a more plant-based diet, but also supports the current drive towards a more circular economy. The studies presented in this thesis have been performed within a public-private partnership, in which a collaboration is found between the Dutch government, university and industry to perform pre-competitive research. Beside the financial support to perform independent scientific research studies, such a public-private partnership facilitates the translation of scientific discoveries into practical applications and products. Private (industry) partners generally have expertise in commercialization and manufacturing, and distribution which is key to bridge the gap between research findings and real-world implementation. This dissertation capitalizes on this collaboration by direct utilization of the results and products used by the private partners in the development of their consumer products.

In the athletic community there is an increasing interest towards specific plant-derived sports nutrition products to support athletes adhering to a vegan and vegetarian diet [20]. More than 80% of the sports nutrition market sales originates from protein products, including powders, bars, and drinks [21]. Given the combined interest towards plant-derived proteins and the continuously growing sports nutrition market, the application of plant-derived proteins in sports nutrition will substantially increase in the years to come. This dissertation, provides key knowledge in this transition by showing that potato-derived protein can effectively support post-exercise muscle protein synthesis rates, and thereby support muscle recovery and remodeling following exercise. Like in athletes, skeletal muscle recovery and/or reconditioning is of equal importance in many clinical situations. The loss of skeletal muscle mass and function is a well-known phenomenon during hospitalization [22, 23]. Apart from the negative effects of physical inactivity, the loss of muscle mass observed during hospitalization may be attributed to an insufficient protein intake as a direct consequence of the lower energy intake [24, 25]. Within the field of clinical nutrition there is equal interest in the use of more sustainable protein sources [26]. In addition, there will be a need to accommodate future patient choices to consume a more plant-based diet. Therefore, it is key to evaluate the anabolic responses of plant-derived protein administration in frail and older individuals, to support optimal recovery with the use of both animal as well as plant-derived protein.

Translation into practice

In today's society, there is a lot of information available and accessible to every individual, and people share their thoughts and opinions with the world by just a few clicks on social media. On the flipside, there is a large spread of misinformation, hype, and very narrow perspectives without scientific rigor. Especially when considering food supplements and diets excluding certain foods or food groups, it is important to elucidate the potential health consequences in an evidence-based manner. Throughout the completion of this dissertation we have not only provided scientific reports and presentations at scientific conferences, but also actively incorporated results in lectures in nutrition and exercise physiology educational courses. Outside the academic world we have, and still see an increasing interest in the transition towards the consumption of more plant-derived proteins, in which we are being approached to translate our knowledge to be applied by e.g. sports nutrition companies and the military.

The transition towards incorporation of more plant-derived protein in our diet, seems inevitable from both a consumers' choice as well as a sustainability perspective, to meet future global protein demands. Therefore, it is important to not only address the potential shortcomings in the anabolic response of plant-derived proteins, but to also give directions towards potential solutions. The scientific field should not be blinded by the initial studies showing a lower anabolic response following soy *vs* dairy protein ingestion [2, 3], but should rather support this transition by providing directions towards potential solutions. In chapter 2 we have given potential solutions to the lower quality of plant-derived proteins, i.e. 1) providing protein isolates, 2) fortifying the protein source with its limiting amino acids, 3) providing protein blends, and 4) consuming more of a lower quality protein. Future research should focus on translating these findings even further, by investigating the clinical relevance of the potential differential anabolic response between plant- and animal-derived proteins. Lastly, the knowledge obtained from plant-derived protein isolates and meat substitutes, requires further translation towards whole meals in the everyday kitchen.

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