Article

Harnessing Mycoprotein: Unravelling Its Impact on Skeletal Muscle Health Through Systematic Review and Meta-Analysis

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ABSTRACT

Background: Mycoprotein, a fungal-derived protein from Fusarium venenatum, has gained attention for its potential benefits in muscle health, particularly as an alternative to traditional animal-based proteins.

Objectives: This systematic review and meta-analysis aimed to evaluate the effects of mycoprotein intake on skeletal muscle protein synthesis, plasma branched-chain amino acids (BCAAs), and post-prandial insulin response in healthy adults.

Methods: The study followed the PRISMA guidelines and was registered in PROSPERO (CRD42024602558). A comprehensive search of the PubMed, Scopus, EuropePMC and Cochrane Library databases was conducted to identify randomized controlled trials comparing mycoprotein interventions with non-mycoprotein control groups. Trials were included if they reported outcomes related to muscle protein synthesis, plasma amino acid levels, or post-prandial insulin response. Risk of bias was assessed using the Cochrane risk-of-bias tool. Meta-analyses were performed using an inverse-variance–weighted, random-effects model.

Results: Four randomized controlled trials involving 82 participants were included. Mycoprotein intake significantly increased muscle protein synthesis rates, with a fractional synthetic rate (FSR) increase of +0.01% per hour (95% CI: 0.01% to 0.02%, $P < 0.001$) compared to control groups. There was no significant difference in plasma BCAA levels between mycoprotein and control groups (mean difference: 2.83 µmol/L, 95% CI: -84.93 to 90.58, $P > 0.05$). However, post-prandial insulin response was significantly higher in the mycoprotein group at 30 minutes post-ingestion (mean difference: 8.15 mU/L, 95% CI: 5.70 to 10.59, $P < 0.001$).

Conclusions: Mycoprotein intake shows potential benefits for increasing muscle protein synthesis and enhancing post-prandial insulin response. However, the limited sample sizes and short durations of the included trials suggest the need for larger, long-term studies to confirm these findings.

Keywords: Branched-chain amino acid, Fungal protein, Muscle protein synthesis, Mycoprotein, Post-prandial insulin response, Skeletal muscle

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INTRODUCTION

Protein intake plays a fundamental role in maintaining overall health, particularly in the context of skeletal muscle function, metabolic regulation, and the prevention of chronic diseases. As the global population ages, there is increasing concern over the progressive loss of muscle mass and strength, commonly referred to as sarcopenia (Bhattacharya et al., 2022; Cruz-Jentoft & Sayer, 2019). Sarcopenia is recognized as a major public health problem, especially among older adults, contributing to frailty, reduced mobility, increased risk of falls, and decreased quality of life (Santilli et al., 2014). According to epidemiological data, approximately 10% of adults aged 60 and older are affected by sarcopenia globally, with prevalence rates as high as 50% among those over 80 years old (Cruz-Jentoft et al., 2019). Maintaining adequate muscle protein synthesis throughout life is therefore crucial in combating sarcopenia and promoting healthy aging (Rogeri et al., 2022a).

Nutrition, particularly protein intake, is a key modifiable factor influencing muscle health. The Recommended Dietary Allowance (RDA) for protein intake in healthy adults is 0.8 grams per kilogram of body weight per day, but research suggests that this amount may be insufficient for older adults to maintain muscle mass and function (Wolfe & Miller, 2008). Higher protein intakes, ranging from 1.2 to 1.6 grams per kilogram of body weight, have been associated with better muscle health outcomes, particularly when paired with resistance exercise (Moore et al., 2015). Traditionally, animal-based proteins such as whey, casein, and meat have been the focus of research due to their complete amino acid profiles and high digestibility. However, growing environmental concerns and the rising popularity of plant-based diets have spurred interest in alternative protein sources.

Mycoprotein, a fungal protein derived from Fusarium venenatum, has emerged as a potential alternative protein source. It is particularly attractive due to its high protein content, fibre, and favourable amino acid composition, including all nine essential amino acids (Finnigan et al., 2019). Furthermore, mycoprotein is low in fat and cholesterol-free, making it an appealing option for individuals seeking healthier protein sources. Given these properties, mycoprotein may not only help support muscle health but also contribute to improved metabolic markers such as insulin sensitivity, which is critical in preventing and managing conditions like type 2 diabetes and obesity (Byrne et al., 2015).

Muscle health is closely linked to metabolic function, and disruptions in muscle protein synthesis are often seen in metabolic disorders such as insulin resistance, diabetes, and obesity. Insulin plays a critical role in regulating both muscle protein synthesis and amino acid uptake (Defronzo et al., 1979). Post-prandial insulin spikes, in response to dietary protein intake, stimulate anabolic processes that promote muscle growth and recovery. Thus, the ability of a protein source to enhance post-prandial insulin levels is an important factor in its effectiveness in supporting muscle health (Rasmussen et al., 2000). Additionally, branched-chain amino acids (BCAAs), particularly leucine, are known to stimulate muscle protein synthesis through activation of the mTOR pathway, further underscoring the importance of dietary protein composition on muscle health (Anthony et al., 2000).

Despite the potential benefits of mycoprotein, the evidence surrounding its impact on muscle protein synthesis, post-prandial insulin response, and amino acid availability remains limited. Previous studies have demonstrated conflicting results regarding the efficacy of mycoprotein compared to other protein sources, particularly in its ability to stimulate muscle protein synthesis and regulate plasma BCAA levels (Dunlop et al., 2017; Monteyne, Coelho, Porter, Abdelrahman, Jameson, Jackman, et al., 2020). Given these uncertainties, it is important to systematically evaluate the current body of evidence to better understand the role of mycoprotein in supporting muscle health and metabolic regulation.

This systematic review and meta-analysis aim to address these gaps in the literature by examining the impact of mycoprotein consumption on skeletal muscle protein synthesis, plasma BCAA concentrations, and post-prandial insulin levels in healthy adults. By synthesizing data from randomized controlled trials, this study seeks to provide a clearer understanding of mycoprotein's role as an alternative protein source and its potential applications in muscle health promotion and chronic disease prevention.

METHODS

The protocol for this systematic review has been registered with PROSPERO (CRD42024602558), and the study was designed and conducted following PRISMA guidelines.

Study eligibility criteria

The eligibility criteria were established using the Patients, Intervention, Comparator, Outcome, and Study Design (PICOS) framework. Studies were included if they were randomized controlled trials investigating the effects of mycoprotein consumption in humans, featuring both a mycoprotein intervention group and a control group without mycoprotein, and if the outcome measures evaluated skeletal muscle analysis, and/or plasma amino acid levels.

Search strategy

We conducted a systematic search of the PubMed, Scopus, Cochrane Library, and EuropePMC databases to locate relevant studies published in any language up to October 20, 2022. The search terms and strategy were provided in the appendix.

Study selection

Studies identified through the search strategy were independently reviewed by two reviewers (AD and EP) after removing duplicates. Additional studies were found through citation chaining. Titles, abstracts, and full texts were screened based on the eligibility criteria, and any disagreements in study selection were resolved through discussion or with the involvement of a third reviewer (DD).

Data extraction

Data extraction was conducted using Covidence, a systematic review management software, to ensure a streamlined and efficient process. A standardized data extraction form was designed to capture key information from each included study. The extracted data encompassed essential elements such as the number of participants, study setting, and population characteristics. Additional details included baseline metrics like age, sex, and body mass index (BMI), as well as the specific form and dose of mycoprotein administered. Control groups were also noted, specifying the form and dose of the comparison protein source. Completion rates were recorded to assess participant retention throughout the study duration. Outcomes of interest, including muscle protein synthesis rates and plasma amino acid concentrations, were extracted alongside the times at which these outcomes were measured (e.g., pre- and post-intervention). The extraction process was performed independently by two reviewers (AD, EP) to minimize bias, with a third reviewer (DD) consulted in cases of disagreement. Any missing data or requests for clarification were addressed directly to the study authors to enhance the completeness and accuracy of the data set.

Risk-of-bias assessment

Data gathered for the risk of bias assessment included factors such as appropriate sequence generation, allocation concealment, blinding, selective reporting, and completeness of outcome data. Two independent reviewers (AD and EP) evaluated the risk of bias in the included studies using the Cochrane risk-of-bias tool for randomized trials (RoB 2). Studies were classified as having low or high risk of bias, or marked as unclear risk if insufficient details were provided. Any disagreements in the assessments were resolved through discussions between the reviewers.

Outcomes

The primary outcomes of interest in this systematic review focused on two main areas: muscle protein synthesis rates and plasma amino acid concentrations. Muscle protein synthesis rates was measured in terms of fractional synthetic rate (FSR), expressed as a percentage per hour ($\%\cdot h^{-1}$). FSR quantifies the rate at which muscle proteins are synthesized and provides insight into the anabolic effects of protein intake and resistance exercise. Studies included in this review reported FSR data under both resting and exercised conditions, allowing for a comprehensive assessment of mycoprotein's efficacy across different states of muscle activity. Secondary outcomes, although not the primary focus, may include assessments of plasma amino acid and serum insulin concentration, which could provide additional context to the impact of mycoprotein on muscle health. The concentration of key amino acids, specifically leucine and phenylalanine, in the plasma was measured post-ingestion of mycoprotein and control protein sources. Leucine, a branched-chain amino acids (BCAA), is particularly significant due to its role in activating the mTOR pathway and stimulating muscle protein synthesis. The plasma concentrations were reported in micromoles per litre ($\mu mol\cdot L^{-1}$), reflecting the availability of amino acids following protein intake.

All outcome measures were critically assessed to ensure consistency and reliability across studies, allowing for meaningful comparisons in the meta-analysis.

Data analysis

Data analysis was performed using RevMan 5.4 software to synthesize the extracted information and evaluate the effects of mycoprotein intake on skeletal muscle outcomes. The analysis included several key steps: For each study included in the review, descriptive statistics such as means and standard deviations (SD) for muscle protein synthesis rates and plasma amino acid concentrations were calculated. This provided a clear overview of the central tendencies and variability within the data. Depending on the data characteristics, both Mean Differences (MD) and Standardized Mean Differences (SMD) were computed. MD was used when comparing studies that reported outcomes in the same units (e.g., $\%\cdot h^{-1}$ for FSR), while SMD was applied when studies reported outcomes in different scales or units. This facilitated the comparison of effect sizes across different studies and protein sources.

Heterogeneity among the studies was assessed using the I^2 statistic, which quantifies the percentage of variation across studies that is attributable to heterogeneity rather than chance. A threshold of $I^2 < 50\%$ indicated low heterogeneity, suggesting that a fixed-effects model could be applied, whereas $I^2 \geq 50\%$ indicated substantial heterogeneity, warranting the use of a random-effects model. Sensitivity analyses were conducted to evaluate the robustness of the findings. This involved excluding studies with high risk of bias or outliers to determine if the overall results were significantly affected by specific studies. The potential for publication bias was evaluated using funnel plots and the Egger's test, which helps to detect asymmetry that may indicate bias in the reporting of study outcomes.

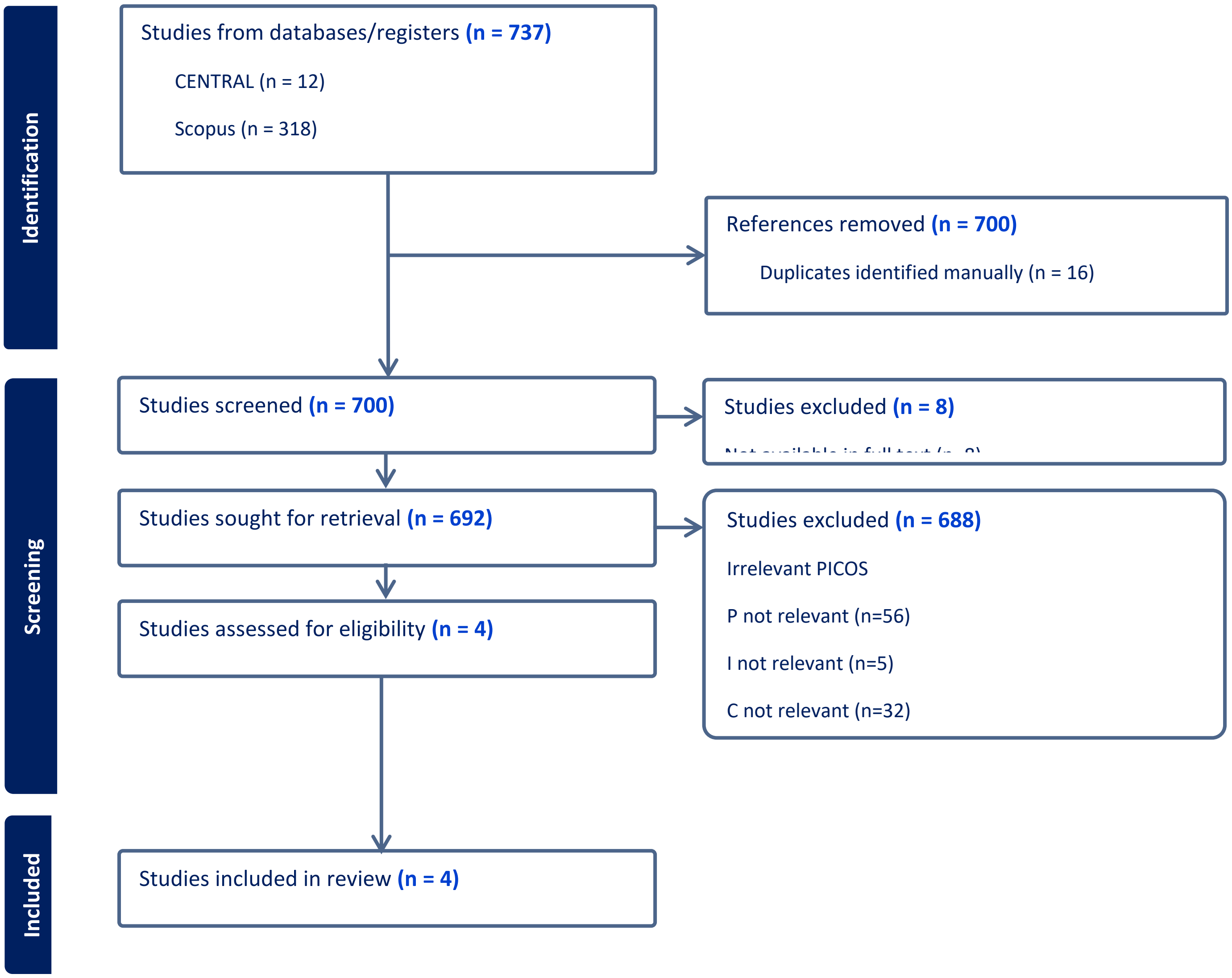

Figure 1. Study selection flow diagram. Adapted from the PRISMA guideline

A p-value of less than 0.05 was considered statistically significant for all analyses. The results were presented with 95% confidence intervals (CIs) to provide an estimate of the precision of the effect sizes. Through these comprehensive data analysis methods, we aimed to provide a thorough understanding of the effects of mycoprotein on muscle protein synthesis and plasma amino acid profiles, contributing valuable insights to the field of nutrition and muscle health.

RESULTS

Search results

A total of 737 records were identified through the search strategy (see Figure 1). Out of these, 16 were manually identified as duplicates, and 21 duplicates were flagged by Covidence. This left 700 unique records that were eligible for full-text review, with 8 ultimately excluded due to the unavailability of full text. In total, 692 studies were sought for retrieval, but 688 were excluded: 56 studies involved populations other than healthy adults, and 5 studies did not involve mycoprotein administration. Additionally, 567 studies were not randomized controlled trials, 32 lacked a non-mycoprotein control arm, and 28 did not report any relevant outcomes. The trials excluded for reasons such as lacking a non-mycoprotein control arm or failing to measure or report any outcomes of interest are detailed in Table 1. Ultimately, 4 studies were included in the meta-analysis.

Characteristics of included studies

Four randomized controlled trials, involving a total of 82 participants, were included and published between 2020 and 2022 (Table 1). All trials were conducted with healthy participants and followed a parallel design (MacHin et al., 2021; Monteyne, Coelho, Porter, Abdelrahman, Jameson, Finnigan, et al., 2020; Monteyne, Coelho, Porter, Abdelrahman, Jameson, Jackman, et al., 2020; West, Monteyne, Whelehan, Abdelrahman, et al., 2023). All four trials reported on muscle protein synthesis rates (FSR) and serum insulin levels, while all four also measured blood plasma amino acid concentrations. The duration of interventions ranged from 3 to 5 days for trials assessing muscle protein synthesis and plasma amino acids, and between 3 hours (0.125 days) and 4 hours (0.17 days) for trials measuring post-prandial insulin concentrations. The intervention dose was 70 g/day of mycoprotein (wet weight), with control doses matched for protein content. Two trials used milk protein as the control (MacHin et al., 2021; Monteyne, Coelho, Porter, Abdelrahman, Jameson, Jackman, et al., 2020), one trial used half the mycoprotein dose enriched with branched-chain amino acids (Monteyne, Coelho, Porter, Abdelrahman, Jameson, Finnigan, et al., 2020), and one trial compared it to protein concentrated from mycoprotein (West, Monteyne, Whelehan, Abdelrahman, et al., 2023).

The number of participants in the trials ranged from 19 to 24, with all participants being male (Table 2). The participants' mean age spanned from 21 to 68 years, and their average BMI was between 23 and 25 kg/m^2. For muscle protein synthesis rates (FSR), the mean values fell between 0.05% and 0.07% per hour. Plasma amino acid concentrations showed mean values ranging from 450 to 650 µmol/L. Additionally, the mean post-prandial serum insulin levels varied across the trials, ranging from 15 to 25 mU/L.

Risk-of-bias assessment

Overall, the risk-of-bias assessment highlights both strengths and weaknesses in the study designs. The studies generally maintained a low risk of bias in random sequence generation and assignment to interventions. The most frequently identified risk being in the measurement of outcomes and selection of reported results (n=4).

Effects of mycoprotein on skeletal muscle

All four studies included in the analysis provided data on the effect of mycoprotein consumption on muscle protein synthesis rates, specifically focusing on fractional synthetic rates (FSR). The pooled results from these studies demonstrated an increase in muscle protein synthesis in the mycoprotein group compared to the control group, with an overall increase of +0.01% per hour in FSR. The 95% confidence interval for this increase ranged from 0.01% to 0.02% per hour, indicating that the true effect is likely to fall within this narrow range, and the P-value of less than 0.001 suggests that this increase is highly statistically significant. Importantly, there was no significant variability or inconsistency in the results across the studies, as indicated by an I^2 value of 0%, which means that none of the variation in the results could be attributed to differences between the studies themselves. This lack of heterogeneity was confirmed by the Chi-square test ($P = 0.44$), meaning that the studies are largely consistent in their findings, which strengthens the confidence in the observed effect of mycoprotein on muscle protein synthesis rates.

Effects of mycoprotein on plasma amino acid

Three separate studies provided data on the effects of mycoprotein intake on plasma amino acids, with a specific focus on branched-chain amino acids (BCAAs). When analysing the results from these studies collectively, the findings indicated that there was no statistically significant difference between the consumption of mycoprotein and other proteins in terms of their influence on plasma BCAA levels. The overall mean difference was calculated to be 2.83, with a 95% confidence interval ranging from -84.93 to 90.58, which suggests that the true difference could lie anywhere within this wide range, including the possibility of no effect at all. Furthermore, a substantial level of heterogeneity was observed across the studies, as demonstrated by an I^2 value of 84%. This means that 84% of the variation in the findings can be attributed to differences between the studies, rather than random chance. The Chi-square test for heterogeneity was also significant ($P = 0.002$), reinforcing the conclusion that the studies vary considerably in their outcomes, which should be taken into account when interpreting these findings.

Effects of mycoprotein on serum insulin concentration

All of the studies included in the analysis reported data on the impact of mycoprotein consumption on post-prandial blood insulin levels, specifically measured at 30 and 45 minutes after meals. The combined analysis showed an overall mean difference of 8.15, with a 95% confidence interval ranging from 5.70 to 10.59, indicating a clear difference in insulin levels between the mycoprotein and other protein groups. However, there was significant variability across the studies, as reflected by an I^2 value of 87%, which suggests that 87% of the variation in the results can be attributed to differences between the studies. This degree of heterogeneity was further supported by the Chi^2 test, which yielded a statistically significant result ($P < 0.0001$), indicating that the differences between the studies are unlikely to be due to random chance alone and should be carefully considered when interpreting the overall effect.

Publication bias

Egger’s regression tests for the various outcomes related to mycoprotein intake showed no evidence of publication bias. For BCAA outcomes, there was no asymmetry observed ($P = 0.382$), indicating consistency across the studies. Similarly, for insulin outcomes, the test showed no evidence of asymmetry ($P = 0.130$), suggesting no significant publication bias. Additionally, the skeletal muscle analysis outcomes also revealed no significant asymmetry ($P = 0.130$). Overall, the tests indicate that publication bias is not a concern across the studies for these outcomes.

DISCUSSION

This systematic review and meta-analysis of 4 randomized controlled trials involving 82 participants demonstrated significant effects of mycoprotein intake on muscle protein synthesis (MPS), with an increase in fractional synthetic rates (FSR) that, if validated in larger studies, could have important implications for muscle health and the prevention of sarcopenia. Although the findings on plasma BCAA levels were inconclusive, the observed increase in MPS suggests that mycoprotein's benefits are not solely dependent on immediate BCAA availability but may involve other metabolic pathways. The increase in post-prandial insulin response also supports the anabolic effects of mycoprotein, which is comparable to or greater than that of traditional animal-based proteins. These results suggest that mycoprotein could play a valuable role in promoting muscle health, particularly in aging populations at risk for sarcopenia.

Our finding that mycoprotein intake significantly increases muscle protein synthesis (MPS) aligns well with other studies that have examined the effects of alternative protein sources on muscle health. Meta-analyses of trials investigating the substitution of animal-based proteins like dairy and meat with plant-based proteins, such as soy (Qin et al., 2022), nuts, or legumes, have consistently demonstrated improvements in muscle anabolism, particularly in populations at risk for sarcopenia (Deutz et al., 2014; Lim et al., 2021; Wolfe & Miller, 2008) Monteyne et al. (Monteyne, Coelho, Porter, Abdelrahman, Jameson, Jackman, et al., 2020) found that mycoprotein stimulates MPS in a dose-dependent manner, outperforming milk protein in both rested and exercised muscle conditions. The anabolic potential of mycoprotein is likely attributable to its complete amino acid profile (Majumder et al., 2023; Pinckaers et al., 2021), particularly its high leucine content (West, Monteyne, Whelehan, van der Heijden, et al., 2023). Leucine is well-documented for its ability to stimulate the mTOR pathway, which is crucial for promoting muscle protein synthesis and preventing muscle degradation (Anthony et al., 2000; Wilkinson et al., 2013).

Furthermore, recent research suggests that mycoprotein's fibrous structure facilitates a slower digestion rate, resulting in sustained amino acid availability for muscle repair and growth (Deutz et al., 2014). This slow-release profile is especially beneficial for older adults, who may require prolonged amino acid availability to counteract anabolic resistance, a condition where the muscles become less responsive to dietary protein (Tipton & Wolfe, 2004). Given the increasing prevalence of sarcopenia in aging populations, mycoprotein's ability to support MPS offers significant potential in preventing muscle loss and promoting healthy aging (Lonnie et al., 2018).

Recent studies suggest that mycoprotein's fibrous structure may also play a role in its ability to enhance muscle health. Mycoprotein contains a higher amount of dietary fibre compared to traditional animal proteins, which may facilitate slower digestion and sustained amino acid availability, a key factor for promoting muscle repair and growth, especially in older adult (Dunlop et al., 2017). The slow-release profile of amino acids, combined with mycoprotein's ability to stimulate the mTOR pathway, provides a mechanistic explanation for its efficacy in supporting MPS even in populations with anabolic resistance, such as the elderly (Moore et al., 2015). This supports prior observations that high-quality plant-based proteins, like mycoprotein, can play a crucial role in promoting healthy aging by preventing muscle loss (Derbyshire, 2022; Lee et al., 2024).

The data collected in this systematic review and meta-analysis do not present conclusive findings for plasma branched-chain amino acids (BCAAs), as there were no significant differences observed between mycoprotein and other protein sources. This finding contrasts with earlier studies on animal proteins, where higher BCAA levels, particularly leucine, were found to be strong predictors of muscle protein synthesis (MPS) (Anthony et al., 2000; Wolfe & Miller, 2008). One explanation for this difference could be the distinct metabolic characteristics of fungal proteins, which may influence amino acid bioavailability differently than animal-based proteins (Ajomiwe et al., 2024; Li et al., 2023). While plasma BCAA levels are important for muscle anabolism, mycoprotein's slower digestion rate may mean that its effects on MPS are not solely dependent on rapid BCAA elevation (Ajomiwe et al., 2024; Li et al., 2023). Instead, the sustained release of amino acids over time may still promote MPS despite lower initial plasma BCAA concentrations (Defronzo et al., 1979). The lack of significant findings in BCAA levels should not overshadow the potential benefits of mycoprotein for muscle health (Stefańska et al., 2024; Vandusseldorp et al., 2018). Mycoprotein has been shown to stimulate MPS despite lower plasma BCAA concentrations, supporting the theory that factors beyond immediate BCAA availability, such as sustained amino acid absorption and enhanced post-prandial insulin response, play a crucial role in muscle anabolism (Dunlop et al., 2017). Additionally, recent research suggests that sustained amino acid release, particularly in high-fibre protein sources like mycoprotein, may promote muscle health by maintaining prolonged anabolic signalling (Monteyne, Coelho, Porter, Abdelrahman, Jameson, Jackman, et al., 2020). Further research is needed to investigate how mycoprotein affects BCAA metabolism and muscle protein synthesis in various populations, particularly those with metabolic conditions such as insulin resistance or type 2 diabetes, where amino acid utilization and insulin sensitivity may differ (Defronzo et al., 1979). A better understanding of these mechanisms could clarify the role of mycoprotein in supporting muscle health across different metabolic contexts.

If the MPS findings of this systematic review and meta-analysis are confirmed in future, larger-scale, randomized trials, the public health implications of mycoprotein intake would be of great significance. Mycoprotein, already a key ingredient in a growing range of meat substitutes and plant-based protein products, is likely to be of particular benefit to aging populations and individuals at risk of sarcopenia (Finnigan et al., 2019; Monteyne, Coelho, Porter, Abdelrahman, Jameson, Jackman, et al., 2020). Increased consumption of mycoprotein and other plant-based proteins has been associated with improved muscle maintenance and reduced risk of age-related muscle loss (MacHin et al., 2021). Furthermore, plant-based diets rich in high-quality protein sources, like mycoprotein, have been shown to support better metabolic health, which is crucial for reducing the risk of chronic diseases such as type 2 diabetes and cardiovascular disease (Hu, 2003; Satija et al., 2017). By promoting muscle health and metabolic function, mycoprotein may offer a valuable dietary intervention with broad public health benefits.

The meta-analysis confirmed that mycoprotein elicits a significant post-prandial insulin response, comparable to or exceeding that of traditional animal proteins, which is crucial for muscle protein synthesis (MPS) as insulin facilitates amino acid uptake into muscle cells and activates anabolic pathways (Byrne et al., 2015; Rasmussen et al., 2000). This insulinotropic effect of mycoprotein is likely influenced by its high dietary fibre content, which modulates post-prandial glucose and insulin dynamics, resulting in a more sustained insulin release and promoting a steady anabolic environment for MPS (Jenkins et al., 2008; Satija et al., 2017). The fibre content in mycoprotein also enhances insulin sensitivity, particularly important for older adults who experience declines in both muscle mass and insulin sensitivity, making mycoprotein beneficial for preventing sarcopenia (Liu & Zhu, 2023; Tezze et al., 2023). By improving insulin sensitivity, mycoprotein supports efficient amino acid uptake and protein synthesis, while also offering metabolic benefits, especially in populations with insulin resistance (Coelho et al., 2021; Yanagisawa, 2023). Unlike animal-based proteins, which can promote insulin resistance due to their fat content, mycoprotein’s low-fat, high-fibre composition makes it a strategic option for managing muscle health and preventing metabolic disorders, including type 2 diabetes (DeFronzo & Tripathy, 2009; Durrer et al., 2017). Given its ability to stimulate a robust insulin response and improve metabolic regulation, mycoprotein stands out as a sustainable, effective dietary intervention for aging populations and individuals with metabolic conditions, enhancing its significance for public health (Clemente-Suárez et al., 2023; Rogeri et al., 2022b).

The findings from this meta-analysis have significant implications for addressing age-related muscle loss and sarcopenia. Sarcopenia affects approximately 10% of adults over the age of 60, with the prevalence rising to 50% in those over 80 years old (Cruz-Jentoft et al., 2019). Adequate protein intake, especially from high-quality sources, is essential for maintaining muscle mass and function. Current dietary guidelines recommend protein intakes of 1.2 to 1.6 g/kg/day for older adults to counteract anabolic resistance and support muscle health (Wolfe et al., 2017). Mycoprotein, with its high protein content and favourable metabolic effects, presents a sustainable and effective option for meeting these protein needs while also offering additional health benefits, such as improved insulin sensitivity and lower environmental impact (Dunlop et al., 2017).

The key strengths of this systematic review and meta-analysis include the broad and systematic search strategy, which covered multiple databases and ensured the inclusion of diverse studies focused on muscle protein synthesis, plasma BCAA levels, and post-prandial insulin response. The use of both fixed- and random-effects models provided a strong indicator of the robustness of the findings, accounting for potential variability between studies. Additionally, sensitivity analyses were conducted to assess the influence of different protein comparator groups, such as animal-based versus plant-based proteins, further clarifying the role of mycoprotein in promoting muscle health (Egger et al., 1997). The fixed-effects models also mitigated small-study effects, adding to the reliability of our conclusions. The inclusion of proportional changes in outcome measures helped to confirm the significant role of mycoprotein in stimulating muscle protein synthesis, despite inconclusive findings for plasma BCAA levels.

Study limitations

Despite the promising findings, this meta-analysis has several notable limitations that warrant careful consideration. The small sample sizes, short intervention durations, and limited evidence base reduce the generalizability of the results and the statistical power of the analyses, especially in subgroup explorations. These limitations prevented the investigation of potentially significant variables, such as long-term muscle strength or functional outcomes, and hindered the ability to explore a possible dose-response relationship. Additionally, the heterogeneity in study designs and participant characteristics complicates direct comparisons between trials, which limits the robustness of the conclusions. Future research should aim to include larger and more diverse populations, such as older adults and individuals with metabolic disorders, to better understand the long-term effects of mycoprotein on muscle health and metabolism.

Future recommendations

Further investigation is needed to explore the mechanistic pathways through which mycoprotein influences muscle protein synthesis, insulin response, and amino acid metabolism. Specifically, research should focus on the role of fibre in modulating post-prandial amino acid availability and insulin dynamics, as well as its impact on long-term outcomes like muscle strength, functional performance, and quality of life in aging populations. These insights would provide valuable information on mycoprotein's potential as a dietary intervention for preventing sarcopenia.

Given the limited number of included studies and the moderate-to-large effect sizes detected for available biomarkers, larger and longer-term randomized controlled trials are essential to fully elucidate the benefits of mycoprotein for muscle health. Addressing these gaps will help better assess its role across diverse populations and provide stronger evidence for its use in clinical and nutritional settings.

CONCLUSION

Mycoprotein intake demonstrates promising benefits in promoting muscle health, particularly by enhancing muscle protein synthesis (MPS) and improving post-prandial insulin response. This systematic review and meta-analysis indicate that mycoprotein can significantly increase fractional synthetic rates (FSR) of muscle proteins, suggesting it may serve as an effective alternative to traditional animal proteins for supporting muscle growth and repair. Additionally, the observed elevation in insulin response post-ingestion highlights mycoprotein's potential role in facilitating amino acid uptake into muscles and stimulating anabolic pathways essential for muscle maintenance. These effects are particularly relevant for aging populations who are at an increased risk of sarcopenia, a condition marked by the progressive loss of muscle mass and strength. Mycoprotein's unique profile—including its complete amino acid composition, high fibre content, and low fat—offers a sustainable and health-promoting option that aligns with modern dietary preferences, especially as interest in plant-based proteins grows. Furthermore, the high fibre content may contribute to slower digestion and a prolonged amino acid release, which can be beneficial for maintaining an anabolic environment over a longer period, particularly in older adults with anabolic resistance.

CONFLICT OF INTEREST

We declare no conflicts of interests in this study.

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REFERENCES

Ajomiwe, N., Boland, M., Phongthai, S., Bagiyal, M., Singh, J., & Kaur, L. (2024). Protein Nutrition: Understanding Structure, Digestibility, and Bioavailability for Optimal Health. In Foods (Vol. 13, Issue 11). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/foods13111771

Anthony, J. C., Yoshizawa, F., Anthony, T. G., Vary, T. C., Jefferson, L. S., & Kimball, S. R. (2000). Biochemical and molecular action of nutrients leucine stimulates translation initiation in skeletal muscle of postabsorptive rats via a rapamycin-sensitive pathway 1. American Society for Nutritional Sciences, 130, 2413–2419. https://academic.oup.com/jn/article-abstract/130/10/2413/4686100

Bhattacharya, S., Bhadra, R., Schols, A. M. W. J., van Helvoort, A., & Sambashivaiah, S. (2022). Nutrition in the prevention and management of sarcopenia - A special focus on Asian Indians. Osteoporosis and Sarcopenia, 8(4), 135–144. https://doi.org/10.1016/j.afos.2022.12.002

Byrne, C. S., Chambers, E. S., Morrison, D. J., & Frost, G. (2015). The role of short chain fatty acids in appetite regulation and energy homeostasis. International Journal of Obesity, 39(9), 1331–1338. https://doi.org/10.1038/ijo.2015.84

Clemente-Suárez, V. J., Martín-Rodríguez, A., Redondo-Flórez, L., López-Mora, C., Yáñez-Sepúlveda, R., & Tornero-Aguilera, J. F. (2023). New Insights and Potential Therapeutic Interventions in Metabolic

Diseases. In International Journal of Molecular Sciences (Vol. 24, Issue 13). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/ijms241310672

Coelho, M. O. C., Monteyne, A. J., Dirks, M. L., Finnigan, T. J. A., Stephens, F. B., & Wall, B. T. (2021). Daily mycoprotein consumption for 1 week does not affect insulin sensitivity or glycaemic control but modulates the plasma lipidome in healthy adults: A randomised controlled trial. British Journal of Nutrition, 125(2), 147–160. https://doi.org/10.1017/S0007114520002524

Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A. A., Schneider, S. M., Sieber, C. C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., Bautmans, I., Baeyens, J. P., Cesari, M., … Schols, J. (2019). Sarcopenia: Revised European consensus on definition and diagnosis. In Age and Ageing (Vol. 48, Issue 1, pp. 16–31). Oxford University Press. https://doi.org/10.1093/ageing/afy169

Cruz-Jentoft, A. J., & Sayer, A. A. (2019). Sarcopenia. In The Lancet (Vol. 393, Issue 10191, pp. 2636–2646). Lancet Publishing Group. https://doi.org/10.1016/S0140-6736(19)31138-9

Defronzo, R. A., Tobin, J. D., & Andres, R. (1979). Glucose clamp technique: a method for quantifying insulin secretion and resistance. American Journal of Physiology, 237(3), E214–E223.

DeFronzo, R. A., & Tripathy, D. (2009). Skeletal muscle insulin resistance is the primary defect in type 2 diabetes. In Diabetes care: Vol. 32 Suppl 2. https://doi.org/10.2337/dc09-s302

Derbyshire, E. (2022). Fungal-Derived Mycoprotein and Health across the Lifespan: A Narrative Review. In Journal of Fungi (Vol. 8, Issue 7). MDPI. https://doi.org/10.3390/jof8070653

Deutz, N. E. P., Bauer, J. M., Barazzoni, R., Biolo, G., Boirie, Y., Bosy-Westphal, A., Cederholm, T., Cruz-Jentoft, A., Krznariç, Z., Nair, K. S., Singer, P., Teta, D., Tipton, K., & Calder, P. C. (2014). Protein intake and exercise for optimal muscle function with aging: Recommendations from the ESPEN Expert Group. Clinical Nutrition, 33(6), 929–936. https://doi.org/10.1016/j.clnu.2014.04.007

Dunlop, M. V., Kilroe, S. P., Bowtell, J. L., Finnigan, T. J. A., Salmon, D. L., & Wall, B. T. (2017). Mycoprotein represents a bioavailable and insulinotropic non-animal-derived dietary protein source: A dose-response study. British Journal of Nutrition, 118(9), 673–685. https://doi.org/10.1017/S0007114517002409

Durrer, C., Francois, M., Neudorf, H., & Little, J. P. (2017). Acute high-intensity interval exercise reduces human monocyte toll-like receptor 2 expression in type 2 diabetes. American Journal of Physiology - Regulatory Integrative and Comparative Physiology, 312(4), R529–R538. https://doi.org/10.1152/ajpregu.00348.2016

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Papers Bias in meta-analysis detected by a simple, graphical test. BMJ, 315, 629–634.

Finnigan, T. J. A., Wall, B. T., Wilde, P. J., Stephens, F. B., Taylor, S. L., & Freedman, M. R. (2019). Mycoprotein: The Future of Nutritious Nonmeat Protein, a Symposium Review. Current Developments in Nutrition, 3(6). https://doi.org/10.1093/cdn/nzz021

Hu, F. B. (2003). Plant-based foods and prevention of cardiovascular disease: an overview. American Journal of Clinical Nutrition, 78, 544s–551s.

Jenkins, D. J. A., Kendall, C. W. C., Faulkner, D. A., Kemp, T., Marchie, A., Nguyen, T. H., Wong, J. M. W., de Souza, R., Emam, A., Vidgen, E., Trautwein, E. A., Lapsley, K. G., Josse, R. G., Leiter, L. A., & Singer, W. (2008). Long-term effects of a plant-based dietary portfolio of cholesterol-lowering foods on blood pressure. European Journal of Clinical Nutrition, 62(6), 781–788. https://doi.org/10.1038/sj.ejcn.1602768

Lee, D., Pan, J. H., Kim, D., Heo, W., Shin, E. C., Kim, Y. J., Shim, Y. Y., Reaney, M. J. T., Ko, S.-G., Hong, S.-B., Cho, H. T., Kim, T. G., Lee, K., & Kim, J. K. (2024). Mycoproteins and their health-promoting properties: Fusarium species and beyond. Comprehensive Reviews in Food Science and Food Safety, 23(3), e13365. https://doi.org/https://doi.org/10.1111/1541-4337.13365

Li, K., Qiao, K., Xiong, J., Guo, H., & Zhang, Y. (2023). Nutritional Values and Bio-Functional Properties of Fungal Proteins: Applications in Foods as a Sustainable Source. In Foods (Vol. 12, Issue 24). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/foods12244388

Lim, M. T., Pan, B. J., Toh, D. W. K., Sutanto, C. N., & Kim, J. E. (2021). Animal protein versus plant protein in supporting lean mass and muscle strength: A systematic review and meta-analysis of randomized controlled trials. In Nutrients (Vol. 13, Issue 2, pp. 1–18). MDPI AG. https://doi.org/10.3390/nu13020661

Liu, Z. jian, & Zhu, C. feng. (2023). Causal relationship between insulin resistance and sarcopenia. In Diabetology and Metabolic Syndrome (Vol. 15, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s13098-023-01022-z

Lonnie, M., Hooker, E., Brunstrom, J. M., Corfe, B. M., Green, M. A., Watson, A. W., Williams, E. A., Stevenson, E. J., Penson, S., & Johnstone, A. M. (2018). Protein for life: Review of optimal protein intake, sustainable dietary sources and the effect on appetite in ageing adults. In Nutrients (Vol. 10, Issue 3). MDPI AG. https://doi.org/10.3390/nu10030360

MacHin, D. J., Coelho, M. O. C., Pavis, G. F., Porter, C., Murton, A. J., Abdelrahman, D. R., DIrks, M. L., Stephens, F. B., & Wall, B. T. (2021). A mycoprotein-based high-protein vegan diet supports equivalent daily myofibrillar protein synthesis rates compared with an isonitrogenous omnivorous diet in older adults: A randomised controlled trial. British Journal of Nutrition, 126(5), 674–684. https://doi.org/10.1017/S0007114520004481

Majumder, R., Miatur, S., Saha, A., & Hossain, S. (2023). Mycoprotein: production and nutritional aspects: a review. In Sustainable Food Technology (Vol. 2, Issue 1, pp. 81–91). Royal Society of Chemistry. https://doi.org/10.1039/d3fb00169e

Monteyne, A. J., Coelho, M. O. C., Porter, C., Abdelrahman, D. R., Jameson, T. S. O., Finnigan, T. J. A., Stephens, F. B., Dirks, M. L., & Wall, B. T. (2020). Branched-chain amino acid fortification does not restore muscle protein synthesis rates following ingestion of lower- compared with higher-dose mycoprotein. Journal of Nutrition, 150(11), 2931–2941. https://doi.org/10.1093/jn/nxaa251

Monteyne, A. J., Coelho, M. O. C., Porter, C., Abdelrahman, D. R., Jameson, T. S. O., Jackman, S. R., Blackwell, J. R., Finnigan, T. J. A., Stephens, F. B., Dirks, M. L., & Wall, B. T. (2020). Mycoprotein ingestion stimulates protein synthesis rates to a greater extent than milk protein in rested and exercised skeletal muscle of healthy young men: A randomized controlled trial. American Journal of Clinical Nutrition, 112(2), 318–333. https://doi.org/10.1093/ajcn/nqaa092

Moore, D. R., Churchward-Venne, T. A., Witard, O., Breen, L., Burd, N. A., Tipton, K. D., & Phillips, S. M. (2015). Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. Journals of Gerontology - Series A Biological Sciences and Medical Sciences, 70(1), 57–62. https://doi.org/10.1093/gerona/glu103

Pinckaers, P. J. M., Trommelen, J., Snijders, T., & van Loon, L. J. C. (2021). The Anabolic Response to Plant-Based Protein Ingestion. In Sports Medicine (Vol. 51, pp. 59–74). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s40279-021-01540-8

Qin, P., Wang, T., & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. Journal of Agriculture and Food Research, 7. https://doi.org/10.1016/j.jafr.2021.100265

Rasmussen, B. B., Tipton, K. D., Miller, S. L., Wolf, S. E., & Wolfe, R. R. (2000). An oral essential amino acid-carbohydrate supplement enhances muscle protein anabolism after resistance exercise. American Physiological Society, 88, 386–392. http://www.jap.org

Rogeri, P. S., Zanella, R., Martins, G. L., Garcia, M. D. A., Leite, G., Lugaresi, R., Gasparini, S. O., Sperandio, G. A., Ferreira, L. H. B., Souza-junior, T. P., & Lancha, A. H. (2022a). Strategies to prevent sarcopenia in the aging process: Role of protein intake and exercise. In Nutrients (Vol. 14, Issue 1). MDPI. https://doi.org/10.3390/nu14010052

Rogeri, P. S., Zanella, R., Martins, G. L., Garcia, M. D. A., Leite, G., Lugaresi, R., Gasparini, S. O., Sperandio, G. A., Ferreira, L. H. B., Souza-junior, T. P., & Lancha, A. H. (2022b). Strategies to prevent sarcopenia in the aging process: Role of protein intake and exercise. In Nutrients (Vol. 14, Issue 1). MDPI. https://doi.org/10.3390/nu14010052

Santilli, V., Bernetti, A., Mangone, M., & Paoloni, M. (2014). Clinical definition of sarcopenia. In Clinical Cases in Mineral and Bone Metabolism (Vol. 11, Issue 3).

Satija, A., Bhupathiraju, S. N., Spiegelman, D., Chiuve, S. E., Manson, J. A. E., Willett, W., Rexrode, K. M., Rimm, E. B., & Hu, F. B. (2017). Healthful and Unhealthful Plant-Based Diets and the Risk of Coronary Heart Disease in U.S. Adults. Journal of the American College of Cardiology, 70(4), 411–422. https://doi.org/10.1016/j.jacc.2017.05.047

Stefańska, O., Rudnicki, J., Szczepocki, M., & Jurek, J. M. (2024). Narrative literature review: Effect of Branched-chain Amino Acids (BCAAs) on muscle hypertrophy and athletic performance. Tanjungpura Journal of Coaching Research, 2(2). https://doi.org/10.26418/tajor.v2i2.78568

Tezze, C., Sandri, M., & Tessari, P. (2023). Anabolic Resistance in the Pathogenesis of Sarcopenia in the Elderly: Role of Nutrition and Exercise in Young and Old People. In Nutrients (Vol. 15, Issue 18). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/nu15184073

Tipton, K. D., & Wolfe, R. R. (2004). Protein and amino acids for athletes. Journal of Sports Sciences, 22(1), 65–79. https://doi.org/10.1080/0264041031000140554

Vandusseldorp, T. A., Escobar, K. A., Johnson, K. E., Stratton, M. T., Moriarty, T., Cole, N., McCormick, J. J., Kerksick, C. M., Vaughan, R. A., Dokladny, K., Kravitz, L., & Mermier, C. M. (2018). Effect of branched-chain amino acid supplementation on recovery following acute eccentric exercise. Nutrients, 10(10). https://doi.org/10.3390/nu10101389

West, S., Monteyne, A. J., Whelehan, G., Abdelrahman, D. R., Murton, A. J., Finnigan, T. J. A., Blackwell, J. R., Stephens, F. B., & Wall, B. T. (2023). Mycoprotein ingestion within or without its wholefood matrix results in equivalent stimulation of myofibrillar protein synthesis rates in resting and exercised muscle of young men. British Journal of Nutrition, 130(1), 20–32. https://doi.org/10.1017/S0007114522003087

West, S., Monteyne, A. J., Whelehan, G., van der Heijden, I., Abdelrahman, D. R., Murton, A. J., Finnigan, T. J. A., Stephens, F. B., & Wall, B. T. (2023). Ingestion of mycoprotein, pea protein, and their blend support comparable postexercise myofibrillar protein synthesis rates in resistance-trained individuals. American Journal of Physiology - Endocrinology and Metabolism, 325(3), E267–E279. https://doi.org/10.1152/ajpendo.00166.2023

Wilkinson, D. J., Hossain, T., Hill, D. S., Phillips, B. E., Crossland, H., Williams, J., Loughna, P., Churchward-Venne, T. A., Breen, L., Phillips, S. M., Etheridge, T., Rathmacher, J. A., Smith, K., Szewczyk, N. J., & Atherton, P. J. (2013). Effects of leucine and its metabolite β-hydroxy-β-methylbutyrate on human skeletal muscle protein metabolism. Journal of Physiology, 591(11), 2911–2923. https://doi.org/10.1113/jphysiol.2013.253203

Wolfe, R. R., Cifelli, A. M., Kostas, G., & Kim, I. Y. (2017). Optimizing protein intake in adults: Interpretation and application of the recommended dietary allowance compared with the acceptable macronutrient distribution range. In Advances in Nutrition (Vol. 8, Issue 2, pp. 266–275). American Society for Nutrition. https://doi.org/10.3945/an.116.013821

Wolfe, R. R., & Miller, S. L. (2008). The recommended dietary allowance of protein: a misunderstood concept. American Medical Association, 299(24), 2891. http://www.FNS.USDA.gov/cnd/Lunch/AboutLunch/NSLPFactSheet

Yanagisawa, Y. (2023). How dietary amino acids and high protein diets influence insulin secretion. In Physiological Reports (Vol. 11, Issue 2). American Physiological Society. https://doi.org/10.14814/phy2.15577