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Plant-based Meats with Higher Protein Bioavailability in the Prevention and Management of Sarcopenia

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Abstract:

Sarcopenia is a global problem. It reduces a large number of people's quality of life and health status, especially for the elderly. Protein is the core nutrient in muscles, and people need to eat enough protein, which helps keep muscle synthesis going. So sufficient protein intake plays an important role in preventing sarcopenia. Plant-based meat is a protein source and has many advantages. For example, it's sustainable, thus helping reduce environmental pollution; it has high nutritional value with abundant protein and essential amino acids. It also has advantages like low fat content and no cholesterol. This makes it particularly suitable for older adults, who need a low-fat and low-cholesterol diet. The purpose of this study is to explore the application in sarcopenia with higher bioavailability. Through high-moisture extrusion, fermentation and sprouting methods, the impact of anti-nutritional factors can be reduced, and the soluble protein content can be increased, so the plant protein bioavailability will increase. And the review also discusses the mechanisms of plant-based meat in preventing sarcopenia. In view of the current preventing situation, this review sums up the advantages of plant-based meat, such as nutritional adaptability and various age-related diseases. There are also some challenges in taste improvement, consumer acceptance, production technology and marketing strategy. With the ongoing trend of population aging, the future development direction is also discussed. Plant-based meat offers theoretical frameworks to leverage it in enhancing elderly health, mitigating sarcopenia, ultimately enhancing their quality of life.

Keywords: Plant-based meat; Sarcopenia; Protein bio-availability.

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1. Introduction

Sarcopenia is a disease that occurs with aging or disease. It causes decrease in lean body mass, a decline in muscle force, and a recession in muscle function. This condition severely compromises the ability of elderly individuals to live independently and take care of themselves, while also significantly contributes to the overall healthcare burden by increasing the incidence of chronic diseases, hospitalization rates, and rehabilitation costs. Addressing sarcopenia remains a critical challenge. Research shows that globally, the incidence of sarcopenia rises notably as people age, with approximately 50 million individuals currently affected worldwide. It is projected that the quantity of people with this disease will reach 500 million in 2050 [1]. Sarcopenia has therefore emerged as a major public health concern.

Current mainstream interventions for sarcopenia include physical exercise, nutritional supplements, and pharmacological treatments. Among these, exercise is the only clinically validated effective approach, as it restores mitochondrial homeostasis, suppresses inflammation, and promotes angiogenesis and neuromuscular innervation by modulating myogenic and osteogenic signaling pathways, and also improves muscle mass and function. However, it is ineffective for individuals who are bedridden long-term. Nutritional supplements can reduce the chance of getting sarcopenia, although their effects are not as potent as exercise. pharmaceutics may enhance some biomarkers, yet they frequently bring about unfavorable reactions such as cardiovascular and prostate-related complications [2]. Consequently, the identification of safer, more universally applicable interventions—those that combine the benefits of nutritional supplementation while addressing the gaps left by exercise interventions—remains crucial.

Among these, plant-based meat has garnered increasing attention as a promising intervention that offers nutritional supplementation advantages.

While animal-derived proteins contribute to the maintenance of muscle health, their production is associated with environmental pollution and ethical concerns. As an emerging protein source, plant-based meat offers numerous advantages. However, conventional plant proteins suffer from suboptimal digestibility, incomplete amino acid profiles, and limited bioavailability.

However, to date, there has been a lack of systematic reviews and analyses regarding the relationship between plant-based meat and sarcopenia. Therefore, this review aims to elucidate the recent advancements in enhancing the bioavailability of plant-based meat proteins through improvements in processing technologies and the optimization of scientific formulations. And through reviewing relevant evidence, the potential of preventing and caring for sarcopenia can be found.

2. Sarcopenia

Sarcopenia is an age-related disease. It means your muscles get weak and lose power slowly. This can raise the chance of bad health results such as slip and fall, disability, institutionalization, a low quality of life, and even death.

Evidence from studies shows that adequate physical exercise and a diet with complete and appropriate amounts of dietary protein, among other environmental stimuli, can repair muscle tissue in the elderly [3]. Dietary protein acts as a crucial partner to physical activity by supplying essential amino acids, making it fundamental for preserving muscle mass in the elderly.

For older adults, engaging in regular exercise alongside sufficient dietary protein is a proven strategy to enhance muscle size, power, and functional capacity. These three parameters—mass, strength, and function—collectively form the diagnostic foundation of sarcopenia.

The combination of regular exercise and muscle contractions with adequate dietary protein intake has demonstrated significant advantages in improving muscle health indicators in older adults. The core of sarcopenia diagnosis revolves around three key indicators: physical function, muscle mass and muscle strength [2].

While plant-based meat is relatively rich in protein, its bioavailability is usually lower than animal proteins' bioavailability. However, certain intervention methods can effectively improve this limitation.

3. Strategies to Improve the Protein Bioavailability in Plant-Based Meats

3.1 High-Moisture Extrusion (HME)

High moisture extrusion (HME) is a technique that controls the degree of plant protein organization. This technology is usually achieved by adjusting parameters such as temperature and moisture [4]. For example, high moisture extrusion processing utilizes high temperature and pressure to break down anti nutritional factors in whole wheat breakfast grains, this helps the body absorb protein from breakfast more effectively [5,6].

3.2 Fermentation

After protein fermentation, the content of soluble proteins, small peptides, and amino acids will obviously increase.

The hydrolysis of proteins and the metabolism and utilization of amino acids lead to the recombination of amino acids, which in turn results in structural changes to the proteins [7]. Fermentation has the ability to effectively break down the anti-nutritional factors within plant -derived proteins, for example, phytate, tannins, and soy globulins. Wang et al. explained that bacterial fermenting of soymilk elevated the amounts of daidzein-type isoflavones compounds and endogenously produced vitamin B2, while also enhancing its digestibility and nutritive value through modifications in the amino acid profile [8].

3.3 Germination

Sprouting is widely used as a biological processing method to diminish antinutrients, improve the ability to absorb dietary proteins, and enhance functional characteristics. When quinoa and field peas sprout, their crude protein content goes up. Because their own protein consumption is less than newly produced proteins. This leads to an increase in most of the protein content after sprouting [9]. Concha et al. studied the effects of sprouting on the hydrolysis of Pisum sativum L. grain proteins and its anti-inflammatory properties. Under the action of proteases, stored proteins are broken down into small molecule peptides and amino acids. After deamination, form nascent proteins by oxidative carbon skeleton bonding with small peptides, this step increases the soluble protein content [10]. And soluble proteins happen to contain components with anti-inflammatory effects. Di et al. tested various ways to sprout sesame. They found that this changed the protein's structure and its function, the in vitro digestibility (IVPD) and solubility of sesame protein are markedly improved due to germination. The IVPD of sesame before sprouting was 43.69 ± 0.33%, and it increased most significantly to 47.97 ± 3.13% after 2 days of sprouting. Even after 4 days of sprouting, the sprouted sample had a greater IVPD than the non-sprouted one, reaching 45.04 ± 0.20%. After 4 days of sprouting, the solubility peaked, approximately 3.58 times that of the pre-sprouting value [11].

3.4 Consumption of a Variety of Plant Proteins

Most plant proteins do not contain all essential amino acids, typically leading to a lower Protein Digestibility-Corrected Amino Acid Score (PDCAAS) compared to animal proteins. Although the ratio of essential amino acids in plant proteins is not as balanced as in animal proteins, adequate intake of diverse plant proteins can fulfill the human body's essential amino acid requirements [12].

4. Itmpact of Plant-Based Meats on Muscle Health in the Elderly

4.1 Clinical Research

A study on sarcopenia in the elderly population in Europe included 986 participants, consisting of 417 males (age 71.1±4.1 years) and 569 females (age 71.1±4.1 years). The data were derived from 7-day dietary records. According to the trial, higher plant-based protein intake leads to the lower risk of sarcopenia. Sarcopenia Risk Scores (SRS) significantly decreased with increasing protein intake. In the overall population, for every 0.1 grams per kilogram of body weight increase in plant protein (with a corresponding reduction in animal protein), the SRS decreased by 0.249 (95% CI: -0.303 to -0.196, $p<0.001$). When stratified by protein intake levels, replacing animal protein with plant protein has significant benefits, suggesting that this conclusion is not influenced by total protein intake. Additionally, both skeletal muscle index (SMI) and grip strength showed an upward trend with increasing protein intake, indicating that sufficient protein intake benefits muscle health in the elderly [13].

A study on a high-plant protein/peptide nutritional supplement for elderly sarcopenia patients included 130 participants, with 65 individuals in the experimental group (add high plant protein and peptide nutritional supplements) and 65 individuals in the placebo group (maltodextrin). The study data were derived from a 12-week trial. The results indicated that the supplement containing high levels of plant proteins and peptides showed significant improvements in sarcopenia-related parameters, effectively increasing muscle force, mass and physical performance, thereby alleviating the sarcopenic condition. The group supplemented with high plant protein and peptide nutritional supplements demonstrated obvious improvements across all measures in contrast to the placebo group. The group exhibited increases in both skeletal muscle index (0.66 kg/m^2; 95% CI, 0.45–0.86; $P<0.0001$) and skeletal muscle mass (2.06 kg; 95% CI, 1.37–2.75 kg; $P<0.0001$). Muscle strength also improved, as evidenced by a greater increase in grip strength (2.83 kg; 95% CI, 2.13–3.53 kg; $P<0.0001$). For physical performance, the total score on the Short Physical Performance Battery (SPPB) rose by 1.03 points (95% CI, 0.69–1.38; $P<0.0001$). This improvement was driven by gains in both the balance test (+0.65 points; 95% CI, 0.44–0.86; $P<0.0001$) and the gait speed test (+0.36 points; 95% CI, 0.24–0.48; $P<0.0001$). The improvement impacts were highly significant, with no noticeable difference in chair stand time scores. Additionally, 28 patients with sarcopenia in the experimental group

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have recovered [14].

Chronic diseases like cardiovascular disease and diabetes share pathophysiological pathways with sarcopenia, with a bidirectional negative interaction that further exacerbates the health burden in elderly patients. A study investigating the relationship between sarcopenia, cardiovascular disease, and diabetes followed 542 patients, and the median follow-up was 24 months. The follow-up period was too short to directly observe cardiovascular disease (CVD) incidence. Therefore, the 10-year CVD probability was used the Framingham Risk Score (FRS) to estimate, rather than directly calculating CVD incidence. The results showed that compared with Type 2 Diabetes Mellitus(T2MD) patients with sarcopenia but without anemia, T2MD patients without sarcopenia but with the same other conditions had a 46.2% higher 10-year risk of high CVD (FRS ≥ 20%) (OR=1.462, 95% CI: 1.085–1.972, p=0.013), implicating sarcopenia as an independent predictor of an elevated 10-year CVD risk in individuals with T2MD. The body mass index (BMI) of non-sarcopenia patients was significantly higher than BMI of sarcopenia patients (male sarcopenia group: 22.23±2.60 kg/m², the sarcopenia-free group: 26.17±3.03 kg/m²; female sarcopenia group: 21.56±3.09 kg/m², non-sarcopenia group: 25.92±3.74 kg/m²; all p<0.001). Additionally, in the sarcopenia group, the triglyceride (TG) levels were lower (male sarcopenia group: 1.52±1.31 mmol/L, non-sarcopenia group: 2.07±2.02 mmol/L; female sarcopenia group: 1.59±1.12 mmol/L, non-sarcopenia group: 1.96±1.59 mmol/L; all p<0.001), and serum albumin (ALB) levels were also lower (male sarcopenia group: 38.14±5.05 g/L, non-sarcopenia group: 39.94±5.56 g/L; female sarcopenia group: 38.7±4.44 g/L, non-sarcopenia group: 39.41±4.5 g/L; all p<0.05), suggesting that sarcopenia may be associated with the nutritional status and lipid metabolism disorders in type 2 diabetes patients. Moreover, sarcopenia was found to be associated with complications such as kidney damage and peripheral neuropathy in those suffering from type 2 diabetes. The study showed that the proportion of patients with a Urine Albumin-to-Creatinine Ratio (UACR≥30 mg/g) was higher in the sarcopenia group (male sarcopenia group: 36.4%, non-sarcopenia group: 30.9%; female sarcopenia group: 44.3%, non-sarcopenia group: 37.8%; all p<0.05). The prevalence of diabetic peripheral neuropathy (DPN) was also significantly higher in the male sarcopenia group compared to the non-sarcopenia group (sarcopenia group: 45.1%, control group: 38.5%, p=0.001), indicating that sarcopenia may exacerbate diabetes-related organ damage [15].

However, some studies have reported contrasting results, indicating that non-soy plant proteins, such as chia seed protein, rice protein and potato protein, do not have a clear effect on the core indicators of sarcopenia, including muscle mass and muscle strength. From a mechanistic perspective, these plant proteins have two major limitations: on one hand, their amino acid composition and digestibility are significantly inferior, with lower levels of essential amino acids and poor digestibility, making them insufficient to meet the needs of sarcopenia patients; on the other hand, unprocessed plant proteins tend to form β-sheet aggregates and contain antinutritional factors, which further reduce the bioavailability of plant proteins and lead to an inadequate supply of raw materials for muscle synthesis [16]. Even though most studies confirm that plant proteins have some positive effects on sarcopenia, their correlation requires further investigation.

4.2 Animal Research

An experiment on the supplementation of plant protein in a low-protein diet for mice was conducted using 24 male SAMP8 mice aged 8 months. The experiment found that plant protein can directly help when a low-protein diet hurts muscle function. It makes muscle strength greater and endurance higher. Its mechanism can be broken down as follows: the body can use the protein better to build muscle. This means it enhances the bioavailability and provides enough amino acids for muscle synthesis. It also regulates muscle protein anabolic balance and alleviates protein-deficiency stress. By doing this, it reduces local inflammation and oxidative stress in muscle, ultimately protecting muscle cells [17].

An experiment was conducted to compare the impact of whey protein, casein, and a mixed protein (P4) on muscle protein synthesis in fasted elderly mice. The study used 51 aged male C57BL/6J mice divided into four groups: fasting control group, whey protein group, P4 mixed protein group, and casein group. The protocol comprised a 14-day adaptation phase followed by a 1-day test. The results for the whey protein group had a 1.6-fold significant increase in MPS (p=0.006), and the P4 group had a 1.5-fold significant increase (p=0.008), although, the effects of the two did not differ significantly from each other. The casein group showed no significant change in MPS (p=0.085). Regarding the activation of MPS-related signaling pathways, the key translational regulatory molecule 4E-BP1: both the phosphorylation to total protein ratio of whey and P4 groups were obviously higher than phosphorylation to total protein ratio of the fasted group (whey group p=0.012, P4 group p=0.001), and the phosphorylation level of 4E-BP1 protein was elevated (whey group p=0.04, P4 group p=0.011), with no changes in total 4E-BP1. The experiment indicated that the milk-based plant protein blend (P4) could induce muscle protein synthesis (MPS) comparable to whey protein in fasting mice, with both activating the 4E-BP1 in the mTOR pathway, outperforming single-casein protein. The muscle leucine content in the whey group, at 0.97 μmol per gram of dry weight, was higher than that in the P4 group, which stood at 0.71 μmol/g dry weight ($p=0.0007$). This suggests that the MPS-stimulating effect of P4 does not rely on a high concentration of leucine, but may stem from a balanced amino acid profile, such as early elevation of multiple indispensable amino acids, the semi-essential amino acid arginine, and good protein bioavailability, which can compensate for deficiencies in individual amino acids during metabolic stress (e.g., fasting) [18].

5. Challenges and Issues Analysis

Currently, the primary approach to the prevention and treatment of sarcopenia remains exercise intervention combined with high-protein diets. However, the digestive and absorption capabilities of elderly individuals are weak. Plant-based meats, with their enhanced bioavailability, can precisely supplement high-quality protein, offering an advantage in nutritional adaptability. Although using plant-based meat with better protein bioavailability to prevent sarcopenia is an effective way, it still has some challenges. For plant-based meat products themselves, in order to make plant-based meats taste and have the same nutrients as animal meat, technology needs to make progress. Furthermore, the research and development costs are high. Because large-scale production often has problems with the stability of nutrients, the plant-based meat hasn't been widely used yet. If plant-based meat is to be commercialized, a stable supply chain and an efficient production model need to be established. For consumers, many people are affected by traditional ideas about food and prefer to choose fresh and true food, so it takes time for consumers to accept plant-based meats. In terms of supervision, related rules and standards are not clear enough, such as ingredient definitions and quality testing. Marketing is also imperfect. It's difficult for plant-based meat to be accurately targeted at the intended audience. We need to pay attention to these problems and solve them quickly. This can help promote the use of plant-based meats to better prevent and care for sarcopenia.

6. Conclusion

Currently, the primary approach to the prevention and treatment of sarcopenia remains exercise intervention combined with high-protein diets. However, the digestive and absorption capabilities of elderly individuals are weak. Plant-based meats, with their enhanced bioavailability, can precisely supplement high-quality protein, offering an advantage in nutritional adaptability. Although using plant-based meat with better protein bioavailability to prevent sarcopenia is an effective way, it still has some challenges. For plant-based meat products themselves, in order to make plant-based meats taste and have the same nutrients as animal meat, technology needs to make progress. Furthermore, the research and development costs are high. Because large-scale production often has problems with the stability of nutrients, the plant-based meat hasn't been widely used yet. If plant-based meat is to be commercialized, a stable supply chain and an efficient production model need to be established. For consumers, many people are affected by traditional ideas about food and prefer to choose fresh and true food, so it takes time for consumers to accept plant-based meats. In terms of supervision, related rules and standards are not clear enough, such as ingredient definitions and quality testing. Marketing is also imperfect. It's difficult for plant-based meat to be accurately targeted at the intended audience. We need to pay attention to these problems and solve them quickly. This can help promote the use of plant-based meats in preventing and managing sarcopenia better.

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