

Role of Proteins in Clinical Nutrition

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ABSTRACT

Clinical nutrition is a valuable tool for improving the nutritional status of patients with or at risk of malnutrition. Proteins are not stored in the human body, therefore, optimal quality and quantity of proteins in clinical nutritional products are of key importance for a successful clinical nutritional therapy. According to the recent trend in food industry and customer behaviour, plant-originated and even insect-derived proteins are seen as alternative protein sources to the traditionally used dairy proteins. However, amino acid profiles and thus, biological values of these protein sources are different from the widely used milk-derived proteins and may have a negative influence on the success of the clinical nutritional therapy. Moreover, production and safety regulations are not yet completely developed for the use of alternative protein sources.

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Introduction

Disease-related malnutrition is a common problem especially in the community where most malnutrition exists. The adverse effects of disease-related malnutrition on clinical outcomes and health care use are well documented and of particular importance in people suffering from chronic conditions such as cancer, chronic obstructive pulmonary disease, inflammatory bowel disease, conditions associated with old age, or in people undergoing surgery [1]. Disease-related malnutrition leads to decreased therapeutic efficacy, more frequent and/or more serious complications, more frequent and/or more serious infections, longer hospital stay and rehabilitation period, increased general practitioner visits, increased therapy-related costs, and ultimately to increased mortality [2-13].

Sarcopenia, the muscle loss due to increasing age or chronic diseases, is a risk factor for falls, fractures, disability, dependency, poor quality of life, increased use of hospital services, institutionalization, toxicity to many chemotherapy drugs, worsening functional decline, and mortality [14-16]. Since muscles are built of proteins, sufficient protein intake is needed to diminish the rate of, or even counter sarcopenia in patients with chronic conditions. Increased protein intake leads to increased muscle mass, stabilised or increased albumin-level, decreased rate of complications, enhanced wound healing after surgery or irradiation, and decreased rate of hospital readmissions [17-20].

The use of clinical nutrition, including oral nutritional supplements (ONS), have shown beneficial effects in patients suffering from disease-related malnutrition who are not able to satisfy their daily

nutritional needs by oral food intake. ONS decrease weight loss or even induce weight gain, improve nutritional status measured by anthropometric parameters, improve patients' quality of life, decrease the rate of complications and length and rate of hospital stays, decrease the rate of hospital readmissions, and decrease therapy- and hospital-related costs [8,13,21,22]. It has been reported that high-protein ONS formulations were able to improve handgrip strength, decrease the rate of complications, and the rate of hospital readmissions across different clinical settings and patient groups [20,22].

With the escalating global demand and concerns over traditional protein sources' sustainability and ethics, the existing protein intolerances (e.g. milk protein, egg protein, soy protein intolerance), and the changing lifestyles (e.g. vegetarian, vegan, paleo) there is a constant quest for new protein sources (e.g. new or complemented dairy proteins, and plant proteins, or algae, fungal, and bacterial proteins) that offer a high protein content with potentially decreased environmental impacts [23]. Sooner or later, this search for alternate protein sources will also reach the field of clinical nutrition. Therefore, with the emerging new protein sources, it may be time to review the available data and the potential role of alternative protein sources in clinical nutritional supplements.

Proteins in Clinical Nutritional Products

Since the aim of clinical nutrition and of the use of clinical nutritional products is to improve patients' nutritional status, and especially muscle mass, these products are supposed to contain proteins of the best available composition and in a sufficient amount to induce muscle mass synthesis in patients. For an optimal muscle build the essential amino acid content and the so-called biological value of the protein are of key importance.

Dietary protein intake stimulates muscle protein synthesis, but the magnitude of response to the dietary protein intake may significantly vary depending on the protein source. The increase in protein synthesis mostly depends on the postprandial availability of essential amino acids, particularly that of leucine. Postprandial availability of essential amino acids is regulated by several physiological processes, such as protein digestion, amino acid absorption, splanchnic amino acids retention, and skeletal muscle perfusion. Dietary factors, including amino acid composition, essential amino acid content, postprandial insulin release, skeletal muscle tissue perfusion, amino acid uptake by muscle, intramyocellular signaling, and anti-nutritional factors also largely affect the postprandial availability of amino acids [24,25]. All amino acids are necessary for protein synthesis, and lack of one or more amino acids may compromise the postprandial muscle protein synthetic response [25]. Branched-chain amino acids (BCAA) leucine, isoleucine, and valine, gained a special interest regarding muscle synthesis, since it has been shown that BCAA can activate molecular pathways that regulate translation initiation, reduce indices of whole-body and muscle protein breakdown, and transiently stimulate muscle protein synthesis rates. However, the stimulatory effect of BCAA on muscle protein synthesis rates is less than the response observed following ingestion of a complete protein source providing the full complement of indispensable amino acids [26].

To complicate the picture, proteins are usually consumed as part of a meal or a product, thus being co-digested with carbohydrates and fats that may modulate protein digestion, absorption, and, ultimately, postprandial amino acid availability [24]. Amino acid uptake has been shown higher in the presence of fat, thus, co-ingestion of proteins and fats should provide a beneficial effect for protein utilization [27].

Since 2011, there has been considerable global research effort to improve the understanding of the quality of different proteins [28]. According to the recommendations of the Food and Agriculture Organization of the United Nations (FAO) published in 2013, a new protein quality measure named Digestible Indispensable Amino Acid Score (DIAAS) has been created to replace the previously used Protein Digestibility Corrected Amino Acid Score (PDCAAS) [29]. Due to the variables used (e.g. type of digestibility measure, amino acid digestibility vs crude protein digestibility, lysine availability, non-truncation of score), DIAAS should accurately predict the amount of absorbed first-limiting amino acid supplied in relation to the requirement for that amino acid, and the amount of utilizable amino acids, provided that the protein requirement is met by dietary intake [28]. A protein source reaching a DIAAS of 100 or above indicates that none of its amino acids is limiting and this sole protein source should be able to provide a quantity of amino acids that meet physiological requirements [30].

Animal-Derived Proteins

Dairy and Meat Proteins

Currently, the most widely used proteins in clinical nutritional products are dairy proteins (milk protein, casein, and whey protein), though due to the changing lifestyles and certain protein intolerances, some products already contain plant proteins only.

According to the results of numerous studies on the postprandial muscle protein synthesis response to dairy and meat proteins, there is a robust increase in muscle protein synthesis after the intake and digestion of animal-derived proteins. This increase is mainly attributed to the rapid rise in the plasma essential amino

acids levels, particularly in the level of leucine [25].

The percentage essential amino acid content of animal-based proteins is generally high and similar to that of the human muscle [25]. According to a comparison study, of the animal-based proteins, whey protein has the highest essential amino acid content of 43%, while milk protein (39%) and calcium caseinate (38%) provide an intermediate and casein (34%) and egg (32%) a lower essential amino acid content, but all these proteins have an essential amino acid content well above the World Health Organization (WHO)/FAO/United Nations University (UNU)-recommended amino acid requirements for adults (based on a 0.66 g/body weight kg/day protein intake) [25]. When BCAA contents were investigated, animal-derived proteins including whey protein, milk protein, casein, caseinate, and egg, were similar to that of the human muscle, and they all reached the WHO/FAO/UNU requirements [25]. Amino acid profiles of animal-derived proteins were also similar to the human muscle amino acid profiles and the % of total protein values met the WHO/FAO/UNU requirements [25].

Despite being good essential and other amino acid sources, not all animal-based proteins are used in the production of ONS. Though beef protein ingestion resulted in higher postprandial serum phenylalanine levels and in similar myofibrillar protein synthesis rates compared to casein, milk proteins are mainly used in ONS since besides being good essential amino acid source they act as proteins that are suitable for the new required technological processes [31,32]. Among different animal- and plant-protein sources, casein and pork have the highest DIAAS value, thus have the greatest ability to supply suitable amino acid quantities [30].

Collagen

Collagen is one of the structural proteins in the human body, mainly found in skin, nails, hair, cartilage, tendons, and bones. It also plays a crucial role in tissue repair / wound healing. Collagens from different sources (bovine, fish) are available for the food industry, but their role in clinical nutrition is still under establishment. Collagens are composed of 19 different amino acids [33]. They are further characterized by their atypical amino acid composition: by a high proline and glycine content, and the absence of cysteine [33]. Since they completely lack one of the EAAs, tryptophane, their assigned DIAAS value is 0 and therefore, they are regarded as low-quality proteins [34,35]. However, due to their containing a unique amino acid, hydroxyproline, that is one of the building blocks of collagens in animals, their role in different clinical conditions is being widely investigated. According to clinical data, supplementation with collagen improves wound healing, skin aging, bone mineral density and osteoarthritis and may merit further investigation in the therapy of different skin conditions [36-39]. According to nutritional studies, supplementation of food with collagen results in no significant decrease of palatability [40,41].

Collagen blended with other proteins may be used in ONS, especially when wound healing or other conditions also need nutritional support. When using fish-derived collagen, its capacity to induce allergic reaction in fish-allergic patients must be taken into consideration [31,42].

Egg White Protein

Egg white (mainly composed of albumin) contains all the essential amino acids and has a DIAAS value of 1.01 thus being able to provide all the necessary amino acids required by the body [30,43,44].

Egg protein has a lower essential amino acid content among animal-derived proteins but has an amino acid profile similar to that of the human muscle, and provide amino acids, essential amino acids, and BCAA contents meeting WHO/FAO/UNU requirements [25]. In clinical studies, egg albumin-based supplement significantly improved serum albumin and was associated with a trend to increased anthropometric parameters and improved Subjective Global Assessment evaluation in dialyzed patients, and improved albumin level in bed-ridden elderly patients [43,44].

Despite its favourable physiological effects, flavouring egg white to meet taste requirements as a food has been a difficult challenge, therefore, egg white is not yet widely used as a protein source in ONS [45].

Plant Proteins

An awareness of health, sustainability, and moral concerns, leads consumers to change their lifestyles, thus, switch from animal-derived food to the plant-based food that also translates into the ONS industry [46]. Moreover, allergies to milk proteins and egg white also raise the need to have ONS products with other protein sources. Plant proteins are already being investigated and used in different foods and products including ONS. Of the investigated plant-based proteins, soy (27%), brown rice (28%), pea (30%), corn (32%), and potato (37%) meet the WHO/FAO/UNU requirements for essential amino acids, but these values are lower than those seen in animal-derived proteins. The essential amino acid contents of oat (21%), lupin (21%), wheat (22%), hemp (23%), are below the WHO/FAO/UNU amino acid requirements, meaning, that the essential amino acid requirement would not be met when one of these proteins would be the only protein source consumed. Except for potato protein, the BCAA contents were lower in plant-based when compared to animal-based proteins and did not reach the WHO/FAO/UNU requirements. Of other essential amino acids, lysine and methionine contents are particularly low in plant-based proteins compared to animal-based and human skeletal muscle proteins [25].

DIAAS values of plant-based proteins are also lower that of the animal-derived proteins, thus, a higher quantity of these proteins should be consumed to meet the essential amino acids requirements established by the WHO/FAO/UNU [30]. To translate the higher quantities into numbers, it has been calculated that 25 g whey protein, 28 g milk protein or caseinate, or 32 g casein should be consumed to provide the same amounts of essential amino acids. The required amounts of various plant-based proteins for the same essential amino acids quantity ranges from 30 g (potato) to 50 g (lupin), while the required amount for total egg consumption is 34 g [25]. In case of ONS, the amount to be consumed is critical, since the lower the daily volume to be consumed, the higher the adherence of patients that directly affect the success of the nutritional therapy [47]. Therefore, the consumption of higher amounts of proteins would create obstacles for patients' adherence and thus, for therapeutic success.

To overcome the required higher consumption, the use of multiple protein sources would be beneficial, since they would provide a more balance amino acid profile. Another solution is the fortification of plant-based proteins with methionine, lysine, and/or leucine [48]. Taste is a crucial character for patients requiring ONS – patients show preference for milk-protein-based products since they have less acidity and less aftertaste [49]. Plant-based proteins are often reported to have negative astringency, dry perception in texture, bitter off-tastes, and grassy, green, and beany off-aromas while leucine has a somewhat unpleasant taste, lysine tastes salty

with some bitter components, and methionine is a very repulsive, metallic, mineral substance judged to be bitter by some subjects [50,51]. Therefore, the use of plant-based proteins in ONS and their fortification with leucine, lysine, and methionine provide additional challenges that must be overcome.

Selective breeding of plants to improve amino acid profiles may also be an option but it takes time to produce such plants, thus, they currently provide no alternative for proteins to be used in ONS [48].

Beside macro- and micronutrients, plant-based foods and proteins also can contain significant amounts of bioactive compounds, some of which are thought to restrict the bioavailability of key nutrients. These compounds, that may be heat-resistant or heat-sensitive, are called antinutrients [52]. The heat-stable antinutrients that may have significance in ONS, are phytic acid, tannins, alkaloids and saponins [53]. Phytic acid can form insoluble complexes with copper, zinc, iron, calcium, and manganese, thus decreasing the absorption of these minerals. Phytic acid also chelate proteins reducing their bioavailability. Saponins decrease protein, mineral, and vitamin absorption, may cause hypoglycaemia, and severe diarrhoea – the latter further decreasing the efficacy of macronutrients provided in ONS. Tannins inhibit hydrolytic enzymes including enzymes participating in digestion. This inhibition leads to the decrease of protein digestibility and amino acid absorption, resulting in diminished utilization of proteins [54].

Some safety concerns are also raised in the scientific literature regarding the bioactive compounds of plants and plant-based food, especially soy. For example, for human studies investigating the effects of foods containing goitrogen on thyroid health some conflicting results are still available. Evidence suggests that suboptimal iodine status may potentiate the negative impacts of dietary goitrogens on thyroid health. For those with thyroid disease, or at higher risk of thyroid disease, long-term daily intake of progoitrin-rich items may decrease iodine uptake [52]. Phytoestrogens have structural similarities to 17- β -oestradiol, the primary sex hormone in females, thus can bind to oestrogen receptors and modulate estrogenic activity [54]. In healthy preschool children (3-6 years old), soy intake negatively correlated to oestradiol and estrone levels in boys, and positively correlated to testosterone and 5-androstene-13 β ,17 α -diol in girls meaning, that soy intake may have an effect on sex steroids metabolism in young children [55]. Sex hormone alterations have been found also in the late stages of childhood, and goitrogenic effects in children with hypothyroidism due to dietary phytoestrogens [56]. In ovariectomised atherosclerotic monkeys, dietary soy intake together with hormone therapy had negative main effects on blood flow, coronary output, and stroke volume during myocardial ischemia / reperfusion injury [57]. Current scientific data are still unable to predict the final effect of phytoestrogens in the breast, and the efficacy of anti-oestrogen adjuvant therapy after breast cancer suggests the possibility that the use of a weak oestrogen could be harmful in patients after a hormone-dependent cancer at the stage of micrometastases [54]. In premenopausal and postmenopausal women, the reported impacts of dietary phytoestrogens on hormones are still inconsistent [56]. Soy protein and isoflavones have not been shown to lessen vasomotor symptoms of menopause, and results are mixed regarding soy's ability to slow postmenopausal bone loss [58]. Due to the controversies around the role of soy oestrogens, soy foods and soy extracts are not recommended for the nonhormone treatment of vasomotor symptoms in menopause by the North American Menopause Society [59].

The evidence regarding phytoestrogens is still controversial, with a large amount of heterogeneity between studies. The advantages / adverse effects and the safety of plant-based proteins containing bioactive compounds still need to be unambiguously established for their use in ONS.

Insect Proteins

Insects are regarded as traditional food in many parts of the world, and farmed insects are increasingly used as a more sustainable and circular alternative protein source for food [60,61].

Proteins represent the main component of the nutrient composition of insects. In a study investigating the amino acid compositions of different insect species proteins, all edible insects met the amino acid requirements of adults for methionine and methionine + cysteine. The Hemiptera order was low in isoleucine, lysine, phenylalanine + tyrosine, and valine and the order Diptera had a low leucine and cysteine content [60]. In another study, insect proteins were shown to be low in methionine and cysteine and high in lysine and threonine [62]. Despite some conflicting data, most edible insects were found to provide satisfactory amounts of the required essential amino acids [60]. However, besides the essential amino acid content, some other characteristics of insect protein may significantly influence their quality and use as protein source. For example, in weanling rats, proteins from cricket meals were equal or superior to soy protein as an amino acid source, while in rats spent silkworm pupae protein showed a significant lower quality than casein despite a higher chemical score regarding food intake, weight gain, protein digestibility, protein efficiency ratio, and net protein utilization. The lower quality was attributed to the bad odour of the silkworm pupae meal and the growth depressing pupal hormone ecdysone [60].

Before insect-derived proteins can routinely be used in human food products, some knowledge gaps regarding ecology, technology, economy and health must still be covered [63]. Health concerns are of top priority within these research areas. The most common chemical hazards in insect-derived nutrients include the presence of heavy metal (cadmium, arsenic, lead, mercury) and the residues of veterinary drugs (antibiotics from substrates), toxins that originate from natural production or accumulation, halogenated organic compounds and agricultural waste products from plant substrates (pesticides, dioxins). Regarding microbiological hazards, zoonoses were seen as the major issue. However, a greater risk is posed by the insects' microflora that may result from inappropriate breeding and the failure to comply with basic sanitary recommendations concerning processing and transport. In a study examining 38 samples subjected to various types of thermal processing, Class I products failed to meet many limits for bacterial count of hygienic criteria for edible insects proposed by Belgium and the Netherlands, despite the absence of classical food pathogens. Dried and powdered insects and dust particles contained *B. cereus*, coliform bacteria, *Serratia liquefaciens*, *Listeria ivanovii*, *Aspergillus* spp., *Penicillium* spp. and *Cryptococcus neoformans* [63].

Undesirable allergic reactions to insect proteins also pose a safety hazard for their use in human foods. Allergy to insect protein may be a primary reaction (e.g. to chitin, troponin, arginine kinase, paramyosin) or a cross-reaction with other allergens (e.g. mealworm beetle protein and crustaceans and house dust mites, or grasshopper, cockroach, common fruit fly and prawns) [63].

Similarly to plant proteins, the anti-nutrients phytates, tannins and saponins are also present in insect products, resulting in the

diminished absorption and utilization of calcium, iron, magnesium, zinc, and proteins provided [63].

To incorporate insect-derived proteins and insect-derived food products in the European diet and dietary products, some additional barrier should be overcome. Appearance and taste are the main barriers against consuming insect-derived products - insect foods simply do not adhere to the image of Western consumers' food, and due to the lack of experience with insects as food, entomophagy is often associated with the prejudice of uncleanness and health risks. Neophobia may also play a role, though with regards to insect consumption, it rather originates from the nature of the food and not from the novelty itself. Providing information about the nutritional value and especially on the essential amino acids daily requirements would not result in a significant increase of acceptance of insect food, while information about the future challenge of food security seems to play a significant role in increasing insect foods acceptance. Peers' recommendations together with familiarity with the food item may also have a positive effect on insect foods consumption. The negative prejudices may also partly originate from the lack of cuisine-related aspects - insect foods should mimic those already incorporated in Western diets. Processing insect-derived food beyond recognition, using them as ingredients instead of as meals, and their incorporation in savoury and salty foods instead of sweet-tasting ones may also induce higher acceptance [64].

As a new type of livestock animal in the European Union (EU), farmed insects are subject to general legislation applicable to all food and feed production, as well as certain provisions that are more specific [61]. The appropriate legislation framework for insect-derived food products including the definition of insect-specific limits for a variety of hazards, both for substrate and insect biomass for food/feed, taking into account the scientific evidence on unavoidable carry-over from substrates and the potential adverse effects on insect welfare should be established [61].

Single-Cell Proteins-Microalgae

With the search for sustainable, scalable, and healthy protein alternatives, focus has been placed on microalgae, unicellular photosynthetic organisms offering high nutritional value, environmental benefits, and diverse food system application [65]. Microalgae have a high protein content, with many species yielding between 40% and 70% protein by dry weight, similarly to animal-derived sources [65]. Though numerous microalgae species contain all the essential amino acids humans require, their essential amino acids content (23%) is below the WHO/FAO/UNU amino acid requirements, with a low leucine content of 5.1%, and with some species containing practically no methionine [25,65,66]. For the same intake of essential amino acids, 48 g microalgae protein should be consumed compared to the 28 g consumption required for milk protein [25]. DIAAS values of several microalgae species (*Tetraselmis chui*, *Chlorella vulgaris* and *Microchloropsis gaditana*) are between 54 and 84 compared to the higher DIAAS values of milk protein and egg protein (117 and 101, respectively) [30]. Though microalgae protein offers a valuable and ecologically efficient alternative for global nutritional and sustainability demands, the remaining challenges of scalability, sensory optimisation, and regulatory framework must still be optimized [65,67].

Summary

ONS are used to ameliorate the nutritional status and improve the muscle mass of patients suffering from age- or chronic disease-related malnutrition and/or sarcopenia. High-protein ONS increase

handgrip strength, decrease the rate of complications, and the rate of hospital readmissions across different clinical settings and patient groups, but the quality of protein in ONS is of key importance to achieve these clinical benefits. Collagens may be used in combination with other complete proteins when their positive effects on wound healing, skin conditions, osteoarthritis, and bone mineral density are called for. Plant-based proteins are an emerging alternative to dairy proteins due to the customer behavioural change and the allergies towards dairy proteins, but the challenges posed by their lower essential amino acid content, less favourable amino acid composition (lower DIASS), antinutrient content must be overcome, and the questions regarding their safety in certain patient populations must convincingly be clarified. Insect proteins and microalgae protein are newly discovered and considered options for sourcing proteins. For microalgae protein use, beside the challenges of optimized essential amino acid content and amino acid profile, a regulatory framework for their application must also be developed. Insect proteins could also provide an alternative once their safety, appropriate breeding and processing regulations, cultural acceptance, and the regulatory framework for their use in ONS are satisfactorily established.

Currently, dairy proteins provide the best protein sources in ONS due to their high essential amino acids content, their amino acid composition very similar to that of the human muscle, high bioavailability (DIASS), and better suitability for the technological processes.

References

- Volkert D, Beck AM, Cederholm T, Cruz-Jentoft A, Goisser S, et al. (2019) ESPEN guideline on clinical nutrition and hydration in geriatrics. *Clin Nutr* 38: 10-47.
- Dewys WD, Begg C, Band PR, Bennett JM, Bertino JR, et al. (1980) Prognostic effect of weight loss prior to chemotherapy in cancer patients. *Am J Med* 69: 491-497.
- Rickard KA, Detamore CM, Coates TD, Grosfeld JL, Weetman RM, et al. (1983) Effect of nutrition staging on treatment delays and outcome in stage IV neuroblastoma. *Cancer* 52: 587-598.
- Andreyev HJN, Norman AR, Oates J, Cunningham D (1998) Why do patients with weight loss have a worse outcome when undergoing chemotherapy for gastrointestinal malignancies? *Eur J Cancer* 34: 503-509.
- Jagoe RT, Goodship THJ, Gibson GJ (2001) The influence of nutritional status on complications after operations for lung cancer. *Ann Thorac Surg* 71: 936-943.
- Ek A-C, Unosson M, Larsson J, von Schenk H, Bjurulf P (1991) The development and healing of pressure sores related to the nutritional state. *Clin Nutr* 10: 245-250.
- Edington J, Boorman J, Durrant ER, Perkins A, Giffin CV, et al. (2000) Prevalence of malnutrition on admission to four hospitals in England. *Clin Nutr* 19: 191-195.
- Braunschweig C, Gomez S, Sheean PM (2000) Impact of declines in nutritional status on outcomes in adult patients hospitalized for more than 7 days. *J Am Diet Assoc* 100: 1316-1322.
- de van der Schueren M, Elia M, Gramlich L, Johnson MP, Lim SI, et al. (2014) Clinical and economic outcomes of nutrition interventions across the continuum of care. *Ann N Y Acad Sci* 1321: 20-40.
- Volkert D, Beck AM, Faxen-Irving G, Frühwald T, Hooper L, et al. (2024) ESPEN guideline on nutrition and hydration in dementia - Update 2024. *Clin Nutr* 3: 1599-1626.
- Ross PJ, Ashley S, Norton A, Priest K, Waters JS, et al. (2004) Do patients with weight loss have a worse outcome when undergoing chemotherapy for lung cancers? *Br J Cancer* 90: 1905-1911.
- Hoong JM, Ferguson M, Hukins C, Collins PF (2017) Economic and operational burden associated with malnutrition in chronic obstructive pulmonary disease. 36: 1105-1109.
- Loser C (2010) Malnutrition in hospital – the clinical and economic implications. *Dtsch Arztebl Int* 107: 911-917.
- Woo J (2017) Sarcopenia. *Clin Geriatr Med* 33: 305-314.
- Ryan AM, Power DG, Daly L, Cushen SJ, Bhuachalla EN, et al. (2016) Cancer-associated malnutrition, cachexia and sarcopenia: the skeleton in the hospital closet 40 years later. *Proc Nutr Soc* 75: 199-211.
- Matera MG, Page C, Cazzola M (2025) Sarcopenia as a treatable trait in COPD: From mechanisms to management. *Respir Med* 248: 108401.
- de Luis DA, de la Fuente B, Izaola O, Martin T, Cuellar L, et al. (2015) Clinical effects of a hypercaloric and hyperproteinic oral supplement enhanced with w3 fatty acids and dietary fiber in postsurgical ambulatory head and neck cancer patients. *Nutr Hosp* 31: 759-763.
- Jensen Mb, Hesselov I (1997) Randomization to nutritional intervention at home did not improve postoperative function, fatigue or well-being. *Br J Surg* 84: 113-118.
- Bauer JD, Capra S (2005) Nutrition intervention improves outcomes in patients with cancer cachexia receiving chemotherapy-a pilot study. *Support Care Cancer* 13: 270-274.
- Cawood AL, Elia M, Stratton RJ (2012) Systematic review and meta-analysis of the effects of high protein oral nutritional supplements. *Ageing Res Rev* 11: 278-296.
- Freijer K, Tan SS, Koopmanschap MA, Meijers JMM, Halfens RJG et al. (2013) The economic costs of disease related malnutrition. *Clin Nutr* 32: 136-141.
- Cawood AL, Burden ST, Smith T, Stratton RJ (2023) A systematic review and meta-analysis of the effects of community use of oral nutritional supplements on clinical outcomes. *Ageing Res Rev* 88: 101953.
- Pereira L, Cotas J, Goncalves AM (2024) Seaweed proteins: A step towards sustainability? 16: 1123.
- Gorissen SHM, Remond D, van Loon LJC (2015) The muscle protein synthetic response to food ingestion. *Meat Sci* 109: 96-100.
- Gorissen SHM, Crombag JJR, Senden JMG, Huub Waterval WA, Bierau J, et al. (2018) Protein content and amino acid composition of commercially available plant-based protein isolates. *Amino Acids* 50: 1685-1695.
- Kaspy MS, Hannaian SJ, Bell ZW, Churchward-Venne TA (2024) The effects of branched-chain amino acids on muscle protein synthesis, muscle protein breakdown and associated molecular signalling responses in humans: an update. *Nutr Res Rev* 37: 273-286.
- Elliot TA, Cree MG, Sanford AP, Wolfe RR, Tipton KD (2006) Milk ingestion stimulates net muscle protein synthesis following resistance exercise. *Med Sci Sports Exerc* 38: 667-674.
- Moughan PJ, Lim WXJ (2024) Digestible indispensable amino acid score (DIAAS): 10 years on. *Front Nutr* 11: 1389719.
- (2013) Dietary protein quality evolution in humans. Report of an FAO expert consultation <https://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf>.
- Herreman L, Nommensen P, Pennings B, Laus MC (2020) Comprehensive overview of the quality of plant- and animal-

- sourced proteins based on the digestible indispensable amino acid score. *Food Sci Nutr* 8: 5379-5391.
31. Burd NA, Gorissen SH, van Vliet S, Snijders T, van Loon LJC (2015) Differences in postprandial protein handling after beef vs. milk ingestion during postexercise recovery: a randomized controlled trial. *Am J Clin Nutr* 102: 828-836.
 32. D'Incecco P, Rosi V, Cabassi G, Hogenboom JA, Pellegrino L (2018) Microfiltration and ultra-high-pressure homogenization for extending the shelf-storage stability of UHT milk. *Food Res Int* 107: 477-485.
 33. Gauza-Wlodarczyk M, Kubisz L, Wlodarczyk D (2017). Amino acid composition in determination of collagen origin and assessment of physical factors effects. *Int J Biol Macromol* 104: 987-991.
 34. Brook MS, Scaife P, Bass JJ, Cegielski J, Watanabe S, et al. (2021) A collagen hydrolysate/milk protein-blend stimulates muscle anabolism equivalently to an isoenergetic milk protein-blend containing a greater quantity of essential amino acids in older men. *Clin Nutr* 40: 4456-4464.
 35. Tormasi J, Benes E, Lengyel Konya E, Berki M, Abranko L (2025) Evaluation of protein quantity and protein nutritional quality of protein bars with different protein sources. *Sci Rep* 15: 9388.
 36. Knefeli H-C, Durani B (2017) Improved wound healing after oral application of specific bioactive collagen peptides. *Nutrafoods* 16: 9-12.
 37. Choi FD, Sung CT, Juhasz MLW, Atanaskova Mesinkovsk N (2019) Oral collagen supplementation: A systematic review of dermatological applications. *J Drugs Dermatol* 18: 9-16.
 38. König D, Oesser S, Scharla S, Zdzieblik D, Gollhofer A (2018) Specific collagen peptides improve bone mineral density and bone markers in postmenopausal women—A randomized controlled study. *Nutrients* 10: 97.
 39. Xu R, Wu J, Zheng L, Zhao M (2023) Undenatured type II collagen and its role in improving osteoarthritis 91: 102080.
 40. Giglio BM, Schincaglia RM, da Silva AS, Fazani ICS, Monteiro PA, et al. (2019) Whey protein supplementation compared to collagen increases blood nesfatin concentrations and decreases android fat in overweight women: A randomized double-blind study. *Nutrients* 11: 2051.
 41. Hastaoglu F, Hastaoglu E, Baglam N, Tas IN (2023) Sensorial and nutritional properties of a collagen-fortified snack bar designed for the elderly. *Nutrients* 15: 3620.
 42. Kalic T, Kamath SD, Ruethers T, Taki AC, Nugraha R, et al. (2020) Collagen - An important fish allergen for improved diagnosis. *J Allergy Clin Immunol Pract* 8: 3084-3092.
 43. Detarun P, Srichamnaturakit V, Isaramalai S, Rakpanusit T (2022) Enhancing nutritional care with egg white supplementation on serum albumin level for home-based bed-ridden elderly patients. *Funct Food Health Dis* 12: 308-324.
 44. Gonzalez-Espinoza L, Gutierrez-Chavez J, Martin del Campo FM, Martinez-Ramirez HR, Cortes-Sanabria L, et al. (2005) Randomized, open label, controlled clinical trial of oral administration of an egg albumin-based protein supplement to patients on continuous ambulatory peritoneal dialysis. *Perit Dial Int* 25: 173-180.
 45. Matsuoka R, Kurihara H, Nishijima N, Oda Y, Handa A (2019) Egg white hydrolysate retains the nutritional value of proteins and is quickly absorbed in rats. *Scientific World Journal* 2019: 5475302.
 46. da Silva Matos J, Zambé Azevedo P, Ely Granato Costa J, de Fatima Mendes Justino H, Lamarao CV, et al. (2024) UHT processing in the context of plant-based beverages: A scientific review on product characteristics and the functional role of plant proteins. *Food Chem Adv* 5: 100848.
 47. Hubbard GP, Elia M, Holdoway A, Stratton RJ (2012) A systematic review of compliance to oral nutritional supplements. *Clin Nutr* 31: 293-312.
 48. van Vliet S, Burd NA, Loon LJC (2015) The skeletal muscle anabolic response to plant- versus animal-based protein consumption. *J Nutr* 145: 1981-1991.
 49. Darmon P, Karsegard VL, Nardo P, Dupertuis YM, Pichard C (2008) Oral nutritional supplements and taste preferences: 545 days of clinical testing in malnourished in-patients. *Clin Nutr* 27: 660-665.
 50. Sarkar A (2024) Oral astringency in plant proteins: An underestimated issue in formulating next-generation plant-based foods. *Ann Rev Food Sci Technol* 15: 103-123.
 51. Schiffman SS, Dackis C (1975) Taste of nutrients: amino acids, vitamins, and fatty acids. *Perception Psychophysics* 17: 140-146.
 52. Petroski W, Minich DM (2020) Is there such a thing as anti-nutrients? A narrative review of perceived problematic plant compounds. *Nutrients* 12: 2929.
 53. Manzanilla-Valdez ML, Ma Z, Mondor M, Hernandez-Alvarez AJ (2024) Decoding the duality of antinutrients: assessing the impact of protein extraction methods on plant-based protein sources. *J Agric Food Chem* 72: 12319-12339.
 54. This P, De la Rochefordiere A, Clough K, Fourquet A, Magdelenat A, et al. (2001) Phytoestrogens after breast cancer. *Endocr Relat Cancer* 8: 129-134.
 55. Wada K, Nakamura K, Masue T, Sahashi Y, Ando K, et al. (2011) Soy intake and urinary sex hormone levels in preschool Japanese children. *Am J Epidemiol* 173: 998-1003.
 56. Dominguez-Lopez I, Yago-Aragon M, Salas-Huetos A, Tresserra-Rimbau A, Hurtado-Barroso S (2020) Effects of dietary phytoestrogens on hormones throughout a human lifespan: A review. *Nutrients* 12: 2456.
 57. Suparto IH, Williams JK, Fox JL, Yusuf JTL, Sajuthy D (2008) Effects of hormone therapy and dietary soy on myocardial ischemia/reperfusion injury in ovariectomized atherosclerotic monkeys. *15: 256-263.*
 58. Sacks FM, Lichtenstein A, Van Horn L, Harris W, Kris-Etherton P, et al. (2006) Soy protein, isoflavones, and cardiovascular health. *Circulation* 113: 1034-1044.
 59. NAMS Position Statement (2023) The 2023 nonhormone therapy position statement of The North American Menopause Society. *Menopause* 30: 573-590.
 60. Rumpold BA, Schlüter OK (2013) Nutritional composition and safety aspects of edible insects. *M57:802-823ol Nutr Food Res* 57: 802-823.
 61. Meijer N, Safitri RA, Tao W, Hoek-Van den Hil EK (2025) Review: European Union legislation and regulatory framework for edible insect production – Safety issues. *Animal* 19: 101468.
 62. DeFoliart GL (1999) Insects as food: Why the Western attitude is important. *Annu Rev Entomol* 44: 21-50.
 63. Skotnicka M, Karwowska K, Klobukowski F, Borkowska A, Pieszko M (2021) Possibilities of the development of edible insect-based foods in Europe. *Foods* 10: 766.
 64. Mancini MC, Antonioli F (2022) Italian consumers standing at the crossroads of alternative protein sources: Cultivated meat, insect-based and novel plant-based foods. *Meat Sci* 193: 108942.
 65. Prates JAM (2025) Unlocking the functional and nutritional potential of microalgae proteins in food systems: A narrative review. *Foods* 14: 1524.

66. Torres-Tiji Y, Fields FJ, Mayfield SP (2020) Microalgae as a future food source. *Biotechnol Adv* 41: 107536.
67. Qazi WM, Ballance S, Kousoulaki K, Uhlen AK, Kleinegriss DMM, et al. (2021) Protein enrichment of wheat bread with microalgae: *Microchloropsis gaditana*, *Tetraselmis chui* and *Chlorella vulgaris* *Foods* 10:3 078.

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