Dean&Francis
ISSN 2959-409X

Nutritional Evaluation of Alternative Proteins vs. Animal Proteins: From Composition and Bioavailability to Consumer Perception and Enhancement Methods

Dingkun Guo[1, *]

[1]College of Agricultural and Environmental Sciences, University of California, Davis, 95616, America
*Corresponding author: dkguo@ucdavis.edu

Abstract:
In recent years, due to the continuous growth of the global population, especially in developing regions where dietary habits are changing, and the general shift towards higher protein intake, the demand for meat products has been steadily increasing. However, traditional animal husbandry remains the main source of global meat supply and has led to increasingly prominent environmental issues. These issues include significant greenhouse gas emissions, which are the main cause of global climate change. In the urgent context, alternative proteins such as plant-based proteins from soybeans, peas, and other crops, fungal proteins, and insect proteins from crickets and whiteflies have gradually become important ways to alleviate resource pressure. Due to their favorable environmental characteristics, including a smaller carbon footprint and lower resource consumption compared to traditional animal husbandry, these alternative proteins have attracted increasing attention from academia and industry in recent years, and have shown enormous market growth potential. This article provides a systematic review of key literature on alternative proteins published both domestically and internationally over the past decade. It focuses on comparing the essential differences between alternative and traditional animal proteins in three aspects: nutritional composition (such as amino acid profile and micronutrient content), bioavailability (i.e. the efficiency of nutrient absorption by the human body), and consumer perception (such as acceptance levels and existing misunderstandings). In addition, this article also analyzes relevant strategies for improving alternative proteins in the future, such as gene editing technology, amino acid complementarity, and biotechnology.

Keywords: Alternative proteins; Nutritional evaluation; Bioavailability; Consumer perception; Enhancement methods.

1. Introduction

Driven by global population growth and dietary upgrades, the increasing demand for meat poses severe environmental challenges to traditional animal protein production: about one-third of the world's land is used for animal husbandry, but the greenhouse gas emissions generated by animal husbandry account for 14.5% of anthropogenic greenhouse gas emissions and consume 60% of the biomass harvested globally [1]. Therefore, the issue of sustainable development has become increasingly important. Under such environmental conditions, alternative proteins with high resource efficiency and low carbon emissions (AP, including plant, insect, and fungal proteins) have become the key to sustainable food systems. However, the core controversy surrounding alternative proteins still exists: animal protein, as a long-term staple of comprehensive amino acids, has high bioavailability and nutrients such as vitamin B12. Currently, due to the nutritional deficiencies of alternative proteins, they do not have the ability to compete with animal protein in the market in a short period of time.

Therefore, this paper aims to screen high-quality research over the past 10 years by comparing plants (soybeans, peas), insects (yellow mealworms, crickets), fungal proteins and animal proteins (beef); And systematically evaluate the nutritional equivalence of alternative proteins and animal proteins using thematic induction method, in order to clarify the advantages and disadvantages of alternative proteins at present. At the same time, provide theoretical support for the reinforcement and processing optimization of alternative proteins to enhance nutrition through the study of relevant technical articles.

2. Comparison of Nutritional Components

2.1 Protein Content

Different types of animal proteins and substitute proteins have differences in protein content, and animal proteins are generally higher.

Among them, the protein density of processed animal proteins is particularly prominent, such as whey protein (dairy derived) with a content of up to 80g/100g, which is currently the source of animal protein with high protein content; And the common whole meat animal protein in daily life, such as beef with a content of 26-28g/100g and chicken breast meat with a content of about 23-25g/100g, belongs to the above average level [2]. Among alternative proteins, insect protein performs the most outstandingly. Taking mealworms as an example, their protein content can reach 60-65g/100g , which is significantly higher than that of whole meat animal proteins such as beef and chicken breast; Fungal proteins (e.g., mycelial protein) range from 30 to 40 g/100 g [3].In plant protein, soybean protein has a relatively high content, about 40-41g/100g, which is also higher than beef [4]. However, other plant substitute proteins such as pea protein and oat protein generally have lower content than insect protein and soybean protein mentioned above.

Overall, in terms of protein content, processed animal proteins such as whey protein, insect proteins such as mealworms, and soy protein are currently the categories with higher protein density, each with its own advantages. However, most common plant substitute proteins and whole meat animal proteins are relatively low.

2.2 Essential Amino Acid Composition

In terms of protein richness, animal proteins generally have a relatively complete amino acid composition. Animal protein generally contains all essential amino acids, which meet the nutritional needs of the human body. The protein digestibility corrected amino acid score (PDCAAS) of beef is 1.00, which is the highest among all digestibility rates [5]. In contrast, alternative proteins generally lack specific essential amino acids. As for soy protein, due to its low methionine content, the PDCAAS of soy protein is only 0.85. The PDCAAS of insect protein is generally the lowest among alternative proteins, while the protein score of crickets is only 0.65. These ratings reflect the current differences in protein richness between alternative proteins and animal proteins [6].

3. Biological Utilization and Digestive Mechanisms

3.1 Mineral Absorption Efficiency

In the comparison of mineral utilization efficiency between animal protein and substitute protein, minerals such as iron and zinc in animal protein have relatively high bioavailability. In plant proteins, mineral absorption is inhibited due to the constraints of some anti nutritional factors such as phytic acid and oxalic acid; For example, the RBV of iron in soybeans is only 5-10% [7]. In contrast, the absorption efficiency of animal protein has not been affected. For example, the relative bioavailability (RBV) of iron in beef is about 20% -30%, and the mineral utilization rate of animal protein is significantly higher than that of substitute protein [8].

ISSN 2959-409X

3.2 Effects of Anti-Nutritional Factors

In the practical application of alternative proteins, anti-nutritional factors are a key issue that limits their nutritional efficiency, especially in plant and insect proteins. They directly reduce the body's absorption of these proteins and nutrients, which is a major disadvantage compared to animal proteins. For plant proteins, phytic acid and protease inhibitors can cause significant harm. Phytic acid, which is common in plant seeds, binds to minerals such as zinc, iron and calcium to form insoluble phytic acid complexes. These cannot be broken down by digestive enzymes, hindering mineral absorption and wasting nutrients. At the same time, protease inhibitors bind to digestive enzymes, inactivating them, slowing protein digestion, and even causing bloating [9]. In insect proteins, despite being rich in nutrients, chitin still poses a digestive challenge. As part of the insect exoskeleton, chitin has benefits but cannot be broken down by human chitinase. Excessive unprocessed insect protein can lead to chitin accumulation in the intestines, blocking the access of nutritional enzymes and causing discomfort [10]. Due to the influence of these anti-nutritional factors, the nutrient absorption rate of alternative proteins is not as ideal as that of animal proteins.

4. Consumer Perception Differences

4.1 Influence of Cultural Backgrounds

The acceptance of alternative protein sources by consumers varies depending on the cultural background of the region. In Western culture, insects do not appear as food, and consumers generally have a low acceptance of insect protein. According to relevant surveys, only 20% of consumers are willing to try insect protein [11]. In contrast, for the Asian region dominated by Southeast Asia, insects are a traditional part of the diet, and people are generally more accepting of insect protein, with nearly 50% of the respondents willing to try insect protein [12]. This significant difference mainly comes from the traditional cognitive status of alternative proteins in culture and the differences in dietary habits in different regions.

4.2 Factors of Age and Income

The age and income of consumers can also affect their perception of alternative proteins. From an age perspective, compared to the elderly population, teenagers have a higher acceptance of new technologies and innovations, with a high acceptance rate of 58% among young people in relevant surveys. In contrast, due to the influence of traditional dietary concepts, the acceptance rate of alternative proteins among middle-aged and elderly people is relatively lower, only 32% [13].

For the impact on income, high-income individuals prioritize health and sustainability in their protein intake, therefore they have a higher acceptance of alternative protein products. Due to price constraints, the relatively high cost of alternative protein products greatly limits the purchasing willingness of low-income groups [14].

5. Nutrient Fortification Methods

5.1 Amino Acid Complementation

In the nutritional comparison between substitute proteins and animal proteins, an imbalance in amino acid composition is a common shortcoming. Most single substitute proteins (such as soy protein lacking methionine and quinoa protein with low lysine content) suffer from insufficient content of specific essential amino acids, which directly results in low protein bioavailability and difficulty in meeting the human body's demand for high-quality protein. Therefore, achieving amino acid complementarity by combining different alternative proteins is an efficient and low-cost strategy to address this deficiency.

Amino acid complementarity allows the mixed protein system to cover all essential amino acids, and the ratio of each amino acid is closer to human needs, thereby significantly improving the nutritional richness and quality of proteins, making them comparable to animal proteins. For example, when soy protein and quinoa protein are mixed in a ratio of 3:1, the abundant lysine in soy protein can compensate for the deficiency of quinoa protein, while the sufficient methionine in quinoa protein can supplement the shortcomings of soy protein. Under the synergistic effect of the two, the protein digestion rate corrected amino acid score(PDCAAS), an internationally recognized protein nutrition evaluation index) of the mixed protein can be improved to 0.95- this score is close to the full score of PDCAAS (1.0), which means that the mixed protein not only has a balanced amino acid composition, but also has a high digestion and absorption rate, and its nutritional quality has reached the level of high-quality animal protein [15]. This nutritional optimization method based on „combination complementarity" has strong application feasibility in the food industry, providing a practical and feasible path for the nutritional upgrade of alternative proteins.

5.2 Processing Optimization

The nutritional limitations of alternative proteins are also reflected in their bioavailability. Due to the presence of anti nutritional factors in some substitute proteins, the nutritional and mineral bioavailability of substitute proteins has also been affected to some extent. There are currently a series of processing strategies to compensate for the functional gap between them and animal proteins. For example, the techniques of squeezing and fermentation can effectively reduce anti nutritional factors and improve nutrient utilization efficiency. The literature shows that by adopting extrusion treatment, the phytic acid content in plant protein can be effectively reduced by 40-60%, which can greatly improve the absorption efficiency of iron [16]. The application of simultaneous fermentation technology not only degrades anti nutritional factors, but also produces beneficial metabolites.

5.3 Bioengineering

In biotechnology, gene editing technology provides a precise solution to the nutritional deficiency problem of protein substitution for animal proteins. Gene editing technology targets genes involved in nutrient synthesis or absorption through targeted modification. For example, in most plant and microbial proteins, the naturally scarce nutrient B12 is upregulated through CRISPR mediated genetic engineering to specifically upregulate the expression of genes related to vitamin B12 biosynthesis in yeast proteins, thereby significantly increasing their vitamin B12 content. Similarly, in plant-based alternative proteins, scientists can introduce or overexpress genes encoding iron transporters (such as ferritin related genes) in crops such as soybeans or peas; This modification not only effectively increases the total iron content of plant proteins themselves, but also enhances the bioavailability of iron, solving the problem of low absorption and utilization of iron in plant proteins by the human body [17]. These applications greatly bridge the nutritional gap between alternative proteins and animal proteins.

6. Conclusion

This study systematically compares alternative proteins and animal proteins across three dimensions: nutritional composition, bioavailability, and consumer cognition, revealing that while alternative proteins still lag significantly behind animal proteins in nutritional content and bioavailability, they hold unique advantages in advancing environmental sustainability—with technologies like genetic engineering poised to narrow this gap in the future; regarding consumer attitudes, cultural differences lead to varied perceptions, such as East Asians showing notably higher acceptance of insects as a protein source than Europeans. However, the research has limitations due to current constraints in alternative protein studies: although literature confirms the feasibility of using alternative proteins for nutritional enhancement, high costs hinder their large-scale application, technological limitations leave no mature methods to address their nutritional deficiencies (requiring more experimental data to verify the stability of their nutritional value), and inherent consumer stereotypes about alternative proteins remain hard to change quickly. For the future development of alternative proteins, the top priority is to optimize their nutritional enhancement technologies to reduce production costs and complexity, while also improving their in-vivo digestibility and nutritional composition; additionally, efforts should be made to boost consumer acceptance and revise existing marketing strategies to drive broader adoption.

References

[1] Sakadevan, K., & Nguyen, M. L. (2017). Livestock production and its impact on nutrient pollution and greenhouse gas emissions. Advances in agronomy, 141, 147-184.

[2] Baste, N. (2011). Whey protein. Scholars' Research Journal, 1(2).

[3] Christias, C., Couvaraki, C., Georgopoulos, S. G., Macris, B., & Vomvoyanni, V. (1975). Protein content and amino acid composition of certain fungi evaluated for microbial protein production. Applied microbiology, 29(2), 250-254.Gangurde, H., Chordiya, M., Patil, P., & ,

[4] Medic, J., Atkinson, C., & Hurburgh Jr, C. R. (2014). Current knowledge in soybean composition. Journal of the American oil chemists' society, 91(3), 363-384.

[5] World Health Organization. (1991). Protein Quality Evaluation: Report of the Joint FAO/WHO Expert Consultation, Bethesda, Md., USA 4-8 December 1989 (Vol. 51). Food & Agriculture Org..

[6] van den Berg, L. A., Mes, J. J., Mensink, M., & Wanders, A. J. (2022). Protein quality of soy and the effect of processing: A quantitative review. Frontiers in Nutrition, 9, 1004754.

Pizarro, F., Olivares, M., Valenzuela, C., Brito, A., Weinborn, V., Flores, S., & Arredondo, M. (2016). The effect of proteins from animal source foods on heme iron bioavailability in humans. Food chemistry, 196, 733-738.

[7] Pizarro, F., Olivares, M., Valenzuela, C., Brito, A., Weinborn, V., Flores, S., & Arredondo, M. (2016). The effect of proteins from animal source foods on heme iron bioavailability in humans. Food chemistry, 196, 733-738.

[8] Hisayasu, S., Orimo, H., Migita, S., Ikeda, Y., Satoh, K., Shinjo, S., ... & Yoshino, Y. (1992). Soybean protein isolate and soybean lectin inhibit iron absorption in rats. The Journal of nutrition, 122(5), 1190-1196.

[9] Gibson, R. S., Raboy, V., & King, J. C. (2018). Implications of phytate in plant-based foods for iron and zinc bioavailability, setting dietary requirements, and formulating programs and policies. Nutrition reviews, 76(11), 793-804.

ISSN 2959-409X

[10] Brigode, C., Hobbi, P., Jafari, H., Verwilghen, F., Baeten, E., & Shavandi, A. (2020). Isolation and physicochemical properties of chitin polymer from insect farm side stream as a new source of renewable biopolymer. Journal of Cleaner Production, 275, 122924.

[11] Mancini, S., Moruzzo, R., Riccioli, F., & Paci, G. (2019). European consumers' readiness to adopt insects as food. A review. Food Research International, 122, 661-678.

[12] Castro, M., & Chambers IV, E. (2019). Willingness to eat an insect based product and impact on brand equity: A global perspective. Journal of Sensory Studies, 34(2), e12486.

[13] Bogueva, D., & Marinova, D. (2020). Cultured meat and Australia's generation Z. Frontiers in Nutrition, 7, 148.

[14] Yang, R., Raper, K. C., & Pruitt, J. R. (2019). The influence of recession and income strata on consumer demand for protein sources. Applied Economics, 51(42), 4615-4628.

[15] Dimina, L., Rémond, D., Huneau, J. F., & Mariotti, F. (2022). Combining plant proteins to achieve amino acid profiles adapted to various nutritional objectives—an exploratory analysis using linear programming. Frontiers in nutrition, 8, 809685.

[16] Duque-Estrada, P., Hardiman, K., Dam, A. B., Dodge, N., Aaslyng, M. D., & Petersen, I. L. (2023). Protein blends and extrusion processing to improve the nutritional quality of plant proteins. Food & Function, 14(16), 7361-7374.

[17] Sun, S. S., & Liu, Q. (2004). Transgenic approaches to improve the nutritional quality of plant proteins. In Vitro Cellular & Developmental Biology-Plant, 40(2), 155-162.