emergent
Life Sciences Research

Review Article

Camelina sativa: A promising plant-based protein source

Hafiz Abdul Munam

Received: 20 March 2026
Accepted: 14 May 2026
Online: 23 May 2026

Authors:
H. A. Munam ✉
National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Punjab, Pakistan

✉ a.munam14@gmail.com

Emer Life Sci Res (2026) 12(1): 26-34

E-ISSN: 2395-6658
P-ISSN: 2395-664X

DOI:
https://dx.doi.org/10.31783/ELSR.2026.12012634

Abstract

The global demand for protein is rising very quickly due to dietary changes, population increase, and sustainability concerns. Because of its benefits for the environment, nutrition, and ethics, plant-based proteins have become a viable substitute for traditional animal-derived proteins. Among these, the Brassicaceae family's underappreciated oilseed crop *Camelina sativa* has drawn notice for its high protein content, advantageous amino acid profile, and useful qualities. Essential amino acids like lysine and methionine are found in camelina protein, along with bioactive substances that may have anti-inflammatory and anti-diabetic properties. Because camelina uses less land and produces fewer greenhouse gas emissions than animal protein production, it is both economically and environmentally viable for large-scale production. To improve protein yield and functioning, several extraction strategies have been investigated, such as alkaline, salt, and ultrasonic-assisted procedures. According to studies, camelina protein has promising emulsifying, foaming, and water-holding properties that make it appropriate for a variety of food applications, including protein supplements, baked goods, and meat substitutes. Camelina protein is a viable and sustainable substitute protein source with enormous potential in the developing global food sector. There are still issues, nevertheless, such as the existence of anti-nutritional substances like phytic acid and glucosinolates, a lack of human consumption studies, and low consumer acceptance.

Keywords camelina protein, food security, nutrition, plant protein, protein extraction

Introduction

The market for proteins is expected to expand at a yearly growth rate at 15.8% [1], with the leading sector alternative dairy and meat reaching 1200 billion USD worldwide by 2030. Other protein classes exhibit growth rates ranging from 6.1% to 20% each year, depending on their function and class [1-2]. At a compound annual growth rate of 9.1%, the global demand for protein components is likely to reach $75 billion by 2027 [3].

New plant-based protein additions, which are gaining popularity, may eventually partially replace traditional dairy and soy protein sources. This interest is being driven by a number of factors, such as the high cost of conventional protein sources, the potential for plant proteins to gain market share, the growing incidence of allergies, and functional limitations. The growing number of vegan and health-conscious consumers is another factor contributing to the growing appeal of plant proteins [4].

Camelina sativa is an affiliate of the Brassicaceae family and is sometimes referred to as "false flex". Its grains contain 20-30% of plant proteins, making them an excellent source. Camelina protein could be a useful substitute for people who are allergic to or sensitive to soy. Interest in camelina protein as a substitute for conventional protein sources like pea and soy has increased due to the growing need for plant-based proteins [4].

Carbon footprints of plant-based and animal-based proteins

Interest in plant-based proteins has increased as more people adopt plant-based diets because of their possible health advantages, environmental sustainability, and ethical reasons. Even though plant-based protein offers several advantages, animal-based protein is still the main source of protein in many diets [4]. However, animal husbandry uses a lot of room to grow food and graze animals, which harms habitat and adds to deforestation. Compared to animal protein, the production of plant-based protein requires less land [5]. Animals rearing primarily contributes significantly to global greenhouse gas emissions through nitrous oxide from manure management and methane from enteric fermentation [6]. An estimated 14.5% of global greenhouse gas emissions induced by human activity are attributed to livestock production [7]. Compared to plant-based protein, the synthesis of animal protein often results in higher greenhouse gas emissions [8]. Changing to a plant-based diet might greatly lower greenhouse gas emissions and slow down climate change [9].

Less land use and water contamination

Concentrated animal feeding operations (CAFOs) produce waste that contaminates land and water sources, putting human health and the environment at risk. According to Eshel et al., [8], the production of plant-based proteins may aid in lowering the pollution brought on by the disposal of animal waste and concentrated animal feeding operations (CAFOs). Giving up animal agriculture can reduce water contamination and the hazards it poses to the environment and human health [7].

Less solid fat and cholesterol

One of the main advantages of plant protein is lower levels of solid fat and cholesterol than other meat-based protein sources. This is significant since a diet high in cholesterol and saturated fat is linked with a high risk of heart disease and other chronic illnesses [10]. Plant-based protein sources like legumes, nuts, and seeds are also high in fiber, which can lower cholesterol and improve heart health [11]. Kumar et al., [12] evaluated the growing importance of plant proteins in numerous applications. These proteins serve as a substitute for meat of animal derived proteins in light of the expanding global population. The food and processing sectors are very interested in knowing the physicochemical characteristics, structural features, amino acid composition, and functional aspects of plant proteins [12].

Sustainable ruminant production

Many researchers found that more plant-based components are being used in the global beef industry. Oat protein is used to increase the supply of beef, product yield, and fat retention. However, nothing is known about the addition of oat protein to ground beef compositions. The study, which separated coarse ground beef into four groups, found that higher oat protein inclusion rates increased cook yields but decreased instrumental color values. More precise measurements of Allo-Kramer shear force were associated with higher levels of oat protein. Although adding oat protein to ground beef patties may increase cookout, the product's color and tenderness may suffer as a result [12-13]. *Camelina Sativa* protein is very helpful for beef cattle nutrition as it has similar digestibility compared to traditional protein sources. Feeding camelina meal to beef also improves the fatty acid profile of beef meat because it increases circulating polyunsaturated fatty acids without negatively impacting ruminal degradability.

Health benefits of *Camelina sativa*

There are a number of benefits when comparing *Camelina sativa* protein to other plant-based protein alternatives. It offers higher concentrations of lysine and methionine, two necessary amino acids that are often deficient [14]. Additionally, the bioactive substances in *Camelina sativa* protein may have anti-diabetic, anti-hypertensive, and anti-inflammatory properties [15]. This protein can be utilised in plant-based meat alternatives, protein bars, and baked goods in the food sector. It can replace casein and egg whites, two common food additives, because of its capacity to emulsify and foam [16].

Growth potential under stressed conditions

Because of its strength and adaptability, this kind of oilseed crop can grow in a wide range of situations. Despite other ecological problems, it can tolerate salinity, cold, and salt [17-18]. *Camelina sativa* is an excellent cover crop for weeds, insects, and pests because of its allelopathic action and resistance to microbiological diseases [19-21]. Their adaptability is demonstrated by their ability to flourish in a range of conditions, including semi-arid ones, with minimal help. *Camelina sativa* can tolerate a wide variety of environmental impacts; its stress resistance values vary between 0.49 and 1.10, while its environmental adaptation values range from 1.15 to 1.17 [22].

Nutritional profile

In North America, *Camelina sativa* contributes a novel part of the oilseed source, particularly for use in aquaculture feed. A byproduct of the oil removal procedure, camelina seeds are camelina meal [16]. Defatted camelina meals contain approximately 45% protein, 4.9% crude fat, up to 15% insoluble fiber, up to 10% carbs, 3% minerals, and 4% phytochemicals, the majority of which are phenolics and other components like vitamins [23]. *Camelina sativa* protein has a great amino acid composition, with amounts of arginine, cysteine, glycine, lysine, methionine, and threonine comparable to those in soybeans. *Camelina sativa* is a viable source of protein for use as a plant-based protein in a variety of food items due to its amino acid makeup.

The exceptional nutritional profile of camelina is one of its distinctive qualities. Significant amounts of protein (27-32%) and oil (38-43%) are present in the grain [23]. According to a different study, camelina cake has a higher protein level than camelina seed, which has a protein value of 24.78%. The protein part of camelina cake is lower than that of soybean meal (43.0-56.3%) and rapeseed food (29.69-39.89%) It is well recognized that the essential amino acid makeup of a protein determines its biological importance. Camelina cake contains between 15.09 and 18.39% necessary amino acids [24]. Camelina cake contains at least seventeen amino acids, with histidine, methionine, isoleucine, leucine, lysine, phenylalanine, and valine being the primary amino acid constituents. Camelina seeds are rich in non-essential amino acids linked with histidine, methionine, arginine, glutamic acid, and aspartate in addition to essential amino acids [25].

Extraction techniques

The two primary techniques for extracting camelina oil are solvent extraction and mechanical expulsion. Because of their high crude protein content, the meals that are left over after the oil removal have potential as animal feed. The meal produced by solvent extraction had a higher content of crude protein and less fat than the expelled meal (3.52 vs. 13.69% and 41.04 vs. 34.65%, respectively). The chemical makeup of solvent-removal camelina meal is comparable to that of canola meal, although it contains more fiber and less crude protein than soybean meal. The protein content of *Camelina sativa* has been assessed using a variety of protein extraction techniques, including alkaline and salt extraction techniques [21]. Compared to alkaline extraction, salt extraction results in a less denatured and more functional camelina protein concentrate (CPC), which is mostly composed of cruciferin and napin proteins. The soy protein isolate (SPI) and the salt-extracted camelina protein concentrate performed similarly, if not better. The CPC extracted by the salt extraction method was much more soluble at pH 3.4 (about 70%) than SPI (about 50%) less soluble at pH 7 [4].

Additionally, salt-extracted CPC showed a far higher capacity for emulsification and foaming than SPI. But compared to CPC, SPI offers superior gelation qualities. After thermic treatment, *Aspergillus oryzae protease* broke down CPC, increasing its solubility to pH 7 [4].

Extraction difficulties

One of the possible obstacles to alkaline extraction is the existence of complex protein components with a broad range of isoelectric points and molecular weight fluctuations. To solve these problems, the researchers employed a novel method called ultrasonic-assisted extraction. This technique has been shown to be superior to conventional alkaline extraction in several aspects, such as increased solubility, reduced solvent consumption, increased extraction yield, and shorter extraction times [26-27].

Proteins from camelina seed cakes were shown to be more successfully extracted when the extraction process was aided by ultrasonication, which was performed at 40 kHz for 20 minutes. All the extracted samples had protein subunit bands using ultrasonication. The camelina protein isolate (CPI) exhibits a higher surface hydrophobicity (93,71 µg BPB) than the soy protein isolate (84,38 µg BPB), according to Tontul et al., [28] method using bromophenol blue (BPB). The CPI's power to absorb oil, hold onto water, forth, and emulsify has been improved because of ultrasonic-assisted extraction (UAE). This implies that CPI could be utilized in place of soy protein in food compositions [16].

A novel, environmentally friendly technique termed aqueous extraction was employed in place of the conventional techniques previously employed. In order to extract camelina seed protein, the seeds are ground in pH 8 water after the mucilage adhering to the seed surface is removed by ultrasonication. The majority of these proteins were 11S globulins, cruciferous and 2S albumin napins. The nine essential amino acids of nutritional importance are included in that process. The decreased solubility of camelina seed proteins in the pH range of 5.5-2 was caused by cruciferins. This novel approach focuses on the potential of camelina seed proteins, which were improved using water extraction and were regarded as plant-based functional additions in the food sector [29].

Studies on *Camelina sativa* protein are quite rare, particularly when it comes to employing it as a source of protein for human meals. Although camelina oil and animal feed uses have garnered a lot of attention, research on the nutritional composition, digestibility, and bioavailability of camelina protein for humans is insufficient [4, 30-31]. Phytic acid and glucosinolates, two anti-nutritional elements included in camelina protein, can lower their bioavailability and affect whether or not they are suitable for human ingestion [24, 32]. However, these compounds can be reduced by a number of processing techniques, including fermentation, enzymatic extraction, variety breeding, and heat treatment. Large-scale applications necessitate the optimization of these methods [23, 29, 33].

Industrial methods for refining camelina meals, a high-protein by-product, for use in human foods are still being researched [4, 21]. Alkaline and salt extraction are examples of conventional extraction methods that can denaturize proteins or produce insufficient protein yield. There, sustainable and eco-friendly extraction methods that preserve protein function are needed, such as membrane filtering, heat extraction, and enzymatic extraction [34, 35].

Sensory properties

Camelina proteins have a favorable nutritional profile, but nothing is known about their sensory qualities (taste and texture) [36]. Taste and texture changes may be required to meet consumer preferences for plant-based proteins. Additionally, compared to other protein substitutes now available on the market, including soy or pea protein, consumer acceptance of camelina protein is still low [23, 36-37]. A better framework is needed to use camelina proteins to the lab grown meat and chicken cuts [38].

Camelina oil affects lipid metabolism

In addition to being a strong source of omega fatty acids, camelina oil has gained a lot of interest lately because of its biological activity and potential for use in the creation of functional foods. Researchers used a rat model to study the lipid power impact of cold -pressed camelina oil. High-fat meals with 20% fat and 1% cholesterol were given to Sprague-Dawley rats. Additionally, 1.1, 2.2, or 4.4 g of camelina oil per kg or 2.2 g of fish oil per kg (control diet) were added to high-fat diets. The findings imply that, via controlling blood cholesterol metabolism and safeguarding liver function, camelina oil has lipid-lowering properties [39].

Camelina as a feed for dairy cows

The nutrient content of camelina seed and its derivatives is like that of other feedstuffs given to dairy cows. Its anti-nutritional characteristics, like those of other oil crops, have prompted authorities to impose restrictions on the allowed amount of camelina seed and oil-extracted products in the animal diet. A diet that includes camelina seed and its byproducts produces milk fat that is rich in health-promoting saturated fat, which is why they include camelina seed. Additionally, processing can lessen its anti-nutritional components, allowing defatted meals to be utilized in higher inclusion than currently advised without compromising the animal's metabolism [40].

Suitable chicken feed

For meaty chicken, camelina seed byproducts, such as cake, are an inexpensive substitute for protein feed sources. Camelina is an oilseed crop with 36.8% oil in the seeds and 6.4–22.7% oil in the cake. The concentration of α-linolenic fatty acid (C18:3n-3; ALA) varies from 25.9 to 36.7% of total fatty acids, which sets camelina apart from other plants in the *Brassicaceae* family. Camelina oil and cake have total tocopherol contents of 751–900 and 687 mg/kg, respectively. The amount of polyunsaturated fatty acids in chicken meat is increased when camelina is added to the diet [12].

Season effects on camelina plants' growth

Varieties like midwinter, fall, seasonal, and spring, genotypes and environmental conditions (temperature, humidity) all affect the nutritional conformation and yield of camelina seed and its derivatives. Compared to spring camelina, winter camelina has a higher root-to-shoot ratio. This is likely because roots have more time to establish themselves in the fall before overwintering and starting to grow the following spring. The soil types, climate, and cultivars of camelina all affect the seed yields [33, 40].

Spray drying vs. vacuum drying to extract Camelina protein

In many studies, the alkaline removal and isoelectric precipitation method was used to extract camelina protein, which was then vacuum-dried, freeze-dried, and sprayed. Camelina protein powders have protein levels ranging from 62.5 to 64.1 g/100 g (dry basis). For spray-dried and vacuum-dried proteins, glutamic acid was the most prevalent amino acid; for freeze-dried camelina protein, it was proline. The maximal denaturation temperature of camelina proteins ranged from 100.5 to 104.3 °C. Compared to other proteins (9.1–19.1 µg/mg), freeze-dried camelina protein has a lower surface hydrophobicity (5.8 µg/mg). Among camelina proteins, spray-dried protein exhibited the maximum water-holding capacity (2.9 g/g), emulsion activity (0.53 mL/mL), stability (0.96 mL/mL), foaming capacity (0.48 mL/mL), and stability (0.92 mL/mL). Additionally, spray-dried camelina protein produces gel at a lesser concentration (about 10%) [33].

Antinutritional components

The anti-nutritional components of camelina meal, particularly glucosinolates, are another limitation. Although processing techniques may be able to reduce the overall glucosinolates, camelina meal contains 23 to 44 millimole/kg of glucosinolates. The camelina meal can be heated to reduce glucosinolates and eliminate any remaining solvent from the solvent-extracted meal. Glucosinolates, which may also be utilized in camelina meals, have been reduced by the fungal fermentation of canola meals. Another way to address the high glucosinolates in camelina meal is to selectively breed camelina variants to reduce glucosinolates in the plant. The current feed laws in the United States and Canada restrict the amount of camelina meal that can be included in the diets of cattle, laying hens, and broiler chickens to 10% [41].

Consumers Preference

Plant-based meals are more environmentally friendly than animal-based meals. Consumers have utilized their enormous purchasing energy to start the food business to rapidly develop new plant-based foods. But as food formulators started using plant-based proteins in both new and old recipes, they soon discovered that PBPs couldn't just be used in place of animal-based proteins. Since their inception, these substances have been criticized for having astringent and bitter sensory qualities that lessen the pleasant sensory experience [42]. So, more efforts are needed to enhance conumser acceptance of PBPs diets.

Safety profile

Camelina sativa can be substituted for traditional protein sources in ruminant diets with no adverse effect. The combination effect of mechanics and genetic engineering methods can improve the nutritional profile of C. sativa by reducing anti-nutritional components and improving the fatty and amino acid profile. When camelina seeds and byproducts are fed to dairy cows, ruminal cellulolytic bacteria and biohydrogenation are reduced, which raises good fatty acids like omega three, polyunsaturated and reduces saturated fatty acid in cow milk.

Camelina sativa and its derivatives can be safely added to dairy cow feed at the right inclusion levels. Many new plant-based meals were created employing extremely complicated combinations of food items and the addition of PBPs in a rush to introduce new goods and profit from emerging trends. Nutritionists, minimalists, and the medical community swiftly condemned these items, saying that many of them were less healthful than the products they were replacing. Successive peers of plant-based food have utilized fewer ingredients, and novel crops brag about having safe labels, as food formulators have gained more knowledge regarding PBPs [43-44].

Conclusion

The protein from Camelina sativa shows great promise as a practical and sustainable substitute for traditional protein sources. It is an important component for the creation of future plant-based products because of its balanced amino acid content, bioactive qualities, and adaptability in food applications. Its minimal environmental impact in comparison to animal-based proteins also supports international initiatives to lower greenhouse gas emissions and advance sustainable agriculture.

Despite these benefits, a number of issues need to be resolved before widespread implementation. More research is necessary due to the existence of anti-nutritional substances, the paucity of information on human digestion and bioavailability, and difficulties with sensory characteristics, including taste and texture. Furthermore, raising consumer awareness and refining extraction methods are critical to boosting its commercial viability. Optimizing processing techniques, lowering anti-nutritional elements, and assessing long-term health effects should be the main goals of future study. With further development, camelina protein can contribute significantly to the sustainable supply of protein needed worldwide.

References

[1] K. L. Hefferon, H. De Steur, F. J. Perez-Cueto and R. Herring **(2023)**. Alternative protein innovations and challenges for industry and consumer: an initial overview. Front. Sustain. Food Syst., **7:** 1038286. doi: 10.3389/fsufs.2023.1038286.

[2] M. A. Ashraf, B. Shen, M. A. Raza, Z. Yang, M. N. Amjad, G. ud Din and L. Yue et al., **(2025)**. Albumin: A review of market trends, purification methods, and biomedical innovations. Curr. Issues Mol. Biol., **47:** 303. doi: 10.3390/cimb47050303.

[3] B. P. Ismail, L. Senaratne-Lenagala, A. Stube and A. Brackenridge **(2020)**. Protein demand: Review of plant and animal proteins used in alternative protein product development and production. Anim. Front., **10:** 53-63.

[4] C. Boyle, L. Hansen, C. Hinnenkamp and B. P. Ismail **(2018)**. Emerging camelina protein: Extraction, modification, and structural/functional characterization. J. Am. Oil Chem. Soc., **95:** 1049-1062.

[5] J. Poore, T. Nemecek **(2018)**. Reducing food's environmental impacts through producers and consumers. Science., **360:** 987-992.

[6] H. Harwatt **(2019)**. Including animal to plant protein shifts in climate change mitigation policy: a proposed three-step strategy. Clim. Pol., **19:** 533-541.

[7] P. J. Gerber, H. Steinfeld, B. Henderson, A. Mottet, C. Opio, J. Dijkman and J. Falcucci et al., **(2013)**. Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Rome: Food and Agriculture Organization of the United Nations.

[8] G. Eshel, A. Shepon, T. Makov and R. Milo **(2014)**. Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States. PNAS., **111:** 11996-12001.

[9] L. Aleksandrowicz, R. Green, E. J. Joy, P. Smith and A. Haines **(2016)**. The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: a systematic review. PloS one., **11:** e0165797. doi: 10.1371/journal.pone.0165797.

[10] P. J. Tuso, M. H. Ismail, B. P. Ha and C. Bartolotto **(2013)**. Nutritional update for physicians: plant-based diets. Perm. J., **17:** 61-66.

[11] C. J. Rebello, F. L. Greenway and J. W. Finley **(2014)**. A review of the nutritional value of legumes and their effects on obesity and its related co-morbidities. Obes. Rev., **15:** 392-407.

[12] M. Kumar, M. Tomar, S. Punia, J. Dhakane-Lad, S. Dhumal, S. Changan and M. Senapathy et al., **(2022)**. Plant-based proteins and their multifaceted industrial applications. LWT-Food Sci. Technol., **154:** 112620. doi: 10.1016/j.lwt.2021.112620.

[13] J. J. Ball, R. P. Wyatt, M. M. Coursen, B. D. Lambert and J. T. Sawyer **(2021)**. Meat substitution with oat protein can improve ground beef patty characteristics. Foods., **10:** 3071. doi: 10.3390/foods10123071.

[14] R. Juodka, R. Nainienė, V. Juškienė, R. Juška, R. Leikus, G. Kadžienė and D. Stankevičienė **(2022)**. Camelina (*Camelina sativa* (L.) Crantz) as feedstuffs in meat type poultry diet: A source of protein and n-3 fatty acids. Animals, **12:** 295. doi: 10.3390/ani12030295.

[15] T. T. N. Ngo, T. R. Senadheera and F. Shahidi **(2022)**. Prediction of bioactive peptides produced from camelina (*Camelina Sativa* (l.) Crantz) seed meal. Available at SSRN 4211674. https://ssrn.com/abstract=4211674.

[16] N. T. T. Ngo and F. Shahidi **(2021)**. Functional properties of protein isolates from camelina (*Camelina sativa* (L.) Crantz) and flixweed (sophia, Descurainis sophia L.) seed meals. Food Prod. Process. Nutr., **3:** 31. doi: 10.1186/s43014-021-00076-8.

[17] E. L. Turina and T. Y. Prakhova **(2020)**. Influence of climatic conditions on productivity and adaptability of *Camelina sativa*. *In*: E3S Web of Conferences., **224:** 04006. doi: 10.1051/e3sconf/202022404006.

[18] B. Bakhshi, H. Rostami-Ahmadvandi and H. R. Fanaei **(2021)**. Camelina, an adaptable oilseed crop for the warm and dried regions of Iran. Cent. Asian J. Plant Sci. Innov., 1: 39-45.

[19] M. Arshad, A.K. Mohanty, R. Van Acker, R. Riddle, J. Todd, H. Khalil and M. Misra **(2022)**. Valorization of camelina oil to biobased materials and biofuels for new industrial uses: a review. RSC Adv., **12:** 27230-27245.

[20] M. Ghidoli, M. Pesenti, F. Colombo, F. F. Nocito, R. Pilu and F. Araniti **(2023)**. *Camelina sativa* (L.) Crantz as a promising cover crop species with allelopathic potential. Agronomy, **13:** 2187. doi: 10.3390/agronomy13082187.

[21] R. Matteo, E. Pagnotta, L. Ugolini, L. Righetti, S. Tavarini and L. Lazzeri **(2023)**. *Camelina sativa* (Cranz.) from minor crop to potential breakthrough. In: F. Muhammad, H. M. Kadambot (*Eds*.), Neglected and Underutilized Crops. Elsevier Academic Press, pp781-801.

[22] R. H. Lohaus, D. Neupane, M. A. Mengistu, J. K. Solomon, and J. C. Cushman **(2020)**. Five-year field trial of eight *Camelina sativa* cultivars for biomass to be used in biofuel under irrigated conditions in a semi-arid climate. Agronomy, **10:** 562. doi: 10.3390/agronomy10040562.

[23] R. Mahious, E. Halvacı, A. Aygün, and F. Şen **(2024)**. The golden discovery of camelina sativa: a pivotal study of ıts unique components and its multiple uses in various applications in science and industry. J. Sci. Rep.-A., **059:** 105-118.

[24] S. Colombini, G. A. Broderick, I. Galasso, T. Martinelli, L. Rapetti, R. Russo and R. Reggiani (2014). Evaluation of *Camelina sativa* (L.) Crantz meal as an alternative protein source in ruminant rations. J. Sci. Food Agric., **94:** 736-743.

[25] Ș. L. Bătrîna, Ș. Jurcoane, I. Popescu, F. Marin, I. M. Imbrea, F. Crista and G. Pop et al., **(2020)**. *Camelina sativa*: A study on amino acid content. Rom. Biotechnol. Lett., **25:** 1136-1142.

[26] A. A. Yagoub, H. Ma and C. Zhou **(2017)**. Ultrasonic-assisted extraction of protein from rapeseed (*Brassica napus* L.) meal: Optimization of extraction conditions and structural characteristics of the protein. Int. Food Res. J., **24:** 621-629.

[27] Y. Zou, L. Wang, P. Li, P. Cai, M. Zhang, Z. Sun and C. Sun et al., **(2017)**. Effects of ultrasound assisted extraction on the physiochemical, structural and functional characteristics of duck liver protein isolate. Process Biochem., **52:** 174-182.

[28] I. Tontul, Z. Kasimoglu, S. Asik, T. Atbakan and A. Topuz **(2018)**. Functional properties of chickpea protein isolates dried by refractance window drying. Int. J. Biol. Macromol., **109:** 1253-1259.

[29] C. Lopez, H. Rabesona, V. Beaumal, H. Sotin, B. Novales and M. Anton **(2024)**. Exploring the biodiversity of plant proteins for sustainable foods: Composition and emulsifying properties of the proteins recovered by aqueous extraction from camelina (*Camelina sativa* L.) seeds. Curr. Res. Food Sci., **9:** 100922. doi: 10.1016/j.crfs.2024.100922.

[30] G. Ali, A. Hannachi, M. Benidir, Z. E. Fellahi, and B. Frih **(2022)**. Agro-biochemical Characterisation of *Camelina sativa*: A review. Agric. Rev., **43:** 278-287.

[31] P. Sentís-Moré, N. Ortega-Olive, I. Robles-Rodriguez, A. Royo-Esnal and M. P. Romero-Fabregat **(2023)**. Protein hydrolysis of Camelina sativa meals: A study of molecular weight distribution and emulsifying properties. Food Bioscience., **56:** 103062. doi: 10.1016/j.fbio.2023.103062.

[32] Y. Singh, M. Cullere, E. Tumova and A. Dalle Zotte **(2023)**. *Camelina sativa* as a sustainable and feasible feedstuff for broiler poultry species: A review. Czech J. Anim. Sci., **68:** 277-295.

[33] J. J. Delver and Z. K. Smith **(2024)**. Opportunities for camelina meal as a livestock feed ingredient. Agriculture., **14:** 116. doi: 10.3390/agriculture14010116.

[34] B. Prandi, M. Di Massimo, T. Tedeschi, L. Rodríguez-Turienzo and Ó. Rodríguez **(2022)**. Ultrasound and microwave-assisted extraction of proteins from coffee green beans: effects of process variables on the protein integrity. Food Bioprocess Technol., **15:** 2712-2722.

[35] Y. V. Smol'nikova, V. L. Bopp, A. V. Kolomeytsev, O. V. Stutko, V. A. Khanipova and D. V. Broshko **(2022)**. Aqueous enzymatic extraction of protein concentrates from camelina sativa oil cake. Food Processing: Tech. Technol., **52:** 199-209.

[36] M. Mondor and A. J. Hernández-Álvarez **(2022)**. *Camelina sativa* composition, attributes, and applications: A review. Eur. J. Lipid Sci. Technol., **124:** 2100035. doi: 10.1002/ejlt.202100035.

[37] P. Qin, T. Wang and Y. Luo **(2022)**. A review on plant-based proteins from soybean: Health benefits and soy product development. J. Agric. Food Res., **7:** 100265. doi: 10.1016/j.jafr.2021.100265.

[38] W. R. Aimutis **(2022)**. Plant-based proteins: the good, bad, and ugly. Annu. Rev. Food Sci. Technol., **13:** 1-17.

[39] M. Kumar, M. Tomar, J. Potkule, Reetu, S. Punia, J. Dhakane-Lad and S. Singh, et al., **(2022)**. Functional characterization of plant-based protein to determine its quality for food applications. Food Hydrocoll., **123:** 106986. doi: 10.1016/j.foodhyd.2021.106986.

[40] P. J. Pinckaers, J. Trommelen, T. Snijders and L. J. Van Loon **(2021)**. The anabolic response to plant-based protein ingestion. Sports Med., **51 (Suppl 1):** 59-74.

[41] X. Xiao, P. R. Zou, F. Hu, W. Zhu and Z. J. Wei **(2023)**. Updates on plant-based protein products as an alternative to animal protein: Technology, properties, and their health benefits. Molecules., **28:** 4016. doi: 10.3390/molecules28104016.

[42] S. Langyan, P. Yadava, F. N. Khan, Z. A. Dar, R. Singh and A. Kumar **(2022)**. Sustaining protein nutrition through plant-based foods. Front. Nutr., **8:** 772573. doi: 10.3389/fnut.2021.772573.

[43] J. Ampofo and M. Ngadi **(2022)**. Ultrasound-assisted processing: Science, technology and challenges for the plant-based protein industry. Ultrason. Sonochem., **84:** 105955. doi: 10.1016/j.ultsonch.2022.105955.

[44] A. Detzel, M. Krüger, M. Busch, I. Blanco-Gutiérrez, C. Varela, R. Manners and J. Bez, et al., **(2022)**. Life cycle assessment of animal-based foods and plant-based protein-rich alternatives: an environmental perspective. J. Sci. Food Agric., **102:** 5098-5110.