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HISTORY, CONSTRAINTS OF HEMP AND FUTURE PROSPECT AS A POTENTIAL LIVESTOCK FEED IN BANGLADESH

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ABSTRACT

This study explores the historical context and potential of hemp as livestock feed in Bangladesh. Hemp, or Cannabis sativa L., has a long history in the region, dating back to the 18th century when it was cultivated for various purposes, including medicinal and intoxicating uses. Hemp in Bangladesh serves various functions, primarily for medicinal purposes across different regions. Globally, the demand for hemp is rising, driven by its applications in fiber production, food, and medicine. Despite legal complexities, hemp has the potential to be a valuable livestock feed additive due to its nutritional qualities. Feeding hemp to ruminant animals can improve the fatty acid profile of their milk and meat. For non-ruminant animals like poultry, hemp seeds offer essential nutrients for growth and health. However, constraints exist, including legal issues and societal misconceptions regarding cannabis in Bangladesh. Changing these perceptions is crucial to realizing the potential of hemp in the country's agriculture and livestock industries.

1. INTRODUCTION

In this study, the term "hemp" refers to *Cannabis sativa* L. and any part of that plant. Hemp goes by various names in different countries. In English, "Hemp" is the most recognized term for cannabis, albeit with multiple meanings, encompassing its identity as a crop, a fiber, and a drug. Meanwhile, "Ganja" serves as the Hindi name for cannabis and is a common and familiar term in many parts of South Asia, including Bangladesh (Rahman *et al.*, 2022). However, in the realm of agriculture, certain crops hold the potential to revolutionize traditional farming practices, addressing the ever-growing challenges of feeding a global population. One such crop is hemp, a versatile and underutilized resource. Hemp serves as a versatile crop, offering a range of uses, including the production of food, fiber, and pharmaceuticals (Berzins *et al.*, 2014; Hill, 1972). The historical legacy of hemp production in Bangladesh has deep roots, dating back to the late 18th century under British colonial rule.

While the exact origins of cannabis cultivation remain shrouded in the mists of history, the earliest documented instances can be traced back to 1722 when the East India Company conducted experimental trials involving hemp as a fiber crop (Rahman *et al.*, 2022). In 1839, the plant's medicinal and intoxicating properties were discovered, driving its popularity as a drug (Mills, 2003). The cultivation of hemp, or "ganja" as it is known in Bangladesh, is believed to have commenced in the Jessore region in the early 18th century and later shifted to Naogaon District. However, its cultivation and production were banned in 1987 in Bangladesh due to international narcotics agreements. Hemp, often cloaked in a shroud of misconception and legal complexities, confronts a series of problems that have hindered its growth in Bangladesh. Legal restrictions surrounding its cultivation, stemming from international narcotics agreements, have cast a shadow over its potential utility. Additionally, prevailing negative societal perceptions and limited scientific evidence for its use in animals further exacerbate these challenges.

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These problems are the crux of a complex narrative that requires a holistic understanding to unlock the true potential of hemp. Recently, its global importance in addressing the increasing demand for both human and animal consumption, its nutritional qualities, and its potential impact on the performance of various animal species. The nutritional qualities of hemp and its effects on the performance of both ruminant and non-ruminant animals highlight the potential benefits it offers. In this study, we aim to unravel the historical background of hemp cultivation in Bangladesh, shedding light on its evolution and the factors contributing to its current status. We also delve into the myriad uses of hemp, from traditional medicine to livestock feed, seeking to understand its potential as a multifunctional crop. Besides, we explore the global importance of hemp production, assessing its relevance on the global stage and the demand it generates. Moreover, it will highlight the bioactivity of hemp and its role in enhancing animal health and the quality of products derived from these animals. This study endeavors to peel back the layers of history, problems, objectives, and importance surrounding hemp cultivation in Bangladesh. Through a comprehensive exploration of its past, present, and potential future, it shines a light on the transformative power of this versatile crop and its role in shaping the future of agriculture and food security.

2. MATERIALS AND METHODS

The information search was carried out with the following keywords: Ganja, hemp, Cannabis sativa, livestock, ruminant, non-ruminant animals, Bangladesh, global, socio-economic status, feeding and management, productivity, production, reproduction, bioactivity, milk and products quality and diseases. Databases such as Google, Google Scholar, Bangladesh Journal-Online (BJO), Research Gate, Scopus, and PubMed on the scientific literature published about hemp production, constraint, and feeding animals in Bangladesh and abroad were reviewed.

Historical background of hemp cultivation in Bangladesh

There is no exact information about when and how the cultivation of hemp started in Bangladesh. The earliest documented instance of hemp cultivation in Bengal can be dated back to 1722 (Ali, 2014; Khansaheb, 2007). During that period, the East India Company conducted experimental trials involving hemp cultivation as a fiber crop. In 1839, the plant's medicinal and intoxicating properties were discovered, propelling its popularity as a drug (Mills, 2003). However, cultivation of hemp is believed to have started in Jessore southern part of Bangladesh in the first decade of the eighteenth century (Ali, 2014). However, in 1873, a report on the cultivation of ganja in Bengal, along with insights into the consumer market for this commodity, was published in the Calcutta Gazette. Notably, the report highlighted that ganja was not cultivated in Jashore during that time because farmers were compelled to cultivate indigo instead (Ali, 2014; Hunter, 1876). Subsequently, the ganja cultivation area shifted to the Naogaon district in northwestern Bangladesh due to favorable environmental conditions (Uddin, 2006). Its cultivation was legally confined to the so-called "Ganja Mahal" in the Naogaon sub-district, comprising parts of three districts—Bogra, Dinajpur, and Rajshahi—before their merger in 1896 (Ali, 2014). Strict control over cultivation and production was entrusted to the Ganja Society, established in 1917, with its headquarters located in Naogaon within Ganja Mahal (Mills, 2003).

Uses of hemp in Bangladesh

An extensive body of literature comprising ethno medicinal plant survey reports has been disseminated in Bangladesh. This investigation discerned that *Cannabis sativa* L. (hemp) exhibited multifarious utilitarian applications across various districts and regions within the nation. Notably, the districts of Kushtia, and Chittagong stand out for their distinctive historical engagement with this plant, encompassing its utilization in sustenance and veterinary practices. Conversely, in other locales, *C. sativa* L. is primarily employed for therapeutic purposes, addressing a spectrum of ailments, including sleep disorders, neuropsychiatric and central nervous system maladies, infections, respiratory conditions, rheumatic afflictions, gastrointestinal disorders, gynecological concerns, cancer, and a myriad of other health-related issues, as delineated in Table 1. This table elucidated the vernacular nomenclature and constituent ingredients employed by local communities hailing from diverse regions within Bangladesh, along with the associated preparation techniques.

Global importance of hemp production

Cannabis sativa L., commonly called hemp, is vital in addressing the growing global demand for human and animal consumption. This demand stems from its diverse applications in fibre production, food, and medicine (Berzins *et al.*, 2014; Hill, 1972). Globally, the demand for hemp is rising, with regional variations; Asia leads with 45%, North America at 22%, and Europe at 19% (New Frontier data, 2021). Within plant taxonomy, the genus Cannabis encompasses three species: *C. sativa, C. indica, and C. ruderalis,* all classified under the solitary species *C. sativa*. While hemp has historically played a significant role in traditional medicine in Bangladesh, its use is declining due to legal complexities. Conversely, there is a notable increase in global consumption of Cannabis and its derivatives. Many countries have legalized cannabis-derived products for medical and recreational use (Pant, 2016). North America and Europe have passed laws permitting medical and recreational cannabis use. Hemp, defined as Cannabis sativa containing less than 0.3% THC on a dry weight basis, is recognized legally in the United States (US) and the European Union (EU). Despite the therapeutic potential of cannabinoids like CBD, limited scientific evidence exists for their use in animals, primarily focused on companion animals. The intricate interplay of legal, medical, and societal factors underscores hemp and Cannabis's multifaceted role in addressing the increasing global demand for human and animal consumption.

Nutritional quality of hemp

Hemp is more useful and applicable in the fields of agriculture, food, feeds, cosmetics and pharmaceuticals companies which have low environmental effects as well as rich source of bioactive components. Besides from other uses, it is also promising feed additive for livestock. Hemp seed is by the byproduct of this crop, and this is useful feed for animals. Despite the use of synthetic antibiotic growth promoter, hemp seed can be used as a livestock feed additive without any residual effects in animals. Hemp seeds are normally used as whole, hulled seed and dehulled seed (mainly kernel) as well as its processed products are also available for consumption. Hempseed is rich source of antioxidant, bioactive peptides, phenolic compounds and phytosterols (Irakli, 2019). Inclusion of hemp oil in livestock feed can be a good source of essential fatty acid (Cozma, 2015) as well as for fat and protein source, hemp cake can be used (Mierlita, 2019). Bodas (2010) stated that hemp seed oil and oil cake have high concentration of polyunsaturated fatty acids. Several terpenes were found in hemp seed oil and beta-caryophyllene was abundant (Leizer, 2000). 18-23% protein, 25-30% oil, 30-40% fiber and 6-7% moisture is present in hemp seed (Leonard, 2020). About 181 proteins are available in hemp seed and concentration edestin and globulin are 67%-75% which is the main storage protein as well as globular protein are also 25-37% (Aiello, 2016). The ratio of soluble and insoluble dietary fiber located in shell of hemp seed is 20:80 where the insoluble fiber of hemp seed contains 46% cellulose, 31% lignin, 22% hemicellulose (Maki, 2000). The core had the lowest concentration of phenolic chemicals, whereas the shells had the highest concentration. The two main phenolic components in hemp that are exhibiting a high antioxidant activity are lignan amides and hydroxy cinnamic acid (Fathordoobady, 2019). Tetrahydrocannabinol (THC) is present in hemp seeds in very small amounts less than 1% (Citti, 2018). In contrast, hemp seeds have a number of anti-nutritional components such phytic acid and trypsin inhibitors that prevent proper nutrition (Pojic, 2014).

Effects of hemp feeding on the performances of ruminant animals

Hemp, a versatile and fast-growing plant, has recently attracted interest for its possible use as ruminant feed for milk production. Ruminants have a unique stomach that allows them to absorb fibrous plant components, thus hemp could be a helpful supplement to their diets. Ruminants are animals that transfer less energy from feed into food due to losses caused by rumen fermentation processes. Ruminants, on the other hand, play a vital role in the bioeconomy by transforming food that people cannot eat (such as forages, crop residues, and agricultural byproducts) into high nutritional value food (Van Soest, 1982). As a result, alternative plants have been recently rediscovered and reintroduced on the agricultural surfaces for increasing livestock production. The hemp plant (*Cannabis sativa L.*) is undoubtedly one of the most cultivated plants throughout history in the world. The development of various feeding techniques to improve the chemical nutritional qualities of dairy milk and milk products, assuming that nutrition might influence milk composition in ruminants, has expanded in recent years. Hemp seeds are indeed a good source of both omega-3 (n-3) and omega-6 (n-6) fatty acids (FAs), particularly alpha-linolenic acid (ALA) for n-3 and linoleic acid (LA) for n-6.

These FAs are essential for human health and must be obtained through the diet because the human body cannot produce them on its own. It is true that the consumption of hemp seeds or hemp seed oil, which is rich in these FAs, can lead to an increase in the levels of these polyunsaturated FAs (PUFAs) in the diet. This, in turn, can potentially lead to an increase in their presence in milk and dairy products if consumed by animals. Feeding hemp seeds or hemp oil to livestock, such as cows, could potentially result in milk with a more favorable n-6/n-3 ratio because of the hemp's high n-3 content. This, in turn, could lead to dairy products with a more balanced FAs profile. It's worth noting that the extent to which this change occurs in animal products depends on various factors, including the animal's diet, genetics, and the duration of hemp seed consumption (Lopez *et al.*, 2016; Bennato *et al.*, 2020; Ianni *et al.*, 2019; Castro *et al.*, 2019; Cattani *et al.*, 2014; Gebreyowhans *et al.*, 2019). Karlsson *et al.* (2010) evaluated the effects of increasing the proportion of hempseed cake (HC) in the diet of dairy lactating cows on milk production and composition and found no effects in dry matter (DM) intake but significant linear increases in crude protein (CP), fat, and NDF intakes were observed with the increase of the proportion of HC in the diets. Mustafa *et al.* (1999) conducted a study regarding the DM and CP in situ degradability in two non-lactating rumen fistulated cows using four different protein sources: hemp, borage, canola, and heated canola meals.

The results of the study revealed that hemp meal was an excellent natural source of rumen undegradable protein (RUP), containing 774 g/kg of CP. This RUP content was found to be equivalent to that of heat-treated canola meal but higher than borage and canola meals. It is also recommended to maintain the diets as isoenergetic and isonitrogenous while adjusting the proportions of other ingredients. Additionally, to assess the potential nutraceutical benefits of hempseed meal, it would be valuable to determine the nutritional value of milk and its derivatives when hemp meal is incorporated into the diets." Ewes' milk naturally contains beneficial substances for human health, such as n-3 FAs and conjugated linoleic acid (CLA). Feeding hemp (both hemp seeds and hemp cake) to ewes increased milk production and fat content but reduced milk lactose. This hemp-based diet also elevated the levels of polyunsaturated fatty acids (particularly n-3 fatty acids) in ewes' milk and improved the n-6/n-3 fatty acid ratio. Moreover, the total content of CLA in the milk doubled in ewes that received hempseed and increased 2.4 times when hemp cake was included in their diet (Mierlita, 2018). The presence of alpha-tocopherol and antioxidant activity increased with hempseed inclusion in the diets, which helps reduce the risk of lipid oxidation in raw milk. In a study by Ianni *et al.* (2019), the impact of enriching the diet of dairy ewes with hempseed (constituting 5% of the dry matter) was evaluated. This dietary enrichment led to an increase in lactose concentration from 4.69% to 5.84%. However, there were no significant differences observed in milk fat, protein, casein, and urea. Additionally, no changes were detected in the total fat, protein, and ash content in the resulting cheeses. Notably, hempseed supplementation positively influenced the metabolic pathways related to energy production in lactating ewes, potentially enhancing their resistance to adverse climatic conditions such as low temperatures (Iannaccone *et al.*, 2019). Mustafa *et al.* (1998) noted that hemp meal (HM) serves as an excellent natural source of rumen undegradable protein (RUP) that is on par with heat-treated canola meal. When used as a protein source in diets with equivalent nitrogen levels (up to 200 g kg-1 of dry matter) compared to canola meal (CM), HM did not have adverse effects on feed intake or nutrient utilization in sheep.

In case goat, Cozma *et al.* (2015) evaluated the effect of a diet supplemented with hempseed oil in Carpathian goats during 31 days of experiment and no significant changes of milk yield were observed receiving the hempseed oil supplementation. Fat content increased significantly during the trial in milk produced by goats receiving hemp oil in comparison with the control group. In another study, evaluated the effects of the inclusion of 9.3% on DM of linseed or hempseed in diet for Alpine lactating goat and found milk yield was unaffected by the dietary treatment but linseed and hempseed supplementation significantly increased the milk fat content. Again, Cozma *et al.* (2015) found a significant increase of the PUFA concentrations (+45%) in milk produced by goats supplemented by hempseed oil, without an effect on n-3 fatty acids content. Overall, beneficial effects on human health can be obtained in goat milk with the inclusion of hempseed oil in the diets. The impact of utilizing hemp in various animal species and their findings are mentioned in Table 4.

Winders *et al.* (2022) carried out an experiment regarding the feeding of hempseed cake alters the bovine gut, respiratory and reproductive microbiota and found significant effects on the community structure and diversity of the ruminal, nasopharyngeal, vaginal, and uterine microbiota in beef heifers. In the rumen, hempseed cake-fed cattle showed increased microbial diversity and richness compared to the control group (fed corn dried distillers' grains with soluble). The ruminal microbiota composition was significantly affected by the inclusion of hempseed cake in the diet, with changes in the abundance of specific bacterial genera. The nasopharyngeal microbiota was also influenced by the diet, but to a lesser extent than sampling time. Hempseed cake did not significantly affect microbial richness and diversity in the nasopharynx. The vaginal microbiota of heifers fed hempseed cake showed reduced microbial richness compared to the control group. The uterus of hempseed cake-fed heifers had greater microbial diversity and richness compared to the control group. In another study, Ben Necib *et al.* (2022) investigates the effects of dietary substitution of whole hemp seeds in comparison with whole linseeds in a diet-induced obesity mouse model and demonstrates that whole hemp seed substitution does not affect weight gain, adiposity, or food intake, while linseed substitution does. Hemp seed substitution mitigates diet-induced obesity-associated increases in intestinal permeability and circulating PAI-1 levels. Both hemp seeds and linseeds are able to modify the expression of several endocannabinoidome genes. Potential beneficial metabolic effects of hemp seeds found, their role in improving intestinal barrier function, and their ability to decrease inflammation in mice under a high-fat, high-sucrose diet compared to linseeds. Endocannabinoids, particularly anandamide (AEA) and 2‑arachidonoylglycerol (2‑AG), are instrumental in regulating energy homeostasis and stress response. Van Ackern *et al.* (2021) contribute to the understanding of the endocannabinoid system (ECS) in dairy cows, which was previously not well-known in ruminants. It demonstrates that intraperitoneal administration of endocannabinoids (AEA and 2-AG) can attenuate stress-induced suppression of feed intake and increase short-term feed intake in cows. This research suggests that endocannabinoids have the potential to improve dairy health and productivity by modulating feed intake, energy metabolism, and stress response in cows. Parker *et al.* (2022) carried out an assessment of spent hemp biomass (SHB) as a potential ingredient in ruminant diet and mentioned that feeding SHB does not induce inflammation or affect the immune system, but it may have effects on metabolism, kidney function, and bone metabolism. It was found that feeding of SHB to lamb can have positive effects such as improved antioxidative status and better digestibility of the diet.

Constraints of hemp cultivation in Bangladesh

The legal cultivation of hemp, known as ganja, in Bangladesh, has a historical legacy dating back to the late 18th century under British colonial rule. This practice continued until 1987, when it ceased due to international narcotics agreements (Rahman *et al.,* 2022). The colonial British government introduced a licensing system in 1876 to regulate production. Before the introduced of licensing system there was no limitation on production and sales. Presently, hemp cultivation and sale are illegal in Bangladesh. Marijuana is classified as a B-Class narcotic per the Narcotics Control Act of 1990. However, Section 9 of the Act allows for the lawful manufacture, processing, import, export, supply, purchase, and sale of narcotics for approved medicinal use or scientific research with proper licensing and permits (Shakil *et al.*, 2021). In Bangladesh, there's a widespread misconception about hemp due to a lack of accurate information about its properties, resulting in a negative societal perception. However, there's a current shift where hemp is increasingly recognized as versatile. Historically, ganja, a variety of hemp, has been used for spiritual purposes in Bangladeshi society, particularly among Sufi Muslims (Haque, 1993; Malek, 1999).

3. CONCLUSION

Hemp, a versatile crop with a historical background in Bangladesh dating back to the late 18th century, offers the potential to revolutionize livestock feed practices in the country. While its historical use centered on narcotic purposes, the growing recognition of its versatile properties is reshaping its role in agriculture. Hemp boasts a range of nutritional benefits, including high-quality proteins, essential fatty acids, and bioactive components. This makes it an attractive candidate as a valuable animal feed additive. The rich protein content, beneficial fatty acids and antioxidant properties in hemp can enhance animal health and elevate the quality of animal-derived products. Introducing hemp into livestock feed can improve animal performance, potentially boosting meat and dairy production. By harnessing the untapped potential of hemp in livestock nutrition, Bangladesh can address food security challenges and contribute to more sustainable and nutritious agricultural practices. Achieving this transformation will necessitate legal and regulatory changes to facilitate its adoption in the country's agricultural sector.

In summary, the historical cultivation of hemp in Bangladesh has laid the groundwork for a new era where hemp has become a key component of livestock feed. Its nutritional richness, coupled with the ongoing shift in perception, promises to diversify agriculture and enhance the quality of animal feed, ultimately benefiting both animal and human health. Legal and regulatory adjustments will play a vital role in realizing this potential.

4. CONFLICT OF INTEREST

All authors have declared that there is no conflict of interests regarding the publication of this article.

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Table 1. Local name and ingredient used by the people of different locations in Bangladesh.

Locations	**Local name**	**Part(s) Used**	**Purposes**	**Formulations**	**Remarks**
Naogaon	Ganja	Seed	Food, oil	Fry ganja seed with rice (50/50) as a food, extracted oil from seed for pain	This study
		Leaf	Medicine	dry leaf powder mixed with mustard oil twice daily for fever and headache	
		Bud	Narcotic	Upper parts of flower spikes used as a drug	
		Stalk	fuel	stems using for cooking	
Rajshahi	Shider Gach	Seed	sex stimulant	The seeds are taken for sexual stimulation.	Nawaz *et al.*, 2009
		Leaf	Insomnia,	Leaves and seeds are dried, powdered and made into balls of about 1/16 kg each. One ball is taken daily for coughs, mucus, as a narcotic and to induce sleep.	
			narcotic		
			mucus, cough		
Kholabaria of Natore	Ganja	Leaf	Dandruff	Leaves make a good sunff for deterging the brain; juice removes dandruff.	Sultana, 2017
		Resin	Headache, asthma	The resin called charas is used prevents and cures headache, asthma	
Kushtia	Ganja	Seed	Birds & poultry feed	Take out the seed by hand	This study
		Bud	Narcotic	Cut the bud in small pieces put it inside the coconut bark ball	
Bandarban	Shiddir Ganja Bhang	Bark	Stomach and Urinal problem	Juice daily 3 times	This study
Chittagong	Ganja, Hemp	Stalk	Fiber	Stalks steeped in water 10-15 days; then beaten out on stone or block of wood in water.	O'Malley,1908
		Flower	Aninal food	Flowers used for cattle food and stalks making Sulphur matches	
Rangamati	Bhang, Siddi	leaf	Treatment of schizophrenia like psychotic episodes.	Leaves are used to make oil then message on the scalp till cure. If a patient is in severe condition, then the leaves were used to make vapor and the vapor is taken by the nose.	Ahmed and Azam,2014

Table 2. Chemical composition of hemp seed

Parameter of Analysis	Content (%)
Total Protein	21.00 ± 0.04
Total lipid	28.00 ± 1.35
Crude Fiber	12.00 ± 0.51
Ash	4.00 ± 0.08
Moisture	10.00 ± 0.33
Total carbohydrates	25.00 ± 1.39

El-Sohaimy, 2022

Essential amino acid and fatty acids are present as a balanced form in hemp seed oil (Callaway, 2004) also mentioned that this contains high level arginine and glutamic acid.

Table 3. Amino acid composition of hemp seed

Essential Amino Acid	Content, g/100 g	Non-Essential amino acids	Content, g/100 g
Isoleucine + Leucine	5.21	Arginine	15.52
Lysine	2.88	Histidine	3.2
Methionine + Cysteine	5.49	Proline	3.44
Phenylalanine + Tyrosine	9.63	Serine	4.05
Threonine	3.79	Alanine	3.85
Tryptophan	0.26	Glycine	3.7
Arginine	15.52	Glutamic acid + glutamine	3.91
Valine	4.53	Asparagine + aspartic acid	12.53
Total of essential amino acids	31.79		

El-Sohaimy, 2022

Table 4. The impact of utilizing hemp in various animal species

Species	Experimental duration	Type of hemp and Amount	Results	Reference
Swedish red dairy cows	5 weeks, 1 week (pre-experimental period)	Hemp seed cake: 14.3, 23.3, 31.8% (dry matter)	14.3% hemp seed cake: higher milk yield, 23.3 or 31.8% hemp seed cake: no benefits in milk performance	Karlsson *et al.* (2010)
Steers	166 days	Full-fat hemp seed: 9 or 14%	Significant increase in CLA a level, also trans and saturated fats in tissues, no effect on DMI, ADG, carcass traits	Gibb *et al.* (2005)
Male Holstein cattle	14 days	Industrial hemp (*Cannabis sativa L.*): 25g mixed in 200g of grain (Target daily dose of 5.5mg/kg cannabidiolic acid)	significant increase in lying behavior, significant decrease in cortisol level and prostaglandin E2(PGE2)	Kleinhenz *et al.* (2022)
Male Holstein calves	Single oral dose, 4 days	Industrial hemp: 35 g (target dose of 5.4 mg/kg cannabidiolic acid)	No significant changes in serum parameters	Kleinhenz *et al.* (2020)
Carpathian goats	31 days	Hempseed oil: 93 g/day	Higher milk fat content, increase in conjugated fatty acid and PUFAs, no effect on milk yield	Cozma *et al.* (2015)

Table 5: Health benefits of peptides derived from hempseed protein.

Bioactivity	Main conclusions	References
Antioxidation	Differences in DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity, exhibiting the lowest IC50 value of around 2.3 mg/mL, along with Fe2+ chelation capacity demonstrated by the lowest IC50 values ranging from 1.6-1.7 mg/mL. Additionally, there is variance in reducing power, as indicated by the highest absorbance at 700 nm ranging from 0.31 to 0.35	Tang *et al.* (2009)
	The DPPH radical scavenging activity was notably less potent when compared to the fractionated peptides. The fractionation of HSP (heat-stable peptide) resulted in notable enhancements in ferric reducing power, DPPH, and hydroxyl radical scavenging activities. However, it led to a reduction in metal chelation capacity. Within the peptide fractions, those with longer chain lengths (ranging from 3-5 kDa and 5-10 kDa) exhibited superior metal chelation and ferric reducing power in comparison to the <1 kDa and 1-3 kDa fractions.	Girgih *et al.* (2011a)
Serum glucose regulation	HSP (heat-stable peptide) subjected to Alcalase treatment at a degree of hydrolysis measuring 27.24±0.88% displayed strong inhibition of alpha-glucosidase activity. This effect was attributed to the presence of two newly discovered alpha-glucosidase inhibitory peptides with the following sequences: Leu-Arg (with a molecular weight of 287.2 Da) and Pro-Leu-Met-Leu-Pro (with a molecular weight of 568.4 Da)	Ren *et al.* (2016)
Angiotensin I-converting enzyme inhibition	More pronounced inhibition in laboratory settings of the functions of angiotensin I-converting enzyme and renin, the primary enzymes responsible for the abnormal increase in blood pressure (hypertension).	Girgih *et al.* (2011b)
Antihypertension and renin inhibition	A 1% concentration of alcalase HPH proved to be the most efficient in lowering systolic blood pressure, leading to a reduction of -32.5±0.7 mmHg within 4 hours. On the other hand, the pepsin HPHs had a more sustained impact, resulting in a decrease of -23.0 ±1.4 mmHg even after 24 hours.	Malomo *et al.* (2015)
	Peptides consisting of a small number of amino acids (≤5), like Trp-Val-Tyr-Tyr (WVYY) and Pro-Ser-Leu-Pro-Ala (PSLPA), demonstrated the highest levels of antioxidant efficacy. Specifically, they exhibited a DPPH scavenging capacity of 67% and 58%, while their metal chelation activity reached 94% and 96%, respectively.	Girgih *et al.* (2014)
Acetylcholinesterase inhibition	Among the HPHs (hydrolyzed proteins), those treated with 1% pepsin exhibited the strongest inhibition of acetylcholinesterase, displaying an IC50 value of 6 µg/mL. In contrast, the IC50 values for the other HPHs ranged from 8 to 11.6 µg/mL.	Malomo & Aluko (2016)