FIHO Position Paper

Hemp in Livestock Feed

Global Review June 2024

CONSENSUS DOCUMENT ON FEED COMPOSITIONAL CONSIDERATIONS FOR HEMPSEED BYPRODUCTS:

KEY NUTRIENTS, ANTI-NUTRIENTS AND RECOMMENDATIONS

Federation of International Hemp Organizations (FIHO)

Research and Standards Committee

Avenue Louise, 65, 1050 Bruxelles, BE
Tel: +32 474 25 75 40 | Email: Info@FIHO.org | https://fiho.org/

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About FIHO

The Federation of International Hemp Organizations (FIHO) has its origins in 2019 with national and subnational hemp organizations reviewing potential integrated policy and research initiatives of mutual benefit. An expanded group of 18 global hemp organizations from Africa, Asia, Europe, North America, South America, and Oceania developed FIHO's structure, mandate, and founding principles over the next two years.

FIHO officially formed in May 2022 and elected its first Board of Directors in November of that same year. In addition to its Board of Directors and three standing committees (Executive, Finance and Audit, and Governance), FIHO formed four working committee (Communications and Engagement, Policy and Regulations, Research and Standards, Sustainability). These committees combine the synergy of hemp experts and resources to address global needs of the industrial hemp sectors, and where needed, a common voice with a concensus approach on important hemp issues. Over 45 hemp groups participate in FIHO's committees. The work is targeted to benefit hemp producers and processors, consumers and the environment in a global manner.

FIHO builds on existing expertise to extend its reach and expand the global understanding of hemp and hemp opportunities. Over 100 qualified industrial hemp experts are available for technical reviews and developmental work. This includes subject matter specialists in food, fibre for building materials, livestock feed, farming and agronomy, sustainability, and value chain professionals.

FIHO's members include:

- Australian Industrial Hemp Alliance (AIHA), Australia
- European Industrial Hemp Association (EIHA), Belgium
- Canadian Hemp Trade Alliance (CHTA), Canada
- Kentucky Hemp Producers Cooperative Association (KHPCA), USA
- National Hemp Growers Association (NHGA), USA
- National Industrial Hemp Council of America (NIHCoA), USA
- Tshwane University of Technology (TUT), South Africa
- WAFBA LLC (WAFBA), USA

This publication is available electronically, at no charge.

For this and many other global hemp industry education, policy, research, standards or sustainability information, consult FIHO's website at www.fiho.org

or contact:

Federation of International Hemp Organizations
Maren Krings - Secretary General
Brussels Belgium
+43 664 12 08 77 9
Email: info@fiho.org

Forward

Industrial hemp is grown in over 75 countries and the seed or kernel of this broadacre outdoor agricultural crop has a high nutritive value for humans and livestock. Hempseed is an excellent source of protein, fibre, amino acids, minerals and healthy fats. Processing of hempseed for food is growing due to the need to supply nutrients for human food and food ingredients.

Within normal management stored seed can undergo quality downgrades, resulting in seed not fit for food purposes. Alternative feeding to livestock can provide a sustainable re-purposing option for food processors and farmers to avoid food wastage. A secondary livestock feed market can boost processor and farmer economic positions, serving to underpin the industrial hempseed value chain. In addition a feed market option can reduce risk for the farmer.

This review is limited to hempseed and seed byproducts intended for use as a nutritional component of livestock feed. These are livestock species[1] such as beef or dairy cattle, poultry (broilers, layers, turkey, quail), hogs, sheep and other ruminants, or farmed fish intended to supply products for food consumption by humans. In addition to protein, seed byproducts can supply dietary fibre and healthy omega 3/6 fatty acids, and seed oil can reduce the environmental footprint of livestock production.

This review includes feed sources fed to livestock and resulting in meat, milk, eggs or organ meats sourced by humans as food products.

A unique characteristic of the industrial hemp plant is the production of plant-based cannabinoids in the flowering top and not the seed. These plant phyto-chemicals have potential for human and animal health products if further concentrated, but *not* at the levels present in seed or its byproducts. Due to incidental contact during harvest, natural residual levels are present on the outer seed shell at less-than trace amounts only. Hempseed does not produce cannabinoids.

The only cannabinoid with the potential for intoxication when concentrated is delta-9 THC tetrahydrocannabinol. However the majority of residual levels on the outside of hempseed are in the acidic precursor THC-A form. This “A” form must be heated at high temperatures for a specific time period to be converted to the biologically available delta-9 THC. This heating does not occur in food or feed processing or internally within an animal’s digestive system.

Due to recent discoveries in human health properties for cannabidiol (CBD) from hemp, nutritive safety in potential animal feed has also been reviewed. The cannabinoids THC and CBD present are not readily available for absorption into animal tissue through feed. It is estimated that THC or CBD present at less-than trace levels, are in turn absorbed at a 9-12% rate by livestock species.

Global research indicates that THC and CBD levels naturally present at less-than trace or residual level in hempseed byproducts, are further reduced when fed at 1-30% portion of a feed ration. The cannabinoids THC and CBD are not transferred to food products at any level of safety significance to humans or livestock.

Feed research and data is summarized, and feeding rates (percentage of ration) are presented to support a safe level of industrial hempseed ingredients in feed for livestock.

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[1] Hempseed byproducts may also be nutritional supplements for companion animals such as horses, dogs or cats however these non-livestock species are not included in the scope of this paper.

Section I: Background: Industrial Hemp – A Global Industry

A. Industrial Hemp Production

Hemp has been cultivated globally for over 5,000 years as a source of food and fibre with references dating back to ancient China and Mesopotamia. Applications of the hemp plant evolved from simple rope and coarse woven fabric to paper and sail cloth. Hempseed has been used in food, and fibre from its stalks have been used in building materials during the period of 2700 BC through to Roman times. It grown in over 60 countries primarily for food and fibre production.

Hemp has historically evolved differently from high-THC cannabis, although the plants have a similar leaf. Hemp or industrial hemp is grown in large extensive outdoor fields, and sown within a planned crop rotation by farmers along with other agricultural crops. The hemp plant is differentiated from high-THC (delta-9 tetrahydrocannabinol) drug cannabis plants and has different value chains and markets in most regions.

In 1961, the United Nations drafted the Single Convention on Narcotic Drugs (C61) in part related to drug habituation and the illicit drug trade concerns of the drug cannabis plant. While industrial hemp was exempted from C61 control ("The Convention shall not apply to the cultivation of the cannabis plant exclusively for industrial or horticultural purposes"), it governments identifying control measures to prevent misuse and illicit drug traffic and by default, continued existing prohibitions on hemp production established in the 1920s and 1930s.

As hemp is reintroduced, many countries have discovered the benefits of this unique crop. It has a high biomass yield above ground, a considerable root system underground, and multiple post-farm uses in food, building and construction, woven /non-woven textiles, consumer and industrial products, and bio-polymers and epoxies. Livestock feed is allowed in countries which never prohibited hemp cultivation. Due to the high profile of a chemical class of natural compounds known as phyto-cannabinoids, considerable science has been utilized to prove the safety and efficacy of hemp as livestock feed.

Agricultural Crop Production

Industrial hemp is sown to diversify crop rotations as part of good crop management. In addition hemp can add to farm incomes, as it may provide a dual crop or options for multiple products to be sold (grain and fibre for example).

Between 90-115 days after seeding the whole seed is harvested using agricultural harvesting equipment, and hauled to storage. The dry-down of whole hempseed can be assisted by removal of weed seeds, field debris, partial leaf and foreign material. This excess material is removed through the seed cleaning process typically using mechanical screening and air systems where foreign material of different size, weight, and densities of non-seed material is removed. Whole seed is transported back into storage bins, and leftover non-food grade material is known as hempseed screenings.

Weather conditions during harvest and moisture levels during on-farm storage determine if downgraded quality in the seed occurs. If this takes place, a re-purposing would be for use as livestock feed and resultant feed ingredients would be beneficial to feed processors and livestock owners.

Re-purposing for nutritional ingredient use in livestock would improve processing efficiencies and sustainability if re-directed to feed and not disposed at landfills.

In other crops the re-directing of lower quality byproducts from cottonseed, soybean, canola, vegetables, corn/maize and other global crops has improved not only the sustainability of these industries but product flow, cash flow and diversified value chains. This improves overall availability of feedstuffs for livestock, and in turn the availability of food and improved food security for humans. And reduces risk in the crop value chain and for the farmer.

What is hemp?

Hemp (industrial hemp) is defined as a Cannabis *sativa L*. plant, or any part of that plant, in which the concentration of total delta-9 tetrahydrocannabinol[2] (THC) in the flowering tops/upper primary leaf is equal to or less than the regulated maximum level as established by authorities having jurisdiction.

Regional authorities define industrial hemp through regulation based on a maximum threshold for THC in the flowering tops, which determines if the plant variety is hemp or not. Multi-generational crop production methods maintain THC levels at or below those thresholds. These threshold definitions vary globally from 0.2% to 1% THC in the flowering tops of the hemp plant.

The level of cannabinoids is very low in the non-flowering components, such that THC is essentially non-recoverable in the rest of the hemp plant. It occurs incidentally at less-than trace levels on the outer seed shell and upper primary leaf.

Total THC is defined as:

delta-9 THC plus (THC-A x 0.877)

Note the THC-A acidic form (tetrahydrocannabinolic acid) is a precursor, and generally not available to mammals unless heated at very high temperatures for a significant time period.

Those temperatures are not reached in food or feed manufacturing or on-farm where livestock are fed.

Cannabidiol or CBD is not identified as intoxicating or habit forming[2] by any food authority and threshold levels are not identified in human food derived from hempseed.

Where is THC found in the plant?

THC or delta-9 tetrahydrocannabinol is a natural constituent of the *cannabis Sativa L* plant's flower and its upper top leaf adjacent to the flower. THC is produced in the flowering tops of this plant and not in the seed.

Cannabinoids such as THC are natural chemicals produced by some plants, including hemp. The two most often cited are THC and cannabidiol (CBD) found at lower levels in outdoor

[2] Delta 9-tetrahydrocannabinol (THC) is the only cannabinoid identified as intoxicating and habit forming by the UN Expert Committee on Drug Dependence (2017-2019). Additional synthetic isomers can be isolated or concentrated by secondary processors but *not* present in hemp seed and byproducts destined for food or animal feed ingredients. There is a significant 10,000-times difference at minimum in the level of THC in the man-made isomers or concentrated cannabinoids for non-food manufactured products. In addition the synthetic isomers would have no value as a feed ingredient for producing livestock intended to supply food products. These concentrated products which are medical cannabis or pharmaceutical are not destined as feed ingredients.

hemp depending on the variety type/purpose. THC and CBD, not produced in the seed, can be found at trace levels on the outer seed shell due to incidental contact with the flowering top during harvesting of the crop. When hempseed is harvested the straw is separated from the seed, which includes some upper leaf/flower material when processed mechanically by harvesting equipment.

Due to this incidental contact, THC may then get transferred during food processing to protein products due to sifting of the dehulled material. While found at less-than trace levels, THC is lipophilic resulting in a tendency to solubilize in fat-containing seed components such as hempseed oil.

There are no concentrated or isolated natural or synthetic cannabinoids in hempseed or its byproducts.

Industrial hemp has been bred for centuries to contain extremely low levels of THC, and is regularly monitored by plant breeders globally to meet that standard.

Table 1:
Maximum THC Limits for Hemp in Selected Regions

Country	THC Content
Australia	1% to 2%
Belize, Bermuda, Czech Republic, Ecuador, Jamaica, Lebanon, Morocco, Russia, Switzerland, Thailand, Uruguay	1%
Italy	< 0.6%
New Zealand, Paraguay	≤ 0.35%, not to exceed 0.5%
Austria, Belgium, Canada, China, Colombia, Denmark, Estonia, European Union, Finland, France, Germany, Ghana, Gibraltar, Greece, Guyana, Hungary, India, Lithuania, Luxembourg, Montenegro, Netherlands, N. Macedonia, Pakistan, Poland, Romania, Serbia, Slovakia, Slovenia, South Africa, Suriname, Sweden, United Kingdom, USA, Uzbekistan, Vanuatu, Zimbabwe	≤ 0.3%

At these less-than trace levels defined for the hemp plant by regulatory agencies, food products from hempseed remain safe for human consumption.

From defined THC level in the hemp plant, maximum thresholds for THC within food processing are set by food authorities.

Maximum thresholds for THC in hempseed products intended as food will vary. This is due to differences in the definition of allowable THC in the hemp plant from country to country.

In some regions of the world, specialized hemp varieties are grown as a horticulture crop to exclusively harvest cannabinoids. Hemp plants are not allowed to pollinate and do not therefore produce hempseed for use in food or feed products. This specialized production targets CBD-containing flowers contained in the inflorescence (upper portion of the plant). Herbal extracts may be produced, without changing the original cannabinoid proportions. Concentrated or isolated cannabinoids may also be extracted from the harvested material for non-food and non-feed uses.

Horticulture style production is intensely managed where plants are provided individual attention. Primary production units are relatively small (i.e. 1-10 hectares). While CBD has promising results within human and companion animal health, it is small-acreage production – estimated to be 1-2% of hemp production on a land-use basis – compared to broadacre hemp grown for hempseed and/or industrial fibre. It is. The bushy horticultural

plant is distinctly different from broadacre hemp with decreased height and more secondary branches. As these plants lack central stems and are not pollinated, they do not produce hempseed for food or feed or for commercial fibre.

A. Hemp Food

The processing of whole hempseed from broadacre outdoor production results in ready-to-eat product, food ingredients, and further food processing feedstock. This includes whole hempseed (achene), dehulled hempseed (fruit), hempseed hulls (pericarp), hempseed fines (hempseed fragments), hempseed oil (fixed oil), toasted hempseed, protein concentrates, and protein isolates.

Hempseed products have been used in many countries for consumption by humans and used in salad or breakfast toppings, protein powder for health drinks (smoothies), healthy snacks, and processed food ingredients. Hempseed oil is a good source of omega 3/6 fatty acids, an is used a vegetable oil and as an ingredient in salad dressings, cosmetics (skincare), natural health products for humans (NHPs) and animals (VHPs), and industrial non-food products.

The only cannabinoid threshold determined by health authorities for hempseed intended for human or animal consumption across the world is total THC is not produced in hempseed. Thresholds were originally set as a precaution, as it is the only naturally occurring cannabinoid identified as intoxicating and habit-forming for humans (United Nations ECDD) when concentrated or isolated in non-food processing. It should be noted that Canada has proposed amending its regulations to remove the maximum threshold for natural constituent total THC in hemp foods, as its 25+ year experience in regulating industrial hemp has demonstrated that THC concentrations never approach levels that are considered a risk to human health or food safety.

Different levels of maximum THC are used by regulators around the world to define of the hemp plant. This, in turn, results in different maximum allowable total THC levels of in food derived from hempseed.

Table 2a: Thresholds for THC and CBD Levels in Food Products Summary				
Jurisdiction	Maximum THC level defined for hemp plant	Total THC allowed in hempseed products for food use	Total THC allowed in hempseed oil intended as food	Total CBD* allowed in hempseed food products
European Union	0.3 % THC	3 ppm plus 50% measurement uncertainty	7.5 ppm plus 50% measurement uncertainty	no maximum threshold
Canada	0.3 % THC	10 ppm	10 ppm	no maximum threshold
United States	0.3 % THC	10 ppm	10 ppm	no maximum threshold
Australia	1 % THC	not more than 5 ppm	not more than 10 ppm	not more than 75 ppm
New Zealand	0.35% does not exceed 0.5% THC	not more than 5 ppm -beverage not more than 0.2 ppm	not more than 10 ppm	not more than 75 ppm
Switzerland	1 % THC	10 ppm	20 ppm	no maximum threshold

Table 2b:
Hempseed product standards – THC and CBD Thresholds

	Comments	THC in hemp food products	THC in hempseed oil	CBD in hemp food products
ASTM Standards International 2022 – standard D8440 [3]	concensus standard	Total delta-9 THC of 20 ppm	Total delta-9 THC of 20 ppm	no maximum threshold
USA GRAS Notices 2018 (Generally Recognized as Safe) Notice No. GRN 771, GRN 778, GRN 765	significant assessment of potential human toxicity levels included in GRAS	Total delta-9 THC of 10 ppm (dehulled hempseed, hempseed protein)	Total delta-9 THC of 10 ppm (hempseed oil)	no maximum threshold
USP-Food Chemical Codex[4] , USA 2021	concensus standard / monograph	Total delta-9 THC of 10 ppm	Total delta-9 THC of 10 ppm	Total CBD not more than 75 ppm (hemp protein, hempseed oil) -purpose is to identify non-adulterated product

Source: FIHO members, Ag Policy Solutions (USA), standard setting bodies, national regulatory agencies

*CBD in industrial hemp grown as an agricultural crop has not been identified at maximum levels in food products except for the USP-FCC in the USA, Australia and New Zealand. This is likely because CBD in seed-derived products are at trace residual levels, not a human safety risk, and not a significant component of food products. Most occurs as THC-A which is not bioavailable.

Notes:

The EU defines maximum THC in hemp plants, however each member country may also define levels for the definition of agricultural hemp in their own country. This is due to historic production and timeline differences ie. varying years where hemp was re-legalized in each region.

Total THC and total CBD includes an adjustment of 0.877 of the level of acidic precursor THC-A or CBD-A component. This adjustment accounts for the absorbable amount remaining after decarboxylation which is a significant heating process. This high heat does not occur in food or animal feed processing.

[3] D8440 Specification for Food Safety and Quality of Hempseed Protein Products Intended for Human Consumption is available for purchase at www.astm.org The standard identifies thresholds for food safety and quality in hemp seed and seed byproducts.

[4] Food Chemical Codex (USA) food identity monographs for hemp seed oil and hemp seed protein are available at https://www.foodchemicalscodex.org/

Regulatory agencies in most jurisdictions apply a maximum allowable total THC limit in hemp foods as a precautionary principle. Some believe this is to discourage product being diverted from the high-THC drug cannabis sector to the food chain. This is very unlikely as high-THC cannabis production utilizes non-pollinated plants that do not produce hempseed. That system focuses plant energy towards trichomes in the flowering tops to produce cannabinoids.

The regulatory levels in hempseed foods serve as a complementary approach to the legalization of medical or recreational cannabis in many countries, and a carryover from the early years of re-legalization of hemp. The THC levels chosen were based on hemp varieties commonly used since 1990; primarily fibre cultivars(varieties) or derivatives of fibre varieties.

Historically from the 1960s to 1970s a 1000-part reduction for maximum chemical levels in food derived from plants was applied as general principle when human tolerance research was not available. In some cases further research identified specific human-safe levels. For many products the 1000-part reduction still influences extreme precautionary margins.

All plants produce natural chemicals which assist adaptability to the outdoor environment and other evolutionary pressures such as disease and insects. Acceptable levels in food consider the nutritional and anti-nutritional properties of plants grown for food and consumption of subsequent food products. Many of these natural chemicals can be a safety concern if concentrated or isolated. Due to the continual “dilution” effect from farm to processor to consumer, these anti-nutritional factors become insignificant or remain at safe levels.

Flax seed, for example, contains the undesirable substance hydrocyanic acid which, when in high concentration, is extremely toxic to humans. However for naturally occurring levels from harvest to food processing and with daily consumption and cumulative toxicity assessments in humans, it is managed successfully. Typically a factor of 2 on average is the upper level threshold between flax products for food, and flax ingredients intended for animal feed when considering anti-nutritional aspects. This is due to additional dilution factors within feed manufacturing, feed inclusion rates, decreased absorption and low resultant deposition to livestock tissues. This is illustrated for hempseed in Figure 6 in the Appendix.

Existing modern crop breeding systems, plant breeding programs, inspected seed certification, and hemp food value chains essentially manage trace THC levels on the outer hull of hempseed before being sold to a food processor. These quality management programs have evolved over time and include integrated company breeding programs and

seed certification programs such as OECD[5] and AOSCA[6]. In some regions such as Europe, Canada and Australia only Certified seed can be used, grown in recognized multiple generational seed certification systems with 3rd party inspection. In those jurisdictions no farm-saved seed can be used and seed for sowing must be purchased from recognized Pedigreed seed growers.

B. THC and CBD levels in hempseed and byproducts

The industrial hemp plant by regulatory definition has low levels of THC in its flowering tops, and then only residual trace levels on the outer shell of the seed. The level of THC is in a natural ratio to the level of CBD in hemp's flowering tops. CBD produced in the upper flowering tops of outdoor broadacre hemp naturally occurs at a higher rate than THC, but at significantly lower levels compared to horticulture-style non-pollinated CBD production.

Zero or "no trace" THC is not a biological reality for the vast majority of hemp, including fiber and grain varieties. There may be a few specialized, gene edited varieties using customized seed propagation for indoor horticulture models, but these are non-seed bearing varieties geared for secondary CBD extraction. For example in the horticulture model in the future it may be possible to evolve from natural levels of 0.8%-2% to 10 to 12% CBD in the flowering top. Again CBD occurs incidentally at a lower rate on the outer shell of hempseed because it is produced in the flowering top of the plant and not the seed.

Hemp contains CBD-A synthase (not THC-A synthase) in its genome which produces primarily CBD-A. CBD-A is the acidic precursor form not available for animals due to the need for high heat conversion. The CBD-A synthase produces THC-A non-specifically in a ratio of around 1 THC-A for every 25 CBD-A (1:25). So a 25% CBD-A hemp flower variety in the horticulture production model contains about 1% THC-A (Dr. Daniel Fowler USA).

The majority of CBD in hempseed products is CBD-A however total CBD is calculated using an adjustment for slight losses during carboxylation:

Total CBD = CBD plus (0.877 x CBD-A)

Because of the presence of CBD-A, the amount of total CBD increases with the higher levels of allowable total THC in the hemp plant's flowering tops. Thus with the 1% THC definition of a hemp plant there will be naturally higher levels of CBD in the flowering tops.

The upper level of 1 THC:25 CBD occurs in the horticultural model at a natural rate in the hemp plant's upper flowering top. This occurs at a lesser extent in outdoor grain varieties, then is moderated with cropping conditions in non-horticulture agricultural production.

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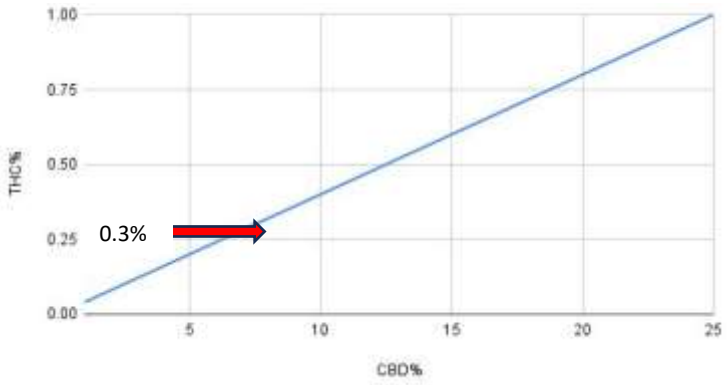
[5] Organization for Economic Co-operation and Development (OECD) is an intergovernmental organization that represents 80% of world trade and includes standards for agricultural seed quality. Many commonwealth and European countries base seed certification on OECD standards, similar to AOSCA standards for equivalent outcomes that are acceptable internationally. Founded in 1948 it is headquartered in Paris France with major offices in Berlin, Mexico City, Tokyo and Washington DC. https://www.oecd.org/agriculture/seeds/

[6] Association of Official Seed Certifying Agencies (AOSCA) is a trade organization with standards on production, identification, distribution and promotion of certified classes of seed and other crop propagation materials. Founded in 1919 it is based in Moline, Illinois USA with member agencies across the world. www.aosca.org

This moderation is due to a more stressful natural environment outdoors and varied growing conditions. Then the cannabinoid levels occur at a further reduced rate on the outer shell of seed due to incidental contact during harvesting.

Estimated THC % and CBD % in Flowering Tops (non-seed) of Hemp in Horticulture model



source: D.Fowler, USA 2024

Figure 1. The above is moderated when hemp is grown in outdoor fields due to environmental conditions where grown (precipitation) and due to the plant focusing its energy on seed production.
At a derivative of these rates incidentally adhering to the seed's outer shell, the resultant residual levels on seed are not a significant source of CBD or THC. In addition the majority is in the biologically unavailable CBD-A or THC-A form.

Due to naturally occurring ratios, the amount of remaining CBD will be higher than THC but still remains at safe and non-recoverable levels when processing hempseed (grain).

Table 3:
Expected Natural Residual Levels in Hempseed Byproducts

Definition of Hemp Plant	**a. Dehulled Seed**		**b. Hempseed Meal**	
	Total THC	*Total CBD*	*Total THC*	*Total CBD*
0.2% THC	0.25 to 1.5 µg/gram	n/a	1.1 to 1.6 µg/gram	n/a
0.3% THC	2 to 5.7 µg/gram	17 to 75 µg/gram	2 to 10 µg/gram	7 to 75 µg/gram
1.0 % THC	Less than 17 µg/gram	51 to 180 µg/gram	6 to 30 µg/gram	21 to 120 µg/gram
Global recommended level	Not more than 20 µg/gram or 20 ppm	No level recommended as not food/feed safety issue.	Not more than 30 µg/gram or 30 ppm	No level recommended as not food/feed safety issue.

For dehulled hempseed or hempseed meal, regulatory bodies intending to avoid adulterated product may safely identify total CBD level at not more than 200 µg/gram or 200 ppm. At those levels 88 to 90% occurs in the non- bioavailable CBD-A form. The threshold may assist in excluding the addition of a concentrated form of processed cannabinoids not naturally resulting from seed or food processing if that is the intent.

Table 3: **Expected Natural Residual Levels in Hempseed Byproducts**
Note: Levels for 0.3% is based on food testing in Canada, 2019 to 2024. Levels for 0.2% is based on EIHA 2015. For 1% THC hemp levels shown result from a multiplication of 0.3% plant definition levels in tested product by factor of 3 and product testing. Note 1 microgram or 1 µg/gram is equal to 1 ppm and 1 mg/kg

Interestingly, the trace amount of THC present on the outer shell of hempseed has been compared to the width of a credit card placed on a 110 metre sports field. Levels of THC in seed byproducts are not statistically significant however an upper threshold has been recommended for feed ingredients intended for livestock. This is in response to regulatory authorities as a global perspective, who often deal with a proliferation of concerns on drugs/ misuse of concentrated or isolated THC for humans from non-seed products. The upper threshold expected in feed is a diluted component when using seed byproducts as a 1 to 30 percent of a livestock feed ration for a specific phase or period of animal growth.

Research with concentrated cannabinoids, non seed-derived product, has indicated that feed inserted with high levels of cannabinoids is unpalatable to livestock. The resultant flavour is tainted so animals will not eat the product unless artificially fed in research programs. This does not however preclude future research on added cannabinoids at safe levels.

The European Food Safety Authority in 2015 concluded:

- Tetrahydrocannabinol, more precisely delta-9-tetrahydrocannabinol (Δ9 -THC) is the most relevant constituent of the hemp plant. Four stereoisomers of Δ 9 -THC are possible, with (-)-trans-Δ 9 -THC being the only naturally occurring stereoisomer.
- In fresh plant material up to 90% of the 'total' Δ 9 -THC is present as the non-psychoactive precursor Δ 9 -THCA-A.
- Capillary gas chromatography coupled with mass spectrometry (GC-MS) following liquid-liquid extraction or solid phase microextraction is the method of choice for the determination of Δ 9 -THC and other cannabinoids in hemp-containing food products. Note: this provides a significantly low level of detection (LOD) however this does not preclude additional methods that can identify THC accurately with a ≤ 4 ppm LOD.
- As high temperatures are not generated during de-hulling and oil extraction of seed, these processes are not expected to result in increased levels of ∆9 -THC in the oil or meal resulting from decarboxylation of precursor acids.
- In humans after oral exposure, Δ 9 -THC is slowly and incompletely absorbed from the gastrointestinal tract. The oral bioavailability is lower compared to inhalation. Studies in both rats and humans indicate that the in vivo conversion of ∆9 -THCA-A to Δ 9 -THC does not occur.

<u>Other hempseed byproducts</u>

The amount of seed-derived CBD will be higher than THC but expected to be less than 75 µg/gram or 75 ppm (USP-FCC review, USA 2022) in hempseed protein concentrates and hempseed oil. This is due to non-protein byproducts such as fibre sifted out when hempseed meal is processed into protein concentrate. Trace levels of non-fibre components including protein and cannabinoids are not "sifted out". Thus as a percent of the overall weight they are then mathematically slightly higher but not concentrated.

In addition when hempseed is crushed to extract seed oil, THC solubilizes to the fat component in the seed oil therefore higher trace THC levels are seen in the seed oil. At the 0.3% plant definition this varies from 3 to 5 ppm to a high of 8 ppm total THC using past and current hemp variety testing. In hempseed oil, CBD levels vary from 18 to 35 ppm total CBD with the majority in the precursor CBD-A form. Source: hemp definition 0.3% Canada 2019

C. Feed Ingredients Needed for Food Production

The current trend in global human population growth demands an increase in the production of animal protein of about 60% or more by 2050 (FAO 2011), with the task for the animal industry to provide a sustainable supply of meat and eggs (FAO 2010). Generally, animal feed accounts for greater than 70% of the total cost in animal production, of which dietary protein together with energy represents a substantial portion. For example, diets for monogastric (single stomach) animals are usually formulated around a cereal-protein-based diet, mainly contributed by corn and soybean meal. Feedstuff price fluctuation and accessibility of dietary ingredients contributes to hempseed byproducts potential as feed ingredients. Source: N.Mohamed et al, Cdn J.Animal Science 2024

The efficacy of hempseed-derived products has been evaluated in poultry, swine, ruminants, and aquaculture diets. These evaluations include measures of animal productivity such as growth rates, feed efficiency, reproduction/hatchability, and carcass quality.

From an environmental perspective, hempseed-derived products have also proven effective as a possible strategy for reducing the environmental footprint in cattle (Wang et al. 2017; Baldini et al. 2020) and swine (Hăbeanu et al. 2022). In an in-vitro study, supplementation of hempseed oil at an inclusion rate of 7% of dry matter (70 kg per tonne) for forage-based diets for cattle, reduced methane emissions by 18% compared to a flaxseed oil or a control without supplemental oil (adapted from Wang et al. 2017). In a swine study by Hăbeanu et al. (2022), a 4.5% decline in enteric methane emission was observed.

Figure 2:
Hempseed byproducts in the food processing and farming industries include:

Whole hempseed	Hempseed screenings	Dehulled hempseed	Hempseed hulls
			
Hempseed meal	**Hempseed fines**	**Hempseed protein concentrates**	**Hempseed protein isolate**
			
Hempseed Oil	Other: grazing of standing hemp crop destroyed by weather (drought, flooding, insect damage) is not included in the discussion but to be added as further research is identified with safety and efficacy data.		
			

It is noted that oilseed crops are the majority protein source for animal nutrition in the EU (64%, adapted from FEIOL). Source: Rakita et al 2023

Access to seed-derived byproducts such as the above bring nutritional value to the livestock feed continuum.

Section II: Composition of Hempseed and Seed Byproducts for Feed

Hemp products such as whole seed, dehulled seed, hempseed oil, hempseed meal, hempseed hulls, and to some extent hempseed screenings have been evaluated in the production of various animals including poultry, swine, ruminants, and aquaculture. These studies indicate hempseed products do not negatively influence animal health indicators or animal performance. Moreover, they enhanced animal products (egg, meat, and milk) with health-benefiting bioactive components such as omega-3 fatty acids, fat, gamma-linolenic acid, and conjugated linoleic acid. Although most supporting evidence from literature on the safety and efficacy may have focused on the application of whole hempseed, hempseed oil, and hempseed meal for use in animal feeds, other hempseed-derived fractions such as such as dehulled seed, hulls, screenings and protein concentrates are nutritionally valuable for animals.

For detail on hempseed ingredient research for each species of livestock please refer to *N.Mohamed and J.House, Safety and Efficacy of Hemp-Derived Products in Animal Feeds – A Narrative Review*. Cdn J.Ani. Sci. 2024.

The authors concluded that within prescribed limits, hempseed-derived products can be regarded as safe and effective feed ingredients and suitable alternatives to the conventional feed ingredients for inclusion in animal feeds.

Information in the following Tables summarize hempseed byproduct sampling from commercial hempseed/food processors in Canada. Animal nutritionists reviewed all potential anti-nutritional factors and indicated all components were within normal and acceptable ranges for livestock feed in Canada. These results are applicable globally.

A. Nutritional

Hempseed byproducts are excellent sources of protein and energy (Mohamed et al. 2024). Data indicates the seed contains 20–25% protein, 20–30% carbohydrates (mostly as fibre), and 25–35% oil (House et al. 2010), and is valuable for livestock and poultry (Callaway 2004; Mustafa et al. 1999; Silversides and LefranÇois 2005).

Hempseed and hempseed meal are also rich in amino acids, particularly high in arginine, glutamic, and aspartic acids. In addition, hempseed oil contains a high content of polyunsaturated fatty acid (approximately 80%) with a favourable ratio of approximately 3 to 1 of linoleic acid to alpha-linolenic acid (Parker et al. 2003). This ratio of these healthy fats is unique to hempseed oil compared to other plant-derived dietary source of omega-3 polyunsaturated fatty acids, such as flaxseed oil (1:4) (Callaway 2004), making it desirable for good health and development in animals (Yao et al. 2012). Moreover hempseed and hempseed oil have been shown to efficiently enrich animal products with the essential fatty acids (Gakhar et al. 2012; Gibb et al. 2005; Neijat et al. 2016a; Neijat et al. 2016b; Silversides and LefranÇois 2005).

Table 4:
Proximate Components in Hempseed-Derived Fractions (%, As-Is Basis)[a]

Parameters	Seed oil [b]	Whole seed	Hempseed hulls	Dehulled seed	Hempseed Meal	Protein concentrate	Coarse seed protein	Screenings	p-value
Dry matter	99.9 ± 0.08	92.8 ± 0.39^{b}	92.1 ± 0.42^{b}	94.4 ± 0.25^{a}	91.8 ± 0.34^{b}	92.8 ± 0.25^{b}	92.6 ± 0.52^{b}	92.1 ± 0.50^{b}	<.0001
Moisture	0.13 ± 0.08	7.24 ± 0.39^{a}	7.89 ± 0.42^{a}	5.61 ± 0.25^{b}	8.21 ± 0.34^{a}	7.24 ± 0.25^{a}	7.36 ± 0.52^{a}	7.91 ± 0.50^{a}	<.0001
Crude protein	0.00	23.9 ± 1.54^{bc}	15.7 ± 2.83^{c}	32.8 ± 0.74^{b}	33.0 ± 1.83^{b}	49.7 ± 4.15^{a}	21.5 ± 12.3^{bc}	26.6 ± 1.31^{bc}	<.0001
Fat	99.8 ± 0.08	32.0 ± 1.07^{b}	12.6 ± 3.50^{c}	50.7 ± 0.95^{a}	8.37 ± 1.17^{c}	8.97 ± 1.60^{c}	7.60 ± 2.03^{c}	27.2 ± 2.19^{b}	<.0001
Fat (GC/FID)	97.2 ± 1.04	32.7 ± 1.08^{b}	13.4 ± 4.14^{d}	49.6 ± 1.15^{a}	8.21 ± 1.08^{d}	8.87 ± 1.62^{d}	7.64 ± 1.87^{d}	25.9 ± 3.18^{c}	<.0001
crude fiber	0.00	22.2 ± 0.40^{cd}	42.5 ± 2.77^{a}	3.37 ± 1.81^{ef}	26.6 ± 2.41^{bc}	10.2 ± 2.33^{def}	38.5 ± 14.3^{ab}	16.4 ± 2.87^{cde}	<.0001
NDF	0.00	29.4 ± 0.85^{b}	58.8 ± 4.85^{a}	2.99 ± 1.45^{c}	39.3 ± 4.42^{ab}	17.0 ± 3.35^{bc}	54.7 ± 19.8^{a}	24.9 ± 5.45^{bc}	<.0001
ADF	0.00	24.7 ± 0.61^{b}	50.2 ± 4.56^{a}	2.91 ± 1.98^{c}	32.4 ± 4.35^{ab}	13.3 ± 3.42^{bc}	45.3 ± 16.8^{a}	20.9 ± 5.15^{bc}	<.0001
Ash	0.05	4.07 ± 0.69^{c}	3.73 ± 0.22^{c}	6.03 ± 0.79^{abc}	6.73 ± 0.39^{ab}	8.29 ± 0.82^{a}	4.81 ± 2.04^{bc}	6.08 ± 0.14^{abc}	<.001
NFC	0.00	10.6 ± 0.39^{b}	17.6 ± 3.16^{a}	1.55 ± 0.88^{c}	17.1 ± 0.62^{a}	15.6 ± 1.18^{a}	20.2 ± 2.68^{a}	15.9 ± 0.10^{a}	<.0001

a. Data represent means ± standard deviation (SD). Different superscripts between hemp-derived fractions in a row are significantly different at P < 0.05. n = 3 sampling sites. Abbreviations: HS = hempseed, HC/HM = hempseed cake/meal, NDF = neutral detergent fiber, ADF = acid detergent fiber, NFC = nonfiber carbohydrate. bNot included in the statistical analysis.

Source: N.Mohamed et al, Chemical Characterization of Hemp (Cannabis sativa L.)-Derived Products and Potential for Animal Feed, Canada; ACS Food Sci. Technol. 2024, 4, 88-103

B. Anti-nutritional

Anti-nutritional components have been tested in hempseed-derived products and results were within normal expected ranges for grain from agricultural crops (Canada 2019-2020). For anti-nutritional properties the levels present will depend on the local region where grain is grown, growing season, the variety to some extent, and the acceptable limits by the authority having jurisdiction. In turn manufacturers of commercial feed will manage the range in incoming lots and re-mediate if needed using existing acceptable feed processing practices.

- Mycotoxins and heavy metal concentrations are low in hemp grown for grain. Both constituents depend on the region and sub-region and can vary based on hemp grain variety and pre-existing conditions in local soil. In addition regulatory authorities may have different maximum thresholds and mitigation options so recommendations will depend on local scenarios. A detailed Canadian study with 11 hemp varieties from 13 locations across Canada indicated levels below regulatory thresholds and international requirements (J.Slaski 2022). It was noted that levels in grains such as sunflower, hemp, flax and durum wheat are dependent on soil acidity, soil type by region, and prior crop nutrient management.
- Aflatoxin B1, B2, G1, G2, ochratoxin A, and total aflatoxin were below detection limits, ie. 0.05, 0.06, 0.07, 0.03, 0.04, and 0.03 μg/g in all hemp-derived products. Total aflatoxin including ochratoxin A was 0.03 below the recommended guideline from the Canadian Food Inspection Agency permitted in complete feed samples for poultry and swine. Note EU Regulation No. 1881/2006 for the sum of B1, B2, G1 and G2 in numerous foodstuffs is 0.015 μg/g. These constituents are managed regularly according to regional safety authorities by all licensed commercial feed manufacturers.
- Tests for 106 potential pesticides (herbicides, fungicides, other) indicate no significant levels in all products tested.
- Values for nitrate were below guidelines set for management of various nitrate levels in forage production. Organic acids such as oxalic, citric, malic and tartaric acid were not seen as a concern in samples tested in Canada. Total saponin content (THC) was uniformly distributed in byproducts, except for hempseed oil which was lower.
- See Appendix section e. for a detailed analysis of seed byproduct samples.

C. Natural Residual Constituent Cannabinoids of Hempseed – THC and CBD

The processing of hempseed for the extraction of hempseed oil, whether performed by solvent or mechanical pressing, generates significant amounts of byproducts at a volume of 60% of the seed weight. Hempseed byproducts were tested for THC and CBD content and presented in Table 5 below.

Table 5:
Cannabinoid Content in Hempseed Byproducts 2019a

cannabinoids[b] (µg/g)	HS oil (HO)	HS	HS hulls (HH)	dehulled HS	extruded HC/ HM	HS protein concentrate	High Fibre HS protein	screenings	p-value
CBD	5.55 ± 0.64^{ab}	1.85^{b}	1.85^{b}	1.85^{b}	1.85^{b}	1.85^{b}	1.85^{b}	297 ± 153^{a}	0.003
CBDA	20.2 ± 8.11^{b}	33.6 ± 4.76^{b}	36.1 ± 8.56^{b}	19.9 ± 5.22^{b}	19.1 ± 6.32^{b}	21.5 ± 8.53^{b}	14.8 ± 10.7^{b}	475 ± 116^{a}	0.021
CBD concentration	22.0 ± 9.54^{b}	31.0 ± 5.00^{b}	34.0 ± 7.00^{b}	17.7 ± 4.73^{b}	17.3 ± 6.03^{b}	19.0 ± 7.81^{b}	13.7 ± 9.24^{b}	714 ± 236^{a}	0.019
Δ9-THC	2.65^{b}	2.65^{b}	2.65^{b}	2.65^{b}	2.65^{b}	2.65^{b}	2.65^{b}	56.1 ± 21.5^{a}	0.002
THCA-A	1.60^{b}	1.60^{b}	1.60^{b}	1.60^{b}	1.60^{b}	1.60^{b}	1.60^{b}	30.7 ± 3.78^{a}	0.002
total potential THC	5.00^{b}	5.00^{b}	5.00^{b}	5.00^{b}	5.00^{b}	5.00^{b}	5.00^{b}	83.0 ± 25.0^{a}	0.002

a. Data represents means ± standard deviation (SD), n = 3 sampling sites. Based on the Kruskal–Wallis test, $P < 0.05$ was assumed as statistically significant. Abbreviations: HS = hempseed, HC/HM = hempseed cake/meal, CBD = cannabidiol, CBDA = cannabidiolic acid, Δ9-THC = Δ9- tetrahydrocannabinol, and THCA-A = tetrahydrocannabinolic acid-A.
b. Detection limits (µg/g) for CBD, CBDA, CBD concentration, Δ9-THC, THCA-A, and total potential THC are 3.7, 2.4, 6.0, 5.3, 3.2, and 10.0, respectively

Discussion

All hempseed-derived products, except the screenings, contain levels of CBD, THC, and THC-A below the detection limits of 3.7, 5.3, and 3.2 µg/g respectively(Neijat 2024 Canada). In addition the total potential THC was below the detection limit of <10 µg/g or 10 ppm in all products except screenings. The content of the main active component (THC) in all hemp-derived products, except screenings, was below the guidelines in the range of 10-20 mg/kg (10-20 ppm) in the European Food Safety Authority (EFSA) Regulation 2015.

Screenings in all crops are leftover material from seed cleaning of grain, essentially a “catch all” product of post-harvest grain material at the farm level. This product is not fed in the raw form due to inconsistency in nutrition and the desire to avoid inadvertent re-seeding of weeds. In addition unwanted weed seed such as wild oats may lodge in an animal’s cheek and result in infections. Variability in raw screenings is managed by feed manufacturers with dockage limits and by mixing with other feed inputs, then pelleting for uniformity and a targeted percent protein. This results in a nutritionally consistent feed supplement for livestock, and repurposing of an otherwise unused product.

A 2022 Agriculture and Agri-Food Canada study feeding hempseed hulls and screenings illustrates the variable nature of screenings, as compared to levels noted in Table 5.

Figure 3.

Raw ingredient	CBD level, µg/g	CBD-A level, µg/g	d9-THC, µg/g	THC-A, µg/g	THC potency, %	CBD potency, %
Hulls	6.6	22.8	1.4	8.5	0.001	0.003
screenings	22	288	8.8	44.2	0.005	0.028

D. Cold-Pressed Hempseed Meal (cake) nutrient comparison to other oilseed crops

Table 6:
Chemical composition (on DM basis) of cold-pressed oilseed cake

Nutrient	RSC	HSC	LSC	SFC	CSC	PSC
Protein (%)	19.4 [15]–45.0 [16]	24.8 [17]–36.1 [18]	32.2 [19]–35.9 [20]	21.6 [5]–37.7 [21]	31.3 [22]–42.0 [23]	38.3 [17]–62.3 [24]
Fat (%)	9.6 [16]–31.3 [10]	8.9 [25]–16.4 [26]	11.5 [21]–21.4 [17]	11.7 [27]–31.4 [21]	10.5 [23]–26.0 [22]	9.0 [24]–36.2 [17]
Ash (%)	4.2 [15]–8.1 [16]	6.3 [25]–7.5 [17]	4.9 [18]–5.9 [20]	4.3 [28]–6.3 [8]	4.5 [29]–6.5 [23]	7.5 [15]–8.1 [21]
Fiber (%)	6.5 [16]–19.5 [15]	25.1 [30]–26.1 [25]	8.6 [31]–9.5 [32]	12.6 [5]–37.0 [28]	11.3 [33]–17.0 [34]	23.1 [15]
NDF (%)	17.0 [35]–33.7 [36]	37.7 [18]–53.4 [17]	17.6 [18]–21.3 [20]	n.d	23.7 [37]–43.4 [29]	11.8 [17]–13.9 [24]
ADF (%)	9.0 [35]–21.0 [36]	29.7 [30]–39.2 [17]	13.0 [19]–14.2 [17]	n.d.	11.1 [38]–21.6 [29]	5.1 [17]–11.1 [24]
Glucosinolates, (μmol/g)	8.8 [35]–16.9 [39]	n.d.	n.d.	n.d.	22.9 [33]–46.1 [37]	n.d.

RSC—rapeseed cake; HSC—hempseed cake; LSC—linseed cake; SFC—sunflower seed cake; CSC—camelina seed cake; PSC—pumpkin seed cake; NDF—neutral detergent fiber; ADF—acid detergent fiber; n.d.—non defined. Figures between square brackets [...] indicate references.

Source: Rakita et al, Europe 2023

E. Current feed approvals by region

Figure 4

Jurisdiction	Total THC maximum allowable level	Total CBD maximum level	Product and Species
Texas USA a) Hempseed meal	a)recommended ASTM limit of 20 ppm	a)None identified	a) Hempseed meal for foal, mare, breeding and maintenance horses at no more than 20% of the diet; and in the diet of layers and breeders (chickens) at no more than 30% of diet
b) Hempseed oil	b) recommended ASTM limit of 20 ppm	b) None identified	b) Hempseed oil for total diet of foal, breeding mare at up to 12% of the total diet, and in chicken (broilers, layers and breeders)
Kentucky USA A. Hempseed meal	a)0.002% (20 ppm)	a) None identified	a) meal inclusion rate for layer, broiler, and breeder chickens at no more than 30% of the diet; and in growing, maintenance, brood mare, and performance horse diets at no more than 20% of the diet
b)Hempseed oil	b)0.002% (20 ppm)	b) None identified	b) seed oil included in diets of layer, broiler, and breeder chickens at no more than 12% of the diet; and in growing, maintenance, brood mare, and performance horse diets at no more than 12%.
AAFCO[7] USA	Tentatively: less than 2 ppm total THC	Tentatively: less than 20 ppm total CBD	Mechanically derived hempseed meal for laying hens at no more than 20% of the diet
Australia	Less than 10 ppm	None identified	Hemp protein in animal foods
European Industrial Hemp Association	Proposed total THC upper limit: Hempseed – 5 ppm	None identified	Proposed total THC upper limit: Hempseed meal (expeller) – 5 ppm Hempseed oil – 15 ppm Complete feed – 3 ppm
Note: upper thresholds may vary due to differing levels of allowable percent THC in the upper flower of the standing hemp plant (differences in definition of hemp in each country).			

[7] American Association of Feed Control Officials January 2024, a national feed regulatory body in the USA.

Section III: Livestock Feed Research

A meta-analysis of livestock feed research in the Canadian Journal of Animal Science summarizes the efficacy of seed byproducts in feed, safety, and potential residual transfer to food products of animal origin. Over 130 peer-reviewed scientific publications in recognized journals were reviewed by Dr. N.Mohamed and J.House, University of Manitoba, Canada.

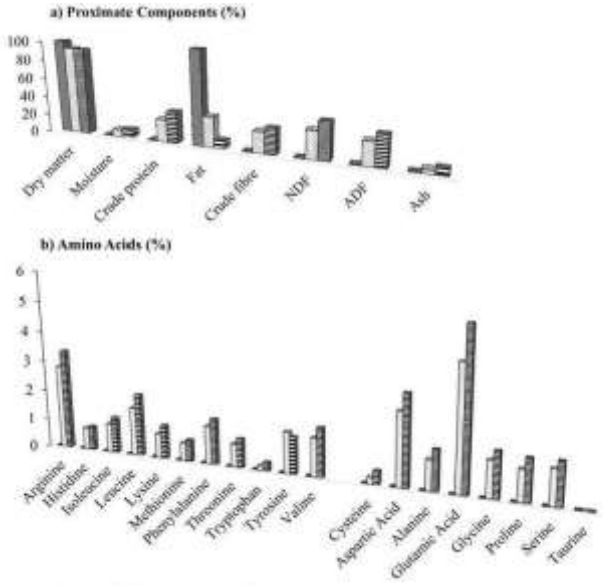


Figure 5. Proximate Analysis of whole hemp seed oil (HO), hemp seed (HS), and hemp seed meal/cake (HC/HM)

Data adopted from Neijat Mohamed et al. (2024).

Cdn. Journal of Animal Science

NDF = neutral detergent fibre, ADF = acid detergent fibre

Feed Manufacturing Processes with Heat Applied

Research in Canada investigated the potential effect of heat within mechanical pelleting and extrusion feed manufacturing processes, to determine if the acidic precursor of THC and CBD (THC-A and CBD-A) are converted by heat to the available forms. With the application of 95°C (pelleting) and 110°C (extrusion) heat, no additional THC-A or CBD-A was converted to the available form. This included hempseed hulls, seed screenings, and hempseed meal which were processed as whole ingredients. Due to physical mixing limitations, hempseed oil was mixed at a 1:1 barley ratio to allow for pelleting. Some loss of CBD after processing was noted in some products. Source: R.Newkirk and J.Wang, 2023. Canadian Feed Resource Centre, Saskatoon SK, Canada.

In 2015 the European Food Safety Authority concluded that hempseed byproducts in animal feed did not pose a risk to human safety, with the definition of a hemp plant at 0.2% THC. Hempseed meal can be used to replace other oilseed meals in diets for cows, pigs and horses. Note in 2024 the definition of a hemp plant in the EU was adjusted to 0.3% THC.

A. Ruminants (livestock with 4 stomach compartments)

In general up to 15% hempseed meal supplemented diets are comparable to diets where canola meal is used as a protein supplement. Hempseed meal is a high-quality and safe protein supplement for nonlactating and lactating dairy cows. It has been shown to increase crude protein digestibility and urea in urine, milk, and blood plasma, as well polyunsaturated fatty acid(s) content of milk fat. Source: Comparing dehulled hemp meal and canola meal as a protein supplement for lactating dairy cows, Addo et al, J. Dairy Sci. 106, Canada 2023.

In addition:

- Iannaccone 2019 showed supplementing with hempseed at 5% of a diet indicated the possibility to increase cold tolerance in lactating ewes. Mierlita 2016 and 2018 reported hempseed byproducts led to an augmentation in milk fat content and energy corrected milk yield.
- Mustafa 1999 showed hempseed meal has potential to effectively replace canola meal as a protein supplement up to 20% of the dietary dry matter for sheep.
- Studies by Cozma 2015, Abrahamsen 2021, Gurung 2022, Šalavardić 2021 indicate supplementing feed for lactating goats with seed oil or meal can be safely used at up to 30% of a ration.
- Gurung in 2022 showed that up to 30% hempseed meal can be fed to growing meat goats.
- Smith 2023 showed up to 20% hempseed meal fed to feeder heifers was effective as a protein supplement in a complete feed.

B. Monogastrics (single-stomach livestock)

Hempseed meal fed at up to 30% inclusion rate to laying hens enhanced the overall value of the eggs with increased deposition of beneficial unsaturated fatty acids, yolk pigmentation, Haugh units and lutein content. The trial also demonstrated that feeding hempseed meal/cake to laying hens did not contribute to tetrahydrocannabinol (THC) or cannabinoid residues in eggs. Source: Effect of Increasing Levels of Dietary Hempseed Cake on Egg Quality in Commercial Laying Hen, R.Kasula et al, International Journal of Poultry Science. USA 2021

Hempseed meal fed at 8% to 24% to broiler poults did not have a detrimental effect on production (Rasool 2018). In another broiler study feeding rates of 10%, 20% and 30% indicated concluded that 30 % inclusion of hempseed meal had no negative effects on the production nor the palatability of the feed. Kalmendal 2008

A study in ducks indicates hempseed meal can be used to produce high-quality meat with an enriched content of GLA. Juodka 2018 Ducks fed with diet containing hempseed cake had significantly higher amounts of linoleic acid, total n-6 polyunsaturated fatty acids, and γ-linolenic acid in both breast and leg muscles. (Sachs, McGlade et al.)

Hempseed meal at 24% inclusion fed to grower pigs resulted in performance similar to linseed cake and faba bean. Meal is suitable as a protein feed ingredient in pig diets. Presto 2011. Hempseed fed at 5% prior to farrowing improved piglet survival.

C. Aquaculture – fish with fins

Research in finned fish is on-going however no publications were available in peer-reviewed journals. At least two studies are underway and results should be available later in 2024. Source: A. Banscota, National Research Council, Halifax Canada 2024.

D. Cannabinoid Absorption by Livestock and Potential Residuals in Food Products

a. Milk, Meat and Tissue in ruminants

Feeding hemp meal to nonlactating and lactating dairy cows does not lead to accumulation of cannabinoids in body tissues and biological fluids. An inclusion rate of 10.2% of hempseed meal fed to non-lactating dairy cattle resulted in no detection of cannabinoids in body tissue, kidney, liver, urine, muscle, or adipose tissue. Feces of cows fed contained 0.68 and 0.67 µg/g DM of CBD and CBDA, respectively. This indicated that most ingested CBD and CBD-A were not absorbed but instead were excreted in the feces. The test method LC/MS following the procedure described by Meng et al. (2018). The limit of detection was 2 ng/g (0.002 ppm) for feed and feces samples, 1 ng/mL for blood plasma, urine, and rumen fluid

samples, and 10 ng/g (0.01 ppm) for tissue samples. Source: Quality and Safety of Hemp Meal as a Protein Supplement for Nonlactating Dairy Cows, Addo et al, Journal of Dairy Science Vol 106, Canada 2023

In dairy cows, the EFSA in 2015 reported that the transfer rate of Δ9 -THC to milk is in the range of 0.10– 0.15%. It concluded the exposure to Δ9 -THC via consumption of milk and dairy products, resulting from the use of hempseed-derived feed materials at the reported concentrations, is unlikely to pose a health concern. Temperatures used in pasteurization of milk are unlikely to result in decarboxylation of any non-psychoactive precursors that may be present as a result of transfer from feed.

Agriculture and Agri-Food Canada studied hempseed hulls and screenings in cannulated beef heifers, lactating ewes and feeder lambs. Results showed no significant carryover of THC or CBD in muscle, milk, fat, liver or kidney. This indicates that even at higher levels of CBD and THC naturally present in seed screenings, when fed at up to 20% of a ration, no significant absorption or deposition to tissue intended as food products occurred.

Table 7:
THC and CBD levels in hempseed hulls, screenings and pelleted rations. Canada

Product	Sample type	CBD level, µg/g	CBD-A level, µg/g	d9-THC, µg/g	THC-A, µg/g	THC potency, %	CBD potency, %
Hulls	Raw ingredient	6.6	22.8	1.4	8.5	0.001	0.003
screenings	Raw ingredient	22	288	8.8	44.2	0.005	0.028
Hulls pellet	20% pellet-to lambs	1.3	2.6	0.1	0.2	0	0
Screenings pellet	20% pellet-to lambs	3.5	17.4	1.1	2.3	0	0.002
Hulls pellet	15% pellet-to ewes	1.2	2.2	0.1	0.2	0	0
Screenings pellet	15% pellet - to ewes	3.4	14.4	0.9	1.7	0	0.002

Source: Ewe and Lamb Feeding Trial, T.McAllister and S.Terry. Lethbridge Research Center, Agriculture and Agri-Food Canada, Lethbridge Alberta, Canada 2022-2023

Notes: Commercial ewes were fed a control diet (15% wheat screenings) and the above two types of hempseed pellets. Commercial lambs were fed a 20% byproduct ration. Milk was sampled from ewes with twins at side, and lambs were slaughtered with samples of muscle (inside round and brisket), fat, liver, and kidney analysed. Blood samples were also taken 15 and 30 days after the initiation of the trial for assessment of cannabinoid residues. Results for tissue samples were at 0 ug/gram or non-detectable, except 3 samples testing at 0.1 µg/gram for the precursor THC-A in 3 of 76 tissue samples tested.

The feed research model with sheep results in conclusions applicable to other ruminants (4 stomach compartments) such as goats, beef and dairy cattle.

The trial concluded:

i. When lactating ewes are fed 8.61 and 8.85% of total diet of hempseed hulls and screenings, respectively, no residues are detected within the milk of the ewes.
ii. There is a 10 ppm allowable limit of THC within human consumed food in Canada (0.3% THC hemp definition), and all THC residues fall well below this limit.
iii. Lambs can be fed up to 20% of hempseed hulls or hempseed screenings without concerns of having a greater than 10 ppm of THC within the carcass of the fed lambs.

b. Poultry – laying hens and broiler chickens

Dalhousie University fed hempseed meal to laying hens at 20% inclusion in the feed ration. THC and CBD content was not detected in yolk and breast meat. Source: S.Collins, Dalhousie University, Canada 2024.

A large USA study feeding up to 30% hempseed meal to commercial laying hens demonstrated that feeding this hempseed byproduct did not contribute to tetrahydrocannabinol (THC) or cannabinoid residues in eggs. Kasula 2021

Research results for broiler chickens (meat production) fed hempseed meal at 8 to 24% of the ration, indicates THC and its metabolites in broiler breast, thigh, liver and kidney occurred at less than the limit of detection of 10ng. Rasool 2018

c. Potential Toxicity

It has been observed that the very low rates of THC and CBD in hempseed byproducts feed ingredients results in a very low probability for toxicity in livestock. And in turn almost no levels of residual effects in humans eating food products of livestock origin. This is due to the existence of THC and CBD at less-than trace levels in the ingredient and the majority in the non-bioavailable form, then a dilution effect when fed at only a component of the ration (1 to 30%) for a specific phase of production ie. 60 to 100 days. In addition the transference rate to animal tissue is low, estimated at 9 to 12 % (up to 15%) and as evidenced by excretion in manure and urine.

At the inclusion rates of up to 20-30% in a feed ration, the potential consumption of THC or CBD by humans in food from animals fed hempseed byproducts is very small given probable daily consumption. In addition:

- The oral bioavailability of CBD in humans is low, varying between approximately 6 and 19% (Mechoulam et al., 2002; Cherniakov et al., 2017; Millar et al., 2020; Perucca and Bialer, 2020).
- USDA reviews concluded the exposure to THC from hulled (dehulled) hempseed, hemp protein powder and hempseed oil is dependent upon consumption habits and is self-limiting due to sensory and functional limitations of the hemp ingredients by humans, so it is not expected to exceed 0.1938 mg/person/day when foods from all groups and containing maximum inclusion levels are consumed at the 90th percentile by any individual age 2 years and older. Source: USA Generally Recognized as Safe 2018, maximum 10 ppm THC hempseed ingredient limits (direct consumption by humans)
- Acute exposure to doses up to 3000 and 9000 mg Δ 9 -THC/kg in dogs and monkeys were not lethal. The oral LD50 for rats and mice were 666 mg Δ 9 -THC/kg and 482 mg Δ 9 -THC/kg, respectively. Source: EFSA, Europe 2015.
- The mean half-life (t1/2) of CBD was reported to be 1.09–1.97 hours after a single oral administration of concentrated CBD non-food product (10 or 20 mg). Source: Review of

the oral toxicity of cannabidiol (CBD), J.Gingrich et al, FDA Maryland USA, J.Food and Chemical Toxicology 176/2023

- CBD does not appreciably bind to the CB1 receptor, which mediates the behavioural activity of THC. Across a range of measures in humans and animals, CBD has been shown to have very different effects from those of THC. CBD is not specifically listed in the schedules of the 1961, 1971 or 1988 United Nations International Drug Control Conventions. There is no evidence that CBD as a substance is liable to similar abuse nor results in similar ill effects to substances in the 1961 or 1971 Conventions. (United Nations ECDD – 39th Session Report 2017, and 40th Session Report 2018)
- Beef cattle fed hempseed meal for 110 days in USA concluded some cannabinoid disposition in adipose (fat) tissue. Assessment of human exposures to CBD/THC residues through the consumption of beef fat from animals fed hempseed meal/cake suggests that the probability of consuming the equivalent of an acute reference dose is remote, even with the use of a conservative reference dose (1 µg kg^{-1} body weight). Source: D.Smith et al, Excretion and residue depletion of cannabinoids in beef cattle fed hempseed cake for 111 days, USA 2023.
- Tissue analysis of 15% and 20% rate of inclusion for hempseed meal in non-lactating and lactating dairy cows shows insignificant levels in tissues and milk. Source: Addo et al, Journal of Dairy Science, Manitoba Canada 2023
- Tissue analysis of 8%, 15% and 20% inclusion rate of hempseed screenings which contain the highest natural residual levels of THC and CBD of all seed byproducts, showed no significant transfer to muscle (brisket, leg), liver, fat, kidney, milk and blood plasma in the ruminant model. T.McAllister and S.Terry, AAFC Lethbridge, Canada 2023.
- Egg analysis from laying hens fed up to 30% hempseed meal showed no significant cannabinoid transfer. R. Kasula, USA 2021. In addition hempseed meal fed to laying hens showed cannabinoid transfer rate to eggs and other tissue at below the limit of detection (S.Collins, Canada 2024)
- In egg production the amount fed is a higher proportion of the productivity period, as laying hens typically see a 200 to 240 day cycle. In feeder cattle (beef) at 370 to 540 days to slaughter, feeding of hemp would occur at a lower proportion of the productivity period due to a higher forage ration in early life cycle stages. The probability of toxicity in meat and other food products is further reduced as studies show the absorption rate in livestock is 9 to 12% with remaining residual CBD or THC eliminated in manure and urine.

E. Gaps in Research

The challenge with livestock research is that cannabinoids are not present at any appreciable level in feed products to identify the highest threshold that can safely be fed to food-producing animals. This may be of interest as food supply pressures grow globally and the need for quality protein ingredients for livestock increases.

There are many studies proving the efficacy or use of hempseed byproducts in livestock feed at recognized/legal definitions of hemp in many countries. Hemp with trace levels of THC has been bred for centuries to supply food and industrial fibre for humans. There are several and significant reduction steps in the feed processing chain for existing/already trace levels of THC and CBD. Hemp grain byproducts are safe for livestock to consume.

As THC levels increase by regulatory authorities, for example from 1% or higher, research may be needed to determine the upper limits in animal feed that maintains a safe food supply. This

level is expected to be higher than the recommendations in this paper, given current status of feed and food research, but it may be prudent to establish upper thresholds in the future.

Research may be considered to identify:

- THC and CBD rate of transfer to eggs when fed at higher feeding rate, for example products from hempseed where the hemp plant is defined as greater than 1% total THC in the hemp plant's flowering tops.
- Highest potential level of natural unconcentrated CBD that can be fed to monogastrics and ruminants without concernable residual levels in meat, milk and eggs.
- Potential upper levels of THC and CBD that can be safely consumed in foods for adult humans, children and pregnant women (human research).
- Food-safe levels when grazing livestock on standing hemp crop in broadacre fields, ruined by weather conditions ie. drought, flood, frost, insect or wildlife damage (known as salvage grazing)
- Food-safe levels when feeding livestock baled or silage feed sourced from hemp crop in broadacre fields, ruined by weather conditions ie. drought, flood, frost, insect or wildlife damage (known as salvaged feed)
- Research on adding lysine to hempseed feed ingredients to improve productivity and identify if is it cost-effective (lysine is the limiting amino acid in some cases)
- Food-safe levels when feeding livestock spent post-extraction cannabinoid biomass or non-seed derived processed material (low-THC material leftover after cannabinoid processing of the flowering top, using food-safe methods of extraction)
- Use of hempseed-derived protein to improve quality in eggs (omega 3/6, other) and in milk (improved fat ratios).
- Potential use of added concentrated non-THC cannabinoids that may assist livestock health, disease immunity, and contribute to reduction in the use of antibiotics for monogastric and ruminant livestock (non-feed or feed supplement aspect)

Existing research has proven the efficacy and safety of hempseed-derived feed ingredients as a protein source for livestock, however further research may assist upper cannabinoid threshold and recommendations for specific livestock species and stage of production.

For example hempseed protein concentrates to be utilized in piglet feed or fin fish within aquaculture, beneficial aspects of seed oil, and seed-derived material as a fibre source for gestating sows. Healthy fats in seed-derived products may assist livestock health.

In addition the increased palatability for these products fed to some livestock species has been anecdotally reported but not further studied. For example, hempseed cake is lower in glucosinolates than canola seed meal or camelina seed meal which may be an acceptability factor.

F. Sustainability

Improved feeding efficiencies overall improve the sustainability footprint of livestock around the world. This contributes directly to the United Nations sustainable development goals and the commitment to improvement within each country. This includes the goal of positive impact on the food supply and human nutrition, climate change mitigation, improving farm and processor economics, reducing food wastage, improved resilience, and spin-off benefits within communities.

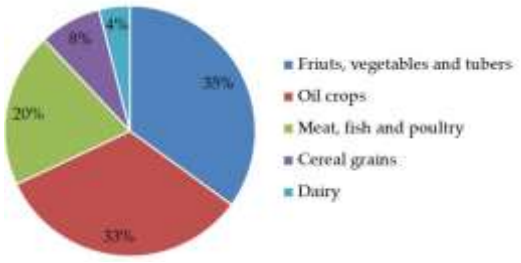


Figure 6: Estimation of food waste produced per sub-sectors at the processing stage in Europe (adapted from Rao, Bastand de Boer). Rakita et al 2023

Additional benchmarks to monitor hempseed and feed-beneficial aspects related to those targets may be of interest, if such work would be cost-effective and identified as important by industry.

Section IV: Conclusion and Recommendations

Extensive animal nutrition studies using hempseed byproducts indicate safe and efficacious use as livestock feed ingredients. In particular research has shown hempseed meal is an effective substitute for soybean or canola meal.

When using hempseed byproducts, attention should be paid to balance diets with other feed ingredient supplements as part of on-going feed management. This includes tailoring feed rations to the specific phase of production, meeting nutrient requirements for that species (energy, protein, macro-nutrients) and adjusting for complementary feedstuffs within a ration. Hempseed byproducts can be effective sources of protein, dietary fibre, amino acids, minerals and healthy fats. In some instances increased levels of hempseed byproducts can influence omega 3/6 levels in resultant food products.

Research data for hempseed meal and hempseed oil indicate efficacy in livestock rations at up to 30% inclusion rates. Natural residual levels of cannabinoids THC or CBD in hempseed do not transfer into livestock feed or resultant livestock tissue intended as food at any significant levels. The majority of those cannabinoids (80 to 90%) are in the precursor form THC-A or CBD-A which are not bioavailable.

Hempseed byproducts can be safely fed to livestock, or farmed animals intended for food production.

Availability of hempseed byproducts, complementarity to other feed ingredients, and price-supply relationships will also affect inclusion rates of hempseed feed ingredients similar to other crop byproducts.

A. Feeding Rates by Livestock Species

Table 8a:
Feed Ingredient Inclusion Rate Recommendations

Species	Whole seed	Hempseed meal	Hempseed oil	Hulls	Screenings	Other observations
Monogastrics (single stomach livestock species)						
Broiler chickens	dehulled - up to 18%	up to 15% and young birds up to 10%	up to 9%	--	--	May possibly modify gut microbiota for benefit of animal
Laying hens -including quail	dehulled – up to 9%	up to 30%	up to 4%	--	--	Higher rates for specialized omega 3/6 eggs; possibly different rates to lower egg cholesterol
Grower hog	--	up to 30%	up to 3%	up to 15%	--	Seed oil- may improve omega 3 levels in meat
Gestating and Lactating sows	up to 5%	--	up to 5%	--	--	When fed prior to farrowing, improved piglet survival was observed
Piglets	--	--	--	--	--	Refined protein concentrates have potential use in these diets but no research yet available (bridging data from hempseed meal may assist)
Other						

Table 8a:
Feed Ingredient Inclusion Rate Recommendations

Species	Whole seed	Hempseed meal	Hempseed oil	Hulls	Screenings	Other observations
Farmed finfish	--	up to 20%	--	--	--	Information to be identified later in 2024 with 2-3 research publications
Ruminants (livestock with 4 stomach compartments)						
Feeder cattle (beef)	up to 14%	Up to 20%	--	Up to 20%	Up to 20%	Observation: hempseed protein with relatively low lysine is excellent source of rumen undegradable protein /may offset potential lysine deficiencies through compensatory mechanisms
Dry dairy cows	--	Up to 10%	--	Up to 20%	Up to 20%	
Lactating dairy cattle	--	Up to 15%	--	--	Up to 15%	
Sheep	Up to 5%	Up to 20%	--	--	Up to 20%	
Goats	--	Up to 30 %	Up to 4%	Up to 20%	--	

Notes:
a) Recommendations to be added in the future as data becomes available for products noted as "- -".
b) In some research publications it is not clear if whole seed or dehulled seed is referred to.

Table 8b:
Recommended Upper Threshold of THC and CBD in Livestock Feed Products

	Dehulled Hempseed		Hempseed Meal	
	Total THC	*Total CBD*	*Total THC*	*Total CBD*
Global recommended level	Not more than 20 µg/gram or 20 ppm	No level recommended due to less-than trace levels, and not a food/feed safety issue.	Not more than 30 µg/gram or 30 ppm	No level recommended due to less-than trace levels, and not a food/feed safety issue.

For the above products, regulatory bodies intending to avoid concentrated additives or adulterated product may safely identify total CBD level at not more than 200 µg/gram or 200 ppm. At those levels 88 to 90% occurs in the non- bioavailable CBD-A form. The threshold may assist for an ingredient definition that excludes the addition of a concentrated form of processed cannabinoids not naturally a residual from seed or food processing.
Safe feed ingredients with added concentrates or isolated cannabinoids may have livestock health benefits subject to future research and/or veterinary health product approval by authorities.

Note: This is based on global research in years 1999 to 2024 for naturally occurring levels of residual THC and CBD in hempseed as a result of incidental contact when harvesting agricultural hemp crops, and for a maximum hemp plant definition of 1% total THC in the flowering tops. FIHO 2024

One microgram per gram or µg/gram is equal to 1 part per million (ppm)

Section V: Terminology and References

Feed Definitions

Dehulled hempseed - internal material of the hempseed. Dehulled hempseed is synonymous with hempseed heart, hempseed nut, and hulled hempseed.

Hempseed fines - fragmented fractions of hempseed derived from a decortication (dehulling) or mechanical cleaning processes. Comprised of broken hempseed, broken dehulled hempseed and hempseed hulls.

Hempseed hulls - pericarp (hull) of the whole hempseed used for human or animal food and health-related products. The term is synonymous with hempseed husks.

Hempseed protein products - products derived from hempseed by removing the oil content, and categorized by protein content as follows:

- Hempseed protein isolate - protein powder derived from hempseed with 80% or higher protein content.
- Refined hempseed protein concentrate - protein powder derived from hempseed between 60% and 79% protein content.
- Hempseed protein concentrate - protein powder derived from hempseed between 40% and 59% protein content.
- Hempseed meal - protein powder or solid material derived from hempseed typically between 25% and 39% protein content. The term is synonymous with hempseed cake, hempseed protein meal, hempseed protein cake, hemp expeller, hempseed oil cake, and hempseed oil meal. It may reach up to 50% protein content in some countries, and in Europe may be known as cake when cold-pressed (mechanical) expulsion is used.
- High fibre hempseed protein - protein powder derived from hempseed with less than 25% protein content, and considered to be a source of fibre by authorities having jurisdiction.

Hempseed screenings - a composite product containing small whole or broken hempseeds, weed seeds and other organic material.

Hempseed (hempseed) - intact achene (fruit) produced from a hemp plant that is capable of normal germination. This is sometimes known as hemp grain or hempseed.

Hempseed oil - oil derived from hempseed. This oil is low in THC and does not contain added cannabinoids.

Industrial hemp – hemp plant containing low levels of THC in its flowering tops, as determined by authorities having jurisdiction.

References

Abrahamsen, F., Reddy, G., Abebe, W. and Gurung, N. 2021. Effect of varying levels of hempseed meal supplementation on humoral and cell-mediated immune responses of goats. Animals (Basel), 11: 2764. doi: 10.3390/ani11102764

Addo, F., Gervais, R., Ominski, K., Yang, C. and Plaizier, J. C. 2023. Comparing dehulled hemp meal and canola meal as a protein supplement for lactating dairy cows. J. Dairy Sci., 106: 8670-8683. doi: 10.3168/jds.2023-23507

Addo, F., Ominski, K., Yang, C. and Plaizier, J. C. 2023. Quality and safety of hemp meal as a protein supplement for nonlactating dairy cows. J. Dairy Sci., 106: 7602-7612

Callaway, J. C. 2004. Hempseed as a nutritional resource: An overview. Euphytica, 140: 65-72. doi: 10.1007/s10681-004-4811-6

Cozma, A., Andrei, S., Pintea, A., Miere, D., Filip, L., Loghin, F. and Ferlay, A. 2015. Effect of hempseed oil supplementation on plasma lipid profile, liver function, milk fatty acid, cholesterol, and vitamin A concentrations in Carpathian goats. Czech J. Anim. Sci., 60: 289-301. doi: 10.17221/8275-CJAS

EFSA 2015. Scientific Opinion on the risks for human health related to the presence of tetrahydrocannabinol (THC) in milk and other food of animal origin. EFSA Panel on Contaminants in the Food Chain. EFSA Journal, 13: n/a. doi: 10.2903/j.efsa.2015.4141

Gakhar, N., Goldberg, E., Jing, M., Gibson, R. and House, J. D. 2012. Effect of feeding hemp seed and hemp seed oil on laying hen performance and egg yolk fatty acid content: evidence of their safety and efficacy for laying hen diets. Poult. Sci., 91: 701-711. doi: 10.3382/ps.2011-01825

Gibb, D. J., Shah, M. A., Mir, P. S. and McAllister, T. A. 2005. Effect of full-fat hemp seed on performance and tissue fatty acids of feedlot cattle. Can. J. Anim. Sci., 85: 223-230. doi: 10.4141/A04-078

Gingrich, J., Choudhuri, S., Cournoyer, P., Downey, J., and Jacobs, K. 2023. Review of the oral toxicity of cannabidiol (CBD), Food and Chemical Toxicology Vol. 176 - 113799

Grotenhermen F, Jarus M & Lohmeyer, 1998, THC Limits for Foods – A Scientific Study, Nova Institute, Germany.

Gurung, R., Ale, K. B., Abrahamsen, F. W., Moyer, K., Sawyer, J. T. and Gurung, N. K. 2022. Carcass traits of growing meat goats fed different levels of hempseed meal. Animals (Basel), 12: 1986. doi: 10.3390/ani12151986

Hăbeanu, M., Gheorghe, A., Surdu, I., Chedea, V. S. and Beia, I. 2018. n-3 PUFA-enriched hemp seed diet modifies beneficially sow milk composition and piglets' performances. Cellulose, 63: 40-45.

Hăbeanu, M., Lefter, N. A., Gheorghe, A., Ropota, M., Toma, S. M., Pistol, G. C., et al. 2022. Alterations in essential fatty acids, immunoglobulins (IgA, IgG, and IgM), and enteric methane emission in primiparous sows fed hemp seed oil and their offspring response. Vet. Sci., 9: 352. doi: 10.3390/vetsci9070352

House, J. D., Neufeld, J. and Leson, G. 2010. Evaluating the quality of protein from hemp seed (Cannabis sativa L.) products through the use of the protein digestibility-corrected amino acid score method. J. Agric. Food Chem., 58: 11801-11807. doi: 10.1021/jf102636b

Hwang, D. 1989. Essential fatty acids and immune response. FASEB J., 3: 2052-2061. doi: 10.1096/fasebj.3.9.2501132

Iannaccone, M., Ianni, A., Contaldi, F., Esposito, S., Martino, C., Bennato, F., et al. 2019. Whole blood transcriptome analysis in ewes fed with hemp seed supplemented diet. Sci. Rep., 9: 16192-9. doi: 10.1038/s41598-019-52712-6

Juodka, R., Juska, R., Juskiene, V., Leikus, R., Stankeviciene, D. and Nainiene, R. 2018. The effect of feeding with hemp and Camelina cakes on the fatty acid profile of duck muscles. Arch. Anim. Breed., 61: 293-303. doi: 10.5194/aab-61-293-2018

Kalmendal, R. 2008. Hemp seed cake fed to broilers. MSc Thesis. SLU, Dept. of Animal Nutrition and Management, Uppsala, Sweden. Available: https://stud.epsilon.slu.se/12202/ [Accessed 15 July 2020]

Kasula, R., Solis, F., Shaffer, B., Connett, R., Barret, C., Cocker, R., and Willingham, E. Research Article Effect of Increasing Levels of Dietary Hemp Seed Cake on Egg Quality in Commercial Laying Hens. Int. J. Poult. Sci., 20 (2): 48-58, 2021

Mohamed, N., Slaski, J. J., Shwaluk, C. and House, J. D. 2024. Chemical characterization of hemp (Cannabis sativa L.)-derived products and potential for animal feed. ACS Food Sci. Technol. , 4: 88-103. doi: 10.1021/acsfoodscitech.3c00391

Mohamed, N. and House, J.D. 2024. Safety and Efficacy of Hemp-Derived Products in Animal Feeds – A Narrative Review. Canadian Journal of Animal Science 2024.

Mustafa, A. F., McKinnon, J. J. and Christensen, D. A. 1999. The nutritive value of hemp meal for ruminants. Can. J. Anim. Sci., 79: 91-95. doi: 10.4141/A98-031

Neijat, M., Gakhar, N., Neufeld, J. and House, J. D. 2014. Performance, egg quality, and blood plasma chemistry of laying hens fed hempseed and hempseed oil. Poult. Sci., 93: 2827- 2840. doi: 10.3382/ps.2014-03936

Neijat, M., Suh, M., Neufeld, J. and House, J. D. 2016a. Increasing levels of dietary hempseed products leads to differential responses in the fatty acid profiles of egg yolk, liver and plasma of laying hens. Lipids, 51: 615-633. doi: 10.1007/s11745-016-4146-9

Parker, T. D., Adams, D. A., Zhou, K., Harris, M. and Yu, L. 2003. Fatty acid composition and oxidative stability of cold-pressed edible seed oils. J. Food Sci., 68: 1240-1243. doi: 10.1111/j.1365-2621.2003.tb09632.x

Presto, M. H., Lyberg, K. and Lindberg, J. E. 2011. Digestibility of amino acids in organically cultivated white-flowering faba bean and cake from cold-pressed rapeseed, linseed and hemp seed in growing pigs. Arch. Anim. Nutr., 65: 21-33. doi: 10.1080/1745039x.2010.534897

Rakita, S., Kokĭc, B., Manoni, M., Mazzoleni, S., Lin, P.;Luciano, A., Ottoboni, M., Cheli, F., Pinotti, L. Cold-Pressed Oilseed Cakes as Alternative and Sustainable Feed Ingredients: A Review. Foods 2023, 12, 432. https://doi.org/10.3390/foods12030432

Rasool, U. 2018. Safety and efficacy of hemp products in broiler production. MSc Thesis. Department of Animal Science University of Manitoba Winnipeg, Manitoba, Canada.

Sachs, J., McGlade, E. and Yurgelun-Todd, D. 2015. Safety and toxicology of cannabinoids. Neurotherapeutics, 12: 735-746. doi: 10.1007/s13311-015-0380-8

Šalavardić, Ž. K., Novoselec, J., Đidara, M., Steiner, Z., Ćavar, S., Modić Šabić, A. and Antunović, Z. 2021. Effect of dietary hempseed cake on milk performance and haematochemicals in lactating Alpine dairy goats. Animal (Cambridge, England), 15: 100255- 100255. doi: 10.1016/j.animal.2021.100255

Silversides, F. G. and LefranÇois, M. R. 2005. The effect of feeding hemp seed meal to laying hens. Br. Poult. Sci., 46: 231-235. doi: 10.1080/0071660500066183

Slaski, J. 2021. Evaluation of propensity of the Canadian hemp varieties in accumulation of elevated heavy metal levels in grain: Phase 2 screening of the National Hemp Variety Trials (InnoTech Alberta, Canada).

Smith, D. J., Serum, E. M., Winders, T. M., Neville, B., Herges, G. R., Dahlen, C. R. and Swanson, K. C. 2023. Excretion and residue depletion of cannabinoids in beef cattle fed hempseed cake for 111 days. Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess., 40: 552-565. doi: 10.1080/19440049.2023.2187645

Šťastník, O., Jůzl, M., Karásek, F., Fernandová, D., Mrkvicová, E., Pavlata, L., et al. 2019. The effect of hempseed expellers on selected quality indicators of broiler chicken's meat. Acta Vet. Brno., 88: 121-128. doi: 10.2754/avb201988010121

Terry, S. and McAllister, T. Hempseed Hulls and Screenings fed to lambs and milking ewes, unpublished data, Lethbridge Res.Stn., Agriculture and Agri-Food Canada, 2023.

United Nations, Expert Committee on Drug Dependence (ECDD) reports 2017 to 2019.

Wang, S., Kreuzer, M., Braun, U. and Schwarm, A. 2017. Effect of unconventional oilseeds (safflower, poppy, hemp, camelina) on in vitro ruminal methane production and fermentation. J. Sci. Food Agric., 97: 3864-3870. doi: 10.1002/jsfa.8260

Wang, Y., Gao, J., Cheng, C., Lv, J., Lambo, M. T., Zhang, G., et al. 2022. Nutritional values of industrial hemp byproducts for dairy cattle. Animals (Basel), 12: 3488. doi: 10.3390/ani12243488

Yao, W., Li, J., Wang, J. j., Zhou, W., Wang, Q., Zhu, R., et al. 2012. Effects of dietary ratio of n-6 to n-3 polyunsaturated fatty acids on immunoglobulins, cytokines, fatty acid composition, and performance of lactating sows and suckling piglets. J. Anim. Sci. Biotechnol., 3: 137-144. doi: 10.1186/2049-1891-3-43

Note: further significant references are contained in the above research publications and resources, as this paper is not intended to capture all hemp feed ingredient research in the past twenty years.

Appreciation in extended to expert researchers, funding agencies and livestock feed nutritionists for contributions to this important body of work. Thanks also to food processors who shared cannabinoid testing results from several countries for seed-derived products.

APPENDIX

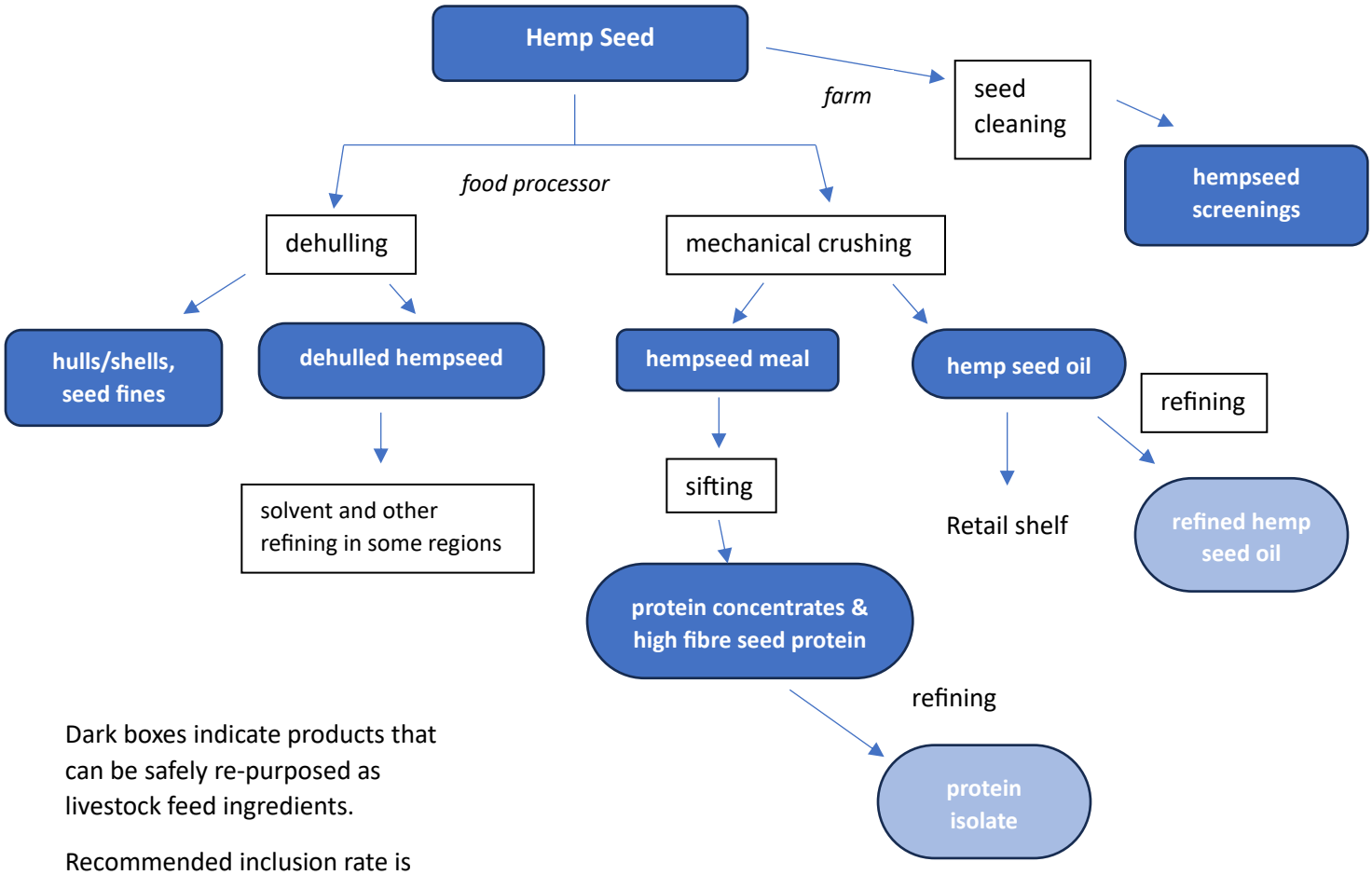
A. Processing of Hempseed

Hempseed Food Manufacturing

Hempseed feed products will be a secondary product of seed processed by food manufacturers, or from farms where it is determined stored seed is not fit for human food. Re-purposing seed products that are not food grade, or are by-products of processing is done globally as a means to efficiently use all products resulting from processing. This includes off-grade products, or other reasons a lot may need to be re-purposed.

Hempseed is crushed and the oil is expelled, with the majority of hempseed byproducts destined as feed ingredients sourced from mechanical or cold pressed extraction.

Figure 7: Schematic of Hempseed Food Processing



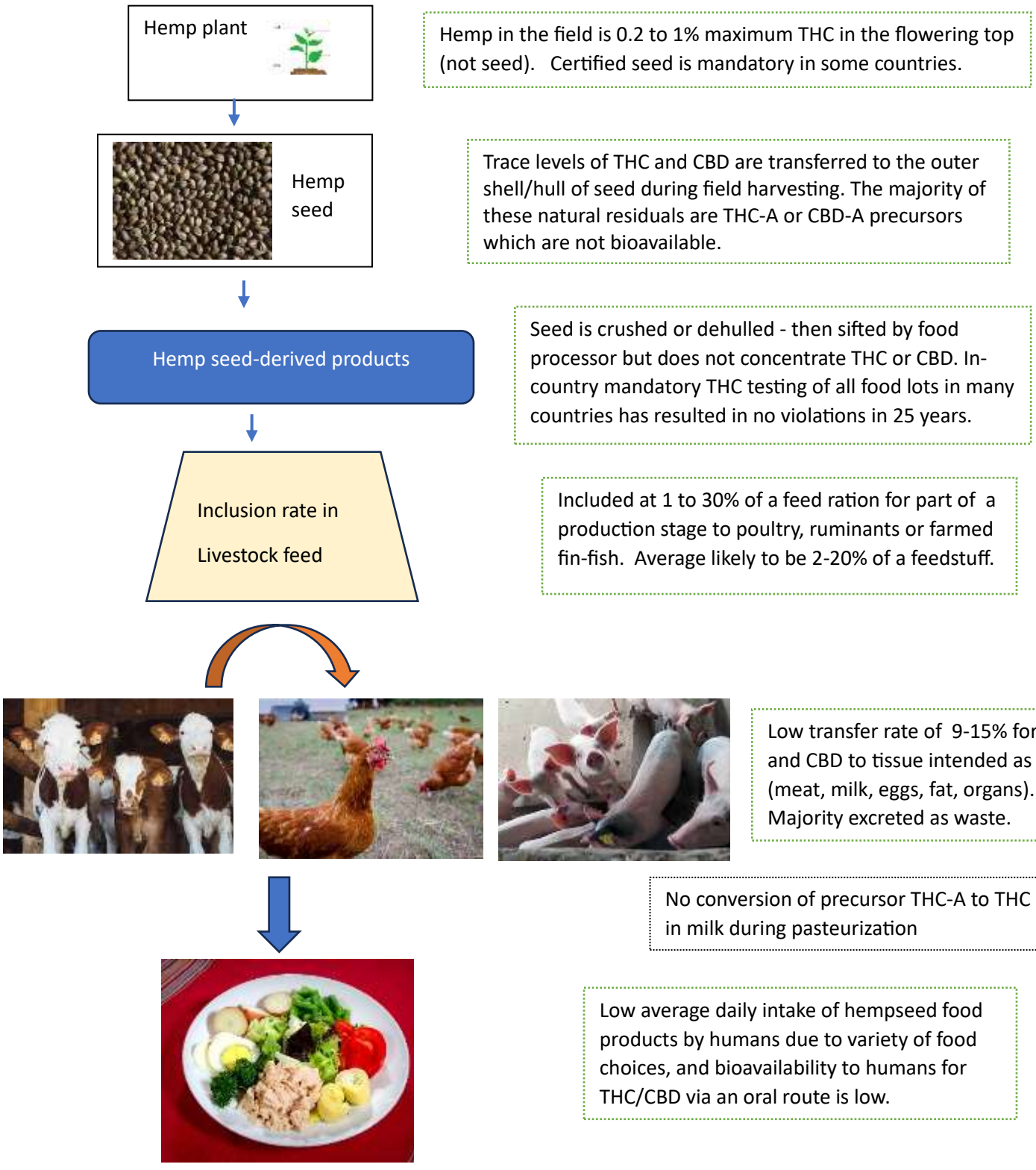
Dark boxes indicate products that can be safely re-purposed as livestock feed ingredients.

Recommended inclusion rate is not more than 30% of a diet given current research as of June 2024.

B. Hempseed Production Chain – from farmer's field to consumer plate as food

THC and CBD is effectively reduced in the production chain from seeding of the hemp plant in the field, to processing of seed, to practices by food and feed manufacturers. In addition there are control mechanisms within food GMPs, regulatory requirements, extremely low natural residual content, partial inclusion in feed, and in the end, low transfer rate to animal tissue intended as food products.

Figure 8



C. Feed Quality Management and Regulatory Oversight

Livestock feed is manufactured using a multitude of raw or semi-processed plant and other components as a source of protein, energy, and fibre. Specific macro-nutrients (vitamins, minerals) are added to balance nutrition levels, and additional flavourings/dietary aids can be mixed in as needed. Commercial scale feedmills receive and store raw product, then mix livestock feed rations according to nutritional requirements for each livestock species and type of production. A qualified nutritionist formulates how incoming grain and byproducts are used, and/or how feed ingredients are mixed into whole rations. Veterinary oversight is typically required if antibiotic or anti-disease or therapeutic aids are added.

Commercial feedmills in many countries adhere to *Good Manufacturing Practices* customized to the animal feed industry, such as voluntary certification based in ISO quality management or HACCP food safety principles. In many countries the HACCP feed programs are based on Codex Alimentarius Commission principles. This includes the assessment of incoming feed ingredients for a range of properties needed for nutrition, and anti-nutritional assessment within audited quality assurance programs. This may include moisture, protein, amino acid, crude fat properties in addition to aflatoxins, elemental impurities and other components.

In addition to industry accepted guidelines, most countries have mandatory feed regulatory requirements. Particularly for the commercial feed industries (grain milling), government oversight is provided through framework legislation and/or on-site inspections. This includes specifications for ingredients, specification thresholds for purity, aflatoxins and plant phyto-chemicals such as hydrocyanic acid for example. If using antibiotics within rations, inspections are more frequently applied and sample testing can be done. Veterinary oversight is also often mandatory for antibiotic use in feed rations, which follow national guidelines for the prudent use of antibiotics.

Crop byproduct inputs, feed processing, feed supplements and complete feed are also subject to inspection by regulatory authorities usually based on safety risk and the type of products processed.

D. Acronyms

AAFCO: American Association of Feed Control Officials (USA)
AOSCA: Association of Official Seed Certifying Agencies (USA)
ASTM: ASTM Standards International, cannabis and hemp committee (international)
CBD: cannabidiol, a non-intoxicating cannabinoid produced in the flower of *cannabis sativa L* plant
ECDD: expert committee on drug dependence, United Nations
FAO: Food and Agriculture Organization, United Nations
GRAS: Generally Recognized as Safe (USA safety assessment)
OECD: Organization for Economic Co-operation and Development (inter-governmental agency)
USP-FCC: United States Pharmacopeia, Food Chemical Codex
THC: Δ9-tetrahydrocannabinol, a cannabinoid produced in the flower of *Cannabis sativa L* plant

E. Anti-nutritional Component Analysis of Hempseed Byproducts [a]

Table 10. HS – hempseed, HC/HM – hempseed cake/meal

Parameters	HS oil (HO)	HS	HS hulls (HH)	Dehulled HS	Extruded HC/HM	HS protein concentrate	Coarse HS protein	Screenings	*p*-value
Aflatoxins									
Aflatoxin B	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Aflatoxin B2	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060
Aflatoxin G1	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070
Aflatoxin G2	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
Ochratoxin A	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Total aflatoxin	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Other anti-nutritives									
TPC (mg GAE/g)[e]	0.12 ±0.041^{e}	0.47 ±0.030^{cd}	0.56 ±0.025^{bcd}	0.25 ±0.069d	0.74 ± 0.16^{abc}	0.75 ± 0.066^{ab}	0.88 ± 0.13^{a}	0.94 ±	<0.0001
TSC (mg AE/g)[f]	4.12 ± 2.59^{c}	10.4 ± 1.22^{b}	10.9 ± 0.81^{b}	9.76 ± 2.40^{b}	20.9 ± 9.06^{a}	18.3 ± 5.36^{a}	16.6 ± 4.09^{ab}	40.7 ±	<0.0001
nitrate (NO_3) (mg/g)	n.d.	0.035 ±0.017ab	0.024 ±0.017bc	0.003 ±0.001c	0.043 ±0.044bc	0.011 ± 0.006^{c}	0.13 ± 0.11^{ab}	0.44 ±0.22a	<0.0001
nitrite (NO_2) (mg/	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	
cyanogens (ppm)	0.33 ±	0.00^{b}	7.28 ± 4.54^{ab}	0.00^{b}	0.00^{b}	0.00^{b}	4.72 ± 3.44^{ab}	86.1 ± 110^{a}	0.003
glucosinolates (μmol/g)	0.30 ±0.02^{ab}	1.13 ± 0.40^{ab}	2.34 ± 0.12^{ab}	2.41 ± 0.02^{ab}	0.00^{b}	0.00^{b}	1.36 ± 0.59^{ab}	2.59 ±	0.002
trypsin (TIU/g)	1427 ± 59.2	1985 ± 235	1810 ± 18.0	2214 ± 599	1907 ± 197	1590 ± 51.7	1426 ± 98.6	1792 ± 116	0.051
lipase (U/g)	3414 ±1751^{bc}	5911 ±1697^{b}	1392^{c}	16,071 ±	1392^{c}	2725 ± 1272^{bc}	1392^{c}	1392^{c}	0.006
phytic acid (mg/g)	n.d.	16.0 ± 4.49^{bc}	4.61 ± 1.34^{c}	33.6 ± 6.20^{a}	26.1 ± 3.61^{ab}	31.3 ± 7.22^{ab}	15.6 ± 13.2^{bc}	20.0 ±	<0.0001
Organic acids (Mg/g)									
Malic acid	n.d.	0.16 ± 0.036b	0.19 ±0.033^{b}	0.12 ±0.043^{b}	0.12 ± 0.043^{b}	0.13 ± 0.034^{b}	0.10 ± 0.020^{b}	1.76 ±1.09^{a}	<0.0001
Tartaric acid	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	
Oxalic acid	n.d.	0.58 ±0.032a	0.79 ±0.046^{a}	0.38 ± 0.10^{b}	0.38 ± 0.048^{b}	0.39 ± 0.065^{b}	0.34 ± 0.067^{c}	0.90 ± 0.34^{a}	<0.0001
Citric acid	n.d.	1.54 ± 0.26ab	1.53 ± 0.16^{ab}	1.26 ± 0.58^{bc}	1.00 ± 0.35^{bc}	0.82 ± 0.25^{bc}	0.69 ± 0.21^{c}	5.48 ±2.29^{a}	<0.0001

a. Data represents means ± standard deviation (SD), otherwise analysis indicates values below detection limits or not detected (n.d.). For all data n = 9, except for cyanogens, glucosinolates, trypsin, and lipase, n = 3. Based on the Kruskal–Wallis test, P < 0.05 was assumed as statistically significant.

b. Detection limits for aflatoxin (µg/g) B1, B2, G1, G2, ochratoxin A, and total aflatoxin are 0.05, 0.06, 0.07, 0.03, 0.04, and 0.03, respectively.

d. Detection limits (mg/g) for phytic acid, nitrate (NO3), and nitrite (NO2) are 0.08, 0.0004, and 0.0002, respectively.

e. Total phenolic content is expressed as GAE = gallic acid equivalents at a concentration range of 0−1000 µg/mL.

f. Total saponin content is expressed as AE = aescin equivalents at a concentration range of 0−7.5 mg/mL.

Source: N.Mohamed et al, Chemical Characterization of Hemp (Cannabis sativa L.)-Derived Products and Potential for Animal Feed, Canada. ACS Food Sci. Technol. 2024, 4, 88-103 See reference for further anti-nutritional component data.