Feeding Value of Oilseeds Rich in Omega 3 Fatty Acids as Potential Ingredients in Broiler Nutrition

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Abstract
Due to the benefits of consuming products rich in omega-3, people have become more aware of the need for a surplus of n-3 fatty acids for meat in their diet. Three oilseeds rich in omega 3 fatty acids (linseed, hemp seeds and camelina seeds) were characterized to determine their nutritional value for inclusion in broiler diets to increase the PUFA content of poultry meat. Chemical determinations revealed a different protein content ranging between 19.74% (hemp seeds) and 26.78% (linseed). In terms of polyunsaturated fatty acids, especially α-linolenic acid was determined for linseed (50.71g/100g total fatty acids), camelina (34.15g/100g total fatty acids) and hemp (14.2g/100g total fatty acids). The selected products rich in polyunsaturated fatty acids will be introduced into the feed and tested on batches of broilers to track the best growth performance.

Keywords: oilseeds, OMEGA-3, polyunsaturated fatty acid, poultry feed.

1. Introduction

The health benefits of consuming foods with a higher proportion of Omega-3 fatty acids have caused consumers to increasingly seek out products that contain them. In the broiler production industry, increasing the nutritional value through a higher proportion of polyunsaturated n-3 fatty acids may increase production costs. The health benefits of Omega-3 are primarily found in the protection of the cardiovascular system, leading to lower blood pressure and heart rate, decreased serum triglycerides, inflammatory markers [1], and arrhythmias [2]. Additionally, they improve endothelial function, insulin sensitivity, and stabilize or even decrease atherosclerotic plaque [3]. Foods that contain Omega-3 fatty acids are primarily fish and fish oil, nuts, wheat germ, and dietary supplements [4].

Flaxseed. The cultivation of flax has been known since ancient times, being one of the first plants cultivated by farmers. The Latin name for flaxseeds is *Linum usitatissimum*, which means "very useful". Flax was cultivated primarily for its stem, later for the seeds from which flaxseed oil is extracted. Producers appreciated the strength and durability of the fibers from the stem [5]. Until the 1990s, flax fibers were mainly used in the production of textiles (linen) and paper, while flaxseed oil is used for industry (painting and carpentry). Oil and flax by-products are also used in animal feed [5].

The terms linseed and linseed are used to differentiate the way the seeds are used. When used in human food the most common term is Flaxseed, while Linseed is used to describe flax when used in industry and for animal feed purposes [6]. Due to the fact that flax seeds have the highest content of Ω-3 fatty acids: α-linolenic acid (ALA), short-chain polyunsaturated fatty acids (PUFA) but also fibers (soluble and insoluble), phytoestrogenic lignans

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(secoisolariciresinol diglycoside-SDG), proteins and a series of antioxidants are considered foods with a high nutritional value [7-9]. The benefits regarding reducing the risks of cardiovascular diseases, decreasing the risk of cancer, due to the anti-inflammatory activity, the laxative effect and the reduction of the unpleasant manifestations of menopause and the mitigation of osteoporosis have led to a very high popularity of consumption of flax seeds. They can be considered a medicine as well as a source of functional food through their intake and benefit for health.

Camelina Sativa is cultivated mainly for the extraction of oil from the seeds. In northern Europe, archaeological studies have shown that this plant was cultivated over 2000 years ago. Camelina seeds (CS) were introduced for human food as a component of bread or pottage. Oil produced from Camelina was used as food oil and medicine in folk medicine but also used for industrial purposes [10]. Due to the continued high protein content, pressed Camelina cakes were used as animal feed [11]. This use of Camelina Cakes was legalized by Commission Directive 2008/76/EC of July 25, 2008, by amending Annex I to Directive 2002/32/EC: L 198/37. Some European countries (Great Britain, Ireland, Germany, Finland and Denmark) have reintroduced and regulated the consumption of Camelina oil for human consumption. Camelina Sativa seeds or oil introduced into bread manage to raise the level of omega-3 fatty acids (alpha linolenic acid) and essential amino acids [12], antioxidants [13], dietary fiber and other microelements. Researchers have studied the chemical composition of Camelina Seeds since the last century. Camelina seeds and cakes were analyzed for the content of oil, fatty acids, proteins, amino acids [14], tocopherols [13], glucosinolates and bioactive compounds [15]. We will see in this paper comparisons in the content of proteins, fatty acids and minerals in Camelina Seeds.

Hemp (*Cannabis sativa*) belongs to the genus Cannabis, family Cannabaceae. It has been cultivated throughout human history due to its industrial use. Fabrics, ropes, paper were made from the fiber and more recently it is also used to insulate buildings [16], but the use does not stop there. Hemp can be grown without the need for pesticides or herbicides, so it is easy to grow in temperate climates. Good yields can be obtained as long as the right soil, fertilizers and water are used [17]. The time required to harvest Hemp is 120 days after the height of the plant can reach up to 3 meters. Considered a traditional crop with multiple industrial uses, hemp has been cultivated and used also for its nutritional and medicinal properties [18-21]. Hemp seeds contain about 25% protein, 30% carbohydrates, 15% insoluble fiber, calcium, phosphorus, potassium, sulfur, magnesium, iron and zinc, as well as carotene, vitamin E, C, B1, B2, B3, B6. Hemp seeds can be considered a good vegetable source of essential fatty acids with a perfect 3:1 ratio of omega-3-linolenic acid and omega-6-linoleic acid, with implications in strengthening the immune system [17] but also a good source of gamma linoleic acid with implications in improving some ailments and along with vitamin D is beneficial in preventing and treating osteoporosis.

The omega-6 and omega-3 fatty acids and relatively high phytosterol content of hemp seeds improve cardiovascular health. Polyunsaturated fats may reduce the risk of cardiac arrest and fatal cardiac arrhythmia, but also reduce blood cholesterol levels and decreased cell proliferation associated with atherosclerosis. Scaly skin disorder, inflammation, diabetes can be reversed consuming essential fatty acids also psoriasis, excessive epidermal water loss, itch and poor wound and are beneficial for atopic eczema.

2. Materials and methods

Our study characterized three seed sources rich in omega 3 polyunsaturated fatty acids (flax, hemp and camelina) physically and chemically in order to be introduced as suitable raw materials in broilers feed and to estimate the effects on performances end meat quality of broilers These plants from whose seeds oils can be extracted, used both in industry and in food, are carefully studied by researchers especially for their high content of Omega 3 oils. The data obtained by our laboratory were corroborated with the academic literature following the consultation and selection of relevant articles that were the basis of this study. The following databases were consulted: Feedstuff, Feedipedia, Web of Science, Google Scholar, MDPI, Springer Link and Elsevier, using as keywords: broiler nutrition, chemical composition of linseed, camelina seed or hemp seed. The seeds were purchased from companies specialized in the processing, sorting and conditioning of seeds from oleaginous plants.

Before being analyzed, the seeds were ground, using a laboratory mill. After this, the samples were weighed and dried for 48 h at a constant temperature of 65°C to be processed and analyzed in the Weende, spectrophotometry and gas chromatography compartments.

Determination of the gross (crude) chemical composition of the seeds

The dry matter (DM) determination was done using the gravimetric method, by drying at 65°C-103°C (Sartorius analytical scale and BMT model ECOCELL Blueline Comfort) respecting ISO standard 6496/2001;

Crude protein (CP) was determined using the Kjeldahl method (semiautomatic KJELTEC auto 1030 – Tecator) conforming to ISO standard 5983-2/2009;

Ether extractives (EE) was done by extraction in organic solvents (SOXTEC-2055 FOSS – Tecator) in accord to ISO standard 6492/2001;

Crude fiber was determined by intermediary filtration (FIBERTEC 2010–Tecator) (ISO 6865/2002)

Ash was determined using the gravimetric method (Caloris furnace CL 1206) (ISO 2171/2010).

Determination of the minerals

Samples of 0.4 g each were processed [22] and analyzed for Ca, Cu, Fe, Mn, Zn concentrations applying flame atomic absorption spectrometry (atomic absorption spectrometer Solaar M6 Dual Zeeman Comfort (Thermo Electron Ltd., Cambridge, UK) after the microwave digestion (Speedwave MWS-2 Comfort, Berghof, Eningen, Germany). The phosphorus content was determined by UV spectrophotometry (UV-Vis spectrophotometer Jasco V530 Tokio, Japan).

Determination of the fatty acids in the plants feeds

The fatty acids were determined by gas chromatography, as shown by [23], by transformation of the fatty acids from the sample into methyl esters, followed by the separation of the components in the chromatographic column, identification by comparison with standard chromatograms and quantitative determination of the fatty acids according to SR CEN ISO/TS 17764 -2: 2008. We used a Perkin Elmer-Clarus 500 chromatograph, fitted with a system for injection into the capillary column, with high polarity stationary phase (BPX70: 60m x 0.25mm inner diameters and 0.25μm thick film); or high polarity cyanopril phases, which have similar resolution for different geometric isomers (THERMO TR-Fame: 120m x 0.25mm ID x 0.25μm film).

3. Results and discussion

From the data obtained both in the determinations within the INCDBNA-IBNA Balotesti, as well as reported in various specialized scientific papers [24-28], it can be observed that the three seeds of oleaginous plants are rich in protein. Thus, the crude protein levels are between 20.3% and 26.78% for flax seeds, 23.48% and 24.78% for Camelina seeds, respectively 18.3% and 23.9% for hemp seeds (Table 1). The crude protein concentration is very important because this parameter is necessary in the production of the combined feed for broilers [29, 30].

It is also observed that the oleaginous sources are characterized by high cellulose content, a limiting factor in feeding birds. Thus, for flax seeds 13.2-33.8% is the weight in dry matter, for Camelina seeds 11.4-29.4% and for hemp seeds 16.5%-40.4%. This fact makes us take into account a limited rate of inclusion of seeds in the feed along with the supplementation with enzymes that help the digestion of the cell wall [31]. The introduction of enzymes makes it possible to increase the amount of seeds introduced in the feed, as well as to increase the level of energy due to the degradation of cellulose into simple sugars.

The levels of macroelements (minerals) need to be known for all feed components, in order to know how much we should supplement if necessary. For studied seeds the levels are included in Table 2.

Calcium in broilers feed influences growth, bone development, leg health, nerve function and immune system [32]. Calcium is vital that to be supplied in needed quantities and on a steady basis to achieve best performance [33].

Phosphorus is also required in the right form and amount to improve skeletal structure and growth. Phosphorus from plant sources is described as 33% available whereby inorganic sources for phosphorus counts for 100% availability. Using phytase enzymes will increse the percentage of available phosphorus from vegetable sources and in general the use of enzymes will increse the performance in broiler production [33].

Table 1. The primary chemical composition of the vegetal seeds studied

FLAXSEED, %	IBNA	FEEDIPEDIA	Zajac et al., 2021 [24]	Khan et al., 2010 [25]
Dry matter, (DM)	92.75	88.2-93.5	91.7	-
Crude protein, (CP)	26.78	20.3-27.9	20.5	24.18
Ether extract, (EE)	32.17	31.2-43.6	44.6	37.77
Crude fiber, (CF)	18.83	13.2-33.8	8.12	25.87
Ash, (Ash.)	2.94	3.3-6.2	3.62	4.78
CAMELINA SEEDS, %	IBNA	Peiretti & Meineri, 2007 [26]	Zajac et al., 2021 [24]	Ciurescu et al., 2016 [27]
Dry matter, (DM)	93.4	93.2	86.2	93.66
Crude protein, (CP)	23.48	24.5	24.6	24.78
Ether extract, (EE)	26.92	30.2	39.3	36.84
Crude fiber, (CF)	17.02	29.4	11.7	11.4
Ash, (Ash.)	12.61	3.2	4.31	4.27
HEMPSEED, %	IBNA	FEEDIPEDIA	Borhade, 2013 [17]	Alonso-Esteban et al., 2022 [28]
Dry matter, (DM)	91.38	90.6	96.93	95.5-93.44
Crude protein, (CP)	19.74	23.9	23.9	18.3-23
Ether extract, (EE)	30.52	35.7	32.91	29.1-32.66
Crude fiber, (CF)	30.12	16.5	17.3	32.5-40.4
Ash, (Ash.)	5.39	5.7	4.32	4.2-6.32

Microelements Cu, Fe, Mn, Zn are crucial for all metabolic functions. Needed trace mineral addition depends on feed ingredients, feed manufacturing process and particular occurrences. In general, organic micro-elements have a good biological obtainability. Zinc and selenium improve feathering and immune response. Zinc also improves footpad health [33].

Table 2. Determined mineral concentration in the plant seeds studied

SOURCE	Macroelements		Microelements			
	Ca, %	P, %	Cu, ppm	Fe, ppm	Mn, ppm	Zn, ppm
FLAXSEED						
IBNA	0.294	0.49	2.07	70.69	21.83	45.61
Khan et al, 2010 [25]	0.39	0.89	4.67	50.56	8.29	13.55
CAMELINA seeds						
IBNA	-	0.49	6.33	369.65	121.72	46.83
Zubr, 2010 [13]	1.00	1.4	9.9	329	40	69
Toncea et al, 2013 [34]	0.18	0.53	-	-	-	-
HEMPSEED						
IBNA	5.39	1.01	10.68	110.03	125.66	62.25
Mihoc et al, 2013 [35]	nd	nd	10-12	130-164	89-108	42-57
Oseyko et al, 2019[36]	0.028	0.11	nd	nd	nd	nd
Oseyko et al, 2019[36]	0.09	0.89	nd	74.7	59.4	56.1

Table 3 shows the fatty acids composition of the seeds. The levels of fatty acids are also important, not only OMEGA3 or OMEGA 6, the principal purpose of the study, but through the entire range of fatty acids, the energy intake in broiler feed is increased. All fatty acids have their importance in regulating the endocrine system and serve as precursors for hormones and steroids.

Table 3. The concentration of the main fatty acids (g FAME/100 g fat) of the vegetable sources tested

FLAXSEED	IBNA	FEEDPEDIA	Bozan &Temelli, 2008 [39]	Sargi et al, 2013[40]
Palmitic Acid C16:0	5.88	6.1	6.86	4.13-66.12
Stearic Acid C18:0	3.90	3.6	4.59	2.67-5.65
Oleic Acid C18:1n9	21.85	18.4	15.07	15.4-19.78
Linoleic Acid C18:2n6	16.67	15.8	13.96	14.02-12.75
Linolenic Acid C18:3n3	50.71	55.7	58.31	48.35-39.66
CAMELINA SEEDS	**IBNA**	**FEEDPEDIA**	**Peiretti &Meineri, 2007 [26]**	**Abramovic & Abram, 2005 [41]**
Palmitic Acid C16:0	6.85	8.0	5.7	6.4
Stearic Acid C18:0	2.20	2.5	2.7	2.6
Oleic Acid C18:1n9	15.58	18.6	12.9	17.4
Linoleic Acid C18:2n6	20.04	24.6	17.7	16.9
Linolenic Acid C18:3n3	34.15	32.4	37.3	35.7
HEMPSEED	**IBNA**	**Vonapartis, 2014 [42]**	**Oseyko, 2019 [36]**	**Mikulcova, 2017 [43]**
Palmitic Acid C16:0	7.63	6.8	5.7-6.3	59-62
Stearic Acid C18:0	3.36	2.49	3.0-3.2	2.2-2.4
Oleic Acid C18:1n9	14.82	11.76	13.3-13.6	9.0-12.1
Linoleic Acid C18:2n6	54.05	56.07	54.8-56-9	55.3-57.3
Linolenic Acid C18:3n3	14.20	15.98	16.0-18.5	16.7-20.3

Fatty acids can be categorized into two categories: saturated fatty acids and unsaturated fatty acids. Unsaturated fatty acids are grouped into mono-saturated (predominantly olive and canola oils) containing only one double bond between two carbon atoms in the main chain and poly-unsaturated fatty acids (PUFA) (corn, sunflower, linseed, camelina, etc.) that contain at least two double bonds. Double bonds can be produced by mammalian cells into all positions on the fatty acid carbon chain except the n-3 and n-6 position [37]. Alpha-linolenic acid 18:3n-3 (ALA) and linoleic acid 18:2n-6 (LA) are called Essential Fatty Acids (EFA). Other fatty acids are not considered 'essential' for humans, because they can be produced by cells from the short chain acids. Omega-3 and omega-6 fatty acids which are found in all cell membranes with essential role cannot switch places in the human body [37]. All cell membranes' polyunsaturated fatty acid (PUFA) composition is heavily influenced by dietary intake, unlike cellular proteins, which are defined by genetics. Appropriate quantity of omega-6 and omega-3 fatty acids in diet must be considered in dietary suggestion and these two classes of PUFAs should be distinguished because they are metabolically and functionally different and have opposite physiological functions. Normal development and homeostasis is achieved through the balance of these polyunsaturated fatty acids. Due to the biological effects of their metabolites (eicosanoids), fatty acids of the n-3 and n-6 families (arachidonic acid [20:4(n-6)]) undergo different metabolisms. For example, eicosanoids derived from arachidonic acid are pro-inflammatory and pro-aggregatory agonists, while those derived from n-3 PUFA tend to inhibit platelet aggregation and be anti-inflammatory [38]. It is indeed a challenge to address a minor nutritional deficiency that can reduce the risk of chronic disease. One of the most interesting current and future effects on public health may come from a higher intake of omega-3 fatty acids such as alpha-linolenic acid (ALA).

Indicators in poultry nutrition

Flaxseed inclusion rate

Inclusion rates of flaxseed for broilers is recommended to vary between 2,5 and 10% of the diet [44]. It has also been suggested that a percentage of up to 12%-15% of flaxseeds in the diets of broilers can increase the omega-3 fatty acid content of the meat without affecting performance too much [45-47]. It is preferable for the flaxseeds to be pelleted or roasted instead of being fed raw to increase digestibility. Flaxseeds have a lower energy value than other oilseeds, with TME (True Metabolizable Energy) values for unprocessed seeds of about 14-15 MJ/kg DM, and reduced digestibility for fats (61%) [48]. The low energy value can be increased through processing. It has been shown that pelleting and autoclaving can increase TME up to 17-18 MJ/kg DM [48]. Pelleting increased the digestibility of total fatty acids by 29%, and respectively, 39% by roasting [45]. Pelleted flaxseeds at an inclusion rate of up to 10% of DM did not affect performance [49]. In studies conducted in Saudi Arabia, the inclusion of 15% roasted flaxseeds in the diet of broilers had a positive effect on animal performance and increased the omega-3 fatty acid content [47].

The growth performance of broilers was achieved by the additional addition of vitamin B6, which substantially reduced the effect of linatine [49]. By adding antioxidants to the feed for birds containing 15% flaxseeds, higher levels of polyunsaturated fatty acids, lower levels of saturated fatty acids, and a lower Ω-6:Ω-3 ratio were achieved [44]. It has been demonstrated that enzymes that degrade fibers (carbohydrateases) and gradual introduction of flaxseeds in the feed mitigate the antinutritional effects of mucilages [50].

Feeding broilers with a mixture of flaxseeds and other seeds significantly improved animal performance, as well as the Ω-3 content in tissues. A feed containing extruded and non-extruded flaxseeds with peas or canola, with an inclusion of 12.5% for partial replacement of soybean meal, produced a similar growth rate and relatively similar feed conversion [51]. A combination with a mixture of 6% flaxseeds and 6% canola resulted in better animal growth than feeds with 8% seeds added separately [52].

Feeding with flaxseeds for more than 16 days can lead to a decrease in pH and subsequently low meat quality (cooking losses, water exudation losses, and greater susceptibility to oxidation) [53]. It has been demonstrated, however, that for a Linolenic Acid content of 300 mg/100 g of meat in breast, thigh, and wing is necessary at least 26 days at a 10% inclusion rate or at least 11 days at a 17% inclusion rate [53]. Other experiments on broilers from different countries report longer feeding periods (36 days at 12% in Canada, 42 days at 15% in Romania) [54-55]. Optimal inclusion rates are likely to be a compromise between health requirements and meat quality. The use of flaxseed has led to different results in research studies. Some authors have shown that incorporating varying amounts of flaxseed led to a diminish in weight compared to the control group, after the third week of feeding with 10% flaxseed. Significant reductions in weight, lower feed conversion rates, and poor energy and protein efficiency were demonstrated, but significant increases in the content of polyunsaturated fatty acids in breast and leg meat were also shown [44]. Other authors did not observe any weight reduction compared to the control group when incorporating flaxseed at a rate of 15% [24] or 60% [56]. Studies have shown that in almost all cases, intestinal activity was improved and the content of polyunsaturated fatty acids increased.

Hemp seed inclusion rate

The inclusion of up to 20% of crushed and dried hemp seeds in the diet of broilers resulted in a higher weight of breast, legs, and thighs. The proteins, lipids, antioxidant activity of cannabidiol, as well as the absence of trypsin inhibitors, acted synergistically to produce this effect [25]. Feeding broilers with ground hemp seeds (with an inclusion rate of 20%) resulted in superior feed conversion, higher slaughter weight, younger age at slaughter, and reduced mortality [25]. Hemp seeds incorporated in diet at up to 7.5% in chicken diets had no negative effect on growth performance and reduced the serum cholesterol [57]. Hemp seed meal replaced in part the soybean meal in broiler feed. Inclusion of hemp seed meal at 1.5-9.0% did not efect immune factors. Including from 1.5-3% is possible to develop B cell differentiation and maturation and also increase the immunity. Levels of 4.5-7.0% intensify nitrogen utilization [57].

Two studies from Sweden have demonstrated the advantages of using hemp seed cakes in the feed of organic broilers. A first study compared the nutritional values of hemp seed cakes and those from rapeseed and found that they were similar and that an inclusion rate of 30% produced no negative effects on feed performance or palatability when provided in the 28-35 days after hatching interval [58]. In a second comparative study, the use of hemp seed cake in the feed of fast-growing organic broilers (10% at 10-28 days, 20% at 28-70 days) did not affect growth or survival. Also, no adverse effect of the inclusion of hemp seed cake in the feed was recorded on the number of Clostridium perfringens in the caecum. The high fiber intake of hempseed forage has resulted in a lower litter condition that can lead to pododermatitis, which reduces the possibility of using open pastures [59].

Including hemp seeds at percentages of 0.5%, 2%, and 5% [60] or 2.5%, 5%, and 7.5% [61] resulted in significant weight loss compared to a control group or to groups fed with lower levels of inclusion. Additionally, an increase in ALA levels was observed.

Camelina seeds inclusion rate

In order to replace soybean meal with other protein-rich sources to be used in bird feed, the use of Camelina seeds (*Camelina sativa* (L.) Crantz), an oleaginous plant containing 36.8% oil, was taken into account. Camelina seeds are used especially in the production of biodiesel. Camelina is remarkable by a unique fatty acid structure, as the content of α-linolenic fatty acid (C18:3n-3; ALA) ranges from 25.9% to 36.7% of total fatty acids. Camelina is very resistant to climate changes, to drought or cold, it can be successfully cultivated on soils with low fertility but also resistant to pests and diseases. Camelina seeds, oil or camelina cakes (by-product obtained after the production of bio-diesel) have a high nutritional value but also a substantial quantity of polyunsaturated fatty acids. Following research, by introducing Camelina products into the birds' feed, it was observed that the content of fatty acids in meat and liver increased and changed. In broiler tissues, the content of α-linolenic and long-chain n-3 PUFA increased and the ratio of polyunsaturated fatty acids Ω-6:Ω-3 decreased [62].

The introduction of camelina oil (4%–6.9%), seeds (5%–10%) or cakes (5%–25%) into chicken feed resuled in a decrease in the n-6/n-3 PUFA ratio of 1.8–8.4, 1.6–1.9, and 1.3–2.9 times, respectively, and 3.29 times lower in liver. After including different amounts of camelina cake in chicken diets, a healthy human nutrition Ω-6:Ω-3 ratio of 1.6 to 2.9 was found in chicken muscle [62].

ALA content in chicken muscles increases 1.3–4.4 times for camelina cakes (8–24%); 2.4–2.9 for seeds (10%) and 2.3–7.2 for oil (2.5–6.9). %) compared to the control group. Inclusion of Camelina cakes (5%-25%), seeds (10%) and oil (2.5%-4%) in broiler diets leads to a total n-3 PUFA content of 1.5-3.9 times higher high in muscle and liver [62].

4. Conclusions

From the analysis of the three raw materials, it is clear that they are a good source of protein, provide high energy content and are especially rich in Ω-3 and Ω-6 polyunsaturated fatty acids. By introducing these materials into poultry feed, we can produce products (chicken meat, eggs) that are rich in these essential fatty acids.

Of the three materials studied, flaxseeds are the most suitable for increasing the level of polyunsaturated fatty acids, while also providing a high amount of crude protein. Therefore, flaxseeds can be introduced in smaller proportions, thus eliminating the limiting factors that we face when using them.

Another important aspect in the decision to use flaxseeds is the cost-benefit ratio, which surpassed all other options in this study.

In terms of crude protein, the analysis results and parameters discovered in specialized scientific works are superior to the other two raw materials studied.

Regarding the content of Linolenic Acid C18:3n3, the highest proportion (over 50% of fatty acids) is observed, as well as an extremely good ratio of (PUFA) polyunsaturated fatty acids n-6/n-3. Due to the high proportion of ALA in flaxseeds, relatively small amounts can be introduced into feed to maintain good feed conversion levels

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