doi:10.1017/S0043933917000423

Recent advances in sunflower seed meal as an alternate source of protein in broilers

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Broiler production in certain countries often suffers from an inadequate supply of local high-quality protein. Increased production of sunflower seeds (*Helianthus annuus L.*) for oil can provide more meal that can provide protein and offset the need for soybean meal, which is often unavailable due to cost. Presently, due to adaptive capabilities in various climatic and soil conditions, sunflower seeds are grown worldwide. Sunflower seed meal (SFSM), a by-product from oil production for human consumption, varies in quality due to variations in oil extraction methods, seed varieties and processing techniques. However, investigators reported that SFSM can replace up to two thirds of the soybean meal protein in the starter and finisher diets of broilers. This review includes the quality of SFSM as related to the effect of processing and as a feed ingredient in broilers diets.

Keywords: recent advances; sunflower seed meal; alternate protein source; broilers

Introduction

Scarcity of feed ingredients is a main obstacle for poultry production in many countries (Rama *et al.*, 2006), due to local availability, cost or import constraints, and the most expensive nutrient is protein (Shi *et al.*, 2012). Due to its ideal amino acids profile and digestibility, soybean meal (SBM) is considered an excellent protein source (Shi *et al.*, 2012; Mushtaq *et al.*, 2006; Laudadio *et al.*, 2014). It is imported to many European and Asian countries (Shi *et al.*, 2012) with concomitant fluctuation in market prices, which creates variation in its inclusion rates for feed formulations (Mushtaq *et al.*, 2006). The non-availability of SBM at economical prices supports a need to search for alternate protein sources in least cost formulations for poultry in certain countries (Laudadio *et al.*, 2014; Rama *et al.*, 2006).

Due to its adaptive capability in various climatic and soil conditions, sunflower (*Helianthus annuus L.*) is cultivated worldwide (San Juan and Villamide, 2000;

© World's Poultry Science Association 2017
World's Poultry Science Journal, Vol. 73, September 2017
Received for publication December 7, 2015
Accepted for publication 23, 2017

https://doi.org/10.1017/S0043933917000423 Published online by Cambridge University Press

Mushtaq *et al.*, 2006; Laudadio *et al.*, 2014; Zhou *et al.*, 2012; Brenes *et al.*, 2008) and ranks third in importance as a source of vegetable oil (Rodriguez *et al.*, 2005). The seeds can be harvested two or three times yearly in tropical areas; the oil is good quality and the meal is a relatively inexpensive protein sources in poultry diets (Hamedi *et al.*, 2011; Shi *et al.*, 2012; Senkoylu and Dale, 2006). The increased production of new varieties with high oleic acid content and the upward trends in formulating high density rations for broiler chickens has prompted evaluation of sunflower seed meal (SFSM) as a protein and energy source in rations (Brenes *et al.*, 2008). SFSM may contain crude protein and crude fibre up to 35% and 25% respectively depending upon the processing techniques. This review paper focuses on processing, use of SFSM in broiler diets and its comparative effects on production parameters in broilers.

Sunflower seed history and processing

Sunflowers are thought to be one of the first plants cultivated in the Americas, and *Helianthus Annuus* was developed in North America by Indian tribes and first commercialised in Russia. Its journey to several areas of the world is outlined in *Table 1*. Early sunflowers seeds were made into bread, cakes or mush after pounding or grinding. Beans, corn and squash could be mixed with meal, and cracked seeds were used as snacks with the oil used in making bread.

Table 1 Spread of sunflower seed meal.

Time	Areas of the World	Significant Contribution	Use
3000 BC	Present-day Arizona and New Mexico, US	Cultivated many seed colours (black, black/white striped, red and white)	Food, dye for textiles, medicine (snake bites and body ointments), oil (skin and hair), stalks (building material) and ceremonies
1500 AD	Europe (by Spanish explorers)	Low cultivation	Ornamental and medicinal
1550	Egypt, India, Mediterranean Europe	Low cultivation	Consumption
1716	England	Patent	Oil extraction
1769	Europe (Tsar Peter the Great)	Increased popularity	Cultivated for oil extraction
1830	Europe	Increased cultivation	Cultivated on a commercial scale
1800 ‘s	Russia	Russian Orthodox Church	Sunflower oil excluded from forbidden list of oil foods during Lent
Early 19th Century	Russia	Farmers	2 million acres grown for oil extraction and human consumption
19th Century	Russia	Government breeding programme (V. S. Pustovoit at Krasnodar)	Increased oil yields

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Table 1 Continued

Time	Areas of the World	Significant Contribution	Use
1880 - 1970	US (possibly by Russian immigrants)	Advertisement of Mammoth Russian seed	Silage seed for poultry
1893	US (by American Consul in St Petersburg)	Producers	Oil crop
Mid - 1900's	Argentina	Russian immigrants	Increased acreage
1926	US	Missouri Sunflower Growers' Association	Oil processing
1920	Canada (from Russian immigrant Mennonites)	Official government breeding programme	Increase acreage due to oil demand
1947	Canada	Farmer	Seed crushing plant established
1964	Canada	Government	Licensed Russian cultivar, Peredovik, with high yield and oil content
1970's	US	Commercial entities	Hybridisation for higher yield, oil production and disease resistance
Late 1970's		Us acreage increased	5 million acres for oil exportation to Europe
2014/15	Production in several areas	Government and producers	Oil extraction (use and exportation) and seed consumptions

(Sunflower, 2015; Botanical-online; 2015, Schneiter, 1997; Putt, 1978)

SFSM production and yearly export and import are shown in *Figure 1a*. *Figure 1b* indicates that (1) worldwide import and export of meal cancelled each other and (2) there was excess meal that could be added to feed for broiler production. Worldwide production between 2010 and 2015 is shown in *Figure 2*. The Ukraine, Russia and India are major producers.

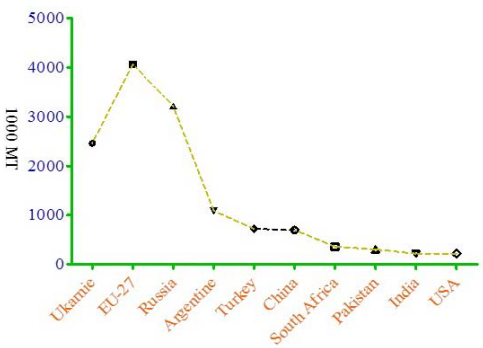


Figure 1 a Sunflower Seed meal production in 2014.

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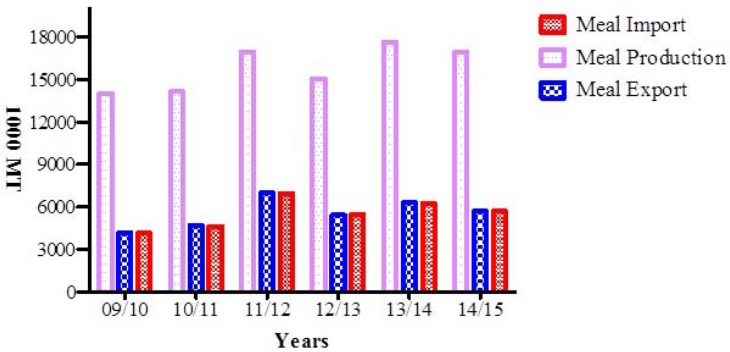


Figure 1 b Yearly sunflower seed meal export and import.

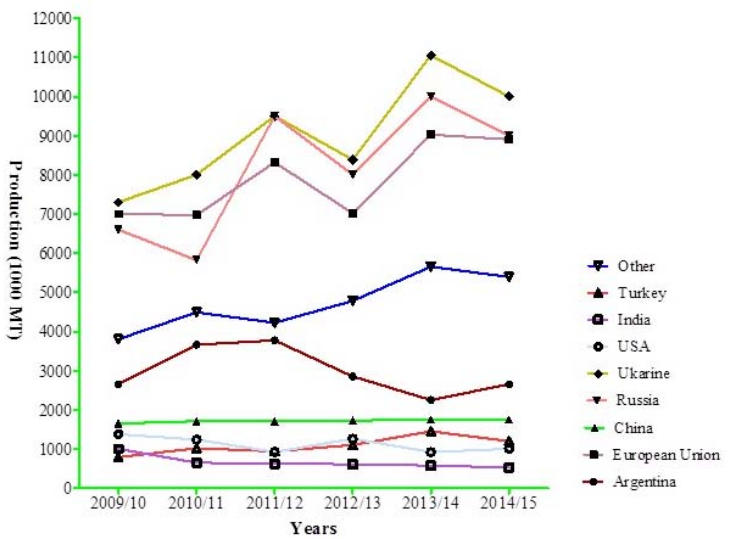


Figure 2 Sunflower production by countries from 2010-2015.

Oil extraction

Sunflower seeds are primarily grown for oil production for human consumption (Kocher *et al.*, 2000) and have a high oil yield (< 50%). The oil extraction process involves mechanical, thermal, and chemical treatments (*Figure 3*) that may affect the nutritional value of sunflower by-products (San Juan and Villamide, 2001). Oil extraction usually involves two consecutive steps. The first step includes cracking of kernels (mechanically by centrifugal or pneumatic shellers or abrasion) to extract most of the sunflower oil through screw-presses (expellers). This results in a 'cake' containing 15-20% oil. Mechanical extraction is used by smallholder farmers in both developing and developed countries. In the second step, industrial scale solvent (usually *n*-hexane)

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extraction increases oil yield (Mandibaya *et al.*, 1999) and results in a defatted SFSM by-product. The cell walls of the endosperm in sunflower seed is totally disrupted initially by pressure treatment and afterwards by *n*-hexane extraction, thus facilitating enzyme action and, therefore, increasing digestibility (San Juan and Villamide, 2000).

High temperatures associated with mechanical pressing (80°C) and solvent evaporation (150°C) can damage protein and amino acids and decrease their availability (Villamide and San Juan, 1998). Generally, the arrangement of lipids within the cell membranes operates as a physical barrier preventing other nutrients from being completely digested. Enhanced digestibility of non-fat constituents occurs due to a greater breakage of cell wall structure during the *n*-hexane extraction, having a greater effect than press extraction. Overall, cell walls of the endosperm in sunflower seed are totally disrupted initially by pressure treatment and afterwards by *n*-hexane extraction, thus facilitating enzyme action and, therefore, increasing digestibility (San Juan and Villamide, 2000). As determined by the KOH solubility test, excess heating/over-processing decreases *in-vivo* availability of lysine, a deficient amino acid in sunflower seed (Zhang and Carl, 1994).

Solvent extraction results in a lower fat content, while de-hulling decreases the fibre content, yielding a meal richer in protein. So, there are fully decorticated meals (high protein, low fibre), partially decorticated meals, and non-decorticated meals (low protein, high fibre) without any clear separation among these grades. Like other protein feeds (fish meal or SBM), SFSM is usually sold on the basis of its protein content (Naidu, 2008). However, the European Union has solvent extraction for SFSM in organic farming (Regulation, 2007). SFSM must be conditioned (dried) for optimal

storage. It can be ground, broken into small pieces, pelletised or extruded for easier handling and storage (Grompone, 2005).

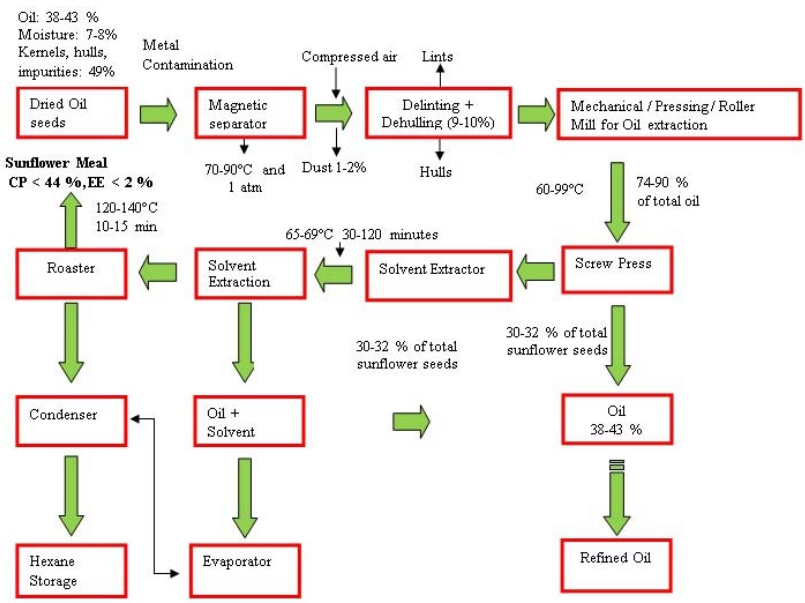


Figure 3 Sunflower seed meal production process.

After oil extraction, the resulting blend is winnowed to separate the hulls from the kernels (Grompone, 2005). Its quality depends on the plant characteristics (seed composition, hulls/ kernel ratio, de-hulling potential, growth stage and storage

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conditions) along with processing (de-hulling, mechanical and/or solvent extraction) techniques (Golob *et al.*, 2008). Certain sunflower varieties have thinner hulls which are more difficult to remove and de-hulling is not recommended as it may result in oil loss with increased extraction costs without enhancing oil and SFSM quality (Grompone, 2005). Characteristically, seeds contain about 20-30% hulls, and 18-22% of the original amount can be removed by a well-managed de-hulling process. De-hulling by 1% improves pressing capacity by 2.5% (Campbell, 1983). Drying facilitates the kernel separation from hulls. The colour of sunflower seed meal ranges from grey to black depending on the degree of de-hulling (Naidu, 2008).

Challenges for upgrading SFSM

DEHULLING

Commonly, SFSM contains 35-40% hulls, 60-65% protein core, 30-34% crude protein (CP), 20-25% cellulose and 8-10% lignin. Efficient solutions for the production of SFSM with CP of 42-46% and 8-14% cellulose have been identified (Sredanovic *et al.*, 2006). De-hulling and oil extraction processes affect the CP contents (29 to 45%) with inverse relation to its fibre (32 to 14%) contents (Villamide and San Juan, 1998). About 55-60 kg SFSM with CP 44-45% and crude fibre (CF) 8-10% can be obtained from 100 kg SFSM with CP (37-38%). A total of 43.3 kg SFSM with CP (43.8%) and CF (12.5%) can be obtained from 100 kg SFSM with CF (37.5%) by centrifugal separation on the sieve with mesh size of 1.5 mm (Sredanovic *et al.*, 2011).

Centrifugal separators fractionise the sunflower hulls from kernels. However, firm material adhering to the hull hinders separation (Levic *et al.*, 1992). While these clumps need to be disintegrated, excessive break-up of hulls is to be avoided (Sredanovic, 2007; Levic *et al.*, 2009) or, otherwise, SFSM will contain reduced CP and higher CF contents. Treatment with a roll crusher followed by centrifugal separation on different sieves (mesh size of 1.5; 1.8 and 2.0 mm) enables yields of 48.75-59.33% of SFSM fractions with high CP (40.12-43.37%) and low CF (10.83-13.61%). After the roll crushing, the particles passing through the sieve increase by 14.3 to 59% (Sredanovic *et al.*, 2011).

Moghaddam *et al.* (2012) concluded that CP levels (29 to 45%) in SFSM depends on the dehulling and oil extraction process and has an inverse relation to fibre content. Higher levels of insoluble fibre reduce the digestibility of nutrients due to reduced intestinal transit time (Rama *et al.*, 2006). SFSM forms powdery dust leading to losses during storage, packaging and transporting and adversely affects homogeneity of compound feeds to which they are added. These disadvantages may be neutralised by pelleting either SFSM or feeds (Sredanovic *et al.*, 2006).

The high fibre contents (26.7%) and its deficiency of lysine are problematic for the inclusion of high amounts of SFSM in broiler diets. A strong negative correlation between the fibre content of the whole sunflower seed and its total metabolizable energy has been reported as well (Viveros *et al.*, 2009; Selvaraj and Purushothaman, 2004). Retaining some oil in meal during processing of sunflower seed produces higher energy SFSM (Senkoylu and Dale, 2006).

DIGESTIBILITY

As shown in *Figure 4*, higher fibre contents, complex protein structure and residual anti-nutrients cause some digestibility challenges leading to poor nutrient utilisation especially in younger birds. The insufficient enzyme activity in young chicks may be complemented through exogenous enzyme supplementation to promote digestion and

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utilisation of diets as activities of digestive enzymes from pancreas and intestine are associated with age (Mushtaq *et al.*, 2006). Fibre may cause abrasion of the intestinal mucosa which increases the amino acid requirements for the synthesis of replacement mucosal cells. Single feeding with SFSM can adversely affect morphological parameters of small intestinal mucosa of cocks, especially in the ileum, that can lead to a reduction in the absorption of nutrients (Hamedi *et al.*, 2011).

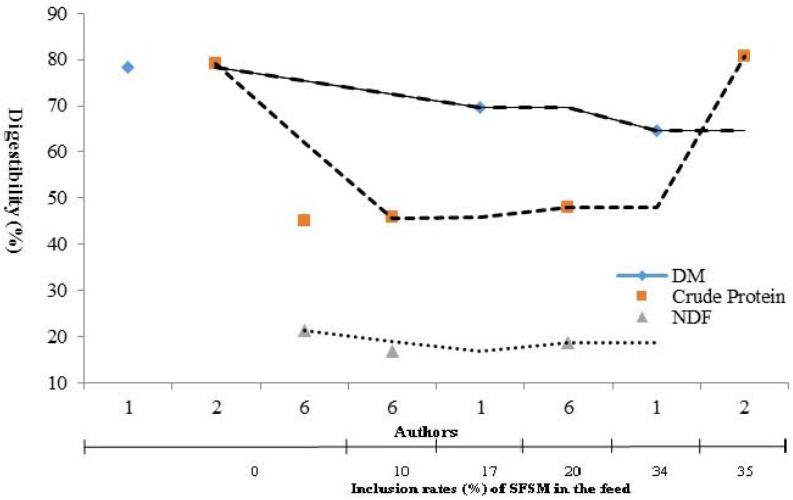


Figure 4 Digestibility (%) of DM, crude protein and NDF at varying levels of SFSM (Authors: 1: Rama *et al.*, 2006; 2: Kocher *et al.*, 2000; 6: Zatari and Sell, 1990b).

USE OF EXOGENOUS ENZYME IN SUNFLOWER SEED MEAL FEED

Due to the deleterious effects on oil presses, hulls cause excessive oil extraction and reduce the quality of both oil and meal (Campbell, 1983). The fibre level of SFSM appears to be the most problematic aspect concerning use of the by-product at high levels in chick diets, causing low ME in diets (Brenes *et al.*, 2008; Senkoylu and Dale, 2006). Fibre and fat have some opposite effects on digestion. The passage rate of digesta is increased by insoluble fibre and decreased by fat, which could affect carbohydrate and protein digestibility (*Table 2*). Lignin and fibre components can adsorb bile acids and reduce the ileal resorption of bile salts, resulting in lower fat digestibility (San Juan and Villamide, 2001). Non-starch polysaccharides (NSPs) and oligosaccharides are innate to almost all ingredients of vegetable origin. Being monogastrics, poultry lacks specific enzyme systems to target NSPs (Aftab, 2009).

Most NSPs (xylans and cellulose) of SFSM are insoluble and are derived from hulls, where they are strongly associated with lignin, whereas most soluble NSPs (mainly pectic compounds) are from the parenchyma. Insoluble fibre and lignin increase the rate of passage of digesta in the small and large intestine. This could lead to shorter enzyme activity and consequently to a lower nutrients digestibility in the small intestine (San Juan and Villamide, 2000). SFSM contains 4.5% soluble and 23% insoluble NSPs (Kocher *et al.*, 2000), the latter consists of 42% cellulose, 24% pectic polysaccharides, 24% 4-O-methl-glucuronoxylans, 5% glucomannans, and 4.5% fucoxyloglucans (Senkoylu and Dale, 2006). The main component of soluble NSPs is reported to be uronic acid (Viveros *et al.*, 2009). Most soluble NSPs (mainly pectic compounds) are from the parenchyma. Soluble NSPs increase digesta viscosity and thereby decrease nutrient

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digestibility. The addition of commercial enzymes to diets of vegetable origin generally results (*Table 2*) in significant improvement in performance and a reduction in intestinal viscosity by breakdown of soluble NSPs (Kocher *et al.*, 2000). Exogenous enzymes have positively affected the performance of diets containing high concentrations of SFSM (Mushtaq *et al.*, 2006).

Earlier reports revealed poor digestibility of SFSM due to its higher lignification. The hemicellulosic compounds are not digested by young birds, whereas adult birds are able to digest substantial amounts of hemicelluloses (Selvaraj and Purushothaman, 2004). Lignification impairs accessibility to the enzymatic degradation as cellulose, hemicellulose, and pectic compounds are major constituents of NSPs of SFSM (Aftab, 2009). Pectic compounds derived from parenchyma tissues of seed are highly degradable by enzymes whereas the less solubilised constituents (cellulose and hemicellulose), derived from the hulls, are not as degradable (Villamide and San Juan, 1998).

Sunflower seeds contain substantial amounts of cell-wall material and a high concentration of fat that could affect the nutritive value. The fat content in liver decreased progressively with increasing dietary SFSM while the protein content increased (Brenes *et al.*, 2008). With increasing dietary SFSM, triglyceride concentration decreased progressively while serum protein concentration decreased. Higher dietary fibre contents in SFSM reduce dietary fat utilisation by decongugation of bile salts which might reduce fat absorption through the gut. Body fat (liver fat) might be utilised for the metabolic needs and therefore increase the HDL concentration in serum (Rama *et al.*, 2006). Fat, protein and other nutrients could be entrapped to varying degrees inside the fibrous structure of the cell walls which can impair the digestion process. As noted above, the use of a crude enzyme preparation might be justified to improve the accessibility of cell contents to digestive enzymes (Brenes *et al.*, 2008).

RATE OF PASSAGE

According to Villamide and San Juan (1998), most of DM (SFSM) was excreted during the first 24 h (70%), and about 10% more was obtained from 24 to 36 h. Energy followed the same excretion pattern.

Table 3 shows the outcomes from various published trials using SFSM in poultry.

Table 3 Results of investigations for sunflower seed meal.

Method	Results	Investigators
Effect of Different Levels of SFSM in Broilers		
SFSM (0, 7, 14 and 21% of feed to cause 2.61, 3.96 and 5.38% CF in the feed) on the performance and digestive organ weight of broilers	↑ WG, FI, and FCR at 14% SFSM, ↓ performance → 21% SFSM. ↑ Relative weights of GIT and gizzard. No effect on abdominal fat.	Moghaddam *et al.* (2012)
SFSM at 10 or 20% levels in the feed (32.6% CP and 18.4% CF)	No effect on weight gain; poor FCR	(Zatari and Sell, 1990b)
15-20% SFS in the feed (8.1-10.3% CF)	↓CF digestibility of starter diet	(Selvaraj and Purushothaman, 2004)
SFSM at 30% levels in the feed (7.1% CF)	No adverse effects on the performance of broilers during two weeks post hatching	(Mushtaq *et al.*, 2006)

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Table 3 Continued

Method	Results	Investigators
Effect of Exogenous Enzymes at Different Levels of SFSM in Broilers		
Effect of SFSM with or without Exogenous enzyme (xylanases, β-glucanases, cellulases, pectinases, proteases, and mannanases)	SFSM → ↑BW and poor FCR at ≤ 20% SFM	(Aftab, 2009)
Multi-enzyme (xylanase and glucanase) at 2 inclusion levels of SFSM (20 and 30% of feed) with 3 levels of digestible Lysine (0.8, 0.9 and 1.0%)	↓ BW and FCR at 20% SFSM with enzymatic supplementation. Quadratic response of digestible Lysine on BW, Linear response on FCR	(Mushtaq *et al.*, 2006)
Replacement (0, 33, 67, 100%) of SBM with 0, 17.3, 34.5 and 65.6% SFSM	No effect on BW however poor FCR with ↑SFSM and can replace up to 2/3 SBM	(Rama *et al.*, 2006)
Effect of Processing on proteins and amino acids		
Over processing	↓ Amino acid availability	(Kocher *et al.*, 2000)
Effect of over-processed SFSM (36% CP)	≤ 60% Protein Solubility values	(Zhang and Carl, 1994)
Effect of SFSM levels of SFSM on nutrient digestibility		
True Digestibility for 32, 35 and 37% CP SFSM	↑CP → ↑ TAAD Digestibility: 76.39, 81.75 and 83.69% for lysine, 89.61, 91.69 and 93% for methionine, 80.72, 82.94 and 83.75% for cystine, 82.72, 83.44 and 85.94% for threonine, 87.72, 89.69 and 90.88% isoleucine, 85.78, 88.0 and 89.44% for TAA	(Villamide and San Juan, 1998)
↑Fibre	↓ Fat digestibility	
↑ Fat in SFSM	↑ Amino acid digestion, methionine: 88.7%, lysine: 73.9%, threonine: 82.0%	(San Juan and Villamide, 2001)
↓ SFSM fibre	↑ Dietary energy value	(Laudadio *et al.*, 2014)
SFSM were screened for pentosans, cellulose, pectin, and total NSPs	Xylanase + cellulase combination found to be superior in SFSM	(Malathi and Devegowda, 2001)

SBM: Soybean Meal, SFS: Sunflower Seeds, FCR: Feed Conversion Ratio, BW: Body Weight, FE: Feed Efficiency, CP: Crude Protein, CF: Crude Protein, FI: Feed Intake, SFSM: Sunflower Meal, NSP: Non-starch Polysaccharides, M + C: Methionine + Cystine, MUFA: Mono-unsaturated fatty acids, PUFA: Poly-unsaturated fatty acids, TAAD: True amino acids digestibility, NSPs: Non-starch polysaccharides, ↑: increase, ↑: decrease, →: may lead to / result in

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Inclusion rates for SFSM

High fibre and lysine deficiency along with a low digestion coefficient for lysine limit SFSM inclusion in poultry feed (Senkoylu and Dale, 2006; Brenes *et al.*, 2008) as compared to other oilseeds, especially soybeans (San Juan and Villamide, 2000). *Figures 5a-f* show graphical effects of varying amounts of sunflower seed meal on feed intake, weight gain and feed conversion ratio.

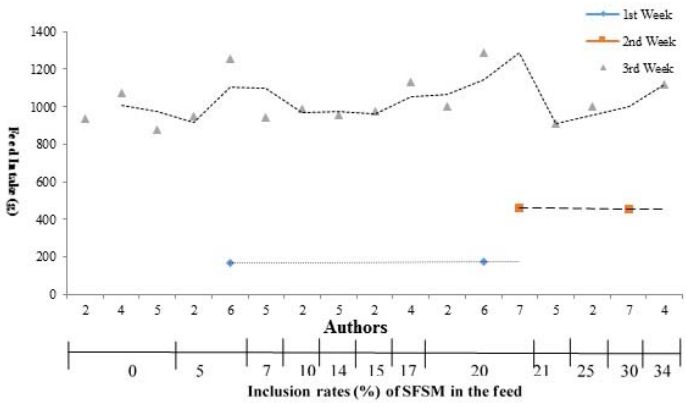


Figure 5a Comparison of effect of inclusion levels of SFSM on feed intake at 1-3 weeks by various researchers (Authors: 1: Zatari and Sell, 1990b; 2: Musharaf, 1991; 3: Kocher *et al.*, 2000; 4: Rama *et al.*, 2006; 5: Moghaddam *et al.*, 2012; 6: Aftab, 2009; 7: Mushtaq *et al.*, 2006; 8: Zhang and Carl, 1994; 9: Zatari and Sell, 1990a).

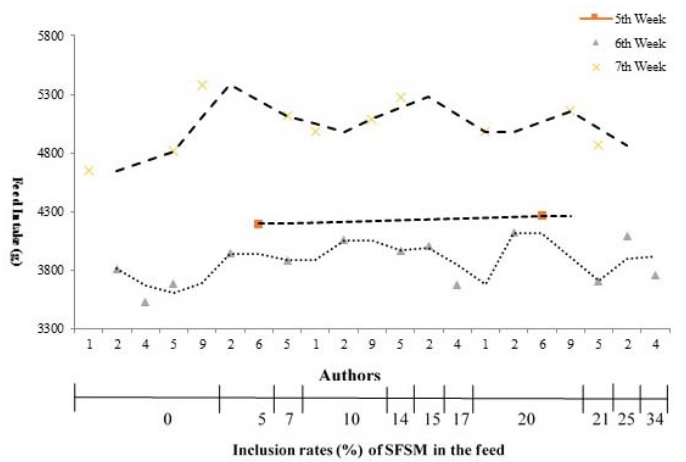


Figure 5b Comparison of effect of SFSM on feed intake at 5-7 weeks by various researchers (Authors: 1: Zatari and Sell, 1990b; 2: Musharaf, 1991; 3: Kocher *et al.*, 2000; 4: Rama *et al.*, 2006; 5: Moghaddam *et al.*, 2012; 6: Aftab, 2009; 7: Mushtaq *et al.*, 2006; 8: Zhang and Carl, 1994; 9: Zatari and Sell, 1990a).

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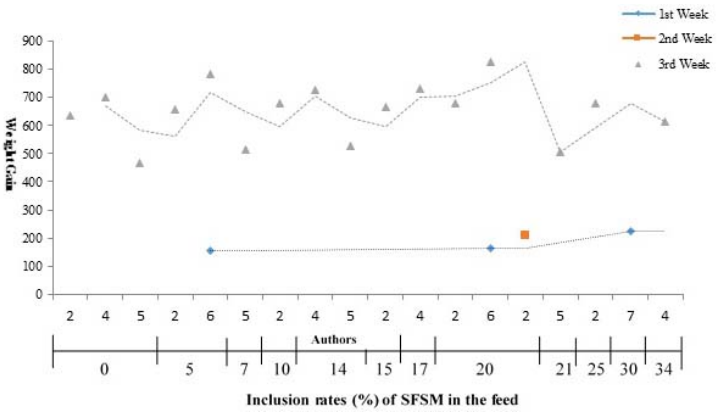


Figure 5c Comparison of effect of SFSM on weight gain at 1-3 weeks by various researchers (Authors: 1: Zatari and Sell, 1990b; 2: Musharaf, 1991; 3: Kocher *et al.*, 2000; 4: Rama *et al.*, 2006; 5: Moghaddam *et al.*, 2012; 6: Aftab, 2009; 7: Mushtaq *et al.*, 2006; 8: Zhang and Carl, 1994; 9: Zatari and Sell, 1990a).

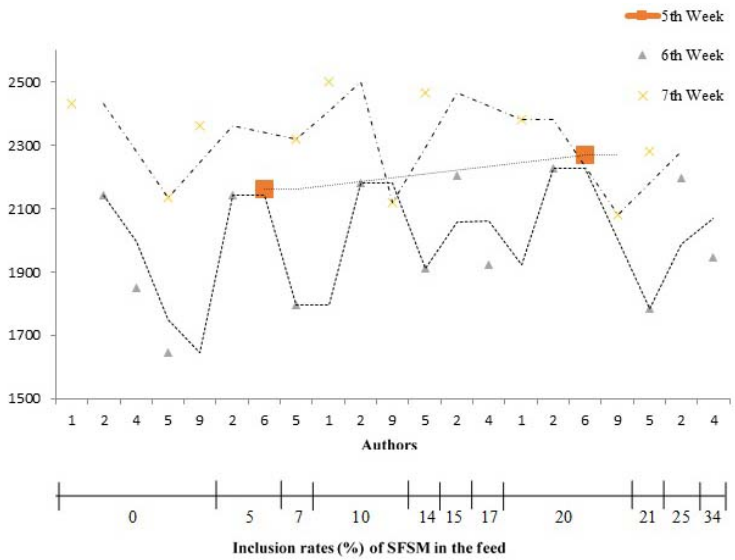


Figure 5d Comparison of effect of SFSM on weight gain at 5-7 weeks by various researchers (Authors: 1: Zatari and Sell, 1990b; 2: Musharaf, 1991; 3: Kocher *et al.*, 2000; 4: Rama *et al.*, 2006; 5: Moghaddam *et al.*, 2012; 6: Aftab, 2009; 7: Mushtaq *et al.*, 2006; 8: Zhang and Carl, 1994; 9: Zatari and Sell, 1990a).

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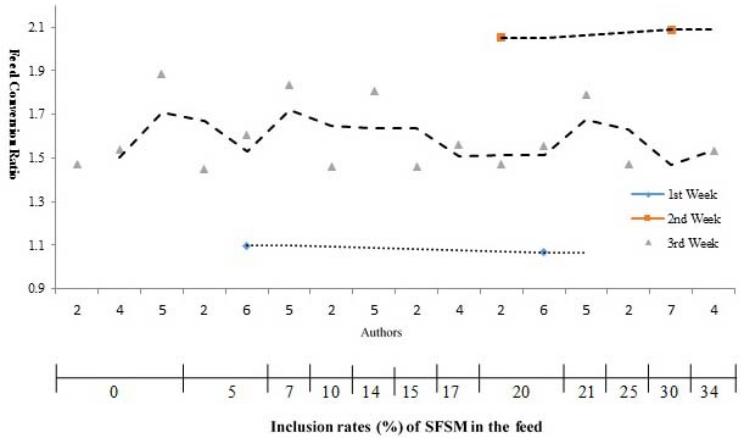


Figure 5e Comparison of effect of SFSM on feed conversion ratio at 1-3 weeks by various researchers (Authors: 1: Zatari and Sell, 1990b; 2: Musharaf, 1991; 3: Kocher *et al.*, 2000; 4: Rama *et al.*, 2006; 5: Moghaddam *et al.*, 2012; 6: Aftab, 2009; 7: Mushtaq *et al.*, 2006; 8: Zhang and Carl, 1994; 9: Zatari and Sell, 1990a).

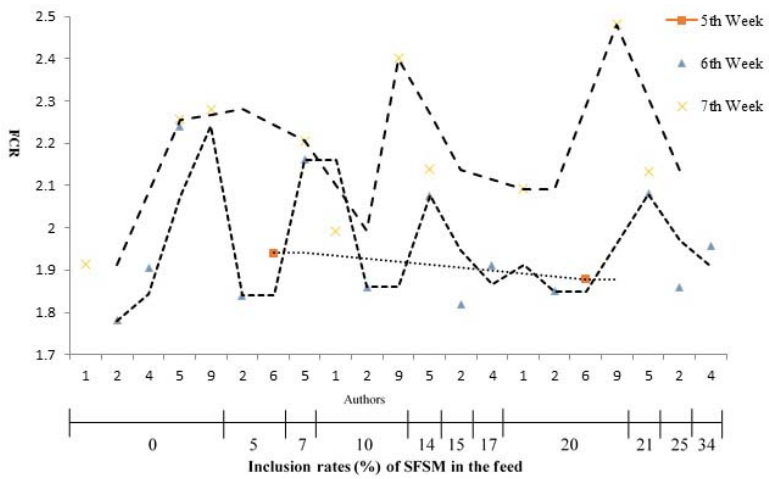


Figure 5f Comparison of effect of SFSM on feed conversion ratio at 5-7 weeks by various researchers (Authors: 1: Zatari and Sell, 1990b; 2: Musharaf, 1991; 3: Kocher *et al.*, 2000; 4: Rama *et al.*, 2006; 5: Moghaddam *et al.*, 2012; 6: Aftab, 2009; 7: Mushtaq *et al.*, 2006; 8: Zhang and Carl, 1994; 9: Zatari and Sell, 1990a).

Despite these limitations, up to 25% sunflower can be used in broilers diets (San Juan and Villamide, 2001) or even up to 35% with supplementation of limiting amino acids without any deleterious effects on production (Rama *et al.*, 2006). Rama *et al.* (2006) showed that SFSM can replace up to two thirds of the SBM protein in the starter and finisher phase diets. Moreover, both canola meal and SFSM can replace SBM at 100% if lysine is added, in spite of high indigestible carbohydrate contents (Kocher *et al.*, 2000). The variation in maximum possible inclusion of SFSM in broiler diets may be due to the variations in energy and amino acids. The relative intestinal and gizzard weight increased

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when SBM was totally replaced with SFSM as indicative of higher levels of fibre in the SFSM (Rama *et al.*, 2006). However, inclusion at greater rates (20 to 30%) reduced the growth rate of the chicks (Brenes *et al.*, 2008).

Conclusions

Sunflower seed meal is obtained by the extraction of oil from sunflower seeds and is found in several parts of the world and can be used as a high protein feed ingredient for broilers. However, chemical, mechanical and thermal treatments can greatly affect the nutritional value of the sunflower by-product during oil extraction. Resultant anti-nutrients, complex protein structure, lack of sufficient amino acids and higher fibre contents can lead to digestibility challenges causing less than optimal nutrient utilisation especially in younger birds. Use of NSP enzymes to improve digestibility and careful monitoring of its inclusion rate enhance the use of SFSM.

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https://doi.org/10.1017/S0043933917000423 Published online by Cambridge University Press

https://doi.org/10.1017/S0043933917000423 Published online by Cambridge University Press

Table 2 NSPs composition of SFSM (g/100 g) compared to other vegetable protein meals.

NSPs	Sunflower Seed (Choct, 1997)		Sunflower Seed meal (Canibe *et al.*, 1999)	(Kocher *et al.*, 2000)	(Sredanovic *et al.*, 2005)	Canola Meal (Safari *et al.*, 2011) Mesh no. 16		Mesh no 18		Mesh no 20		Soybean seed Meal Choct *et al.* (2010)	
	*	**				*	**	*	**	*	**	*	**
Cellulose	--	8.7	1.4 ±0.29	--	8.7	--	--	--	--	--	--	--	4.42-6.2
Rhamnose	0.2	0.3	0.1 ± 0.04	0.37	0.5	ND	0.1	0.1	0.1	0.1	0.1	0.06-0.1	0.2-0.23
Fucose	0.1	0.1	0.1±0.0	0.11	0.2	ND	0.1	0	0.2	0.1	0.1	0.04	2.39
Ribose	--	--	--	0.07	--	--	--	--	--	--	--	--	--
Arabinose	0.6	3.0	1.5 ±0.14	3.44	3.6	1.1	3.1	0.6	3.5	0.9	3.4	0.53-0.9	0.31-0.6
Xylose	t	5.3	0.5 ± 0.015	6.18	5.3	0.4	1.7	0.1	1.7	0.3	1.7	0.11-0.2	1.7-1.71
Mannose	0.1	1.1	0.6 ± 0.09	1.57	1.2	0.3	0.6	0.4	0.3	0.3	0.3	0.21-0.5	0.21-0.5
Galactose	0.3	0.9	0.5 ± 0.07	2.25	1.2	0.6	1.1	0.4	1.1	0.5	1.2	0.57-1.6	2.5-3.94
Glucose	t	0.4	0.3 ± 0.26	14.11	0.4	0.2	5.7	0.4	5.6	0.5	5.9	0.31-0.6	0.1-0.31
Uronic Acid	3.2	3.4	1.1± 0.09	--	6.6	--	--	--	--	--	--	1.07-2.5	2.3-2.54
Total	4.5	23.1	6.0 ± 0.49	25.53	27.6	2.9±0.1	14.8±0.1	2.2±0.3	15±0.3	2.5 ±0.1	15±0.1	2.73-6.3	9.2-16.4

*: Soluble, **Insoluble, ND: Not detected, t: traces

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