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EFFECT OF PROCESSING ON THE NUTRIENTS AND ANTI-NUTRIENTS COMPOSITION OF SUNFLOWER (Helianthus annus) SEED MEALS

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Abstract : Raw, cooked and toasted meals from Sunflower (Helianthus annuus) seeds were analysed for proximate, mineral and anti-nutrient composition and the changes accompanying chemical composition when processing sunflower seedmeal were investigated. There was significant ($P<0.05$) variation in the crude protein, crude lipid, crude fibre and Ash content of undeffated and defatted sesame seed meal. Defatting the dehulled samples of the sunflower meal increased its protein contents. Sodium, magnesium and potassium were the most abundant macro minerals in sunflwer seedmeal, Iron was the most abundant micro mineral in the seed meal used. A significant ($P<0.05$) reduction was observed in the mineral composition with processing time. As was observed in the raw sample, copper and manganese were not detected in some processed sample. A reduction in mineral contents of the cooked samples was observed. Raw sunflower seedmeal contains the highest level of antinutrients with respect to Trypsin Inhibitor (TIA), lectin, tannin, phytin, saponin and oxalate. Cooking and toasting reduced antinutrient contents of sesame seedmeal at lower processing time. TIA and lectin content were completely removed at higher processing time of 30 minutes.

1. Introduction

Plant oilseeds and pulses constitute a readily available source of dietary protein for use within compound and aquafeed (Tacon, 1997) but their use within compound aqua feed is restricted by the presence of one or more endogerous antinutrients (NRC, 1993). Sunflower (Helianthus annus) is one of the important annual crop of the world, grown for oil (Salunkhe et al., 1991). Sunflower seeds are rich sources of protein, minerals such as calcium and phosphorus (Salunkhe et al., 1991). Hence they have nutrient quality favorably comparable with other oil seeds and legumes. Like all other oilseeds, their use as fish feed ingredient is limited by the presence of anti-metabolites primarily; trypsin inhibitor, phytate (Salunkhe et al., 1991, Smith, 1968, Agren and Lieden, 1968), and Saponin (Tacon, 1997) for sunflower seeds. Makkar and Becker 1999 observed that to evaluate an unknown seed or seed meal, it is imperative to have a detailed description of its chemical and nutritional properties, to obtain knowledge on acceptability and utilization by livestock, to investigate the presence of toxins and anti nutritional factors and to develop processes to detoxify deleterious factors present and finally to utilize the detoxified product for animal diets. Processing oil seeds and other plant protein to remove bioactive compound that may negatively affect their utilisation as component of animal feed are always accompanied by changes in their nutritional composition. This study therefore aimed at establishing such chemical changes as accompanying cooking and toasting raw, defatted dehulled sunflower and sesame seed meals.

2. Materials and Methods

2.1 Processing of Sunflower Seed

The dehulled seed meal was obtained from a farm in Kebbi State. It was processed as follow.

Raw Sunflower Samples : These were prepared by grinding the samples in a laboratory mill and then mechanically defatted by the use of locally made screw press.

Cooked sunflower seed samples : Three batches of sunflower seed were put in boiling water (100ºC) for 10, 20 and 30 minutes to serve as processing time interval. They were dried, milled, and mechanically defatted using locally made screw press and designated as C_{10}, C_{20} and C_{30} respectively according to their time of processing.

Toasted sunflower seed sample : Three batches of sunflower seeds were put in a pyrex beaker and heated at 204ºC for 5, 10, and 15 minutes respectively. The toasted seeds were ground, and mechanically defatted using locally made screw press and designated as T_5, T_{10}, and T_{15} respectively; according to time of processing.

2.2 Chemical Analysis

The proximate composition of dehulled defatted sunflower seed meal for moisture, fat, ash, protein and fibre were carried out in triplicate using the methods described by Association of Analytical Chemist (1991). Nitrogen free extract was estimated by difference.

Macro and micro minerals were analysed from solutions obtained by first dry -ashing the sample at 525ºC and dissolving in volumetric flasks using distilled, de-ionised water with a few drops of concentrated hydrochloric acid. Sodium and potassium were determined using a flame photometer (corning, UK, Model 405), phosphorus was determined colorimetrically using a Spectronic 20 (Gallen Kamp, UK) as described by Pearson 1976. All other minerals were determined using atomic absorbtion spectrophotometer (PYE Unicom, UK, Model SP9).

Trypsin Inhibitory Activity (TIA) was expressed in terms of the extent to which an aqueous extract of the flours inhibited the action of bovine trypsin on the substrate (Benzoyl - DL - arginine - p nitroanilide hydrochloride, BAPNA). TIA was subsequently determined spectrophotometrically as described by Smith et al. (1980).

Haemaglutinin was extracted from the defatted Sunflower and sesame flour by the four- step method of Huprikar and Sohonie (1965). The heamaglutinating activities of the extract will then be determined using 0.25% saline - washed trypsinating erythrocytes in a two - fold dilution technique.

Phytin was determined using a combination of two methods. Extraction and precipation of phytate was carried out, while iron in the precipate was determined by the method of Mackower (1970). Phytic acid and phytin- phosphorus contents was determined according to the method of Young and Greaves (1940). Phitin-Phosphorus was calculated as a percentage of total phosphorus.

Hydrolysable tannin was determined as tannic acid, following the procedure of Makkar(1994).

2.3 Statistical Analysis

All determinations were conducted in triplicates and the means ± SD of three values were reported. Data were suggested to analysis of variance (ANOVA) using SPSS 13.0 version. Duncan Multiple Range Test was used to separate significant differences among treatment means.

3. Results

3.1 Proximate Composition

Data on the proximate composition raw and processed dehulled defatted sunflower seedmeal are presented in Table-1.

Table-1 : Proximate Composition (g/100g) of Sunfllower Seedmeal

	Lipid Unextracted raw seeds	**RAW**	**C_{10}**	**C_{20}**	**C_{30}**	**T_5**	**T_{10}**	**T_{15}**
Moisture	8.9±.15^{d}	9.48±.15^{a}	9.1±.12^{cd}	9.32±.09^{abc}	9.2±.05^{bc}	9.23±.08^{bc}	9.36±.18^{ab}	9.48±.06^{a}
Crude protein	22.32±1.23^{e}	40.01±1.74^{bc}	39.36±3.51^{bcd}	37.89±1.49^{cd}	35.98±1.26^{d}	42.08±1.68^{ab}	44.29±2.26^{a}	39.76±1.42^{bc}
Crude lipid	44.62±21^{a}	20.28±3.12^{b}	12.36±.64^{c}	13.21±.74^{c}	12.88±.19^{c}	13.28±1.09^{c}	12.33±.84^{c}	12.05±2.92^{c}
Crude fibre	3.72±.69^{a}	12.80±1.53^{b}	14.53±1.27^{b}	14.64±2.64^{b}	14.28±2.56^{b}	14.22±2.23^{b}	14.38±.66^{b}	15.37±.56^{b}
Ash	5.83±.37	5.89±.59	6.73±.78	6.21±1.32	5.85±.43	5.99±1.01	6.32±1.31	6.23±.45
NFE	14.51±.81^{b}	13.33±4.2^{b}	17.92±4.72^{ab}	18.73±3.35^{ab}	21.81±1.5^{a}	15.18±2.03^{b}	13.33±1.20^{b}	17.79±4.4^{ab}

Figures in each row with different superscript are significantly different (P<0.05) from each other

There was significant difference (P<0.05) in the crude protein, crude lipid, crude fibre and ash content of the dehulled undefattted and dehulled defatted sample of sunflower meal. Defatting the dehulled seed increased the crude protein value significantly. There was a significant (P<0.05) decrease in the crude protein content of the cooked samples while the toasted samples had a significantly (P<0.05) higher protein content when compared with raw.

3.2 Mineral Composition

The mineral composition of raw and processed dehulled defatted sunflower meal are shown in Table-2.

Table-2 : Mineral Composition (mg/100g) of Sunflower Seedmeal

	RAW	**C_{10}**	**C_{20}**	**C_{30}**	**T_5**	**T_{10}**	**T_{15}**
Potassium	12.44±.01^{g}	16.37±.02^{c}	18.92±.05^{a}	14.24±.02^{f}	18.60±.02^{b}	14.61±.06^{d}	14.57±.11^{e}
Calcium	12.91±.02^{b}	12.37±.02^{d}	12.32±.01^{e}	11.67±.01^{g}	12.51±.01^{c}	12.15±.0001^{f}	15.12±.0007^{a}
Sodium	14.58±.02^{f}	21.06±.02^{a}	15.32±.01^{e}	16.37±.02^{c}	18.62±.02^{b}	12.07±.01^{g}	15.79±02^{d}
Magnesium	17.17±.004^{e}	19.82±.008^{a}	19.30±.009^{c}	16.62±.01^{f}	19.43±.02^{b}	16.57±.02^{g}	18.22±.01^{d}
Manganese	.02±.0001^{c}	.03±.002^{b}	ND	ND	ND	.02±.0006^{a}	.05±.002^{c}
Iron	..03±.0002^{e}	.002±.0001^{g}	.055±.0001^{c}	.017±.002^{f}	.037±.001^{d}	.169±.0007^{a}	.079±.006^{b}
Copper	.01±.0003^{d}	ND	ND	ND	.011±.0003^{c}	.067±.0001^{a}	.0427±.0002^{b}

Figures in each row with different superscript are significantly different (P<0.05) from each other

There were significant differences (P<0.05) in the mineral composition between the raw and the processed. Sodium,magnesium, and potassium were the most abundant macro minerals in sunflower seed meal. The most abundant micro mineral in the seed meal was iron. There was significant (P<0.05) difference in the mineral composition of sunflower meal with processing time when compared with raw. copper and manganese were not detected in some cooked and toasted samples.

3.3 ANTI-NUTRIENTS COMPOSITION

The anti-nutrients composition of raw and processed dehulled defatted sunflower seed meal are shown in Table-3. There were significant differences (P<0.05) in the anti-nutrients composition between the raw and the processed meal. A reduction trend was observed in the level of anti-nutrients in the various samples with processing time. The levels of anti-nutrients in the raw samples of sunflower seed meal with respect to TIA, Lectin, Tannins, Saponins , oxalates were significantly (P<0.05) higher than that of the processed samples of the same seed meal. A reduction trend was observed in the level of anti-nutrients in the various samples with processing time. The TIA and Lectin contents of sunflower seed meal was completely eliminated when the seed was processed for 30 minutes.

Table-3 : Antinutrient Composition of raw and Processed Sunflower Seedmeals

	RSF	**CSF_{10}**	**CSF_{20}**	**CSF_{30}**	**TSF_5**	**TSF_{10}**	**TSF_{15}**
TIA mg/g	0.34±.0.07^{a}	0.15±.004^{b}	0.07±0.02^{c}	ND	0.13±0.01^{bc}	0.11±0.01^{bc}	ND
Lectin %	0.23±.007^{a}	0.14±0.00^{b}	0.06±0.01^{c}	ND	0.08±0.01^{c}	0.05±.01^{d}	ND
Tannin mg/100g	2.85±0.43^{a}	2.19±0.51^{ab}	1.36±0.46^{c}	0.55±0.33^{d}	2.64±0.04^{a}	2.21±0.01^{ab}	1.62±0.01^{bc}
Phytin mg/100g	13.15±0.07^{a}	11.00±0.99^{b}	8.95±0.50^{cd}	4.35±1.63^{e}	13.00±0.01^{a}	10.43±0.03^{bc}	8.13±0.01^{cd}
Saponin %	4.11±0.41^{a}	2.76±0.36^{cd}	2.64±0.25^{d}	1.67±0.42^{e}	3.97±0.16^{ab}	3.34±0.28^{bc}	2.81±0.02^{cd}
Oxalate mg/100gm	16.41±0.61^{a}	10.91±1.99^{b}	8.70±0.83^{bcd}	6.94±0.93^{d}	10.81±0.01^{b}	9.60±0.30^{bc}	8.39±0.50^{cd}

Figures in each row with different superscript are significantly different (P<0.05) from each other

4.0 Discussion

The value of proximate composition of raw undefatted sunflower obtained in this study agrees with the earlier work by Kinman and Earle, (1974), Adams (1978), Gopalan et al., (1982), Dreher et al., (1983a). The defatted meal or cakes have a higher content of protein. The value obtained for the protein content of defatted sunflower agreed with that of Robertson and Russel, (1972) but slightly varies from that reported by Bau et al., 1983 who reported value ranging from 53 to 66% protein content of dehulled defatted meal. The variation obtained might be due to genetic and environmental factors (Mantha and Subrahmanyam, 1973; Smith et al., 1978; Goyne et al., 1979). T Lower crude protein in cooked sunflower seed meal might be as a result of leaching of soluble component of the protein into cooking water. Adeparusi (2001) made similar observation, when antoclaving lima beans, Phaseolus lunatus L.

Higher content of macro-mineral potassium, sodium, calcium and magnesium in sunflower seed meal recorded in this study agree with earlier works by Joshi 1961; Agren and Gibson 1968; Gopalan et al., 1982 Weiss, 1983; Smith, 1971; Adam 1975.

The reduction in the TIA of sunflower seed meal recorded in this study for the two processing technique employed agrees with the work of Norton 1991 who recommended moist heat treatment (autoclaving for 15-30 minutes as a means of reducing the amount of TIA in seed meal below critical level. The critical level as explained by Francis et al.,2001 is the level of TIA at which most cultured fish and other farm animals will be able to compensate for the presence of TIA by increasing trypsin production within their system and this is below 5 mg/g. The optimum level for the destruction of TIA has been reported to be between 80 and 90% equivalent to a dietary TIA of 1-5 mg/g. The degree of destruction depends upon temperature, duration of heating, particle size and moisture conditions (Lim and Akiyama, 1992; Jansman and Poel, 1993). In general, the reduction of TIA is accompanied by a marked improvement in the nutritive value of protein source (Lim and Akiyama, 1992, Shimeno et a/., 1992; Rumsey et al., 1993). NRC 1993 remarked that excessive heat treatment reduces the availability of heat sensitive amino acids and in particular that of lysine.

The lectin content of the sunflower seedmeal was reduced at lower cooking and toasting time, This results agrees with the earlier work by Aregheore et al., 1998 who reported a reduction in lectin content of Jatropha seed meal by moist heating. A reduction trend was observed in the level of anti-nutrients in the various samples with processing time. However the lectin content was completely eliminated at higher cooking and toasting time (30 minutes and 15 minutes respectively) .Although Grant ,1991 reported inactivation of lectin at lower cooking time of 10 minutes. Similar report was made in the work of Adeparusi 2001 who reported complete elimination of lectin contents of lima bean (Phaseolus lunatus) by dry and moist heat treatment applied. It is remarkable that lectins are usually reported as being heat-labile, their stability varies between plants species (Poel et al., 1990, Almeida et al., 1991).

Phytin contents of the sunflower seed meal was significantly reduced with processing time. This is in agreement with the work of Hossain and Jauncey, 1990 who reported reduction of phytic acisds in linseed and sesame meals by up to 72 and 74% respectively. Phytates can reduce bio-availability of minerals, impaired protein digestibility caused by formation of phytic-protein complexes and depressed absorption of nutrients due to damage to the pyloric caeca region of the intestine (Francis et al., 2001).

Tannin contents of sunflower seed meal also reduced with processing time. Moist heat treatment gave a higher reduction in tannin than dry heat treatment. This agrees with the report of Nyachoti et al., 1997 and Adeparusi, 2001. Tannins anti-nutritional effects include interference with the digestive processes either by binding enzymes or by binding to feed components like proteins or minerals (Elkin and Roger, 1990, Hagerman et al., 1992). Tannins also have the ability to complex with vitamin B_{12} (Liener, 1980, Francis et al., 2001). Tannins are also known

to interact with other anti-nutrients; Fish and Thompson, 1991 reported the inhibitory action of tannins on amylase by interaction between tannins and Lectin. So also interaction between tannins and cyanogenic glucosides reduced the deleterious effect of the latter (Goldstein and Spencer, 1985).

Moist heat treatment reduced the saponin contents of sesame than dry heat treatment. Francis et al., 2001 recommended that because of high solubility of most saponin in water, aqeous extraction would remove most saponins from feed ingredients. The anti-nutritional effects of saponins include increased permeability of small intestinal mucosa cells thereby inhibiting nutrient transport. Other properties of saponin may also play a role in its growth depressing action. Endogenous saponins have been found to reduce protein digestibility of soybean by chymotrypsin (Shimoyamada et al., 1998), probably by the formation of sparingly digestible saponin-protein complexes (Potter et al., 1993). Complex formation between saponins and other anti-nutrients as reported by Makkar et al., 1995a could lead to inactivation of the toxic effect of both the substances. This is considered to be due to chemical reactions between them, leading to the formation of tannin-saponin complexes thereby inactivating the biological activity of both tannins and saponin.

Same trend of results as above was observed with respect to oxalate contents of sunflower seed meal. Narasinga Rao, 1985, Gopalan et al., 1982 and Deosthale, 1981 reported that oxalates reduce the physiological availability of calcium from seeds.

5. Conclusion

Cooking and Toasting impacted some chemical changes in the nutritional composition of sunflower and sesame seed meal.

REFERENCES

Adams, C.F. 1975. Nutritive Value of American Foods. Agricultural Handbook 456, Washington, DC: us Department of Agriculture

Adeparusi E.O. 2001. Effect of processing on the nutrients and anti-nutrients of lima bean (Phaseolus lunatus L.) flour Nahrung/Food 45 No 2, pp 94 - 96.

Agren G., amd Gibson R., 1968. Food composition table for use in Ethiopia. Addis Ababa: children's Nutrition Unit.

Agren G, and Lieden S.A. 1968. Some chemical and biological properties of a protein concentrate from sunflower seeds. Acta chem.. scan. 22: 1981 - 85.

AOAC 1990 Official Methods of Analysis (K-Helrich ed.) 15th edition vol.1. Association of Official Analytical Chemists (AOAC), Arlingron, VA.

Almeida, N.G., Calderon de la Barca, A.M. and Valencia, M.E. 1991. Effect of different heat treatments on antinutritional activity of Phaseolus vulgaris (variety Ojo de Cabra) Lectin. J.Agric. food. Chem. 39 (9): 1627-1630.

Aregheore, E.M., Makkar, H.P.S., Becker, K., 1998. Assessment of lectin activity in a toxic and a non-toxic variety of Jatropha curcas using latex agglutination and haemagglutination methods and inactivation of lectin by heat treatments. J. Sci. Food Agric. 77, 349 - 352.

Bau H.M., Mohatadi - Nia.DJ., Mejean, L., Debru G.1983. Preparation of colourless sunflower products. Effect of processing on physicochemical and nutritional properties. J.AM. oil Chem. Soc. 60: 1141 -48

Deosthale Y.G., 1991. Trace element composition of common oilseeds. J. Am. Oil Chem,. Soc. 58: 998-990.

Elkin, R.G. and Rogler, J.C. 1990. Comparative effects of dietary tannins in ducks, chicks and rats. Poultry Science, 69 (10): 1685-1693.

Fish B.C., Thompson L.U., 1991. Lectin - tannin interactions and their influence on pancreatic amylase activity and starch digestibility - J Agric. Food Chem. 39 727 -731.

Francis G., Makkar H.P.S., K. Becker, 2001. Anti-nutritional factors present in plant derived alternative fish feed ingredients and their effects in fish. Aquaculture 199, 197-227.

Goldstein W.S., Spencer K.C., 19985. Inhibition of Cyano-genesis by tannin. J Chem. Ecol. 11,847-857.

Goyne, P.J., Simpson, B.W., Woodruff D.R., and Churchett J.D. 1979. Environmental influence on sunflower achne growth, oil content and oil quality. Austr. J. Exp. Agric Anim - Husb-19: 82-88

Gopalan C., Ramasaatri, B.V., and Balasubramanian S.C. 1982. Nutritive value of Indian Foods. PP. 59 - 114, Hyderasad, National Institute of Nutrition.

Hossain M.A., Jauncey K. 1990. Detoxication of oil seed and sesame meal and evaluation of these nutritive values in the diets of common carp (Cyprinus carpio L.) Asian Fisheries Science: 169 - 183.

Hagerman, A. E., Robbin, C.T., Weerasuriya, Y., Wilson, T.C. and McArthur, C., 1992. Tannin chemistry in relation to digestion. J. Range Management(USA) 45 (1): 57-62.

Jansman, A.J.M. and Poel A.F.B., 1993. Anti-nutritional factors in legume seeds. Nutritional effects and (bio-) technological inactivation. Seventh Forum for Applied Biotechnology, Gent (Belgium), 3 September - 10ctober 1993, Mededelingen Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, University of Gent, 58 (4a): 1657-1668.

Joshi, A.B. 1961. Sesamum. Hyderabad; Indian Central Oil seeds Committee.

Kinman M.L and Earle, F.R. 1964. Agronomic performance and chemical composition of the seed of sunflower hybrid. Crop Sci. 4:417 - 420.

Liener, I.E., 1980. Toxic Constituents of Plant Foodstuffs. Academic Press, New York

Lim C., Akinyama D. 1992. Full fat utilization of soybean meal by fish. Asian Fish Sci. 5,181-197.

Makkar, H.P.S., Becker, K.,1999. Nutritional studies on rats and fish carp, Cyprinus carpio fed diets containing unheated and heated Jatropha curcas meal of a non-toxic provenance. Plant Foods Hum. Nutr.53,183-192.

Makkar,H.P.S.,Blumrnel,M.,Becker,K.,1995a. In vitro effects of and interactions between tannins and saponins and fate of tannins in the rumen. J. Sci. Food Agric. 69, 481 - 493.

Manthia K.S. and Subrahmanyam, V.V.R. 1973. Sunflower seed and Oil: a review J. Oil. Technol. Assoc. India 5:11 - 17 and 26 - 34. 10003, NY, pp. 1-502.

Narasinga Rao, M.S. 1985. Nutritional aspects of oilseeds -an overview. In oilseeds production - constraints and opportunities ed. H.C. Sriavastava, S. Bhaskaran , B. Vatsya and K.K.G. Menon. pp 628 -634. New Delhi Oxford and IBH.

Norton, G.,1991. Proteinase inhibitors. In: D'Mello, F.J.P., Duffus, C.M., Duffus, J.H.Eds., Toxic Substances in Crop Plants. The Royal Society of Chemistry, Thomas Graham House, Science Park, Cambridge CB4 4WF, Cambridge, pp. 68 -106.

Nyachoti, C.M., Atkinson, J. and Leeson L. 1997. Sorghum Tannin: A review. World Poultry Science Journal 53: 1-21

NRC (National Research Council) 1993. Nutrient Requirement of Fish. Committee on Animal Nutrition, Board on Agriculture. National Research Council. National Academic Press, Washinton D.C., USA 114P.

Pearson D., 1976. Chemical analysis of food. 7 ed. J.A. Church, London, U.K.

Poel, A.F.B. van der, Blonk, J., Zuilichem, D.J. and Oort, M.G.,1990. Thermal inactivation of lectins and trypsin inhibitor activity during steam processingof dry beans (Phaseolus vulgaris) and effects on protein quality. J. Food. Sci. Technol 53 (2): 215-228.

Potter, S.M., Jimenez-Flores, R., Pollack, J., Lone, T.A., Berber-jimenez, M.D., 1993. Protein saponin interaction and its influence on blood lipids. J. Agric. Food Chem.41, 1287-1291.

Roberson J.A. and Russel R.B. 1972. Sunflower: Americans neglected crop. J. Am. OilChem. Sci. 49:239-244.

Rumsey, G.L., Hughes, S.G., Winfree, R.A., 1993. Chemical and nutritional evaluation of soy protein preparations as primary nitrogen sources of rainbow trout Oncorhynchus mykiss . Anim. Feed Sci.Technol. 40, 135 -151.

Shimoyamada, M., Ikedo, S., Ootsubo, R., Watanabe, K., 1998. Effects of soybean saponins on chymotryptic hydrolyses of soybean proteins. J. Agric. Food Chem. 46 (12), 4793-4797.

Shimeno, S., Hidetsuyo, H., Yamane, R., Masumoto T. and Ueno, S-l., 1992. Changes in the nutritive value of defatted soybean meal with duration of heating time for young yellowtail. Nippon Suisan Gakkaishi, 58 (7): 1351-1359.

Smith G.A., Smith N., Bender, M.J and Snyman J.W. 1978. effect of cultivar, envitronment and fertilizer on some chemical characteristics of sunflower seed. S. Africa J. Anim. Sci. 8: 27 - 32

Smith K.J 1968. A review of the nutritional quality of sunflower meal. Feedstuff. 40: 20-23.

Smith K.J 1971. Nutritional framework of oilseed protein J.Am oil Chem. Sci. 48: 625 -629.

Salunkhe D.K Chavan J.K, Adsule R.N., Kadam S.S 1991 World Oilseeds: Chemistry, Technology and Utilisation. PP 554. New York. Van Nostrand Reinhold.

Tacon A.G.J (1997) Fishmeal replacers: review of ant-nutrients within oilseeds and pulses - a limiting factor for the aqua feed green revolution? In Tacon A, Basurco B. (Eds.) Feeding Tomorrow's Fish. Proceedings of the workshop of the CIHEAM Network in Technology of Aquaculture in the meditera neam (TECAM). Jointly organized by CIHOAM, FAO and IEO, 24 - 26 June 1996, Mazzanni, Spain. Cahiers options-mediferraneenes vol 22 pp. 153 - 182.

Weiss E.A. 1983. Oilseed crops. Pp. 597-639. New York. Longman.