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Oilseeds Dietary Fiber and Their Health Benefits

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Abstract

Recently, epidemiological studies confirm that dietary fiber intake is linked with a reduced risk of death. So, this review illustrated dietary fiber (DF) composition and classification. It also shows the extraction methods, factors that influence its functionality, and how it affects microbiota. The main components in oilseeds are fatty acids (FA), protein, dietary fiber, and other micronutrients. It also acts as an antioxidant, anti-bacterial, anti-cancer, anti-cholesterol, anti-cardiovascular, and anti-inflammatory agent, in addition to its role in diabetes, diarrhea, constipation, and obesity, as well as their utilization in the field of cosmetics. In this review, the health benefits of some popular oilseeds dietary fiber such as (flaxseed, cotton, sunflower, soybean, sesame, and mustard) were evaluated. Oilseeds DF are of great importance to human health by reducing the risks of some diseases.

Keywords: Dietary fiber; functionality; oilseeds; health benefits

1. Introduction

Plant cells need a sturdy wall to keep the structure and function of the plant intact. Plant cell walls (PCW) are rich in polysaccharides, but they differ in chemistry and structure depending on their source. The ratios and amounts of all the PCW constituents vary according to the botanical source, function, maturity, and origin of the plant tissue **[1]**. In addition to their health benefits, all plant-based foods are considered great sources of nutrition for humans. There is an increasing interest in using feeds that originate from fruit, vegetable wastes, and oilseed by-products.

1. Dietary fiber

Crude fiber (CF) may be clarified as the residue left over after the chemical treatment with alkali, sulphuric acid, and alcohol. The main component of CF is a polysaccharide named cellulose. Other constituents (such as hemicelluloses, pectins, and lignins) with cellulose are commonly known as dietary fiber (DF). The difference between CF and DF is shown in **Table (1)**. The geographic area where the plants are grown up (such as sunlight, soil, water, and air) affects the fibers composition. The peculiarity (oddity) means that whole fibers contain the same components, but with different concentrations, which make them act differently **[2]**.

1.1. Fibers Types and Composition

Fibers consist of numerous components mainly cellulose, hemicelluloses, wax, lignin, and pectin. The chemical structures of fibers are shown in **Figure (1)**.

Cellulose: Cellulose is a natural fiber and considers the main structural component fiber of all plants. Glucose is composed of long chains of b-1, 4 linked glycosides, linked together in microfibrils bundles. The hydrogen bonding in cellulose determines its

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crystallinity, and controls its physical properties. Cellulose provides the stiffness, strength, and stability of fibers.

Hemicelluloses: Hemicelluloses are polysaccharides with low molecular weight compared with cellulose. These polysaccharides are linked together in shortened branched chains. Hemicelluloses are able to attract and hold water (hydrophilic nature).

Wax: The most waxes in plant are syntheses of long chain substituted aliphatic hydrocarbons. They contain fatty acids, alkaline substances, primary and secondary alcohols, aldehydes, ketones, alone with some several ingredients.

Lignin: It imparts rigidity to plants and is a complicated aromatic hydrocarbon polymer and it is important to gain great heights of the plant. Lignin has an amorphous structure, with a high molecular weight with a three-dimensional polymer. However, it is less polar than cellulose and acts as a chemical adhesive between and within the fibers.

Pectin: This type of fiber is responsible for the plants flexibility and found in bast fibers and fruits. The reduction in the plant strength is mainly due to the pectin degradation.

Table 1 the difference between crude fiber and dietary fiber

Differences	Crude fiber	Dietary fiber
Origin	A part of insoluble fiber is found in the edible portion of the plant cell wall.	The sum of both soluble and non-soluble fiber groups.
Solubility	Not soluble in water.	Either soluble or non-soluble in water.
Fermentation	Not fermented inside the digestive tract.	Subject to fermentation inside the digestive system.
Composition	Do not contain pectins, gums, and mucilages.	Contains pectins, gums, and mucilages.

https://en.wikipedia.org/wiki/Dietary_fiber

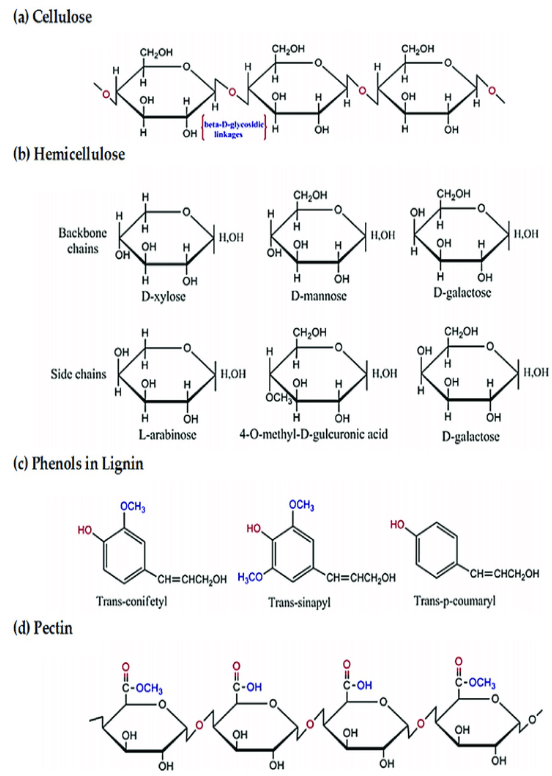

Fig. 1. The chemical structure of fiber constituents' cellulose, hemicelluloses phenols in lignin and pectin [3]

1.2. Classification of Dietary Fiber

Total dietary fiber (TDF) is divided to soluble dietary fiber (SDF) and insoluble dietary fiber (IDF), both of which consist of compact indigestible polysaccharides, as shown in **Figure (2)**, it is found in plant foods, such as whole grains, cereals, legumes, vegetables, seeds,fruits, and nuts [4].

Fig. 2. Classification of Dietary fiber in human nutrition according to solubility [4]

1.3. Methods of extraction dietary fiber

Dietary fibers from different sources have been extracted by numerous methods. But before DF extraction, there is a pretreatment process for plant material to prepare it for DF extraction. This pretreatment includes physical, mechanical, or enzymatic treatment. It occurs by grinding material to fine particles or micronization by milling or by germination and commercial and noncommercial enzymes as illustrated in **Figure (3)**. The extraction process passes through different stages, as illustrated in **Figure (4) [5].**

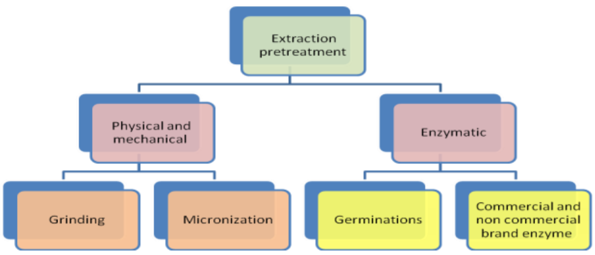

Fig. 3. Pretreatment methods for dietary fiber extraction from plant products [5]

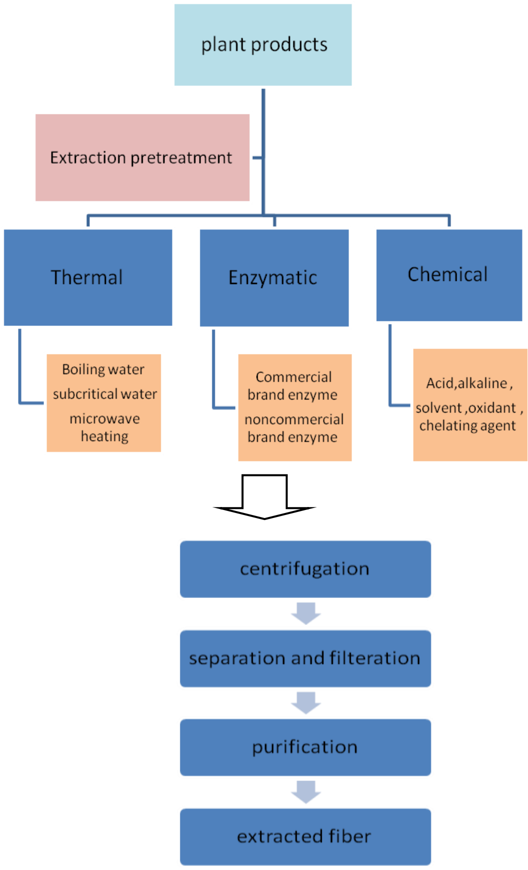

Fig. 4. Process flowchart for dietary fiber extraction from plant products [5]

The chemical composition, functional properties, and solubility are affected by the extraction conditions. Chemical, Thermal, enzymatic, and microwave or ultrasound-assisted extractions may result in different functional, physicochemical, and structural properties of DF. Recently, high-pressure processing has been a technology utilized for the improvement of DF extraction that may change its functionality, with promising results on its functional and physiological properties **[6]**.

1.4. Dietary Fiber Functionality

The functionality of DF might be divided into physiological and technological. The compositional and structural differences between IDF and SDF fractions affect directly its functionality. Some DF properties such as functional technological properties, as shown in **Figure (5**), are related to enhancers of viscosity, gel formation, emulsion stabilizers, and hydration properties such as swelling capacity (SC), water-holding capacity (WHC), and oil-holding capacity (OHC).

DF is composed of complex carbohydrates from the cell walls of plant such as pectin, cellulose, lignin and hemicellulose, in addition to some other polysaccharides such as mucilages and gums **[7]**. Akl *et al.***[8]** extracted two types of soluble DF called mucilage from garden cress seed meal (GCSM) which exhibit protective effects against enterocolitis and can be considered natural nutraceuticals with effective antioxidant activity (**Table 2)**. Mucilage (SDF) includes other nutrients such as protein and minerals when extracted from flaxseed meal (FSM) and GCSM by using hot water (MHW) and with the aid of ultrasonic (MUS), **[8, 9]**

DF is an important functional ingredient because of its ability to alter the matrix structural properties where it is implanted. Fiber-gels are systems that can perform as a solid while retaining fluid characteristics **[10].** Additionally, several DF polysaccharides extracted from flaxseed mucilage are used as fat replacers in manufacturing cream cheese free from fat due to the foam stabilizing and emulsion adequacies and the ability to create high-viscosity solutions, beside their prebiotic activities **[9, 11]**. **Table (3**) illustrated some analysis of the functional and physicochemical characterization of DFs in some oilseed sources.

Table 2. Chemical composition of the three types of mucilage garden cress MHW and MUS and flaxseed mucilage FM.

Chemical composition %	GMHW	GMUS	FSM
Moisture	14.9	12.9	12.8
Protein	31.2	34.1	34.9
Oil	00	00	00
Ash	11.3	13.4	5.1
References	[8]	[8]	[9]

Table 3 Analysis of Functional and physicochemical characterization of DFs

Sources	Analysis of Functional and Physicochemical	References
DF from sesame seed coats (testae)	WHC, OHC, bulk density, antioxidant activities	**[12]**
Soluble DFs from black soybean hulls	and OHC	**[13]**
Flaxseed mucilage	WHC, OHC, bulk density, viscosity Antioxidant activities	**[9]**
Garden cress mucilage	WHC, OHC, bulk density, foaming capacity, foaming stability, viscosity antioxidant activities	**[8]**
DFs derived from defatted rice bran	Viscosity	**[14]**

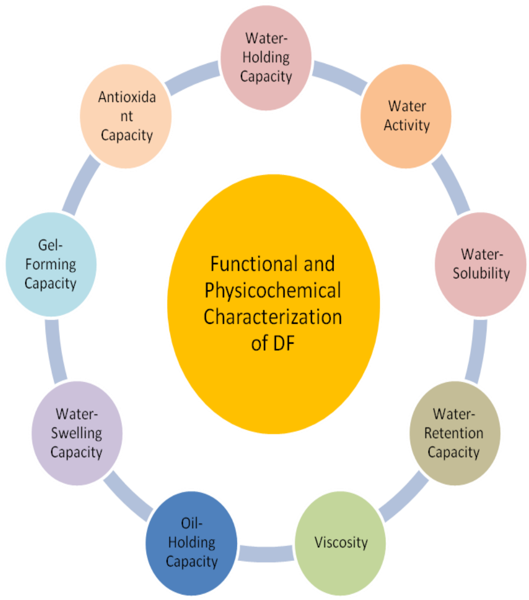

Fig. 5. Functional and physicochemical characterization of DFs

1.5. Interrelationship between nutrition, intestinal health and microbiota

There is a close bidirectional correlation between nutrition, intestinal health, and microbiota, as shown in **Figure (6)**. Intestinal health is affected by the ability to absorb nutrients that may affect various systematic functions **[15]**. The soluble fraction of DF is fermented more quickly, which results in higher levels of volatile fatty acids (VFAs) and a proliferation of beneficial microbiota. Hence, inclusion of DF in pigs' diets can improve their intestinal health, even though this may result in lower digestibility than other nutrients **[16]**. DF affects the fermentation of GIT by stimulating the metabolism or growth of certain types of bacteria **[17]**. This increased the number of cellulolytic bacteria promotes rectal fermentation, VFA production, and lowers the pH of the intestinal contents. This decrease in intestinal pH promotes the beneficial bacteria growth (e.g. *Lactobacilli spp. Bifidobacteria spp.*). In contrast to the pathogenic strains like *Salmonella,* or *Clostridium* that inhibits the host health **[18]**.

Since humans lack enzymes that can split up DF, they pass these materials through the upper digestive tract and into the colon intact. Insoluble fiber usually found in the form of relatively dense particles. It resists the infiltration of colonic microbiota and is therefore highly resistant to fermentation by gut bacteria, which allows DF to play a vital role in promoting healthy colonic epithelium, bowel scouring, and stool development. SDF, in comparison with IDF, is more fermented in the colon by microflora **[19, 20]**. Inclusion of IDF in chicken diets affects the development of the digestive organs, intestinal morphology, growth performance, nutrient absorption, and microbiota in the intestine. Intestinal viscosity may be increased by SDF and is linked to the reduction in absorption of nutrient, and negatively affect the intestinal microflora **[21]**. Di Rosa et al.**[22]** discussed the role of dietary fibers in the management of inflammatory bowel diseases (IBD) symptoms, there is no dietary component is considered responsible for IBD and there is not a specific therapeutic diet for it.

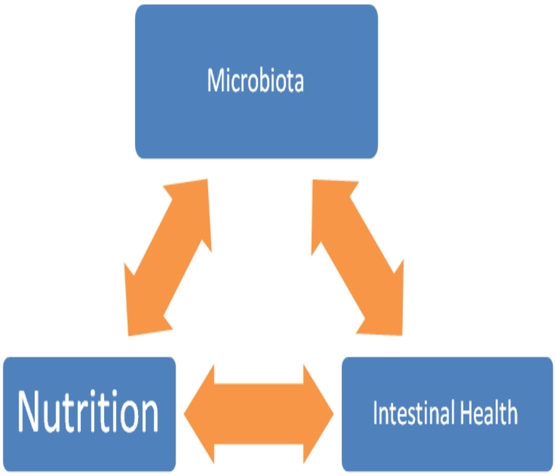

Fig. 6 The interrelationship between nutrition, intestinal health, and microbiota

2. Oilseeds

Oilseeds are considered the most important food sources because they contain many beneficial components utilized in nutrition. In addition to their health benefits, the first important constituent of OS is oil. It may be edible, such as (soya, corn, sunflower, flaxseed, olive oil, etc.) or non-edible, such as (jojoba and jatropha,which are used for industrial purposes). The edible oil is used for nutritional purposes. The second constituent is protein, mostly OS rich in protein but with different ratios of amino acids, beside dietary fiber, polysaccharides and minerals in appreciable amounts.

2.1. Oilseeds definition and composition

According to FAO, oilseeds are divided into permanent oilseed crops (olive, coconut, and oil palm) and temporary oilseed crops (linseed, soya bean, mustard, castor bean, etc) **(Table 4) [23]**. Classification of these crops was conducted based on the crop genus, species, product types, and whether the crop is permanent or temporary. Oilseeds are an important source of animals and human nutrition, with protein and fat levels generally ranging from 20 to 40 and 20-50 percent respectively **[24].**

Oilseeds are wealthy in their structure and rich in protein and fiber as represented in **Table (5)**, which shows the chemical composition of some oilseeds and meals, such as flaxseed meal FSM, garden cress seed meal GCSM, olive cake OC, peanut meal PM, soybean SB, and sesame seed SS,expressed as a percentage of dry weight.

Table 4. Classification of oilseed crops according to FAO (2005) and its botanical name

Oilseed crops	Botanical name
Permanent oilseed crops	
Olives	Oleaeuropaea
Coconuts	Cocosnucifera
Oil palm	Elaeisguineensis
Other oleaginous fruits	
Temporary oilseed crops	
Linseed	Linum usitatissimum
Soya beans	Glycine max
Niger seed	Guizotiaabyssinica
Castor bean	Ricinuscommunis
Groundnut	Arachishypogaea
Mustard	Brassica nigra; Sinapis alba
Safflower	Carthamustinctorius
Sunflower	Helianthus annuus
Sesame	Sesamumindicum
Rapeseed	Brassica napus

Source: FAO [23].

Table 5 Chemical composition of oilseed and defatted meals expressed as a percentage of dry weight.

Chemical Composition %	Moisture	Protein	Oil	Ash	Crude fiber	Nitrogen free extract	References
FSM	8.4	34.2	1.4	7.2	9.1	39.6	**[25]**
GCSM	5,82	48.1	.8	6.8	10.4	28.03	**[26]**
OC		9-14		6-8	15-35	22	**[27]**
PM	6.6	59.8	.8	5.3	5.91	21.5	**[28]**
SB	-	16.3	13-25		35.8		**[29]**
SS	3.6	18.9	56	3.1	6.7	-	**[30]**

2.2. Major nutrients in oilseed and their roles in human nutrition

2.2.1. Fatty acids in oilseeds

Seed oil is mainly composed of polyunsaturated fatty acids (PUFA), which have high concentrations of linoleic acid. The oils are rich in omega-6 fatty acids, such as soy, nuts, safflower, sunflower, etc. But soybean oil and canola oil contain low levels of omega-3 FA (α-linoleic acid). Flaxseed oil contains a high percentage of unsaturated fatty acids, many of which are made up of omega-3 fatty acids. Simopoulos suggested that omega-3 (PUFAs) has the potential immunomodulatory activities **[31]**. The health benefits of omega-3 FA for human are due to their ability to lower the risk of cardiovascular diseases **[32]**.

Omega3 FA is easily oxidized through processing, distribution, and handling because it has a high degree of unsaturation. Oxidation resulted in the formation of unlikable odors, tastes, product shelf life, and the promotion of free radicals **[33]**. Schmidt *et al.* **[34]** noted that soybean oil decreased coronary heart disease. Virgin coconut oil contains medium-chain fats, which are similar in composition to those in breast milk and can give babies immunity against disease. This substance has antimicrobial, antioxidant, and anti-inflammatory properties which protect the arteries from atherosclerosis and the human heart from cardiovascular disease **[35]**. Sterols found in seed oil have effects on bile acid absorption and cholesterol **[36, 37]**.

2.2.2. Dietary fiber

Flaxseed Meal is rich in fiber; which is mostly soluble (20%), in the form of mucilage and gums. The soluble fiber in FSM can cause a laxative effect, and researches have shown that it also has cholesterol-lowering qualities. This means it can reduce the risk for heart disease. Dietary fiber; which is insoluble in water, decreases insulin resistance and is helpful in healing constipation and maintaining overall bowel health. **Table (6**) shows the natural fibers composition in FS and CS. A high-fiber diet is linked to the increase of stool bulk, shorter bowel transit time, and healthy gut flora. These effects are all positive, indicating that a high-fiber diet is beneficial for the bowel. A low fiber diet is linked with many chronic diseases, including heart disease, obesity, inflammatory bowel disease, colorectal cancer, and diabetes. The high fiber content of a flax meal makes it an ideal addition to your diet **[38]**.

Table (6) Composition of Natural Fibers in flaxseed and cottonseed (%)

Name of fiber	Flaxseed	Cotton seed
Cellulose	70.5	89
Hemicellulose	16.5	4
Lignin	2.5	0.75
Pectin	0.9	6
waxes	-	0.6
references	**[39]**	**[39]**

2.2.3. Protein

Sunflower meal forms a valuable source of protein consumed by humans and as a supplementary food in non-ruminant and ruminant feeds, that improve the milk production and the animal growth as well as the relative biomass generation. It performs as a rich source of proteins; the amino acids containing sulfur (methionine and cysteine) and other essential amino acids like valine, leucine, isoleucine, alanine, tryptophan, and phenylalanine; minerals, and vitamins such as thiamine, phosphorus, nicotinic acid, riboflavin, pantothenic acid, and biotin help in the development and growth of muscle **[40]**. The composition of amino acids of flax protein is similar to that of soy protein. The protein isolate prepared from flaxseed exhibited a protective impact on the kidney and liver against lead toxicity when added to lemon juice **[41].**

2.3. Health benefits of oilseeds

2.3.1. Flaxseed (FS)

FS is well known for the many different chemicals it contains, including important nutrients like PUFA, lignans, and proteins. Additionally, the seed's fibers and lignans are also beneficial to health**.** FS is known as the rich source of DFs that includes IDF (cellulose, lignin, and hemicelluloses) and SDF (mucilage). These fibers have been found to have several health benefits. Its fiber content ranges from 22% to 26%, twice the percentage of high fiber beans. Dry whole flaxseed provides between 20% and 25% of the daily fiber needed. Flaxseed contains a high percentage of both SDF &IDF, ranging from 20 to 80 percent. It has a correlation with health in particular with weight regulation. It decreases the nutrients absorption and suppresses hunger **[42, 43, 44]**.

DF, lignan, and Omega-3 FA are the main bioactive constituents of FS which may be utilized through worth-added products. FS has been effectively exploited in the preparation of various value-added products. The whole fractions of the FS plant are exploited in the preparation of commercially some value products directly or after processing. Consumption of flaxseed in the diet prevents numerous types of diseases such as coronary diseases, diabetes, cancer, gastrointestinal, renal, bone disorders, and obesity. There has been little research on the effects of flaxseed usage as a commercial value-added product such as dairy, bakery, snack, extruded, fermented, and other traditional products on the nutritional, phytochemical, physicochemical, and sensory properties **[45]**. The rich diet is generally associated with fibers supporting health and reducing the risk of many diseases **[46]**. **Figure (7)** summarized the nutritional profile of flaxseed as suggested by Hussain *et al.* **[47]**. Linseeds also have a high level of lignin, which can improve the digestion **[48]**. Garden cress seeds and Linseed are popularized because of their health effects on the body and the heart **[49]**. In Canada, many studies have been conducted and the approved health claim is that FS lowers cholesterol. Many studies have shown that it can modestly reduce post-meal glucose absorption, lower many inflammatory markers, reduce serum total, and LDL-cholesterol concentrations, and increase serum levels of ALA, omega-3 fatty acids, and eicosapentaenoic acid. FS or Partially defatted are also reduced total cholesterol **[50, 51]**. With IC_{50} values of 22.6 and 22.3 /ml, the phenolic extract of flaxseed meal exhibited anticancer effects against lung carcinoma and colon carcinoma, respectively. A breast tumor-reducing effect may be attributed to the elevated constitute of SDG lignin, **[9, 52]**.

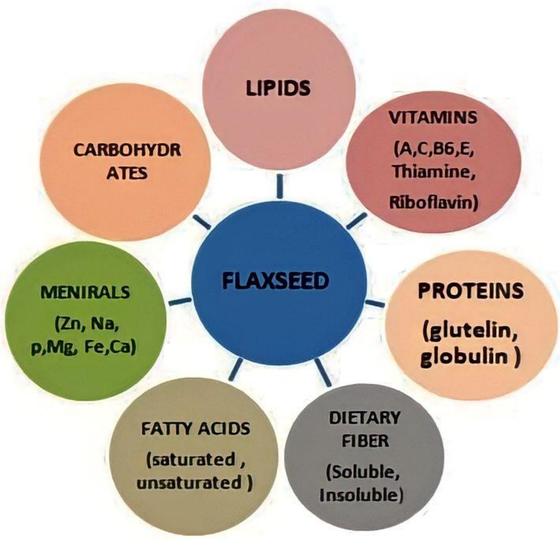

Fig. 7 Nutritional profile of flax seed [47]

2.3.2. Cotton seed (CS)

The Composition of cottonseed illustrated in **Figure (8)** shows that 250 kg of cotton bolls produce 150kg of CS (containing protein, oil, and carbohydrate) and 100kg of lint fiber. Proteins from cottonseed were isolated by cold, hot-pressed solvent extraction and subcritical fluid extraction. These materials showed a good water and oil absorption properties, different hydrolysis surface hydrophobicity, and emulsifying abilities **[53]**. Liadakis *et al.* **[54]** used organic solvent extractions such as 1-butanol hydrochloride to remove gossypol from being involved in the food industry. Wedegaertner & Rathore obtained gossypol-free cottonseed protein, through genetic engineering to fulfill the protein needs in the human diet.Protein from cotton seed increases the dry strength of cotton-based nonwovens so, the tensile strength increased by increasing protein concentration, which is suggested by infrared and thermogravimetric analysis **[55, 56]**.

Gossypol can bind the iron in the diet and decreases the digestibility of protein by inhibiting the activity of trypsin and pepsin in the intestine. Increase the usefulness of CSM by increasing iron and lysine supplementation in poultry nutrition, which alleviates the poisonous effect of gossypol. So, CSM is safe and can be used in the feeding of poultry at a 10-15% instead of soybean meal **[57]**.

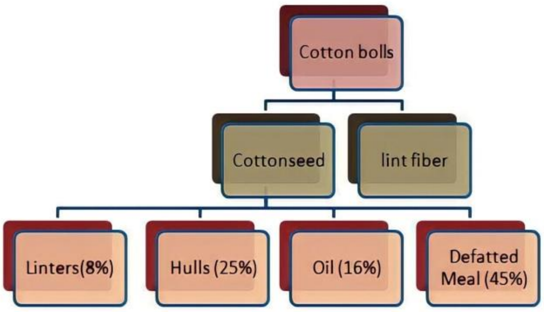

Fig 8. Composition of cottonseed, [58]

2.3.3. Sesame seed (SS)

Sesame seeds, like other oilseeds, are very rich in protein, fiber, and minerals such as calcium, zinc, iron, copper, thiamin, vitamin E, and other nutrients. The knowledge about the functional and characteristic properties of the sesame protein enables it to be applied in food formulation systems such as sauce and meat products, and as food ingredients **[59]**. There are numerous bioactive compounds determined in sesame seed meal ethanolic extract such as quercetin, catechin, ferulic acid, and gallic acid that possess antioxidant activities and lecithin that are effective for reducing hepatic steatosis **[60, 61]**. Ethanolic sesame extract is used in the preparation of film with antimicrobial activities against a wide range of bacteria **[60]**.

2.3.4. Sunflower

Sunflower (SF) products like oil, sunflower meal, snacks, processed seeds, and extracts are known to be beneficial to human health and the livestock. However, the full potential of sunflower products has not been explored yet. Sunflower-based products can be utilized as composite foods in the creation of different forms of the human diet with complex nutritional indices that upgrade human health **[62]**.

The health benefits of SF are attributed to their major nutritional components, which include proteins, high mono, and polyunsaturated fats, phytosterols, tocopherols, zinc, folate, copper, iron, and vitamin B exhibiting antidiabetic, antimicrobial, anti-inflammatory, antioxidants, and antihypertensive **[63]**. The major fatty acid components of SF oil include stearic, oleic, linoleic, and palmitic acid. Also, sunflower oil contains waxes, carotenoids, tocopherols, and lecithin **[64]**.

Fig. 9 Pharmacological and health benefits of sunflower [65]

2.3.5. Soybean (SB)

Soy foods are becoming more popular all over the world as people become more aware of their many health benefits. Soy is available in various forms, including boiled soybeans, soy flour, soy oil, soy sauce, soy milk, soy tofu, soy curd, and fortified soy products for women and infants. Soy is used to treat high blood pressure, high cholesterol & prevention of blood vessel and heart disease. It is also utilized for sorting out type 2, diabetes, lung function, asthma, all kinds of cancer (endometrial cancer, lung cancer, thyroid cancer, and prostate cancer) weak bones (osteoporosis), and progressive relief for lung disease. Other uses of this product include treating diarrhea and constipation, and for people with kidney disease, it lowers the level of protein in the urine, improves memory, and treats muscle soreness **[66]**.

2.3.6. Mustard seeds (MS)

Mustard seeds (MS) are utilized in the medicinal purposes for a very long time, and they are also a popular culinary spice. The MS are derived from the Brassica juncea plant, and also vegetables like Brussels sprouts, broccoli, and cabbage, etc. Many people believe that spices, including mustard seeds, are healthy because they contain several phytonutrients and they are rich in vitamins, minerals, and antioxidants.

Mustard is a good resource of B-vitamins such as niacin, folates, thiamin, pyridoxine (B6), pantothenic acid and riboflavin. These vitamins are essential for the body in the sense that it needs them from external sources to replace what it has lost. These B complex groups of vitamins help to produce enzymes, support nerve function, and control your body's metabolic processes. Mustard is also rich of many health-promoting minerals, and minerals that are especially focused on in these seeds are manganese, calcium, iron, selenium, copper, and zinc. Calcium helps to make and maintain teeth and bones. Manganese is a cofactor for the superoxide dismutase enzyme and Copper and Iron are essential for red blood cells production and the body's cellular metabolism. Mustard oil and its seeds have been traditionally utilized in relieve muscle pain, arthritis, and rheumatism beside its role hair growth stimulating. The seeds in this herb are effective as laxatives, stimulants to the stomach's mucous membrane, and cause increased secretion of intestinal. **[67, 68]**.

2.4. Oilseeds and cosmetics

Most oilseed crops contain noticeable amounts of fatty acids, like oleic and linoleic acids. Linoleic acid is utilized as a skin moisturizer, in the healing of sunburns, dermatomes, and the treatment of acne vulgaris **[69]**. Madhavan *et al.* **[70]** investigated the utilization of virgin coconut oil as a conditioner for skin and hair in addition to some other cosmetic products. The antioxidant and anti-inflammatory effects of these ingredients indicated that these oils are beneficial for some skin diseases wound healing, and repair of the skin barrier **[71]**.

The components of fixed plant oil include free fatty acids, triglycerides, tocopherols, stanols, sterols, phospholipids, squalene, waxes, and phenolic compounds **[72]**. These compounds, when applied topically, have different effects on skin physiology (inflammation status, antioxidant response, the skin's barrier, and proliferation). Two types of oil from the oil palm were reported by Basiron, namely, palm kernel oil and palm oil **[73]**. Palm oil is used in the food and pharmaceutical industries, while palm kernel oil and soybean oil are utilized to make detergents, soaps, and toiletry products. While castor and olive oils are utilized in furfural cosmetic production **[37]**.

3. Conclusions

There has been a lot of attention recently on obtaining fiber-rich ingredients from oilseed by-products because they are high in SDF and IDF. The DFs have been shown to exhibit great physiological functionality, not just because of their DF content, but also because of other health-beneficial compounds (antioxidants). Despite the presence of further nutrients in DF extracts; such as protein, minerals, and carbohydrates, DF is the essential component that is used to enhance the quality of food products and participate in the production of commercial value-added products such as dairy, bakery, and snacks. All of the previous oilseeds mentioned in this review provided numerous health benefits, including antioxidants, antimicrobials, anti-cholesterol, anti-inflammatory, anti-cancer, anti-cardiovascular, constipation, diarrhea, and other bowel health benefits. It is used in cosmetic and skin products because of its fatty acid components.

4. Conflicts of interest

“There are no conflicts to declare

5. Acknowledgments

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6. References

1. Padayachee, A., Day, L., Howell, K., Gidley, M. J. (2017). Complexity and health functionality of plant cell wall fibers from fruits and vegetables. Critical Review, Food Science and Nutrition, **57**(1), 59-81.
2. Komuraiah, A., Kumar, N. S., & Prasad, B. D. (2014). Chemical composition of natural fibers and its influence on their mechanical properties. Mechanics of Composite Materials, **50**(3), 359-376.
3. Bahrami, M., Abenojar, J., & Martínez, M. Á. (2020). Recent progress in hybrid biocomposites: Mechanical properties, water

absorption, and flame retardancy. Materials, **13**(22), 5145.

4. Martín-Cabrejas, M. A. (2019). CHAPTER 1: Legumes: An Overview, in *Legumes: Nutritional Quality, Processing and Potential Health Benefits*, 1-18. From Book Series: Food Chemistry, Function and Analysis DOI: *10.1039/9781788015721-00001*
5. *Tejada*-Ortigoza, V., Garcia-Amezquita, L.E., Serna-Saldívar, S.O. et al.,(2016). Advances in the Functional Characterization and Extraction Processes of Dietary Fiber. Food Eng Rev **8**, 251–271. *https://doi.org/10.1007/s12393-015-9134-y*
6. Mateos-Aparicio, I., Mateos-Peinado, C., & Rupérez, P. (2010). High hydrostatic pressure improves the functionality of dietary fibre in okara by-product from soybean. Innovative Food Science & Emerging Technologies, **11**(3), 445-450.
7. Bertin, C., Rouau , X., Thibault, J. F. (1988). Structure and properties of sugar beet fibres. Journal Science of Food Agriculture **44**:15-29. doi:10.1002/ jsfa.2740440104.
8. Akl, E. M., Taha, F. S., Mohamed, S. S., Mohamed R. S. (2021). Characterization of Garden Cress Mucilage and its Prophylactic Effect Against Indomethacin-Induced Enter-Colitis in Rats. Biointerface research and applied chemistry 11(6), 13911- 13923. https://doi.org/10.33263/BRIAC116.1391113923
9. Akl, E. M., Abdelhamid, S. M., Wagdy, S. M., and Salama H. H. (2020). "Manufacture of Functional Fat-Free Cream Cheese Fortified with Probiotic Bacteria and Flaxseed Mucilage as a Fat Replacing Agent", Current Nutrition & Food Science **16**(9), 1393-1403. https://doi.org/10.2174/1573401316666200227112157
10. Angioloni, A., Collar, C. (2009) Small and large deformation viscoelastic behaviour of selected fibre blends with gelling properties. Food Hydrocoll 23:742–748. doi:10.1016/j.foodhyd. 2008.04.005
11. Lazaridou, A., & Biliaderis, C. G. (2007). Molecular aspects of cereal β-glucan functionality: Physical properties, technological applications and physiological effects. Journal of Cereal Science, 46(2), 101-118.
12. Elleuch, M., Bedigian, D., Besbes, S., Blecker, C., & Attia, H. (2012). Dietary fibre characteristics and antioxidant activity of sesame seed coats (testae). International Journal of Food Properties, **15**(1), 25-37.
13. Shen, M., Weihao,W., & Cao, L. (2020). Soluble dietary fibers from black soybean hulls: Physical and enzymatic modification, structure, physical properties, and cholesterol binding capacity. Journal of Food Science, **85**, 1668–1674.
14. Daou, C.; Zhang, H. (2014). Functional and physiological properties of total, soluble, and insoluble dietary fibres derived from defatted rice bran. Journal of Food Science Technology, **51**, 3878–3885.
15. Oviedo-Rondón, E. O. (2019). Holistic view of intestinal health in poultry. Animal Feed Science and Technology, 250, 1-8.
16. Jha, R., & Berrocoso, J. D. (2015). Dietary fiber utilization and its effects on physiological functions and gut health of swine. Animal, **9**(9), 1441-1452.
17. Williams, B. A., Verstegen, M. W., & Tamminga, S. (2001). Fermentation in the large intestine of single-stomached animals and its relationship to animal health. Nutrition Research Reviews **14**, 207–227.
18. Bouhnik, Y., Raskine, L., Simoneau, G., Vicaut, E., Neut, C., Flourié, B., Brouns, F., and Bornet, F. R. (2004). Capacity of nondigestible carbohydrates to stimulate bifidobacteriain healthy humans. American Journal of Clinical Nutrition **80**, 1658-1664.
19. Brownlee, I. A. (2011). The physiological roles of dietary fibre. Food Hydrocolloids **25**(2), 238-250.
20. Gerasimidis, K.; Nichols, B.; McGowan, M.; Svolos, V.; Papadopoulou, et al. (2022). The Effects of Commonly Consumed Dietary Fibres on the Gut Microbiome and Its Fibre Fermentative Capacity in Adults with Inflammatory Bowel Disease in Remission. Nutrients, **14**, 1053.
21. Tejeda, O.J.; & Kim,W. K. (2021). Role of Dietary Fiber in Poultry Nutrition. Animals, 11, 461. https:// doi.org/10.3390/ani11020461

22. Di Rosa, C.; Altomare, A.; Imperia, E.; Spiezia, C.; Khazrai, Y.M.; Guarino, M.P.L. The Role of Dietary Fibers in the Management of IBD Symptoms.Nutrients 2022, 14, 4775.
23. FAO (2005) World Programme for the Census of Agriculture 2010. Food and Agriculture Organization FAO of the United Nations, Rome, 142–146.
24. Abiodun, O. A. (2017). The role of oilseed crops in the human diet and industrial use. Oilseed crops: yield and adaptations under environmental stress, 249-263.
25. Akl, E. M., Mohamed, S. S., Hashem, A. I., Taha, F. S. (2017). Optimum extraction of phenolic compounds from flaxseed meal. American Journal of Food Technology, 12(3),152-169.
26. Younos, M., & Akl, E. (2022). Evaluation of Enzymatic Phenolic Extract from Garden Cress Seed Meal against Aflatoxigenic Fungi Isolated from Eggplant fruits. Egyptian Journal of Chemistry, 65(4), 287 – 299.
27. Sansoucy, R. (1987). Olive by-products for animal feed. Review. FAO Animal Production and Health Paper, 43
28. Akl, E. M., Mohamed, S. S., Mohamed, G. F., Taha, F.S. (2019). Innovative extraction techniques for the optimum extraction of phenolic compounds from peanut meal and evaluation of their biological activities. Advances in Nutrition & Food Science,4(2),1-9.
29. Saha, A., & Mandal, S. (2019). Nutritional benefit of soybean and its advancement in research. Sustainable Food Production**,** **5**, 6-16.
30. Hassan, M. A. (2012). Studies on Egyptian sesame seeds (Sesamum indicum L.) and its products 1-physicochemical analysis and phenolic acids of roasted Egyptian sesame seeds (Sesamum indicum L.). World Journal of Dairy & Food Sciences, 7(2), 195-201.
31. Simopoulos, A.P. (2002). Omega-3 fatty acids in inflammation and autoimmune diseases. Journal of the American College of Nutrition, **21**(6), 495–505.
32. Zhao, G., Etherton, T.D., & Martin, K.R., *et al*. (2007). Dietary α-linolenic acid inhibits pro-inflammatory cytokine production by peripheral blood mononuclear cells in hypercholesterolemic subjects. The American Journal of Clinical Nutrition, **85**(2), 385–391.
33. Tonon, R.V., Grosso, C.R.F., & Hubinger, M.D. (2011). Influence of emulsion composition and inlet air temperature on the microencapsulation of flaxseed oil by spray drying. Food Research International, **44**(1), 282–289.
34. Farvid, M. S., Ding, M., Pan, A., Sun, Q., Chiuve, S. E., Steffen, L. M., ... & Hu, F. B. (2014). Dietary linoleic acid and risk of coronary heart disease: a systematic review and meta-analysis of prospective cohort studies. *Circulation*, *130*(18), 1568-1578.
35. Madhavan, K., Arumuganathan, T., & Mathew, A. C. (2010b). Virgin coconut oil. NAIP on value chain in coconut. Central Plantation Crops Research Institute. Technical Bulletin No. 61, 1-12.
36. Hakala, K., Vuoristo, M., Luukkonen, P., Järvinen, H. J., & Miettinen, T. A. (1997). Impaired absorption of cholesterol and bile acids in patients with an ileoanal anastomosis. Gut, 41(6), 771-777.
37. Rodrıguez, G., Lama, A., & Rodrıguez R, et al., (2008) Olive stone an attractive source of bioactive and valuable compounds, Bioresource Technology, 99, 5261-5269.
38. Chishty, S., & Bissu, M. (2016). Health benefits and nutritional value of flaxseed-a review. Indian Journal of Applied Research, 6(1), 243-245.
39. Mwaikambo, L. A., & Ansell, M. P. (2006). Mechanical properties of alkali treated plant fibres and their potential as reinforcement materials. I. Hemp fibres. Journal of Materials Science, 41(8), 2483-2496.
40. Laguna, O., Barakat, A., Alhamada, H., Durand, E., Baréa, B., Fine, F., Lecomte, J. (2018). Production of proteins and phenolic compounds enriched fractions from rapeseed and sunflower meals by dry fractionation processes. Industrial Crops and Products, 118, 160-172. https://doi.org/10.1016/j.indcrop.2018.03.045
41. Mohamed, R. S., Fouda, K., & Akl, E. M. (2020). Hepatorenal protective effect of flaxseed protein isolate incorporated in lemon juice against lead toxicity in rats. Toxicology Reports, 7, 30-35.

42. Qian K.Y., Cui S.W., & Goff H.D. (2012). Flaxseed gum from flaxseed hull Extraction, fractionation, and characterization. Food Hydrocolloids, 28, 275-283.
43. Kristensen, M., Jensen, M. G., Aarestrup, J., Petersen, K. E., Søndergaard, L., Mikkelsen, M. S., & Astrup, A. (2012). Flaxseed dietary fibers lower cholesterol and increase fecal fat excretion, but magnitude of effect depend on food type. Nutrition & metabolism, 9(1), 1-8.
44. Cui, W., Kenaschuk, E, Mazza, G. (1996). Influence of genotype on chemical composition and rheological properties of flaxseed gums. Food Hydrocolloids, 10, 221-227.
45. Corrêa, L. B., Cardozo, L. F. D. F., Ribeiro, I. C. D. A., Boaventura, G. T., & Chagas, M. A. (2017). Influence of prolonged flaxseed (Linum usitatissimum) consumption over epididymis and testicle histoarchitecture of Wistar rats. Pesquisa Veterinária Brasileira, 37, 650-656.
46. Veronese, N., Solmi, M., Caruso, M.G., Giannelli, G., Osella, A.R., & Evangelou E, et al. (2018). Dietary fiber and health outcomes: an umbrella review of systematic reviews and meta-analyses. The American Journal of Clinical Nutrition, 107 (3), 436–444.doi:10.1093/ajcn/nqx082PMID 29566200
47. Hussain, M. S., Kaur, G., Mohapatra, C. (2021). Nutritional composition and functions of flaxseed (Linum usitatissimum linn.). Food Therapy Health Care, 3(4), 88-91. https://doi.org/10.53388/FTHC2021030488.
48. Jain, T. (2020). Fatty acid composition of oilseed crops: a review. Emerging Technologies in Food Science, 147-153
49. Jain, T., Grover, K., Kaur, G., (2016). Effect of processing on nutrients and fatty acid composition of garden cress (*Lepidium sativum*) seeds. Food Chemistry, 213:806–812
50. Parikh, M., Netticadan, T., & Pierce, G. N. (2018). Flaxseed: its bioactive components and their cardiovascular benefits. American Journal of Physiology-Heart and Circulatory Physiology. 314, H146–H159, doi:10.1152/ajpheart.00400.2017.
51. Bassett, C. M., Rodriguez-Leyva, D., & Pierce, G. N. (2009). Experimental and clinical research findings on the cardiovascular benefits of consuming flaxseed. Applied physiology, nutrition, and metabolism, 34(5), 965-974.
52. Chen, J., Saggar, J. K., Ward, W. E., & Thompson, L. U. (2011). Effects of flaxseed lignan and oil on bone health of breast-tumor-bearing mice treated with or without tamoxifen. Journal of Toxicology and Environmental Health, Part A, **74**(12), 757-768.
53. Ma, M., Ren, Y., Xie, W., Zhou, D., Tang, S., Kuang, M., Wang, Y., & Du, S. (2018). Physicochemical and functional properties of protein isolate obtained from cottonseed meal. Food Chemistry, 240, 856-862.
54. Liadakis, G.N.; Floridis, A.; Tzia, C.; Oreopoulou, V. (1993). Protein isolates with reduced gossypol content from screw-pressed cottonseed meal. Journal of Agriculture and Food Chemistry, 41, 918-922.
55. Wedegaertner, T., & Rathore, K. (2015). Elimination of gossypol in cottonseed will improve its utilization. Procedia Environmental Science, **29**, 124–125. [CrossRef]
56. Villalpando, A., Easson, M., Cheng, H.N., Condon, B. (2019). Use of cottonseed protein as a strength additive for nonwoven cotton. Texture . Research Journal **89**, 1725–1733.
57. Świątkiewicz, S., Arczewska-Włosek, A., & Józefiak, D. (2016). The use of cottonseed meal as a protein source for poultry: An updated review. World's Poultry Science Journal, **72**(3), 473-484. doi:10.1017/S0043933916000258
58. Onsaard, E. (2012). Sesame proteins. International Food Research Journal, **19**(4): 1287-1295.
59. Cheng, H. N., He, Z., Ford, C., Wyckoff, W., & Wu, Q. (2020). A review of cottonseed protein chemistry and non-food applications. Sustainable Chemistry, **1**(3), 256-274.
60. Akl, E. M., Dacrory, S., Abdel-Aziz, M.S., Kamel, S., & Fahim, A. M. (2021). Preparation and characterization of novel antibacterial blended films based on modified carboxymethyl cellulose/phenolic

compounds. Polymer Bulletin, **78**(2), 1061-1085.

61. Jellin, J. M., Gregory, P. J., Batz, F., Hitchens, K., Bonakdar, R., & Scott, G. N. (2000). Pharmacist's letter/prescriber's letter natural medicines comprehensive database. Therapeutic Research Faculty, Stockton, CA, 1-1527
62. Grasso, S., Omoarukhe, E., Wen, X., Papoutsis, K., & Methven, L. (2019). The use of upcycled defatted sunflower seed flour as a functional ingredient in biscuits. Foods, 8(8), 305. https://doi.org/10.3390/foods 8080305
63. Nandha, R., Singh, H., Garg, K., & Rani, S. (2014). Therapeutic potential of sunflower seeds: An overview. International Journal of Research and Development in Pharmacy and Life Sciences, **3**(3), 967–972
64. Kozłowska, M., & Gruczyńska, E. (2018). Comparison of the oxidative stability of soybean and sunflower oils enriched with herbal plant extracts. Chemical Papers, **72**(10), 2607-2615. https://doi.org/10.1007/s11696-018-0516-5
65. Adeleke, B. S., & Babalola, O. O. (2020). Oilseed crop sunflower (Helianthus annuus) as a source of food: Nutritional and health benefits. Food Science & Nutrition, **8**(9), 4666-4684.
66. Bolla, K. N. (2015). Soybean consumption and health benefits. International Journal of Scientific &Technology Research, **4**(7), 50-3.
67. Sarwar, M., Ahmad, N., Khan, G. Z., & Tofique, M. (2009). Varietals Resistance and Susceptibility in Mustard (Brassica campestris L.) Genotypes against Aphid Myzus persicae (Sulzer) (Homoptera: Aphididae). The Nucleus, **46**(4), 507-512.
68. Sarwar, M. F., Sarwar, M. H., Sarwar, M., Qadri, N. A., & Moghal, S. (2013). The role of oilseeds nutrition in human health: A critical review. Journal of Cereals and Oilseeds, **4**(8), 97-100.
69. Lautenschlager, H. (2003) Essential fatty acid: cosmetic from inside and outside. Beauty Forum 54-56.
70. Madhavan, K., Naresh Kumar, S. and Shamina Azeez. 2005. Virgin coconut oil by fermentation method. Indian Coconut Journal 35(12): 8-9.
71. Lin, T. K., Zhong, L., & Santiago, J. L. (2017). Anti-inflammatory and skin barrier repair effects of topical application of some plant oils. International Journal of Molecular Sciences, 19(1), 70.
72. Lercker, G., & Rodriguez-Estrada, M. T. (2000). Chromatographic analysis of unsaponifiable compounds of olive oils and fat-containing foods. Journal of Chromatography A, 881(1-2), 105-129.
73. Basiron, Y. (2007). Palm oil production through sustainable plantations. European Journal of Lipid Science and Technology **109**: 289-295.