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THE USE OF OILSEED WASTES IN THE FOOD INDUSTRY

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ABSTRACT

The food industry produces millions of tons of food waste worldwide, which can be used as a source of valuable ingredients with high added value. The use of food waste as a source of low-cost valuable compounds is important for environmental protection as well as for sustainable green technology. Especially during the processing of oilseeds, plenty of by-products emerge. It has been determined that oilseed by-products contain considerable amounts of protein, carbohydrates, fiber, bioactive components, antioxidants, vitamins, and minerals. Antioxidants such as polyphenols can be extracted from oilseed meals as functional food products. Since protein isolates obtained from oilseed meals have rich amino acid content and functional properties, they can be included in the human diet by adding them to various foods. This review includes information about the nutritional values of oilseed residues and the importance of their use in the food industry.

Introduction

The food industry produces millions of tons of food waste worldwide, which can be used as a source of valuable ingredients (proteins, fibers, polysaccharides, flavor compounds or various phytochemicals) with high added value. These bioactive compounds can be used as functional ingredients in food, pharmaceutical, medical, cosmetic, and other products. The use of recovered bioactive molecules as functional ingredients is important for the development of innovative food and non-food products that are beneficial for health. The use of food waste as a source of low-cost valuable compounds also provides an effective alternative as a sustainable green technology (Garcia-Garcia et

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al., 2019). Waste from various branches of the food industry can be divided into two main groups (plant and animal origin) and seven subcategories. The seven subcategories are cereals, roots-tubers, oilseeds-legumes, fruits-vegetables, meat products, fish-seafood, and dairy products (Galanakis, 2012).

Regardless of the food industry examined, by-products and/or waste products always arise at various stages of the supply chain. Many studies have focused on the recovery of valuable compounds from these by-products or wastes generated during agricultural and food processing stages (Ghasemi Ghodrat et al., 2018).

According to the data of the Food and Agriculture Organization of the United Nations (FAO, 2020), the most produced oilseeds in the world are sunflower, soybean and canola. These are oilseeds that have a major place in the food and agriculture industry. The main use of oil plants is the oil industry, and various extraction techniques are used depending on the raw material and the desired end product (Mullen et al., 2015). After the oil is extracted, various waste products such as bark, leaves, petals, stems, pollen, heads and seeds are left behind.

By-products formed after oilseed processing are rich in bioactive compounds such as proteins, dietary fibres, colourants, antioxidants and other substances with positive health benefits, making them suitable for use as human food or feed (Oreopoulou & Tzia, 2007). The abundance of oilseed waste in the industry reveals the need to re-evaluate these by-products to reduce environmental pollution, prevent food waste and increase the value of the production process. In this sense, the study focused on by-products formed during oilseed processing, their properties, and compositions.

Oil Seed Residues and Usage Possibilities in the Food Industry

The main by-product obtained after the extraction of oil from oil seeds is oil cake. These cakes are divided into two categories: edible and inedible. Edible residues (soybeans, peanuts, canola seeds, sunflowers, sesame, flaxseeds) have high nutritional value. These residues are used in the production of processed ingredients such as protein concentrate, isolates, hydrolysates etc. Additionally, it can be used in the production of substrates (bioactive compounds, surfactants, enzymes, antibiotics, vitamins, pigments, flavors and amino acids, etc.) and as a source of antioxidants for animal and human consumption. Defatted edible oil cakes can be used in the diet of malnourished people by adding them to bakery products, baby products and multi-purpose supplements. Inedible oilseed meals are used as fertilizer due to the presence of toxic compounds. The wastes of foods with high nutritional value such as soybeans, peanuts, canola seeds, sunflowers, sesame and flaxseeds have begun to be used in the production of many different functional foods (Gupta et al., 2018). Soybean residue is used as a protein supplement for all kinds of animals and is therefore the most widely used oilseed by-product. The composition of this soy residue consists of 44-50% crude protein and a low percentage (1%) of oil (Singh et al., 2008). Soybean cakes are a good protein supplement as well as meat and fish protein substitutes. Soy flour can be added to foods to improve their technological properties (emulsification, water absorption, adhesion, etc.) and nutritional content (such as improving the nutritional status of children and adults who consume soy protein flour). Soy flour residue can be used as an ingredient in baked goods (e.g. bread,

biscuits, buns, rusks and cakes), textured soy protein, protein isolates and concentrates, extruded snacks, flours and fermented products (Deak et al., 2008; Thrane et al., 2017).

Sunflower seeds, one of the oilseeds that make up the majority of world oilseed production, are characterized by solid black shells that hold tightly to the seed. Protein and crude fiber are the main components in sunflower residue, accounting for around 20-60% and 5-34% respectively. Phenols, especially chlorogenic acid, are important for nutrition as their content in sunflower residue is around 2-6% (Suput et al., 2018). Ash and moisture do not change regardless of the process performed (Pedroche, 2015).

However, the uses of sunflower residue are limited due to the presence of antinutritional compounds such as polyphenolic substances. The presence of chlorogenic and caffeic acids causes significant changes in the color, proteins and food matrices of the food. It also reduces the nutritional value of the final product due to its interactions with some amino acids such as lysine and methionine. Removing these substances is a promising method that will enable sunflower meal to be used more in food applications and replace more expensive protein sources such as soy proteins.

In the study conducted by Shchekoldina & Aider (2014), functional bread characterized by high water and oil absorption capacities was produced by supplementing wheat flour with protein isolate produced from sunflower residue. It was determined that bread supplemented with sunflower residue had higher bulk volume and nutritional quality compared to control bread. Another study has proven that commercially high protein extruded chips can be produced at different barrel temperatures by adding different amounts of corn semolina and rice flour to sunflower subdue, which has a significant amount of protein (Koç, 2023).

Peanut residue is obtained after oil is extracted from peanuts. The resulting pulp contains approximately 6% oil, but this percentage decreases after the extraction of the remaining oil with solvents. Peanut residue also contains significant amounts of protein and carbohydrates (Yu et al., 2007; Jamdar et al., 2010). An edible flour with low fat and high protein content can be obtained from peanut cake by removing the shells and roasting/desulfurizing/recovering the kernels. It can be consumed as flour alone or in combination with wheat (Zhao et al., 2012). Since peanut shells contain high antioxidants, studies have found that they can help increase the antioxidant content of functional foods. (Meng et al., 2020). A study by Collins & Post (1981) investigated the potential use of peanut shells as dietary fiber in functional food products.

Canola residues are rich in proteins (up to 52%) that are the main components, and also contain sugar, fat and crude fiber. The main amyloid compounds are cellulose (2.8-7%), pectin (6.5-14.5%), arabinogalactan (3.5%), arabinan (6.9%), amyloid (15.5%) (Rodrigues et al., 2012). The application of canola seed residue as a protein source in the food industry is an alternative that leads to a better and more complete use of this by-product. The biochemical properties of industrially produced canola seed residue vary and therefore detailed analysis is required before using it as a protein source (Ivanova et al., 2016). Canola waste which contains abundant protein could be used in the production of emerging meat alternative products (Banovic & Sveinsdóttir, 2021). Due to

the water absorption and foaming properties of canola proteins, they are used in the food industry, especially in the production of dairy and meat products and in the stabilization of emulsions in salad dressings and mayonnaise. (Khattab & Arntfield, 2009)

Flaxseed proteins are potent multifunctional ingredients for food formulation due to their techno-functionality, food preservation capacity and health benefits (Giacomino et al., 2013). In terms of its techno-functional properties, it can also be used as a mixture by adding other flaxseed bioactive components such as lignans and fiber to increase the value of flaxseed residue (Rabetafika et al., 2011). Defatted flaxseed flour and rice flour were mixed to produce gluten-free pasta that is rich in dietary fiber and with high nutritional value product (Moura et al., 2016).

Sesame residue is a by-product rich in protein and starch. It is used as fertilizer and feed, which causes waste of resources. By removing the sesame seed shell before oil extraction, a high-quality protein concentrate rich in sulfur-containing amino acids can be obtained and can be used as a supplement with its high amino acid content or as an additive in confectionery and bakery products (Nevara et al., 2023). In addition to its use as a protein source, many studies have been conducted on the addition of reducing sugars and amino acids that can improve product flavor, in connection with the effects of sesame residue polypeptide systems on the Maillard reaction. Some studies have shown that the oxidative balance of sesame oil can be improved by reducing the peptides and sugars in sesame pulp (Qin et al., 2020). Hu et al. (2021) improved the flavor and physicochemical properties of sesame residue proteins using Maillard flavor products. Shen et al. (2021) used different sulfur-containing substances and sesame residue to produce Maillard reaction products with high flavor acceptance that can be used to improve the flavor of certain foods.

Nutritional Values of Some Oilseed Residues

The oil cakes obtained by oil extraction are a rich source of various nutrients such as protein, carbohydrates, dietary fiber, minerals, and phytonutrients (Sarker et al., 2015). Peanut meal has the highest (45-50%) protein content, followed by soybean, cottonseed, rapeseed, sesame, sunflower, palm oil and olive oil residue. Oilseeds are one of the main plants in the world with high nutritional content. They are a valuable food product due to their high protein and oil content. In addition to their high protein content, they contain polyunsaturated fatty acids in terms of their fatty acid composition. Although cereals, which are the basic foodstuff, contain approximately 7-14% protein and 2-5% fat, oilseeds are an important source of the food industry due to their approximately 20-40% protein and approximately 20-50% fat levels. In addition, oilseeds are generally rich in bioactive substances known to have antioxidant activity such as phenolic compounds, flavonoids, lignans, tocopherols, tocotrienols. Also, oilseeds are a rich source of fiber, carbohydrates, vitamins, minerals and some antinutritional factors such as glucosinolates, phytates, etc. (Abiodun, 2017).

Considering the rapid increase in the world population, protein malnutrition and the renewability aspects of oilseed residues, oilseed proteins are considered a valuable alternative to animal proteins (Moure et al., 2006). It is stated that some oilseed proteins have lower content in terms of sulfur amino acid components compared to proteins of animal origin. The amino acid composition of oilseed residues is often compared to soybean, which is considered a useful source of amino acids for infants and

children according to the WHO (Tan et al., 2011a; Rodrigues et al., 2012).

Protein-rich oil residue can be used to produce protein hydrolysates, protein isolates and protein concentrates. Protein isolates can be used in the preparation of a variety of protein-rich foods. These can be protein drinks, shakes, cheese analogues, extrusions, protein-rich pastas, ready-to-drink powders, baby foods and complementary foods, energy bars, frozen desserts, sour cream, sour cream sauces and meat analogues (Arrutia et al., 2020).

Protein hydrolysates are produced from the hydrolysis of protein isolates and can be used in the food industry. Hydrolysis causes structural changes that improve the hydration, gelation, solubility, surfactant properties, and functionality of proteins. Owing to the protein hydrolysate, protein fragments known as bioactive peptides are formed, which have biological activities (antioxidant, antithrombotic, hypercholesterolemic, bile acid binding, immunomodulatory effects) that have a positive effect on human health (Gupta et al., 2018; Chatterjee et al., 2015; Karaogul & Nedjip, 2024; Ugurtay & Karaogul, 2022).

Polyphenols from oilseed residues have high antioxidant properties associated with positive health effects such as reduction of lipids in plasma, skin photoprotection, Vaso protection, neuroprotection, anti-aging, anticancer, antimicrobial, antifungal and antiviral activities (Marrugat et al., 2004; Atten et al., 2005; Su et al., 2011; Bekhit et al., 2011; Jacobs et al., 2012; Cheng et al., 2012; Menaa & Menaa, 2014; Hamad et al., 2017; Karaogul et al., 2016). Oil cake contains free, esterified or condensed phenolic acids, flavonoids and lignans, which reduce oxidative stress and help prevent various types of cancer (Mohdaly et al., 2013; Nadeem et al., 2014). These components can be extracted using solvents (organic solvents alone or in mixtures, non-toxic solvents such as water can also be used, but these must be combined with other gentle extraction techniques), high pressure, microwaves, and supercritical fluid (Baiano, 2014).

Anti-Nutritional Factors in Oilseed Residues

Many compounds present in oil seed have been found to have anti-nutritional effects that include trypsin inhibitors, goitrogens, aflatoxin, phenolic compound, gossypol, oxalic acid, chlorogenic acid, protease inhibitors, lectins, saponin allergens, phytic acid and glucosinolate. They either reduce the digestibility of oil seed or cause toxic effects on their consumption. Therefore, it is necessary to eliminate these substances by processing or genetic manipulation (Jithender et al., 2019).

Oilseed residues cannot be used to their full potential due to the dangers associated with the consumption of anti-nutritional factors they contain (Bekhit et al., 2018) as well as possible degredation (Karaoğul et al., 2020; Yucegonul et al., 2024). The direct use of oilseed meals in human nutrition may be limited by the presence of antinutrients that affect their sensory properties, protein digestibility and bioavailability of elements (Gupta et al., 2018). The main antinutritional factor of canola residue is sinapine. This factor is 30 times higher compared to soybeans. Sinapine binds to protein and forms a complex that provides dark color, bitter taste and poor digestibility due to oxidation (Tan et al., 2011b). Cyanogenic glycosides are the major antinutritional factor found in flaxseed residue. Hydrogen cyanide can be formed in the digestive system and cause acute toxicity (Teh & Bekhit, 2015).

Most oilseed (canola, sesame, sunflower, soybean, peanut, hemp seed) residue may contain antinutritional factors such as phytic acid and trypsin inhibitors that can reduce protein and vitamin utilization (Dong et al., 2000). Phytic acid, phytate and insoluble complex-forming minerals can reduce the bioavailability and digestibility of nutrients by binding them with proteins and amino acids (Das et al., 2015). Elimination or neutralization of these toxic substances can be achieved by various methods, including physical (deshelling, heat cooking, autoclaving, frying), chemical (ammoniation, addition of choline, methionine, ferrous sulfate, sodium carbonate), enzymatic and fermentative (Bello et al., 2013; Teh & Bekhit, 2015; Lopusiewicz et al., 2019).

Conclusion

Many by-products occur during the processing of oilseeds. In the past, these by-products were used as waste, fertilizer and animal feed. Oilseed residues are by-products of oil extraction that have little commercial value. The value of oilseed residues can be increased by using them in human nutrition and health. It has been determined that oilseed by-products contain rich amounts of protein, carbohydrates, fiber, bioactive components, antioxidants, vitamins and minerals. Antioxidants such as polyphenols can be extracted from oilseed meals as functional food products. Since protein isolates obtained from oilseed meals have rich amino acid content and functional properties, they can be added to various foods and included in the human diet. As a result, the evaluation of oilseed by-products is important for sustainable nutrition, waste utilization and green transformation. Therefore, green technologies focused on sustainable processes need to be developed for all these industries. Conducting further studies on the use of valuable nutritional contents in oilseed meals is also of great importance for the environment and green future.

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