

REVIEW

CURRENT TRENDS AND FUTURE PERSPECTIVES IN THE VALORIZATION OF FOOD OIL BY-PRODUCTS

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Received: March, 05, 2026

Accepted: September, 23, 2026

Abstract: Food oil by-products generated during vegetable oil processing are increasingly recognized as valuable resources within sustainable food systems. This review aims to evaluate current trends and future perspectives in the valorization of food oil by-products, focusing on technological developments, functional applications, and circular economy integration. A systematic literature search covering the period 2010 – 2025 was conducted using Web of Science, ScienceDirect, PubMed, ResearchGate, and Google Scholar databases in accordance with PRISMA guidelines, and 40 studies were included. Findings indicate that oilseed meals, press cakes, deodorizer distillates, lecithin fractions, and refining residues contain proteins, phenolic compounds, dietary fiber, and bioactive lipids with potential applications in food, feed, cosmetics, pharmaceuticals, and bio-based materials. Emerging technologies such as green extraction, enzymatic processing, membrane separation, and extrusion enhance functional properties and product quality. However, limitations related to food safety assessment, contaminant risks, and regulatory uncertainties remain significant barriers. Future research should prioritize safety standardization, process optimization, and regulatory harmonization to support sustainable industrial utilization globally.

Keywords: *by-products, current trends, food industries, food oil, valorization*

INTRODUCTION

Food waste, which has become a global and economic problem, is thrown away without being reused in animal nutrition or in different areas, creating environmental problems as well as ethical problems considering the many countries that cannot reach food due to famine [1, 2]. Many studies list the environmental impacts of household wastes such as agricultural land used in the production stages, energy, water and fuel costs and greenhouse gas emissions [3]. The concept of food waste is defined as food that is thrown away without being consumed for any reason in the food chain from production to consumption [4].

Today, the effective use and sustainability of limited resources are considered very important. The increase in the proportion of working population in our country and in the world directs people to prevent waste and reuse by using waste. This situation, called transition to circular bioeconomy, has become an urgent priority at the global level in the face of increasing environmental degradation, depletion of fossil resources and socioeconomic instability [5]. Food production and processing systems, which were previously considered linear in nature, are now being redesigned as integrated biorefinery systems that allow both economic and environmental value to be derived from by-product streams. In this context, by-products from the food oil industry stand out as an abundant and largely untapped resource with the potential to be converted into a variety of high value-added products such as chemicals, materials, fuels and biopolymers [6, 7].

Traditionally, by-products such as oilseed meals, press residues, refining sludges and oil refining wastes have been diverted to low-value applications such as animal feed, compost or landfill [8]. However, these by-products contain a rich matrix of components such as lipids, proteins, phenolic compounds and fermentable carbohydrates, which can be converted into a wide range of high value products through green chemical conversion and biotechnological processes [9]. Products such as biofuels (bioethanol), lactic acid, bioplastics such as PHB, microbial oils, surfactants and antioxidant compounds are successfully derived from oil processing by-products and are used in different sectors such as energy, food packaging and cosmetics [10, 11].

Lignocellulosic by-products from beer, wine, coffee, sugar cane, vegetable and fruit processing have reached a significant volume on an industrial scale (Figure 1). These materials are mostly in the form of bark, stems, roots, seeds, pulp and so on [10, 12, 13]. However, despite their nutrient-rich content, most of them are still treated as "waste", either sent to landfills or disposed of by incineration. These approaches not only waste resources, but also create significant environmental, social and economic problems [14, 15]. Inappropriate waste disposal contributes to the global climate crisis by increasing greenhouse gas emissions. On the other hand, it is also reported to cause the emission of toxic gases that threaten public health [16].



Figure 1. Lignocellulosic by-products

Underlying all these approaches is the idea that waste is no longer just a substance to be 'disposed of', but also a resource that can be re-evaluated. For this reason, scientific studies developed within the framework of sustainable chemistry principles first carry out the chemical characterization of these by-products, then develop processes for the extraction of value-added components by methods that do not harm the environment, and finally evaluate the applicability of these compounds on an industrial scale [17 – 19]. Thus, leftovers from food production can be re-incorporated into the food chain in a way that supports not only nature but also human life [20].

Biorefinery models (Figure 2) with integrated management systems make it possible to combine the recovery of valuable components with downstream fermentation or enzymatic processes, enabling the reuse of products with zero waste in the industry. This approach is characterised as critical to overcome key challenges such as profitability, scalability and market saturation [21]. As emphasised in Lin *et al.* [22], co-production of niche products (e.g. nutraceuticals, biological actives) with high-volume low-value products increases the economic viability of the processes. It also acts as a buffer against

fluctuations in demand for certain compounds. The integration of chemical processes into production systems has brought efficiency in infrastructure, energy and water. It has also significantly reduced the costs of storage, logistics and raw material requirements [23, 24]. This industrial model, called industrial symbiosis, integrates waste management with innovation and promotes a circular economy that diversifies local economies. In addition, the use of food oil by-products is not only industrial, but also extends sustainable food packaging and storage times. Antioxidant and antimicrobial compounds from the processing of oil by-products can be added to biodegradable films and coatings, preventing the harmful effects of plastics and protecting food [25 – 29].

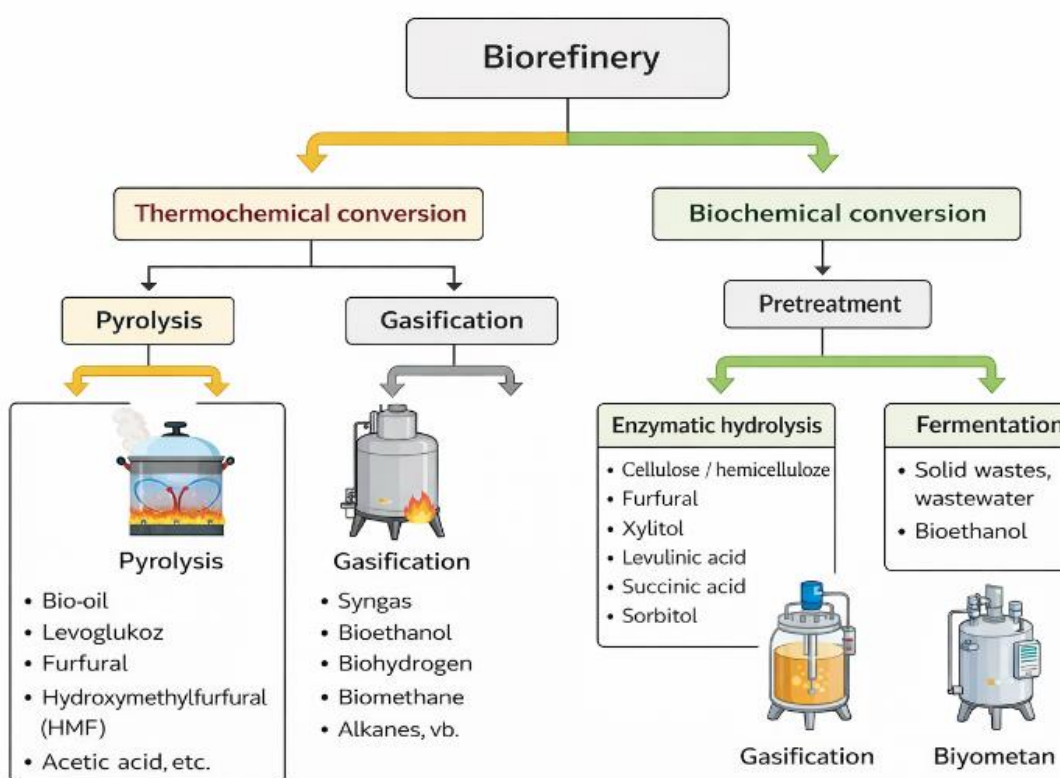


Figure 2. Biorefinery model

Sustainable, scalable and environmental strategies are important for the food industry and sustainable food, considering the worldwide increase in food oils and the associated increase in the amount of waste [22, 30, 31]. In this context, the research aimed to examine the utilization processes of by-products generated in the production of food oils in the context of technology, trends and future perspectives. In particular, the focus is on technical and technological innovations in the waste utilization process and the benefits of integrating waste management with the circular economic model of the food industry and its contribution to product development. In this way, it will contribute to the creation of a sustainable food production process in which the waste management process is blended with innovation.

MATERIALS AND METHODS

Research materials

The material of this study consisted of scientific articles and documents obtained as a result of a comprehensive literature search using specific keywords. In this context, the research material includes publications identified by keyword combinations such as 'utilization of food oil by-products', 'utilization of oilseed residues', 'oleogel applications', 'functional properties of oil-based by-products' and 'sustainable utilization of lipid-rich wastes'. International academic databases such as Web of Science, Science Direct, PubMed, Research Gate and Google Scholar were used in the data collection process. The sources analyzed within the scope of the study mainly consist of current research and review articles published in the last ten years (2010-2025). The selected publications were analyzed in terms of structural properties, functional properties, current applications in food and health sectors and future evaluation potentials of oil-based by-products. The findings were systematically categorized and presented in the 'findings and discussion' section.

Data analysis

The research started with the identification phase and a total of 76 sources were accessed at this stage. After removing duplicate records, 65 documents were evaluated in the screening phase. In the relevance assessment phase, 64 full texts were analyzed and 24 of them were not included in the scope of the research. The excluded studies included 15 thesis-based documents, 3 irrelevant documents, 4 documents with theoretical content and 2 documents without findings. The remaining 40 documents were included in the study. In this study, a flow diagram was prepared in line with the PRISMA guide [32] and presented in Figure 3.

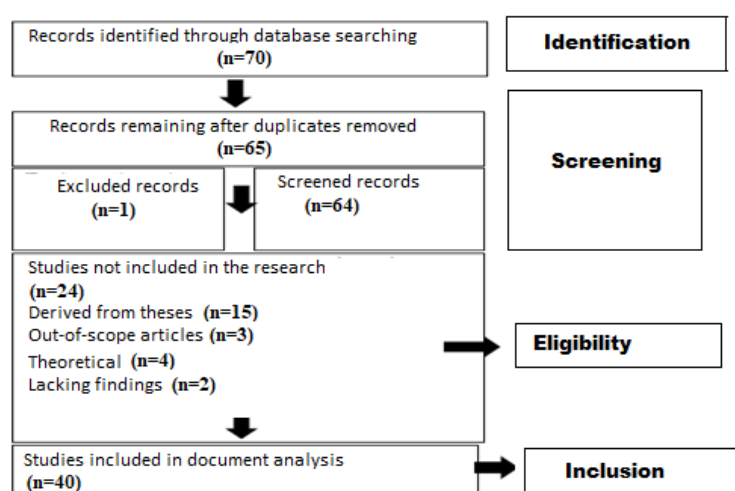


Figure 3. PRISMA diagram

As shown in Figure 1, the sources included in the study were analyzed using document analysis and secondary data analysis techniques. Advantages (e.g. cost reduction, resource utilization efficiency, environmental sustainability) and challenges (e.g.

regulatory requirements, technical infrastructure deficiencies, consumer acceptance) related to the utilization of food oil by-products were systematically classified and addressed through document analysis. Document analysis was used to qualitatively assess the impacts of food oil by-products on production processes, food safety and sustainability. In addition, secondary data analysis on data from previous studies was conducted to identify the impacts of these by-products on the economy, sectoral productivity and sustainability.

RESULTS AND DISCUSSION

Valorization of oil and fat by-products from food processing processes plays an important role in the transition of the global food system towards sustainability. The use of these by-products in food, feed, cosmetics and biotechnological applications both reduces the environmental burden and creates economic value in line with circular economy principles [33 – 35]. Reuse of food waste is directly related to sustainable development goals. According to FAO, approximately 1.3 billion tons of food is wasted annually worldwide and the environmental cost of this waste is quite high [36]. The utilization of food oil by-products contributes to the reduction of this waste and provides economic gains to producers by reducing waste management costs. It has also been emphasized that it creates the opportunity to enter new markets by increasing product diversity [37 – 39]. The main by-products are generated during the chemical and physical refining stages of crude vegetable oils, including degumming, neutralization, bleaching and deodorization [40] (Figure 4).

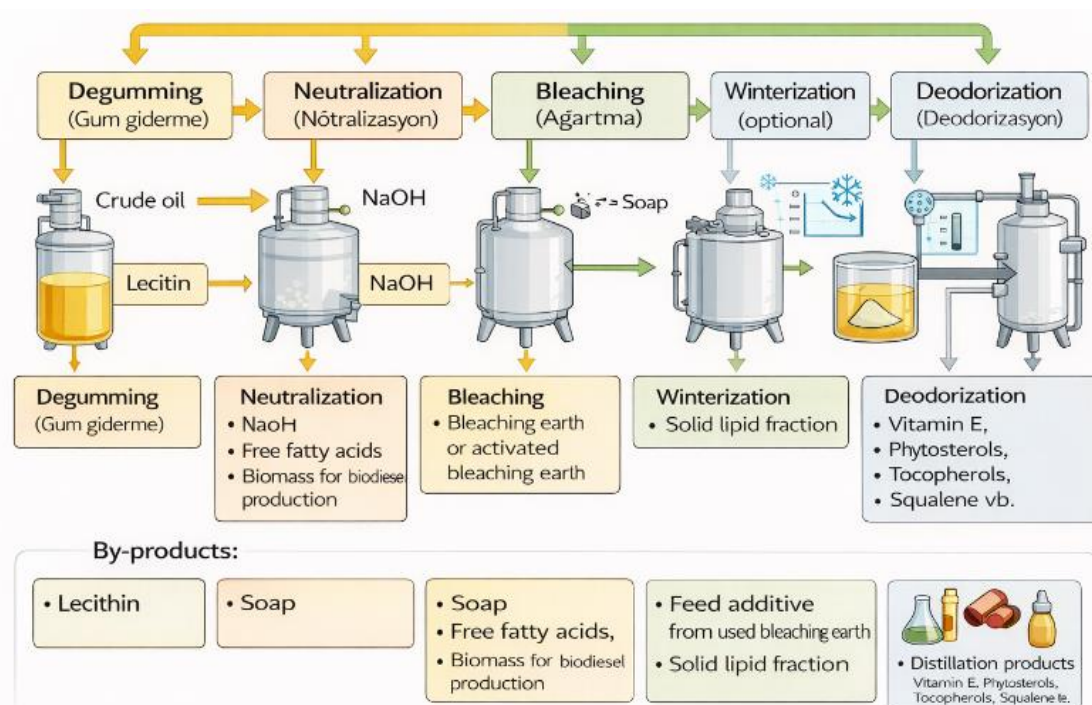


Figure 4. General overview of the chemical and physical refining process of crude oil

By-products obtained from the processing of vegetable oils contain components with both nutritional and industrial potential. Therefore, they play a critical role in establishing sustainable food systems and meeting the need for raw materials. However, it is stated that the processes used in the utilization of these products as food or feed should be carefully considered in terms of nutritional value and food safety [32 – 35, 40]. As a matter of fact, one of the basic dynamics of sustainable food production is to provide economic benefit by re-evaluating the by-products obtained during food processing. By-products and waste processing residues are rich in functional components and are reintroduced back into the food chain, thus not only reducing waste but also providing environmental, economic and nutritional value [32, 33].

Socas-Rodríguez *et al.* [33] reported that wastes obtained from fruit, vegetable, dairy, meat and seafood processing industries contain high levels of biologically active compounds such as protein, fiber, antioxidants, essential fatty acids and vitamins. Due to these properties, it is stated that it is possible to utilize these wastes in functional food, animal feed, cosmetic and pharmaceutical applications. However, this reuse process brings with it some safety risks. In many studies, physicochemical or microbiological assessments of the safety of food by-products were not performed. Also, in some examples, the formation levels of harmful compounds (e.g. acrylamide) that may arise as a result of the processing of by-products such as coffee husk (cascara) and olive pulp have been investigated and it has been reported that they remain at safe levels under certain processing conditions [41 – 44]. In addition, it is stated that free fatty acids and oxidative degradation products are minimized and product quality and safety are improved by using advanced technologies such as supercritical fluid extraction in oils obtained from fish by-products [45].

It is stated that the by-products remaining from plant and animal oil production processes are rich in functional compounds such as polyphenols, dietary fiber, essential amino acids, proteins, carotenoids and vitamins. Especially fruit and vegetable pulps (e.g. grape seed, pomegranate peel, tomato peel) attract attention in terms of their polyphenol content and are evaluated as food preservatives or health-supporting ingredients thanks to their antioxidant properties [42, 45, 46]. It has been shown that grape seed flour has antioxidant capacity that can be used in both cosmetic and functional food production [47]. Oilseed meals (sunflower, rapeseed and soybean, etc.) obtained in vegetable oil production have significant potential in terms of food technology due to their high protein content (approximately 45 - 65 %) and bioactive compounds such as phenolic compounds, flavonoids and lignans [34]. These substances can help prevent cardiovascular diseases by reducing oxidative stress. At the same time, these products are low-cost and continuously available raw materials throughout the year. Similarly, "brewer's spent grain (BSG)", which is malt pulp resulting from beer production, is a component rich in fiber, protein and glutamine; It is used as a functional additive in different food products such as bread, pasta and even baby food [34, 48].

Approximately 15 % of livestock and aquaculture feeds (940 million tons of dry matter) consist of raw materials suitable for direct human consumption (cereals, legumes, oils and whole fish). This ratio increases to 68 % and 38 %, respectively, especially in poultry and pig meat production [35]. This situation both increases food-feed competition and leads to inefficient use of natural resources.

Sandström *et al.* [35] study shows that the global food supply can be increased by 13 % in calories and 15 % in protein by using food system by-products (e.g. oilseed meal and

cakes, brewery pulp, molasses, citrus pulp and animal by-products) as feed. This increase also makes it possible to use more than 100 million hectares of agricultural land for different purposes. Although by-products have high potential, not all have the same effect on animal nutrition. For example, plant by-products with high fiber content (straw, straw, etc.) have limited use because they cannot be digested by monogastric animals. In contrast, protein-dense products such as oilseed meals and distiller's grains can completely replace raw materials suitable for human consumption, especially in dairy cattle [34, 35]. The use of by-products obtained from animal fats and fish processing waste instead of fish meal and fish oil is also suitable in terms of protein and essential fatty acids, but has some limitations (Figure 5) in terms of nutritional quality such as omega-3 profile [35].

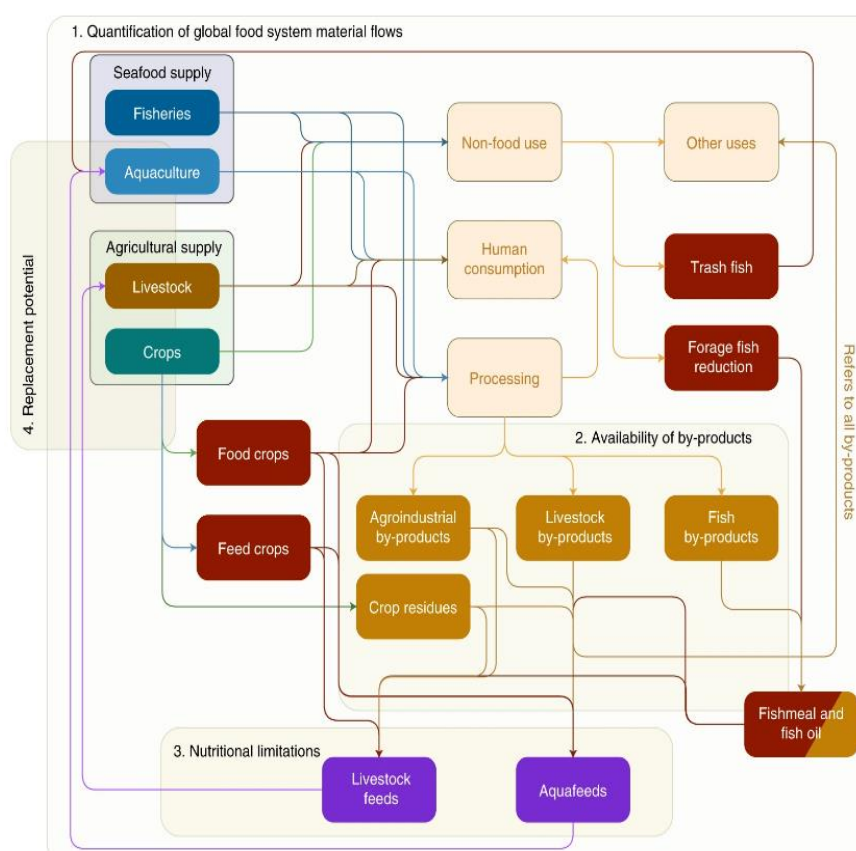


Figure 5. Global food system material flows [35]

Among the fruit and vegetable processing by-products, especially apple, citrus, grape and carrot pulps are integrated into extrusion processes thanks to their fiber ratios and bioactive substance contents [49]. Carrot and tomato pulps have been determined to have positive effects on antioxidant capacity and shelf life thanks to their high carotene and fiber content [50]. Wheat, oat, rye and rice bran from grain processing by-products provide both insoluble fiber (especially cellulose and hemicellulose) and soluble fibers such as β -glucan to extruded products [51 – 53]. Oat bran has shown improvement in swelling capacity and viscosity properties with increasing soluble fiber content after extrusion [54]. Oilseed meals – such as soybean, sesame, hemp and cottonseed – are particularly notable for their high protein content. Protein content ranging from 34.5 –

55.3 % in defatted soybean and hemp meals can act as structure builder, stabilizer and viscosity regulator in extruded products [55, 56].

When evaluated in terms of functional properties, the effects of pulps on water retention capacity (WRC), swelling capacity (SC), oil retention capacity (OHC) and viscosity stand out. Apple and cranberry pulp showed high water retention capacity due to its amorphous lignin and high soluble fiber content [57]. Pineapple pulp has high water and oil retention properties with its 45 % insoluble fiber content and has potential as a texture modifier [58]. On the other hand, the extrusion process can change the physical properties of by-products and in some cases increase their functional values. Heat and shear forces applied during extrusion increase the soluble fiber ratio, which increases the water solubility index (WSI) and swelling capacity [59]. However, in some cases, high fiber content can disrupt the structure of the starch matrix, reduce the expansion ratio (ER) and increase product hardness [60]. Therefore, parameters such as microstructure, fiber type (soluble/insoluble), particle size and inclusion ratio of by-products should be carefully optimized. It has been reported that by appropriately adjusting the extrusion parameters (humidity, temperature, screw speed), the expansion properties of the products can be preserved despite the inclusion of by-products [50]. In addition, thanks to the increase in the soluble fiber ratio with pretreatment (fermentation), product texture and volume are preserved even in formulations containing high by-products [52].

In order for these products to be used in food, safety assessments must be transparent and systematic. However, Socas-Rodríguez *et al.* [33] state that although there are many assessments in the existing literature, microbiological and chemical safety tests in particular have not been systematically conducted. It has been emphasized that fruit and vegetable pulps may contain pesticide residues, mycotoxins such as patulin or natural toxins (e.g. glycoalkaloids, tomatine) [34]. Similarly, by-products with high moisture content (BSG, etc.) can rapidly undergo microbial spoilage and create an environment suitable for the development of toxigenic molds such as *Aspergillus* and *Penicillium*. This situation increases the risk of mycotoxin formation, especially despite low water activity [3, 34].

Although the European Union legislation includes quite detailed regulations on food safety, it still contains uncertainties, especially in the evaluation of innovative products (novel food, etc.) and food additives [33]. Fish oils obtained from seafood processing waste are rich in long-chain omega-3 fatty acids (EPA and DHA) and are used in baby foods and functional products [45]. These applications both increase product diversity and reduce waste management burden. Therefore, regulations are needed for both consumer safety and the safe introduction of potentially valuable by-products into the market in the processing of by-products.

One of the most important obstacles to the evaluation of food by-products for human or animal consumption is the limited safety assessments and insufficient regulatory infrastructure. Socas-Rodríguez *et al.* [33] stated that there are many applications of the re-evaluation of food by-products in the existing literature, but only a few studies have included microbiological and chemical safety analyses of these products. In a study on coffee husks (cascara), acrylamide formation was evaluated during the sun-drying process and was shown to be below the European Union limit values [43]. Similarly, fish oil extraction with supercritical CO₂ was found to reduce the amount of free fatty acids and minimize oxidative degradation [43]. However, one of the biggest risks in terms of safety is the concentration of contaminants such as pesticides, heavy metals and

mycotoxins in processed products. Moncalvo *et al.* [61] reported that during the extraction of phenolic compounds from grape skins, some pesticide residues remained in the final product above the limits set by the European Union. Therefore, the extraction process should consider not only the efficiency of the target components but also the elimination of contaminants. From a legislative perspective, although there are various regulations for food additives, feed ingredients and "novel foods" in the European Union, a framework for systematic regulation of ingredients derived from waste in particular is lacking [33]. This makes it difficult for manufacturers to exploit this potential due to legal uncertainty. Current EU legislation does not provide a framework that directly covers the evaluation of such by-products. The EU regulation on pesticide residues (EC No 1881/2006) does not cover secondary products such as malt pulp, fruit peels or oilseed meal products [34]. This deficiency reduces the willingness of manufacturers to bring these products to the market due to legal uncertainty.

Efforts to develop sustainable and functional products cannot achieve commercial success unless they gain the trust of the consumer. EU consumers are more cautious about food safety issues, and the distrust brought about by the distance between them and food producers reduces the level of acceptance of foods based on processed by-products [62]. However, studies show that presenting these products as functional foods and clearly providing information on their health and environmental benefits can positively affect consumer acceptance. Reuse and value creation activities are directly compatible with the circular economy and the EU Green Deal goals. However, in order to realize this potential, the EU's general food laws need to be expanded to cover these products and special regulations need to be made for by-products, especially in terms of microbiological criteria, pesticide residues and toxicological limits [62 – 64]. In addition, the structuring of specific food safety standards (GFSI, BRC) to include such products can overcome legal gaps in practice and should lead to legislative changes [65].

Sandström *et al.* [35] analyzes the geographical distribution of waste and by-products of the food system, current feed uses, and potential substitution scenarios based on a systematic data base, revealing the plannability of this transformation on a global scale. Gharby [40] states that the refining process of vegetable oils is essential for the removal of undesirable components such as free fatty acids, pesticide residues, heavy metals, polyaromatic hydrocarbons (PAHs), and mycotoxins. However, it has been shown that during refining, bioactive compounds that are beneficial to health, such as tocopherols, phytosterols, polyphenols, and phospholipids, are largely lost. Tocopherol losses vary between 7.7 and 76.5 % in physical refining and between 26.8 and 79.4 % in chemical refining [40]. The loss of these bioactive compounds not only reduces the nutritional value but also negatively affects the oxidative stability of refined oils. This is an important factor to be considered in the evaluation of oil by-products, especially in functional food production [66]. Another drawback of refining is that new toxic compounds may be formed during processing. For example, 3-MCPD esters and trans fatty acids may be formed during the deodorization process carried out at high temperature and low pressure [40]. Since these compounds have potential carcinogenic effects, they stand out as critical parameters that need to be optimized during the refining process. Similarly, adsorbents such as activated carbon or bentonite used during excessive bleaching processes are effective in removing lipophilic toxic compounds such as PAHs, but they also cause the adsorption of some beneficial compounds [67].

It has been stated that the valorization of the "soapstock", "deodorizer distillate" and phospholipid-rich "lecithin" fractions obtained as a result of refining is very important in making the food system more circular. It is possible to use these by-products as feed additives, biodiesel raw materials or functional ingredient sources [40, 68]. Gharby [40] emphasizes that physical refining is preferable in terms of sustainability because it is more environmentally friendly, low-cost and produces less waste than chemical refining. However, the fact that this method is not suitable for oils with high phospholipid content indicates technical limitations [40]. In this context, optimization of refining in sustainable vegetable oil production requires a multi-dimensional evaluation not only in terms of economic efficiency but also in terms of nutritional quality, safety and environmental impacts [33]. New generation technologies such as enzymatic degumming, membrane filtration and low-temperature deodorization are offered as options both to maintain quality and to reduce by-product losses [34]. As a result, successful results have been obtained in the conversion of food oil by-products into functional products by extrusion. However, it shows that both the structural properties of the ingredients and the process parameters must be optimized in a holistic way in order to obtain the desired technological and sensory properties.

CONCLUSIONS

The evaluation of oil and oil by-products obtained from food processing processes, when evaluated in terms of sustainability of the global food system, has been seen to be important since their use in food, feed, cosmetics and biotechnological applications both reduces the environmental burden and creates economic added value in line with the principles of circular economy. By-products such as pulp and oil cake obtained from vegetable oil production constitute an important resource in the construction of sustainable food systems thanks to the nutritional and functional components they contain. However, since these products contain biologically active compounds such as protein, fiber, antioxidants and vitamins, they need to be considered in terms of nutritional value and food safety. The limited microbiological and chemical safety tests and the detection of contaminants such as pesticides, heavy metals or mycotoxins above the regulatory limits in some products create legal and safety-based uncertainties in the use of these products for direct human consumption or as animal feed. It has become possible to transform fruit, vegetable, grain and oilseed processing by-products into functional products with advanced food technologies such as extrusion. Such processing methods improve the technological properties of the products such as water retention, swelling, viscosity, and also increase their nutritional value, and it has been stated that optimizing the process requires the evaluation of fiber type, particle size, product content, and process parameters together. It has been stated that difficulties generally reduce the willingness of manufacturers to offer these products to the market. Special regulations are needed for innovative products and additives, and it has been seen that it is necessary to establish clear legal frameworks in terms of microbiological criteria, pesticide residue levels, and toxicological limits. Re-evaluation of food by-products is a multidimensional issue that needs to be addressed in the context of environmental sustainability, economic efficiency, and food safety, and it is thought that innovative technologies, updating legal

infrastructures, and ensuring consumer confidence will benefit sustainable food and food production.

REFERENCES

1. Meijaard, E., Virah-Sawmy, M., Newing, H. S., Ingram, V., Holle, M. J. M., Pasmans, T., Omar, S., van den Hombergh, H., Unus, N., Fosch, A., Ferraz de Arruda, H., Allen, J., Tsagarakis, K., Ogbu, M. C., Diaz-Ismael, A., Hance, J., Moreno, Y., O'Keeffe, S., Slavin, J., Slingerland, M., Meijaard, E. M., Macfarlane, N., Jimenez, R., Wich, S. A., Sheil, D.: *Exploring the future of vegetable oils: Oil crop implications – fats, forests, forecasts, and futures*, IUCN and SNSB, Gland, Switzerland, **2024**, 93;
2. Chirsanova, C.A., Calcatiniuc, D.: The impact of food waste and ways to minimize it, *Journal of Social Sciences*, **2021**, 1 (1), 128-139;
3. Gautam, M., Agrawal, M.: Greenhouse gas emissions from municipal solid waste management: a review of global scenario in: *Carbon Footprint Case Studies: Municipal Solid Waste Management, Sustainable Road Transport and Carbon Sequestration* (Editor: Muthu, S.S.), **2020**, 123-160;
4. Ishangulyyev, R., Kim, S., Lee, S.H.: Understanding food loss and waste – why are we losing and wasting food?, *Foods*, **2019**, 8 (8), 297;
5. Ogbu, M.C., Kosoe, E.A., Iyiola, A.O., Fawole, W.O.: Circular Economy Approaches in Bioeconomy in the Global South in: *Sustainable Bioeconomy Development in the Global South: Volume II Bioeconomy Techniques* (Editors: Ogbu, M.C., Izah, S.C., Vazquez-Arenas, J.G., Feleke, S.T., Wei, X.), Springer Nature Singapore, **2025**, 131-157;
6. Oyediji, S., Patel, N., Krishnamurthy, R., & Fatoba, P. O.: Agricultural wastes to value-added products: economic and environmental perspectives for waste conversion in: *Biowaste to Value-added Products: Economics and Technologies* (Editors: Bayer, T., Kircher, M.), **2024**, 215-248;
7. Bhoi, R., Patro, A., Sarkar, A.: Sustainable Transformation of Agricultural Waste into Value-Added End Products Through Thermochemical Approach in: *Agricultural Waste to Value-Added Products: Bioproducts and its Applications* (Editors: Neelancherry, R., Gao, B., Wisniewski Jr, A.), Springer Nature Singapore, **2024**, 1-25;
8. Wibisono, D.A.S., Saw, C.Y., Wu, T.Y., Chau, C.F.: Advancing Industrial Food Byproduct Management: Strategies, Technologies, and Progress in Waste Reduction, *Processes*, **2025**, 13 (1), 84;
9. Liguori, R., Amore, A., Faraco, V.: Waste valorization by biotechnological conversion into added value products, *Applied Microbiology and Biotechnology*, **2013**, 97 (14), 6129-6147;
10. Mujtaba, M., Fraceto, L.F., Fazeli, M., Mukherjee, S., Savassa, S.M., de Medeiros, G.A., Vilaplana, F.: Lignocellulosic biomass from agricultural waste to the circular economy: a review, *Journal of Cleaner Production*, **2023**, 402, 136815;
11. Usmani, Z., Sharma, M., Gaffey, J., Sharma, M., Dewhurst, R.J., Moreau, B., Gupta, V.K.: Valorization of dairy waste and by-products through microbial bioprocesses, *Bioresource Technology*, **2022**, 346, 126444;
12. Alan, H., Köker, A.R.: Analyzing and mapping agricultural waste recycling research: An integrative review for conceptual framework and future directions, *Resources Policy*, **2023**, 85, 103987;
13. Nath, A., Das, K., Dhal, G.C.: Global Status of Agricultural Waste-Based Industries, Challenges, and Future Prospects in: *Agricultural Waste to Value-Added Products: Technical, Economic and Sustainable Aspects* (Editors: Neelancherry, R., Gao, B., Wisniewski Jr, A.), **2023**, 21-45;
14. Karthika, A., Seenivasagan, R., Vasanthy, M.: A review on technological approach for obtaining nutrient from solid waste in: *Organic Pollutants: Toxicity and Solutions* (Editors: Vasanthy, M., Sivasankar, V., Sunitha, T.G.), **2022**, 475-502;
15. Seberini, A.: Economic, social and environmental world impacts of food waste on society and Zero waste as a global approach to their elimination, *SHS Web of Conferences*, **2020**, 74, 03010;
16. Sharma, B., Vaish, B., Srivastava, V., Singh, S., Singh, P., Singh, R.P.: An insight to atmospheric pollution-improper waste management and climate change nexus in: *Modern Age Environmental Problems and Their Remediation* (Editors: Oves, M., Zain Khan, M., M.I. Ismail, I.), **2018**, 23-47;

17. Brown, D.A.: Comparative ethical issues entailed in the geological disposal of radioactive waste and carbon dioxide in: *Geological Disposal of Carbon Dioxide and Radioactive Waste: A Comparative Assessment* (Editor: Toth, F.L.), **2011**, 317-337;
18. Walton, C.W., Briggs, K.S., Loos, K.J.: Waste minimization and remediation in the metal finishing industries in: *Industrial Environmental Chemistry: Waste Minimization in Industrial Processes and Remediation of Hazardous Waste* (Editors: Sawyer, D.T., Martell, A.E.), **1992**, 71-87;
19. Grinberga-Zalite, G., Zvirbule, A.: Analysis of waste minimization challenges to European food production enterprises, *Emerging Science Journal*, **2022**, 6 (3), 530-543;
20. Reissig, P., Lebendiker, A.: Transitioning from food systems toward food ecosystems in: *Transdisciplinary Case Studies on Design for Food and Sustainability* (Editor: Massari, S.), Woodhead Publishing, **2021**, 75-94;
21. Moro-Visconti, R., Cruz Rambaud, S., López Pascual, J.: Sustainability in FinTechs: An explanation through business model scalability and market valuation, *Sustainability*, **2020**, 12 (24), 10316;
22. Lin, C.S.K., Koutinas, A.A., Stamatelatou, K., Mubofu, E.B., Matharu, A.S., Kopsahelis, N., Luque, R.: Current and future trends in food waste valorization for the production of chemicals, materials and fuels: a global perspective, *Biofuels Bioproducts and Biorefining*, **2014**, 8 (5), 686-715;
23. Urra-Calfuñir, B.A., Monardes-Concha, C.A., Miranda-González, P.A.: Agri-food supply chain optimization through a decentralized production process in the olive oil industry, *Computers and Industrial Engineering*, **2024**, 192, 110185;
24. Nandakumar, K., Joshi, J.B., Valsaraj, K.T., Nigam, K.D.: Perspectives on Manufacturing Innovation in Chemical Process Industries, *ACS Engineering Au*, **2022**, 2 (1), 3-11;
25. Cárcamo, E.A.B., Peñabaena-Niebles, R.: Opportunities and challenges for the waste management in emerging and frontier countries through industrial symbiosis, *Journal of Cleaner Production*, **2022**, 363, 132607;
26. Lopes de Sousa Jabbour, A.B., Frascareli, F.C.D.O., Santibanez Gonzalez, E.D., Chiappetta Jabbour, C.J.: Are food supply chains taking advantage of the circular economy?, *Production Planning and Control*, **2023**, 34 (10), 967-983;
27. Donner, M., Gohier, R., de Vries, H.: A new circular business model typology for creating value from agro-waste, *Science of the Total Environment*, **2020**, 716, 137065;
28. Dilucia, F., Lacivita, V., Conte, A., Del Nobile, M.A.: Sustainable use of fruit and vegetable by-products to enhance food packaging performance, *Foods*, **2020**, 9 (7), 857;
29. Nunes, M.A., Pimentel, F.B., Costa, A.S., Alves, R.C., Oliveira, M.B.P.: Olive by-products for functional and food applications, *Innovative Food Science and Emerging Technologies*, **2016**, 35, 139-148;
30. Garcia-Herrero, I., Hoehn, D., Margallo, M., Laso, J., Bala, A., Batlle-Bayer, L., Aldaco, R.: On the estimation of potential food waste reduction, *Food Policy*, **2018**, 80, 24-38;
31. Thyberg, K.L., Tonjes, D.J.: Drivers of food waste and implications for policy development, *Resources Conservation and Recycling*, **2016**, 106, 110-123;
32. Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G.: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, *BMJ*, **2009**, 339;
33. Socas-Rodríguez, B., Álvarez-Rivera, G., Valdés, A., Ibáñez, E., Cifuentes, A.: Food by-products and food wastes: are they safe enough for their valorization?, *Trends in Food Science and Technology*, **2021**, 114, 133-147;
34. Rao, M., Bast, A., De Boer, A.: Valorized food processing by-products in the EU: finding the balance between safety, nutrition, and sustainability, *Sustainability*, **2021**, 13 (8), 4428;
35. Sandström, V., Chrysafi, A., Lamminen, M., Troell, M., Jalava, M., Piipponen, J., Kummu, M.: Food system by-products upcycled in livestock and aquaculture feeds can increase global food supply, *Nature Food*, **2022**, 3 (9), 729-740;
36. Munesue, Y., Masui, T., Fushima, T.: The effects of reducing food losses and food waste on global food insecurity, natural resources, and greenhouse gas emissions, *Environmental Economics and Policy Studies*, **2015**, 17 (1), 43-77;
37. Nayak, A., Bhushan, B.: An overview of recent trends on the waste valorization techniques for food wastes, *Journal of Environmental Management*, **2019**, 233, 352-370;

38. Sorrenti, V., Burò, I., Consoli, V., Vanella, L.: Recent advances in health benefits of bioactive compounds from food wastes and by-products: biochemical aspects, *International Journal of Molecular Sciences*, **2023**, 24 (2), 2019;
39. Foo, W.H., Koay, S.S.N., Chia, S.R., Chia, W.Y., Tang, D.Y.Y., Nomanbhay, S., Chew, K.W.: Recent advances in the conversion of waste cooking oil into value-added products, *Fuel*, **2022**, 324, 124539;
40. Gharby, S.: Refining vegetable oils: chemical and physical refining, *Scientific World Journal*, **2022**, 2022, 6627013;
41. Darko, H.S.O., Ismaiel, L., Fanesi, B., Pacetti, D., Lucci, P.: Current trends in food processing by-products as sources of high value-added compounds in food fortification, *Foods*, **2024**, 13 (16), 2658;
42. Awad, A.M., Kumar, P., Ismail-Fitry, M.R., Jusoh, S., Ab Aziz, M.F., Sazili, A.Q.: Green extraction of bioactive compounds from plant biomass and their application in meat as natural antioxidant, *Antioxidants*, **2021**, 10 (9), 1465;
43. Iriondo-DeHond, A., Iriondo-DeHond, M., Del Castillo, M.D.: Applications of compounds from coffee processing by-products, *Biomolecules*, **2020**, 10 (9), 1219;
44. Ribeiro, T.B., Voss, G.B., Coelho, M.C., Pintado, M.E.: Food waste and by-product valorization as an integrated approach with zero waste in: *Future Foods* (Editor: Bhat, R.), Academic Press, **2022**, 569-596;
45. Rubio-Rodríguez, N., De Diego, S.M., Beltrán, S., Jaime, I., Sanz, M.T., Rovira, J.: Supercritical fluid extraction of fish oil from fish by-products: a comparison with other extraction methods, *Journal of Food Engineering*, **2012**, 109 (2), 238-248;
46. Ben-Othman, S., Jödu, I., Bhat, R.: Bioactives from agri-food wastes: present insights and future challenges, *Molecules*, **2020**, 25 (3), 510;
47. Multescu, M., Marinas, I.C., Susman, I.E., Belc, N.: Byproducts from the vegetable oil industry as a potential source of antioxidants, *Foods*, **2022**, 11 (2), 253;
48. Lynch, K.M., Zannini, E., Coffey, A., Arendt, E.K.: Lactic acid bacteria exopolysaccharides in foods and beverages: isolation, properties and health benefits, *Annual Review of Food Science and Technology*, **2018**, 9, 155-176;
49. Dey, D., Richter, J.K., Ek, P., Gu, B.J., Ganjyal, G.M.: Utilization of food processing by-products in extrusion processing: a review, *Frontiers in Sustainable Food Systems*, **2021**, 4, 603751;
50. Kaisangsri, N., Kowalski, R.J., Wijesekara, I., Kerdchoechuen, O., Laohakunjit, N., Ganjyal, G.M.: Carrot pomace enhances the expansion and nutritional quality of corn starch extrudates, *LWT-Food Science and Technology*, **2016**, 68, 391-399;
51. Fleischman, E.F., Kowalski, R.J., Morris, C.F., Nguyen, T., Li, C., Ganjyal, G., Ross, C.F.: Physical, textural and antioxidant properties of extruded wheat flour snack supplemented with bran, *Journal of Food Science*, **2016**, 81 (11), E2726-E2733;
52. Nikinmaa, M., Alam, S.A., Raulio, M., Katina, K., Kajala, I., Nordlund, E., Sozer, N.: Bioprocessing of bran with EPS producing microorganisms, *LWT*, **2017**, 77, 170-177;
53. Dey, D.: Exploring the physicochemical interactions between ingredients to enable incorporation of insoluble fibers into direct expanded starch extrudates, Ph.D. Thesis, Washington State University, **2022**;
54. Zhang, M., Bai, X., Zhang, Z.: Extrusion process improves the functionality of soluble dietary fiber in oat bran, *Journal of Cereal Science*, **2011**, 54 (1), 98-103;
55. Da Graca Costa do Nascimento, E.M., Piler Carvalho, C.W., Takeiti, C.Y., Castro Freitas, D.D.G., Ramirez Ascheri, J.L.: Use of sesame oil cake on corn expanded extrudates, *Food Research International*, **2012**, 45 (1), 434-443;
56. Jozinović, A., Ačkar, Đ., Jokić, S., Babić, J., Balentić, J.P., Banožić, M., Šubarić, D.: Optimisation of extrusion variables for production of corn snacks enriched with hemp cake, *Czech Journal of Food Sciences*, **2017**, 35 (6), 563-571;
57. Wang, S., Gu, B.J., Ganjyal, G.M.: Impacts of the inclusion of fruit pomace types on expansion of corn starch extrudates, *LWT*, **2019**, 110, 223-230;
58. Selani, M.M., Brazaca, S.G.C., dos Santos Dias, C.T., Ratnayake, W.S., Flores, R.A., Bianchini, A.: Characterisation and potential application of pineapple pomace in extruded product, *Food Chemistry*, **2014**, 163, 23-30;

59. Masatcioglu, M.T., Yalcin, E., Hwan, P.J., Ryu, G.H., Celik, S., Koksel, H.: Hull-less barley flour supplemented corn extrudates, *Innovative Food Science and Emerging Technologies*, **2014**, 26, 302-309;
60. Mohamad Mazlan, M., Talib, R.A., Mail, N.F., Taip, F.S., Chin, N.L., Sulaiman, R., Mohd Nor, M.Z.: Effects of extrusion variables on corn-mango peel extrudates properties, *International Journal of Food Properties*, **2019**, 22 (1), 54-70;
61. Moncalvo, A., Marinoni, L., Dordoni, R., Duserm Garrido, G., Lavelli, V., Spigno, G.: Waste grape skins safety aspects for functional powders, *Food Additives and Contaminants Part A*, **2016**, 33 (7), 1116-1126;
62. Van Gunst, A., Roodenburg, A.J.: Consumer distrust about E-numbers: a qualitative study among food experts, *Foods*, **2019**, 8 (5), 178;
63. Focker, M., Van Asselt, E.D., Berendsen, B.J.A., Van De Schans, M.G.M., Van Leeuwen, S.P.J., Visser, S.M., Van der Fels-Klerx, H.J.: Review of food safety hazards in circular food systems in Europe, *Food Research International*, **2022**, 158, 111505;
64. Anjum, V., Dixit, V., Jha, P., Potoroko, I.: Food products regulations in the European Union in: *Global Regulations of Medicinal, Pharmaceutical and Food Products* (Editors: Ali, F., Nollet, L.M.L.), CRC Press, **2024**, 255-287;
65. Vilas-Boas, A.A., Pintado, M., Oliveira, A.L.: Natural bioactive compounds from food waste: toxicity and safety concerns, *Foods*, **2021**, 10 (7), 1564;
66. Hashempour-Baltork, F., Farshi, P., Alizadeh, A.M., Azadmard-Damirchi, S., Torbati, M.: Nutritional aspects of vegetable oils: refined or unrefined?, *European Journal of Lipid Science and Technology*, **2022**, 124, 2100149;
67. Aliyar-Zanjani, N., Piravi-Vanak, Z., Ghavami, M.: Effect of activated carbon on reduction of PAHs in soybean oil, *Grasas y Aceites*, **2019**, 70 (3), e304;
68. Dumont, M.J., Narine, S.S.: Characterization of flax and soybean soapstocks by GC-FID, *Journal of the American Oil Chemists' Society*, **2007**, 84 (11), 1101-1105.