Scientific Papers. Series D. Animal Science. Vol. LXVII, No. 1, 2024
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

THE VALORIZATION OF PLANT AND ANIMAL BY-PRODUCTS FOR FOOD SUSTAINABILITY

Adina NICHITA, Mona Elena POPA

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, Bucharest, Romania

Corresponding author email: nichitaadina1979@gmail.com

Abstract

This review is based on a bibliographic study of over 70 articles published between 2001-2023 and tried to highlight the most important valorization directions, as well as the most used valorization methods of waste from the food industry, for the purpose of environmental sustainability. The recycling of waste in the cascade helps to solve problems related to the environment, economic, social, ethical, etc. Waste recovery methods are diversified depending on the type of waste, requiring in-depth studies, innovative technologies, an appropriate legislative framework, as well as alternative solutions, etc., so as to obtain zero waste. Current perspectives come in the face of finding alternative solutions, such as meat analogous and food industry sustainability approaches.

Key words*: animal by-products, sustainability, vegetable by-products.*

INTRODUCTION

In recent decades, the food industry has become a focal point in discussions about environmental protection and sustainability. (Zioga al., 2022).

The earth is an important source of natural resources which, in connection with the activities of operators in different sectors, generate a wide range of waste. (Srivastava et al., 2023).

Agriculture and the food industry are key branches of the European economy (Palvic et al., 2023), but they bring with them significant challenges related to the management of waste and economic losses (Ilyas et al., 2021).

The lack of effective waste management directions resulting from the processing of raw materials and the processing of products leads to the formation of significant amounts of waste that affect the environment in quantitative and qualitative terms (Awasthi et al., 2021).

To address this problem, improving waste management in agriculture and the food industry through recycling and recovery of by-products has become crucial globally (Lamolinara et al., 2022).

This approach promotes the sustainable use of resources by valorizing by-products and residues in a variety of ways (Ubando et al., 2020).

An example of an effective way of using agricultural waste is anaerobic digestion, which transforms organic materials into biogas and other valuable products (Nagarajan et al., 2023).

As awareness of the negative impact of animal production grows, an increased direction of technological development towards plant proteins is observed (Szpincer et al., 2022; Estel et al., 2021; Lai et al., 2017).

Proteins are found in higher amounts in animal products (Singh & Krishnaswamy, 2022), but the shift to plant proteins is a significant trend in the food industry, with benefits for both human health and the environment (Sabater et al., 2021).

Inefficient management of waste from the primary processing of plant raw materials, as well as waste from product processing, results in the quantitative formation of waste and implicitly environmental pollution (Awasthi et al., 2021).

The review aims to identify the main directions for the valorization of various by-products of plant and animal origin resulting from agriculture and industrial food processing, for the purpose of environmental sustainability, etc.

MATERIALS AND METHODS

For this research we have analyzed Scopus Elsevier data base and SpringerLink Journals by specific key words like, “vegetable by-products”; “animal by-products”; “sustainability”. We have also used official information of different states.

With an estimated world population of approximately 10 billion people by 2050, there is a growing demand for food and biomass to meet this increased need (Vicente et al., 2023). This increase in food production and consumption also results in a significant amount of agri-food waste that requires effective management and recovery (Saratale et al., 2021). One of the significant aspects is the massive production of plastic materials globally, which reaches about 40 billion tons per year (Li & Wilkins, 2020).

This high production of plastic generates serious problems related to environmental pollution, risks to human health and toxic impact on ecosystems. In this context, the management of agri-food waste can contribute to addressing this problem through the processes of valorization and transformation of this waste into sustainable alternatives to plastic. A notable example is the use of agro-food waste as raw materials to obtain fermentable sugars and subsequently biofuels (Kumar et al., 2022).

This process involves steps such as pre-treating raw materials to obtain fermentable sugars, fermenting these sugars to produce biofuels, and purifying these biofuels, such as ethanol, through distillation. This approach contributes not only to the recovery of agri-food waste, but also to the reduction of dependence on fossil fuels, with significant benefits for the environment and climate change. At the same time, fruit and vegetable by-products, which contain high concentrations of bioactive compounds, represent a valuable source for obtaining bioactive substances with health benefits (Renard, 2018).

The extraction and valorization of these compounds from co-products contributes to the minimization of waste and the development of food products with added value. For the processing of agricultural waste, such as melon peels or peanut shells, it is essential to pre-treat them to obtain value-added products (Ajayi & Lateff, 2023). The full recovery of eggplant waste, through the extraction of anthocyanins and pectin, is carried out by different methods and techniques developed and improved, with ultrasound and microwaves (Karimi et al., 2021).

Table 1. Schematic presentation of the use of agri-food waste for the production of value-added products (Source: Kumar et al., 2022)

Waste material	Pre-treatment Method	Value Added Products
-Fruit & Vegetable processing waste -Edible oil waste -Coffee processing waste -Kitchen waste -Meat & poultry waste -Brewery waste	-Microwave radiation -Ultrasound method -Steam explosion -Liquid hot water treatment -Ammonia fiber explosion -Pyrolysis -Microfluidics	-Biofuel -Biosurfactant -Bio composites - Biofertilizer -Biopolymer -Na-ion batteries

Although many research has been done in the valorization of food industry waste, many challenges are still need to be further addressed. Few challenges are described in the Figure1.

An interesting aspect addressed in these researches is fermentation, which is being investigated as an efficient and economical way of valorizing indigenous African leafy vegetables. Controlled fermentation involves the use of lactic acid bacteria, representing one of the promising approaches in this context. This fermentation process significantly improves the nutritional content of vegetables and extends their shelf life (Misci et al., 2022).

The pretreatment of melon skins, peanut skins, etc., is a necessary step in obtaining products with added value (Ajayi & Lateff, 2023).

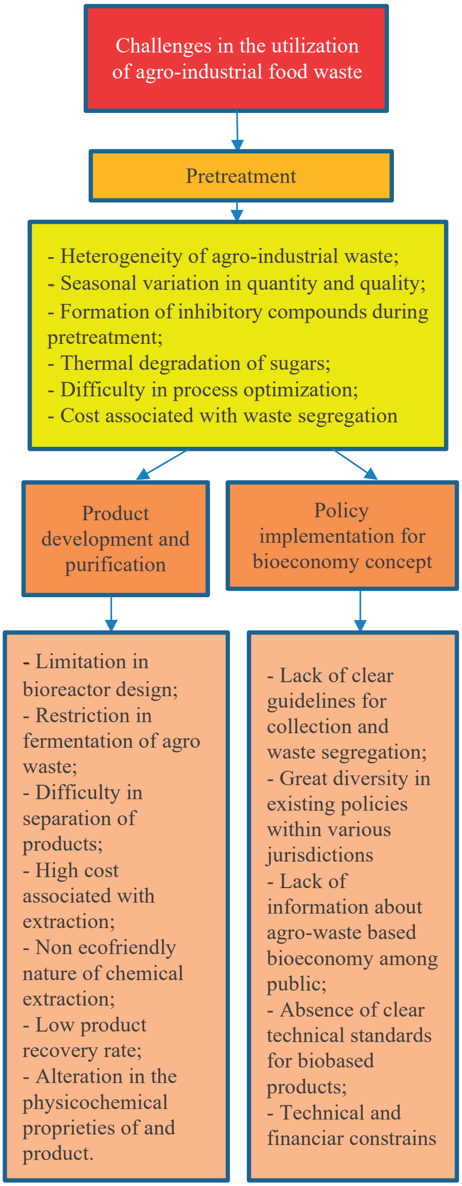

Figure 1. Challenges in the sustainable utilization of agro-industrial waste
(Source: Kumar et al., 2022)

Pressed drupes resulting as waste from oil extraction could be exploited by hydrolysis to obtain therapeutic benefits that have a higher value than the current value as animal feed (Sari et al., 2022).

Anaerobic digestion technology is becoming more and more important due to its contribution to environmental sustainability and the circular bioeconomy (Tavera-Ruiz et al., 2023), anaerobic digestion being a way of valorizing agricultural waste (Nagarajan et al., 2023).

RESULTS AND DISCUSSIONS

Directions for valorization of plant & animal by-products

Annually, approximately 1.3 billion tons of waste and by-products are generated globally, and 38% of this comes from food processing (Gottardi et al., 2021).

The waste resulting from the slaughter of animals is rich in proteins and lipids and represents a valuable resource for the cosmetic and medical industry (Javourez et al., 2021).

By-products from various processing steps, such as whey, molasses, starch, fresh fruits and vegetables, can be redirected to various food matrices, producing edible bioproducts such as lactic acid and cellular proteins. Contaminated, altered or expired waste can be used in anaerobic digestion processes (Awasthi et al., 2022; Awasthi et al., 2022b; Sar T. et al., 2021).

The valorization of these wastes and other agro-food by-products aims to stimulate innovative technologies, thus contributing to a more efficient management of resources (Javourez et al., 2021). Another important aspect in the recovery of waste and by-products is their use to replace plastic materials with ecological bioplastics in the form of polyhydroxyalkanoates, which are biodegradable and biocompostable (Saratale et al., 2021).

The dairy industry generates significant amounts of waste in the form of whey. This whey contains important nutrients like lactose, lipids, soluble proteins and others. The use of this whey can contribute to the reduction of environmental impact and the development of value-added products (Gutierrez-Hernandez et al., 2022).

Agro-industrial wastes can be used for fermentation, thus contributing to the improvement of economy and productivity (Arya et al., 2022).

Industrial biotechnologies and the use of microbes in various applications, such as the production of bioplastics, food additives, cosmetics and valuable chemicals, have become key components of the global bioeconomy (Pfeifer et al., 2021).

In addition, organic waste from the food and agricultural industry represents an important resource of recoverable biomass for the purpose of producing renewable energy (Akbi et al., 2017), contributing to reducing dependence on traditional energy sources and combating climate change (Usmani et al., 2023).

It is clear that this approach has significant potential to bring about considerable improvements in the food industry and in the fight against climate change (Stadler & Chauvet, 2018; Surendra et al., 2020).

In addition to energy production, agro-food by-products and waste can also serve as raw materials for the food industry. Fermentation and bioconversion processes can convert these wastes into value-added products such as lactic acid or cellular proteins (Awasthi et al., 2022; Arya et al., 2022).

This approach not only reduces wastage of resources but also helps increase the productivity of the economy. In addition, the development of biorefineries represents a promising direction in the exploitation of renewable resources (Kasani et al., 2022).

These biorefineries can be used to extract various valuable chemicals from agri-food waste, thereby helping to reduce pressure on natural resources. Valorization of waste and agri-food by-products has a significant impact on the food industry and food safety. With a growing population, it is essential to develop strategies for the use of resources that are sustainable in the long term, which involves the transformation of waste from milk production into valuable products such as lactic acid or soluble proteins (Gutierrez-Hernandez et al., 2022).

A review indicates the industrial processing of sugar beet to obtain sugar, resulting in significant quantities of sugar beet pulp, which in the past was mainly used as animal feed. However, recent developments have opened new perspectives, suggesting that this sugar beet pulp can be efficiently exploited to obtain biofuels, biohydrogen and other valuable chemicals such as alcohols, microbial enzymes, lactic acid, citric acid, single-cell proteins and biodegradable materials (Usmani et al., 2022). In addition, fruits, vegetables and other food products are rich sources of dietary carbohydrates and bioactive phytochemical compounds that, in addition to their basic nutritional intake, also provide significant health benefits (Dranca & Oroian, 2018; Liu, 2013).

These directions for the valorization of plant by-products demonstrate the enormous potential of transforming waste into valuable resources within the food and chemical industries. Pectin, known for its traditional use as a gelling and thickening agent in food industry, now has an expanded role as a functional agent or fat substitute that promotes health (Dranca & Oroian, 2018).

Moreover, the isolation of pectin from plant materials or agro-food by-products has opened applications in the pharmaceutical and medical industry, due to its bioactive benefits (Dranca & Oroian, 2018).

A concrete example is the use of the by-products resulting from the processing of melons (*Cucumis melo* L.), which generate seeds and peel rich in antioxidants. These melon peel extracts contain phytochemical compounds with antimicrobial, antiviral, antioxidant, anti-inflammatory and antidiabetic properties, opening new perspectives for the development of functional foods (Gómez-Garcia et al., 2020).

Another example is the industrial processing of eggplant, which generates by-products such as eggplant skins. These peels are rich in anthocyanins, with antioxidant, antimicrobial and antitumor properties. The use of these eggplant peels can be a promising alternative to synthetic additives in the food industry (Karimi et al., 2021).

Avocado processing results in the generation of impressive amounts of pits that represent 13-18% of the fruit's mass. Avocado seeds represent a significant proportion of the mass of the fruit, which can be exploited in various fields, from the production of avocado oil to their use as biofertilizers (Tesfaye et al., 2022).

These examples highlight that agri-food by-products can have significant value if properly managed and exploited. Biorefineries represent a promising approach for this valorization, contributing to a circular and sustainable economy (Kasani et al., 2022; Rodriguez-Martinez et al., 2022).

The secondary products resulting from the wine and olive oil industry are rich in bioactive compounds (Balli et al., 2021).

Olive waste contains phenolic compounds, their concentration being influenced by the growing area and variety. The phenolic fraction consists of different groups: phenolic acids, phenolic alcohols, flavonoids and secoiridoids (Veneziani et al., 2017).

Grape seeds contain polyphenols, such as flavanols, flavonols, anthocyanins and stilbenes, being mainly located in the skin, while others, such as catechins and procyanidins, are only present in the seeds in concentrations that vary according to terrain, variety, etc. (Moro et al., 2021).

Olive waste contains phenolic compounds, their concentration being influenced by the growing area and variety. The phenolic fraction consists of different groups: phenolic acids, phenolic alcohols, flavonoids and secoiridoids (Veneziani et al., 2017). The fructification of waste from the food industry aims to stimulate innovative technologies to improve the use of resources in the cascade (Javourez et al., 2021).

Due to the presence of carotenoids and implicitly their bioactive properties, waste of vegetable origin offers wide opportunities for sustainable productions, being able to be used to color fruit juices, pasta, meat, etc. (Cassani et al., 2022). Vegetable and fruit by-products contain high concentrations of bioactive compounds, which makes the extraction of bioactive substances a capitalization strategy (Renard, 2018).

Anthocyanins from eggplant peel are an important alternative to synthetic additives that can be used to extend the shelf life of food products (Karimi et al., 2021).

A review indicates the deepening of studies for the blood root vegetable (*Haemodorum spicatum*) which is part of the family Haemodoraceae, which grows especially in Western Australia. The bulbs, stem, leaves and seeds of the vegetable produce natural dyes: red, pink, purple and green. Red pigments (Hemocorina) are responsible for the spicy and hot flavor of the bulbs (Macintyre & Dobson, 2017).

The red pigment of *Haemodorum spicatum* can be seen as an alternative substitute for replacing artificial dyes with natural dyes to increase the demand for organic, non-toxic and healthy food (Liang et al., 2023).

Trends and perspectives

The evolution of anaerobic digestion technology is becoming increasingly important in the context of environmental sustainability and the circular economy (Tavera-Ruiz et al., 2023). This technology contributes significantly to reducing the negative impact on the environment and to the efficient use of resources. Waste management thus becomes a key solution in the transition to a circular economy in the food sector (Lavelli, 2021; Jurgilevich et al., 2016).

Industrial waste and by-products from the food industry can serve as sustainable and renewable sources of biomass that can be used to produce electricity, bioliquids, biofuels and more (Gill, 2022). This approach can contribute to the diversification of biomass sources and the development of renewable energy sources.

The circular economy, with an emphasis on food traceability, is a key element in promoting a sustainable food system. This approach aims to produce healthy and environmentally friendly food (Tesfaye et al., 2022).

The current trends regarding the recovery of waste from the food sector, but also the finding of innovative solutions regarding the partial or total replacement of animal proteins with vegetable proteins are evaluated by scientists from the food sector, which contribute to the need to find answers to some ethical requirements, pro-health and, last but not least, environmental sustainability (Kotecka-Majchrzak et al., 2020).

The current trend in the valorization of peas, soybeans, peanuts is to obtain meat alternatives due to their excellent gelling properties and the potential to form fibrous structures (Zhang et al., 2021).

Also, the use of natural dyes in food products aims to improve their sensory quality and give them attractive colors (Cassani et al., 2022). Natural pigments from plant wastes, such as carotenoids, can provide significant benefits through their bioactive properties, including antioxidant and antitumor roles (Cassani et al., 2022).

Industrial biotechnologies have an important role in the future of the European and global bioeconomy. Current studies and advances have indicated that bioconversion or fermentation generates a wide range of food products, chemicals, energy and even hydrocarbons (Stadler & Chauvet, 2018).

Finally, plant-based dairy and meat alternatives have the potential to contribute to environmental sustainability by reducing greenhouse gas emissions and improving food systems (Giacalone et al., 2022). Technological innovations in this field focus on optimizing the quality of food products according to consumer requirements and environmental sustainability objectives (Abecassis et al., 2018).

CONCLUSIONS

The article emphasizes the importance of cascading recovery of raw materials for environmental sustainability. Research and innovative technologies hold promise for finding sustainable alternatives, such as meat analogs, that can meet market needs and reduce reliance on traditional resources. Soy foods are considered to have a prosperous future on the international market, highlighting the increased interest in vegetable proteins.

The concept of waste recovery from agriculture and the food industry is essential in the development of a circular bioeconomy. It includes steps such as the transformation of food by-products into new products, the implementation of innovative technologies, the use of ecological methods and the creation of model biorefineries. These efforts have the potential to contribute to efficient use of resources and environmental protection.

The main conclusions and key aspects derived based on the studied materials are the following:

Organic agriculture: It represents an important alternative for the cascading use of raw materials and for ensuring a sustainable production of organic products. This can meet the growing demand for such products.

Innovations in food production: Research and innovative technologies play a crucial role in developing alternatives, such as meat analogs, to meet consumer demands and contribute to environmental sustainability.

Circular bioeconomy: The concept of animal and plant waste recovery is part of a circular bioeconomy approach. It involves the use of food by-products to create new food products, the development of innovative technologies and the application of ecological methods to reduce the impact on the environment.

In conclusion, cascading resources, promoting organic agriculture, developing sustainable alternatives in the food industry and adopting ecological practices are important steps towards a more circular and environmentally friendly economy.

Organic waste and by-products can be used as a sustainable, renewable, unlimited source of biomass to generate electricity, bioliquids, biofuel, etc.

REFERENCES

Abecassis, J., Cuq, B., Escudier, J. L., Garic, G., Kondjoyan, A., Planchot, V., Salmon, J. M., & de Vries, H. (2018). Food chains; the cradle for scientific ideas and the target for technological innovations. *Innovative Food Science and Emerging Technologies,* 46, 6-17.

Ajayi, V. A., & Lateef, A. (2023). Biotechnological valorization of agrowastes for circular bioeconomy: Melon seed shell, groundnut shell and groundnut peel. *Cleaner and Circular Bioeconomy,* 4, 100039.

Akbi, A., Saber, M., Aziza, M., & Yassaa, N. (2017). An overview of sustainable bioenergy potential in Algeria. *Renewable and Sustainable Energy Reviews,* 72, 240-245.

Arya, P. S., Yagnik, S. M., Rajput, K. N., Panchal, R. R., & Raval, V.H. (2022). Valorization of agro-food wastes: Ease of concomitant-enzymes production with application in food and biofuel industries. *Bioresource Technology,* 316, 127738.

Awasthi, M. K., Ferreira, J. A., Sirohi, R., Sarsaiya, S., Khoshnevisan, B., Baladi, S., Sindhu, R., Binod, P., Pandey, A., Juneja, A., Kumar, D., Zhang, Z., & Taherzadeh, M. J. (2021). A critical review on the development stage of biorefinery systems towards the management of apple processing-derived waste. *Renewable and Sustainable Energy Reviews,* 143, 110972.

Awasthi, M. K., Harirchi, S., Sar, T., Vigneswaran, V.S., Rajendran, K., Gomez-Garcia, R., Hellwing, C., Binod, P., Sindhu, R., Madhavan, A., Anoop Kumar, A. N., Kumar, V., Kumar, D., Zengqiang, Z., & Taherzadeh, M. J. (2022). Myco-biorefinery approaches for food waste valorization: Present statuts and future prospects. *Bioresource Technology,* 360, 127592.

Awasthi, M. K., Lukitawesa, L., Duan, Y. M., Taherzadeh, M. J., & Zhang, Z. Q. (2022b). Bacterial dynamics during the anaerobic digestion of toxic citrus fruit waste and semicontinues volatile fatty acids production in membrane bioreactors. *Fuel,* 319, 123812.

Balli, D., Cecchi, L., Innocenti, M., Bellumori, M., & Mulinacci, N. (2021). Food by-products valorization: Grape pomace and olive pomace (pate) as sources of phenolic compounds and fiber for enrichment of tagliatelle pasta. *Food Chemistry,* 255, 129642.

Cassani, L., Marcovich, N. E., & Gomez-Zavaglia, A. (2022). Valorization of fruit and vegetables agro-wasters for the sustainable production of carotenoid-based colorants with enhanced bioavailability. *Food Reaserch International,* 152, 110924.

Dranca, F. & Oroian, M. (2018). Extraction, purification and characterization of pectin from alternative sources with potential technological applications. *Food Research International,* 113, 327-350.

Estel, M., Huhghes, J., & Grafenauer, S. (2021). Plant protein and plant-based meat alternatives: Consumer and nutrition professional attitudes and perception. *Sustainability, 13(*3), 1-18.

Giacalone, D., Clausen, M. P., & Jaeger, S. R. (2022). Understanding barriers to consumption of plant-based food and beverages: insights from sensory and consumer science. *Science Direct. Current Opinion in Food Science,* 48, 100919.

Gil, A. (2022). Challenges on waste-to-energy for the valorization of industrial wastes: Electricity, heat and cold, bioliquids and biofuels. *Environmental Nanotechnology, Monotoring & Management,* 17, 100615.

Gómez-Garcia, R., Campos, D. A., Aguilar, C. N., Manureira, A. R., & Pintado, M. (2020). Valorization of melon fruit (*Cucumis melo* L.) by-products: Phytochemical and Biofunctional properties with Emphasis on Recent Trends and Advances. *Trends in Food Science &Technology,* 99, 507-519.

Gottardi, D., Siroli, L., Vannini, L., Patrignani, F., & Lanciotti, R. (2021). Recovery and valorization of agry-food wasted and by-products using the non-conventional yeast *Yarrowia lipolytica*. *Trends in Food Science &Technology,* 115, 74-86.

Guttierez-Hernandez, C. A., Hernandez-Almanza, A., Hernandez-Beltran, J. U., Balagurusamy, N., & Hernandez-Teran, F. (2022). Cheese whey valorization to obtain single-cell oils of industrial interest: An review. *Food Bioscience,* 50, 102086.

Ilyas, T., Chowdhary, P., Chaurasia, D., Gnansounou, E., Pandey, A., & Chaturvedi, P. (2021). Sustainable green processing of grape pomace the production of value -added products: An overview. *Environmental Technology & Innovation,* 23, 101592.

Javourez, U., O Ḋonohue, M., & Hamelin, L. (2021). Waste-to-nutrition: a review of current and emerging conversion pathways. *Biotechnology Advances,* 53, 107857.

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikainen, J., Saikku, L., & Schosler, H. (2016). Transition towards Circulare Economy in the Food System. *Sustainability, 8* (69), 1-14.

Karimi, A., Kazemi, M., Samani, S. M., & Simal-Gandara, J. (2021). Bioactive compounds from by-products of eggplant: Functional properties, potential applications and advances in valorization methods. *Trends in Food Science & Technology,* 112, 518-531.

Kasani, A. A., Esmaeilli, A., & Golzary, A. (2022). Software tools for microalgae biorefineries: Cultivation, separation, conversion process integration, modeling, and optimization. *Algal Research,* 61, 102597.

Kotecka-Majchrzak, K., Sumara, A., Fornal, E., & Montowska, M. (2020). Oilseed proteins - Properties and applications a food ingredient. *Trends in Food Science & Technology, 106, 160-170.*

Kumar, V., Sharma, N., Umesh, M., Selvaraj, M., Al-Shehry, M., Chakraborty, P., Dugan, L., Sharma, S., Pasrija, R., Awasthi, M. K., Ramakrishna, Lakkaboyana, S., Andler, R., Bhatnagar, A., & Maitra, S. S. (2022). Emerging challenges for the agro-industrial food waste utilization: A review on food waste biorefinery. *Bioresiurce Technology,* 362, 127790.

Lai, W. T., Khong, N. M. H., Lim, S. S., Hee, Y. Y., Sim, B. I., Lau, K.I., & Lai, O. M. (2017). A review: Modified agricultural by-products for the development and fortification of food products and nutraceuticals. *Trends in Food Sciences &Technology,* 59, 148-160.

Lamolinara, B., Perez- Martinez, A., Guardado-Yordi, E., Fiallos, C. G., Dieguez-Santana, K., & Ruiz-Mercado, G. J. (2022). Anaerobic digestate management, environmental impacts, and techno-economic challenges. *Waste Management,* 140, 14-30.

Lavelli, V. (2021). Circular food supply chains-Impact on value addition and safety. *Trends in Food Science & Technology,* 114, 323-332.

Li, M. & Wilkins, M. R. (2020). Recent advances in polyhydroxyalkanoate production: feedstocks, strains and process developments. *Int. J. Biol. Macromol.,* 156, 691-703.

Liang, Z., Zhang, P., Xiong, Y., Johnson, S. K., & Fang, Z. (2023). Phenolic and carotenoid characterization of ethanol extract of an Australian native plant *Haemodorum spicatum. Food Chemestry,* 399, 133969.

Liu, R. H. (2013). Health-promoting components of fruits and vegetables in the diet. *Advances in Advances in Nutrition, 4(*3)*,* 384S–392S.

Macintyne, K. & Dobson, B. (2017). Geophagy: The earth-eaters of lower Southwestern Australia. https://anthropologyfromtheshed.com/project/geophagy-the-earth-eaters-of-lower-southwestern-australia/.

Misci, C., Taskin, E., Vaccari, F., Dall' Asta, Imathiu, S., Cocconcelli, P. S., & Puglisi, E. (2022). Valorization of *Afrixa ingigenous* leafy vegetables: The role of phyllosphere microbiota. *Food Research International,* 162, 111944.

Moro, K. I. B., Bender, A. B. B., Ferreira, D. F., Speroni, C. S., Bain, J. S., Picolli da Silva, L., & Penna, N.G. (2021). Recovery of phenolic compounds from grape pomace

(*Vitis vinifera* L.) by microwave hydrodiffusion and gravity. *LWT-Foof Science and Technology,* 150, 112066.

Nagarajan, A., Goyette, B., Vijaya, R., Bhaskar, A., & Rajagopal, R. (2023). Nutrient recovery via struvite production from livestock manure-digestate streams: Towards closet loop bio-economy. *Process Safety and Environmental Protection,* 171, 273-288.

Palvic, B., Acimovic, M., Sknepnek, A., Miletic, D., Mrkonjiv, W., Kljakic, A. C., Jerkovic, J., Misan, A., Milica, P., Stupar, A., Zekovic, Z., & Teslic, N., (2023). Sustainable raw materials for efficient valorization and recovery of bioactive compounds. *Industrial Crops & Products, 193, 116167.*

Pfeifer, K., Ergal, I., Koller, M., Basen, M., Scuster, B., & Rittmann, S. K. M. R. (2021). Archaea Biotechnology. *Biotechnology ADVANCE,* 47, 107668.

Renard, C. M. G. C. (2018). Extraction of bioactives from fruit and vegetables: State of the art and perspectives. *LWT-Foos Science and Technology,* 93, 290-395.

Rodriguez-Martinez, B., Romani, A., Eibes, G., Garrote, G., Gullon, B., & del Rio, P. G. (2022). Potential and prospects for utilization of avocado by-products in integrated biorefineries. *Food Bioscience,* 47, 101781.

Sabater, C., Calvete-Torre, I., Villamiel, M., Javier Moreno, F., Margolles, A., & Ruiz, L. (2021). Vegetable waste and by-products to feed a healthy gut microbiota: Current evidence, machine learning and computational tools to design novel microbiome -targeted foods. *Trends in Food Science & Technology,* 118, 399-417.

Sar, T., Harirchi, S., Ramezani, M., Bulkan, G., Akbas, M. Y., Pandey, A., & Taherzadeh, M. J. (2021). Potential utilization of dairy industries by-products and wastes through microbial processes: A critical review. *Sci. Total Environ.,* 152253.

Saratale, R. G., Cho, S. K., Saratale, G. D., Kadam, A. A., Ghodache, G. S., Kumar, M., Bharavaga, R. N., Kumar, G., Kim, D. S., Mulla, S. I., & Shin, H. S. (2021). A comprehensive overview and recent advances on polyhydoxyalkanoates (PHA)production using various organic waste streams. *Bioresource Technology,* 325, 124685.

Sari, T. P., Sirohi, R., Krishania, M., Bhoj, S., Samtya, M., Duggal, M., Kumar, D., & Budgujar, P. C. (2022). Critical overview of biorefinery approaches foe valorization of protein rich tree nut oil industry by-product. *Bioresource Technology,* 362, 127775.

Singh, P., & Krishnaswamy, K. (2022). Sustainable zero-waste processing system for soybeans and soy by-product valorization. *Trends in Food Science & Technology,* 128, 331-344.

Srivastava, R. K., Shetti, N. P., Reddy, K. R., Nadagouda, M. N., Badawi, M., Bonilla-Petriciolet, A., & Aminabhavi, T.M. (2023). Valorization of biowastes for clean energy production, environmental depollution and soil fertility. *Journal of Environmental Management,* 332, 117410.

Stadler, T., & Chauvet, J. M. (2018). New innovative ecosystems in France to develop the Bioeconomy. *New Biotechnology,* 40, 113-118.

Surendra, K.C., Tomberlin, J. K., Van Huis, A., Cammack, J. A., Heckmann, L. H. L., & Khanal, S. K. (2020). Rethinking organic wastes bioconversion: Evaluating the potential of the black soldier fly (*Hermetia illucens* (L.)) (Diptera: Stratiomyidae) (BSF). *Waste Management,* 117, 58-80.

Szpicer, A., Onopiuk, A., Barczak, M., & Kurek, M. (2022). The optimization of a gluten-free and soy-free plant-based meat analogue recipe enriched with anthocyanins microcapsules. *LWT-Food Sciences and Technology,* 168, 113849.

Tavera-Ruiz, C., Marti-Herrero, J., Mendieta, O., Jaimes-Estevez, J., Gauthier-Maradei, P., Azimov, U., Escalante, H., & Castro, L. (2023). Current understanding and perspectives on anaerobic digestion in developing countries: Colombia case study. *Renewable and Sustainable Energy Reviews,* 173, 11397.

Tesfaye, T., Ayele, M., Gabril, M., Ferede, E., Limeneh, D. Y., & Kong, F. (2022). Beneficiation of avocado processing industry by-products: A review on future prospect. *Current Research in Green and Sustainable Chemistry,* 5, 100253.

Ubando, A. T., Felix, C. B., & Chen, W. H. (2020). Biorefineries in circular bioeconomy: A comprehensive review. *Bioresurce Technology,* 299, 122585.

Usmani, A., Sharma, M., Diwan, D., Tripathi, M., Whale, E., Jayacody, L. N., Moreau, B., Thakur, V. K., Touhy, M., & Gupta, V. K. (2022). Valorization of sugar beet pulp to value-added products: A review. *Bioresource Technology,* 346, 126580.

Usmani, Z., Sharma, M., Tripathi, M., Nizami, A. S., Gong, L., Nguyen, Q. D., Reddy, M. S., Thakur, V. K., & Gupta, V. K. (2023). Converting biowaste streams into energy-leveraging microwaste assisted valorization technologies for enhanced conversion. *Journal of the Energy Institute,* 207, 101161.

Veneziani, G., Novelli, E., Esposto, S., Taticchi, A., & Servili, M. (2017). *Applications of recovered bioactive compounds in food products*. In: Charis M. Galanakis, editors: Olive Mill Waste, Oxford; Academic Press, p.231-253.

Vicente, F. A., Urbancic, V., Licozar, B., Simoes, P. N., & Pereira, J. F. B. (2023). Aqueous biphasic systems as a key tool for food processing. *Science Direct. Current Opinion in Food Science,* 50, 100991.

Zhang, T. Dou, W., Zhang, X., Zhao, Y., Zhang, Y., Jiang, L., & Sui, X. (2021). The development history and recent updates on soy protein-based meat alternatives. *Trends in Food Science &Technology,* 109, 702-710.

Zioga, E., Tostesen, M., Madsen, S. K., Shetty, R., & Bang-Berthelsen, C. H. (2022). Bringing plant-based Cli-meat closer to original meat experience: insights in flavor. *Future Foods,* 5, 100138.