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DIETARY FIBER EXTRACTION FROM AGRICULTURAL RESIDUES AND AGROINDUSTRIAL WASTE WITH EMERGING TECHNOLOGIES: A SYSTEMATIC REVIEW

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SUMMARY

The wastage of food items emerges as a critical concern impacting both food security and the economy. Additionally, it contributes to environmental degradation and climate change. Valorizing food waste and investigating its new potential uses in the food business and beyond may help to manage these issues. Bioactive components or dietary fibers are food trash types often useful as crude resources. Apple pomace and citrus peel are regular sources of dietary fibers, particularly pectin. Recently developed food waste streams and by-products are now considerable potential nutritional fiber sources. Hence, a need to restrict traditional procedures requires using unique extraction approaches. Past studies on the dietary fiber extraction from agricultural leftovers are central discussions in this manuscript. A comprehensive review commenced using different databases, including Science Direct and Scopus. Out of 308 scientific publications, 10 fundamental studies on the extraction techniques 'ultrasound' and 'microwave' were choices after filtering the data. With a focus on reevaluating agricultural residues for utilization in food, biotechnology, and medicines, these vital studies explored the effects of dietary fiber extraction techniques.

Keywords: Food waste, fibers, ultrasound, microwave, agro-industry, food security, environmental pollution, climate change

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Key findings: Plant-based wastes have served for nutritional fiber extractions through various techniques. Depending on plant resources, future researchers and industry might benefit by exploring and using favorable extraction procedures with ideal circumstances. By reevaluating agricultural residues for utilization in food, biotechnology, and medicines, these decisive studies identified various techniques used for the extraction of dietary fibers.

INTRODUCTION

Food production, including fruits, vegetables, and tubers, becomes a massive agricultural waste. Organic materials, such as leaves, stems, shells, and straws, are plant parts and agricultural waste produced during various farming processes (Pathania and Kaur, 2022). Typically, crop stubbles and remnants are unused surplus being burned or left in fields, which cause pollution concerns due to improper disposal (Porichha *et al*., 2021). The carbohydrate, known as dietary fiber, also exists in plant-based meals, such as fruits, vegetables, legumes, and cereals. Dietary fiber also serves as an ingredient in food and seems connected to soluble and insoluble fibers (Pathania and Kaur, 2022).

Conventional extraction methods have disadvantages for many reasons. Their adoption of green technologies has hard advantages. In the extraction process, these techniques also eliminate and reduce energy consumption using solvents eutectic greens (ethanol, ethanol with water, ethanol + glycerol, and ethanol + acid glacial acetic). For improving the performance of fiber dietetics, the potential main techniques, like ultrasound-assisted extraction (UAE), microwaves (EAM), pressurized liquids (ELP), and supercritical fluids, are practical and are also environment-friendly.

This review sought to publicize the application of green extraction technologies, emphasizing the techniques of UAE and EAM to obtain dietary fibers from agricultural wastes. Likewise, focusing on these techniques for performance improvement, which are also economical and environment-friendly. A general question states, "What are the emerging technologies used in plant fiber extraction from agricultural residues?" For this reason, the review focused on the following objectives: a) to present the theoretical characteristics of emerging technologies and dietary fibers and b) to analyze the most relevant contributions of emerging technologies used in vegetable fiber extraction from agricultural residues.

The document structure derives from the statement of objectives, and the methodology used in the past review process follows below. Subsequently, the results section aims to achieve the goals based on the selected articles. Finally, the discussion and conclusions on applying the most common emerging technologies in dietary fiber extraction from agro-industrial wastes is an outcome.

METHODOLOGY

According to PRISMA (Preferred Reporting Items for Systematic Review of DNA Meta-Analysis Structure) criteria, the relevant articles underwent evaluation and assessment at different stages for their suitability in the presented study. They also picked the measures, and the articles meeting the needs are available in Figure 1.

Strategy of search and selection of studies

The presented research began by searching and evaluating the data obtained from the Scopus and Science Direct databases. At the start of data gathering, 766 articles emerged, with 185 belonging to Scopus and 581 to the Science Direct database. Fourteen of the research articles' assessments used the Quality and Methodological framework, while 26 underwent inclusion and exclusion criteria. Figure 1 also shows a schematic analysis of the research articles and their sorting process regarding their inclusion and exclusion flows in the current study.

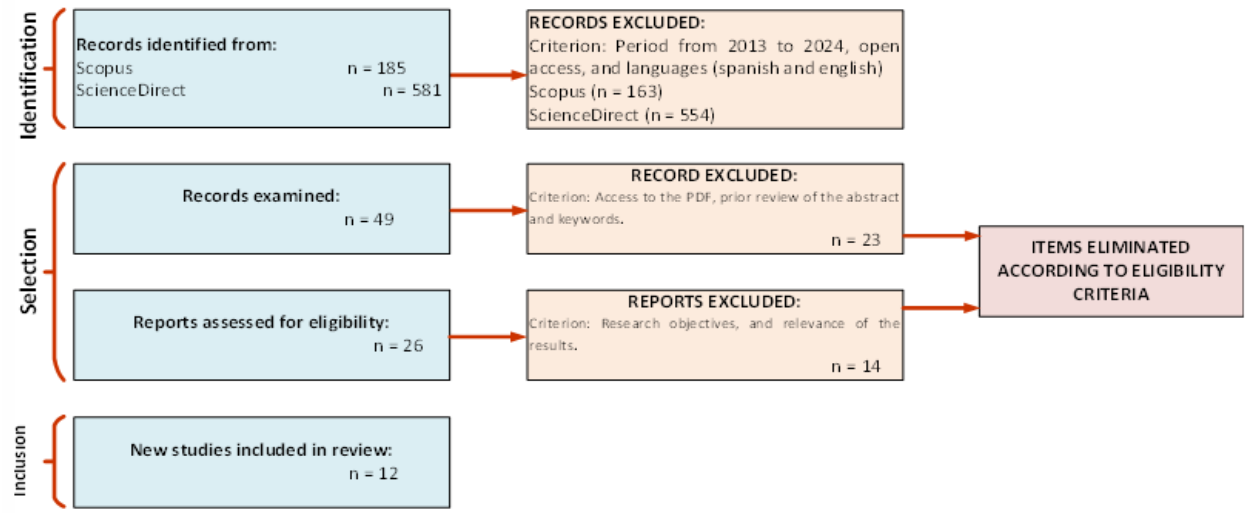

Figure 1. Process of selection of studies.

Review of detailed literature: Strategy of search and criteria of selection

At present, searching electronic databases is the most favorable method; nonetheless, it lacks strategy. Given the existence of a database overlap, the solution was straightforward (Grijalva *et al.,* 2019). Dietary fibers, fiber extraction, emerging technology, ultrasound method, microwave method, agricultural residues, and food waste were some English-language keywords utilized to find relevant content in the concerned databases. Their Writings Full texts retrieval continued from Scopus electronic database, Us and Science Direct, in various scientific journals published between 2014 and 2023.

Evaluation of the methodological quality

Criteria of inclusion

Research that met the following criteria was a sample in the study.

- Techniques for obtaining dietary fiber: two approaches to enzymatic and sound pre-treatment with ultrasound and microwaves were previously used techniques primarily to study agricultural waste to acquire dietary fibers.
- The long-awaited guy of the result: ultrasound, microwave, and other technologies were considerations in the subsequent review volume on dietetic fiber studies.

Criteria of exclusion

Not all things became samples. The phenological circumstances of these experiments with fertilizer level were different from those of vegetables, fruits, and other foods. Therefore, it is a must to pray for them i) Notes, ii) Health or Medicine Studies, and iii) publishing date.

Examination of their data

The information about each retrieved research article employed reading the whole text and then extracting it into a single standardized data leaf. The included articles in the presented research reached evaluation using the PRISMA criteria.

Reconciling information

The findings depended on the systematic review by compiling all the included qualitative research into one table detailing each study's methodology. The entered findings came from selected research articles.

RESULTS AND DISCUSSION

Theoretical characteristics of emerging technologies and dietary fiber

On intensive evaluation, 10 studies appeared effective in using microwave (EAM) and ultrasound (UAE) techniques to obtain dietary fiber as a byproduct from agricultural waste. The latest systematic review that examined rum to studies focused on the extra action of dietary fibers proceeded (Ismaiel *et al*., 2022; Mahmood and Jaafar, 2024). These past studies determined the use of microwave and ultrasound techniques for nutritional supplements that improve the performance and physical and chemical properties while accounting for temperature and temporal parameters (Li *et al.,* 2022). Furthermore, the research enunciated that technological approaches proved more successful by using vegetable wastes. These studies specifically focus on the methodology of dietary fiber extraction, ensuring the method's applicability in fibers (Table 1).

Ultrasound

Ultrasound relies on the propagation of mechanical waves formed by combining high and low pressures, known as compression and rarefaction. The key driving force behind ultrasonic extraction is acoustic cavitation, which generates compression and expansion in the solvent molecules. It eventually resulted in the formation of bubbles as a consequence of variations in temperature and pressure (Shirsath *et al.,* 2012). Agro-industrial waste (oat shell, soy, and coffee) was a specimen to evaluate fiber dietetics with a combined hydrothermal-chemical approach, which proved an efficient way to develop NuEvos Ingredients Like La Fibers (Silva *et al.,* 2022). On the other hand, dietetics extraction engaged various techniques, such as acid treatments, alkaline and enzymatic treatments, microwave, and enzymatic combination extraction, displaying the yields and their impact on their features and functional properties (Zhang *et al.,* 2023).

Microwave

Microwave-assisted extraction (MAE) comprises electromagnetic waves and a variety of factors, such as irradiation time, power, nature of the solvent, temperature, and the solvent and plant material ratio. A transcendental interaction is the radiation that heats the water containing the cells, breaking the cell wall, allowing the substances to move outside and the solvent to enter the plant matrix (Dahmoune *et al.,* 2014).

Electrical pulses

A non-thermal processing technology exists based on applying short, high-voltage pulses using electrodes. This method causes a phenomenon called electroporation (it forms openings in the cell envelopes through which the components of interest located in the cell can exit inside the cells) (Huang *et al.,* 2012).

Dietary fibers

It is the consumable portion of plants called analogous carbohydrates that resist digestion and absorption in the small intestine. However, these carbohydrates can undergo total and sometimes partial fermentation in the large intestine (Escudero and González, 2006).

Extraction of dietry fibers from agricultural waste

The systematic review also revealed that there are studies that concentrated on the methods of fiber extraction, dietetics, and the removal of waste from vegetables and agricultural products. For them, the fiber extraction methods correspond to 30 studies that met the inclusion and exclusion criteria (Table 2). These studies proceeded per the criteria.

Dietary fibers materialized in farm waste through an intricate process. Using techniques for dietary fiber extraction from plants include microwaves and ultrasonic waves. It concentrates on the methodology of two approaches and the use of alkaline, acidic,

Table 1. Methods of extraction of fiber dietetics from agricultural waste.

No.	Title	Authors	Guy of study	Population of study	Methods
1	A Study Comparative About the Extraction and the Properties Physicochemicals of Fiber Dietetics Soluble of the Rice Bran Glutinous Using Different Methods	Hu *et al.* (2022)	Study of Case Y Control	Bran of Rice Glutinous	Extraction with hot water and enzymatic treatment assisted for ultrasound
2	Extraction of Fiber Dietetics and Phytochemicals of Seeds of Pumpkin of Bottle (*Lagenaria siceraria*), its Properties Physicochemical Application	Devi *et al.* (2023)	Study of Case Y Control	Seeds of Pumpkin	Extraction Alkaline (AED), Enzymatic (EEDF) and Alkaline Assisted for Ultrasound (UAE)
3	Effects of Different Treatments About the Composition, Properties Physicochemical, Biological of the Fiber Dietetics Soluble in Bran of Buckwheat	Ma *et al.* (2023)	Study of Case Y Control	Bran of Wheat Saracen	Extrusion, explosion of steam, microwave, toasted, steam overheated, ultrasound and enzymolysis
4	Effect of Dietary Fiber AC of Celery Extracted In Dressings for Salads Low in Calories with Probiotics	Tanganurat *et al.* (2023)	Study of Case Y Control	Celery	Extraction using water, alkaline (NaOH), enzymes and ultrasound
5	Characterization of the Properties Structural, Physicochemicals Y Functional of Fibers Dietetics Soluble Obtained A to leave of La Peanut Peel by Means of Different Methods of Extraction	Wang *et al.* (2023)	Study of Case Y Control	Shell of Peanut	Method of extraction= Enzymatic (E-SDF), Extraction For Microwave (M-SDF)
6	Impact of The Methods of Extraction About the Functional Properties and La Kinetics of Extraction of La Fiber Dietetics Insoluble of the Wow! of Green Peas: A Comparative Analysis	Kumari *et al.* (2022)	Study with Comparative Analysis	Shell of Green Peas (GPP)	Extraction Alkaline, Extraction Assisted for Ultrasound and Method of Extraction Alkaline Assisted for Ultrasound (ODF)
7	Applying Ultrasound-Assisted Processing to Obtain Cellulose Fibres from Rice Straw to Be Used As Reinforcing Agent	Freitas *et al.* (2022)	Study of Case Y Control	Rice straw	Ultrasound-heating method
8	Influence of methods of Modification on the Properties Physicochemicals Y Structural of La Fiber Dietetics Soluble A To leave of Bran of Corn	Li *et al.* (2022)	Study of Case Y Control	Salvado of Corn	Extraction Enzymatic Combine Harvester of Double Screw, Double Screw Enzymatic, Ultrasonics and Ultrasonics Combine harvester of the Methods with Hydrolysis Enzymatic Dual.
9	Fractions Delicious in Fiber Dietary isolated from stems of Broccoli Like IngrediEntity Functional Potential with compounds Phenolic Y Glucosinolates	Núñez- Gómez *et al.* (2022)	Study of Case Y Control	Stems of Broccoli	Extraction with ethanol and water
10	Valorization of pineapple waste for the extraction of bioactive compounds and glycosides using autohydrolysis	Sepúlveda *et al.* (2018)	Study of Case Y Control	Pineapple	Autohydrolysis
11	Optimization of La Extraction Enzymatic AsisTida by Ultrasound of Arabinoxylan A To leave of Bran of Wheat	Wang *et al.* (2014)	Study of Case Y Control	Wheat bran	Technology of extraction enzymatic assisted for ultrasound
12	Optimization of La Preparation Assisted For Ultrasounds of FiBra Dietetics A To leave of Pericarp of Corn Using La Methodology of Surface of Answer	Wang *et al.* (2014)	Study of Case Y Control	Corn pericarp	Surface of answer for ultrasound

Source: Own Preparation

Table 2. Methods of fiber dietetics extraction from various sources.

Authors & Year	Journal	Title	Samples	Methods
Lúcia-Silva-Oliveira *et al.* (2022.)	Technology In Nutrition and Science of Them Food	Effects Positive of La Fiber Dietetics A PartiR of Wow! of Sweet potato [Ipomea Sweet potatoes(L.) Lam.] Through Different Methods of ExtractionAbout TheMicrobiotaFecal Human Through Fermentation In Vitro	Shell of sweet potato	Hot water methods, Microwave, Ultrasounds and Water Sub-criticism
Fuso *et al.* (2023)	Foods	Extraction Soft Assisted For Protease of Fiber Soluble Y Protein of By-products Of Fruits: One Perspective of Biorefinery	Seeds/grai n	Extraction Assisted For Enzymes Soft (EAE)
Zhang *et al.* (2023)	Elsevier	Effects of Three MÉtodos of Extraction About The Properties Structural Functional of Fibers Dietetics Insoluble A To leave of Mycoproteins	Mycoprotei ns	Treatments enzymatics, acids and alkaline
Fidriyanto *et al.* (2023)	Food Prod Process Nutr	Analysis MultivaRiado of Properties Structural Y Functional of Fibers of Marc of Apple Using Different Methods of Extraction	Marc of Apple	Extraction (water hot, acid and alkali)
Li *et al.* (2014)	Journal of Food Engineering and Processes	Extraction And functional properties of the water-soluble dietary fiber of apple pomace	Apple pomace	Cellulase, microwave and ultrasound-assisted method
Li *et al.* (2022)	Food Y Function	Comparison of the Properties of Digestion Structural, FuncIonal E*In vitro* of bread incorporated with soluble dietary fibers of Prepared pamenut peel For three modifications assisted by Microwave	Shell of Grapefruit	Treatment with microwave and Hydroxide of Sodium SDF (MST-SDF), the Treatment Enzymatic with a microwave SDF (MET-SDF) and the Treatment with Microwave Treatment Ultrasonic SDF (MUT-SDF).
Spadoni and Karboune (2020)	Journal of Food Science	Comparison of Approaches of Extraction Alkaline Enzymatic Y Microwave-assisted for the generation of oligosaccharides A To leave of Marc of Blueberry American (*Vaccinium Macrocarpon*)	Marc of Blueberry American	Method alkaline assisted for microwave
Peng *et al.* (2021)	LWT	The combined treatment of microwave and enzymatic Improvement La LiberAtion of Compounds Phenolic United Insoluble of the insoluble dietary fiber of the shell of Grapefruit	Shell of Grapefruit	Extraction for Microwave (M-BP), Hydrolysis Enzymatic (E-BP) and Treatment Team of Microwave and Enzymes (ME- BP)
Lai *et al.* (2015)	Magazine of La Association China of Cereals Y Oils	Technology of Extraction Enzymatic Assisted For Ultrasound of dietary fiber from residues of Sweet potato	Residue of Sweet potato	Method enzymatic assisted for ultrasound
Shao *et al.* (2014)	Frontiers of Agriculture In China	Extraction of soluble dietary fiber and hemicelulose from of Waste *of Cornus Officinalis*Y Preparation of Water Drinkable With fiber	Residues of *Cornus Officinalis*	Methodology of Surface of Answer
Ma *et al.* (2023)	Bioscience Food	Effects of Different Treatments About La Composition, Properties PhysicalUímicas Y Biological of La Fiber Dietetics Soluble In bran of Wheat Saracen	Bran of Wheat Saracen	Treatments that include Extrusion, Explosion of Steam, Microwave, Toasted, Steam Overheated, Ultrasound Y Enzymolysis,
Dhar and Deka (2022)	Journal of Food Process Engineering	Effect of the Extraction Assisted For Ultrasounds of Fiber Dietary from the residues of pineapple Queen variety more Sweet Of Tripura (India)	Waste of Rose What Een	Method of Extraction Alkaline Traditional and Surface of RespUesta
Singh *et al.* (2022)	Journal of Food Processing DNA Preservation	Effect of La Extraction Assisted For Ultrasound of Fiber Dietetics of La Shell of Rose Y His Application With Rice NEGro Rich In anthocyanins	Shell of Rose	Extraction assisted for Ultrasound
Ma *et al.* (2023)	Bioscience To theImentaria	Effects of Different Treatments About La Composition, Properties Physicochemicals Y Biological of La Fiber Dietetics Soluble In bran of Wheat Saracen	Bran of Wheat Saracen	Treatments that include Extrusion, Explosion of Steam, MicrOondas,Toasted, Steam Overheated, Ultrasound and Enzymolysis

Source: Own elaboration

and enzymatic therapies. Generally, these methods have both positive and negative effects on the agro-industry residues and their characteristics. Additionally, to extract dietary fibers from plant residues and food, it is vital to conduct a thorough phenological and structural analysis of all of the product's components. It will further ensure that the methods were effectively applicable and minimize the errors associated with their extraction (Table 1).

CONCLUSIONS

The study found that ultrasound technology was most effective in dietary fiber extraction. Similarly, compared with microwave technology, the process is significantly superior in extracting dietary fibers from cereals, fruits, and vegetables. Additionally, it is quite simple to incorporate into cereals, fruits, and vegetables. The study also found that eutectic solvents are more practical and less harmful to the environment than other solvents.

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