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# Green Food Processing Techniques: A Review

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***ABSTRACT: The significance of new food processing methods in supporting a sustainable food business is discussed in this study. These methods in the frontiers of food processing, food chemistry, and food microbiology (such as microwave, ultrasound, pulse electric field, Instant controlled pressure decrease, and supercritical fluid processing) are not new and have been utilized by academics and industry for more than 30 years. We'll focus on the methods and instruments available to make preservation, transformation, and extraction more environmentally friendly, and showcase them as research, education, and industrial success stories. Green and sustainable process design is a popular study subject in the food business right now. We intended to present a multidimensional approach (new technologies, process intensification, and the bio-refinery idea) for implementing this concept at the scientific, educational, and industrial levels in this paper.***

***KEYWORDS: Extraction, Green Food Processing, Innovative Techniques, Preservation, Transformation.***

## 1. INTRODUCTION

Fruits and vegetables, fats and oils, sugar, dairy, meat, coffee and chocolate, meal and flours, and other organic and mineral compounds are all complex combinations of vitamins, carbohydrates, proteins and lipids, fibers, smells, colors, antioxidants, and other organic and mineral compounds. Such goods must first be processed and stored for ready-to-eat meals, as well as extracted for food components, before they can be commercialized. This may be accomplished via a variety of techniques, including frying, drying, filtering, and cooking. Many food components and products, however, are known to be thermally sensitive and susceptible to chemical, physical, and microbiological alterations[1]. These traditional food-processing techniques may result in the loss of certain nutritious components, poor production efficiency, and time- and energy-consuming operations (prolonged heating and stirring, use of huge quantities of water, etc. These flaws have led to the use of new sustainable "green and innovative" techniques in processing, pasteurization, and extraction, such as ultrasound-assisted processing, supercritical fluid extraction and processing, microwave processing, controlled pressure drop process, and pulse electric field, which typically require less time, water, and energy[2].

The enormous efforts spent on greening the food process may be assessed by looking at publications and periodicals dedicated to these topics. In applied research and industry, food technology in severe or non-classical circumstances is presently a rapidly developing field. By reducing the use of water and solvents, eliminating wastewater, conserving fossil energy, and reducing the generation of hazardous substances, alternatives to traditional processing, preservation, and extraction procedures may improve production efficiency and contribute to environmental preservation[3]. Green Food Processing, based on green chemistry and green engineering, must be implemented within those constraints: Green Food Processing is based on the discovery and design of technological processes that save energy and water, enable by-product recycling via bio-refinery, and guarantee a safe and high-quality result[4].

This study provides a comprehensive overview of current information on green food processing methods for preservation, transformation, and extraction as research, education, and industry success stories. The major solutions identified to design and demonstrate green food processing on a laboratory, classroom, and industrial scale to approach an optimal consumption of raw food materials, water, and energy will be found by readers such as chemists, biochemists, chemical engineers, physicians, and food technologists, whether from academia or industry. is filled with steam and pressured to a processing level[5]. The controlled pressure-drop valve is instantly opened in less than 200 ms after this treatment time, resulting in a sudden pressure decrease within the treatment vessel. After the steam is released, the reactor's air pressure is restored. DIC treatment is used in a variety of industries, including food, cosmetics, and pharmaceuticals, to address problems of control and quality enhancement while lowering energy costs. DIC is useful for a variety of tasks, including transformation, preservation, and extraction. For each operation, the method has always encouraged the integration of instantaneous phenomena in order to enhance the fundamental transfer processes[6].

When the kinetics of dehydration are especially poor owing to difficulties of water transfer through material due to resistance of the inherent structure of the material, the DIC treatment coupled with traditional hot air drying may be regarded as a technique for accelerating the drying. A three-stage spray-drying method that uses DIC treatment of powders sodium castigates, way proteins and saturated steam as a texturing fluid to allow for the alteration of powder granule structure as well as the creation of vacuoles and holes. DIC improves the specific surface area of spray-dried powder, which eliminates the difficulties associated with fine powder dustiness[7]. The use of DIC treatment to increase granule powder of heat-sensitive foods like apple and onion seems to be a viable option. Following a partial drying phase, DIC treatment improves the dehydration kinetics by including a texturing process that allows the partly dried product to be enlarged. The second drying phase after DIC treatment is cut in half, from 6 hours for an untreated apple to 1 hour for a treated sample.

The effective diffusivity of onion is increased following DIC treatment. At the same water content 100 percent. DIC pretreatment with a pressure of 0.1 to 0.3 MPa and a brief heating duration of a few seconds (5 to 45 s) coupled with freezing and thawing improves apple drying/rehydration operations with excellent textural preservation[8]. DIC is an excellent alternative to traditional hot air drying and freeze-drying, particularly for drying delicate fruits like strawberries. Furthermore, DIC combined with hot air drying preserves nutritional value and bioactive molecules. When compared to other traditional drying techniques, treated strawberries were richer in anthocyanins and phenolic compounds under optimum DIC settings (0.35 MPa for 10 s). DIC is acknowledged as a decontamination and debacterization method for foodstuffs. This application is protected by three patents. The technique enables DIC to eliminate microorganisms even in spore form via two primary mechanisms: a regulated heat treatment and pressure relaxation, which causes microorganisms to explode. Archaeological excavations often rejuvenate wood that has spent a long time in water usually saltwater. The DIC treatment may reverse these effects and stabilize the archeologically waterlogged woods from various museums[9].

When allergens in peanuts, lentils, chickpeas, and soybean proteins are thermally treated, DIC treatment results in a decrease in total in vitro IgE binding with a 3minute treatment at 6 bar, the immune reactivity of soybean proteins was nearly completely eliminated. Furthermore, DIC treatment (0.4 MPa for 25 seconds) reduced the lgE binding of whey proteins (ß-lacto globulin and -lactalbumin) and reduced the allergenicity of whey proteins. Combining PEF treatment with additional treatments (heat, pH, antimicrobial) may be beneficial depending on the desired inactivation, target, product composition, and starting temperature. Such combinations may be able to provide the necessary lethality while using less electrical energy and a lower field strength. Bacterial spores can withstand severe conditions for extended periods of time due to their stiff architecture. Temperature and electric fields greater than 60°C and 30 kV/cm, respectively, were efficient in inactivating spores. When compared to heat treatment, PEF seems to have the advantage of affecting less nutritional and sensory characteristics of food materials. In comparison to heat pasteurization, PEF-treated drinks seem to have more polyphenols, carotenoids, and vitamins[10].

## 2. DISCUSSION

Food preservation is often done via freezing. Unfortunately, such treatment causes food texture and taste to deteriorate throughout later transformation processes. The creation, size, and recrystallization of crystals after freezing are the primary causes of frozen food quality degradation. Because of the temporary increase in membrane permeabilization caused by reversible electroporation, cryoprotectants may be introduced into biological cells. During freezing, this class of molecules prevents the production of crystals. The freezing/thawing process is noticeably accelerated as a result of this combination. Dehydration is one of the oldest methods for preserving food. During the drying of food matrices, undamaged cell membranes in food materials serve as a very restricting factor barrier to water transfer. The creation of pores after PEF treatment improves cell membrane permeability, which promotes mass transfer. Traditional methods such as osmotic dehydration, freeze drying, radiant and convective heat were effectively coupled with PEF treatment.

The findings are promising since the combination of PEF and osmotic dehydration caused an increase in water loss and solute migration into the food matrix. Extraction of molecules of industrial interest using solvents diffusion and force fields (pressing, filtration, and centrifugation) is extensively employed in the manufacture of liquid meals and drinks. Mass transfer is aided by pretreatments that alter the permeability of cell membranes, such as grinding, heating, or enzymatic treatment. However, these methods may use a lot of energy and result in the loss of important dietary components. In this area, the use of PEF has become extremely popular since it allows for crucial acceleration of the solid–liquid extraction. When PEF is used, various agro-industrial extraction methods become more selective and energy efficient. Other approaches to improve transformation processes have been suggested in recent years, in addition to preservation and extraction applications. PEF has been used to improve the mechanical removal of unwanted food components. Skin removal from certain fruits (tomato, mango, etc.) produced results comparable to steam peeling but with less energy input.

The number of uses for pulsed electric fields is growing all the time. As dependable pulse modulators and tum-key systems, new concepts are being tried in the lab and on an industrial scale. New PEF equipment manufacturers, such as Elea, Steribeam, Scandinova, and Pure Pulse, have recently arisen in Germany, Sweden, and the Netherlands, showing the food industry's increasing interest in the technology's use. IXL Netherlands B.V. sells a cooking equipment called Nutri-Pulse e-Cooker that claims to be capable of preparing food using electroporation and pulse ohmic heating, which results in improved preservation of the original nutritional content as well as the original flavor, color, structure, and taste. There are two kinds of equipment settings for extraction and fractionation.

Autoclaves are used to extract supercritical fluids (SFE) from solid materials industrial units may be composed of several autoclaves for semi-continuous processing. Countercurrent columns are used for liquid fractionation with SCF for continuous processing. SCF extraction systems for solid processing are made up of four basic components: I a volumetric pump, which may be preceded by a cooler to convert the gaseous component into a liquid condition, (ii) a heat exchanger, (iii) an extractor, where pressure is created and maintained by a back pressure regulating valve, and (iv) a separator. To accomplish repeated fractionation of the molecules, present in the extracts, up to three separators may be connected in series.

The extraction and separation of the solute from the solvent are the two major stages in SCF extraction from solids. The fluid must be brought to a supercritical condition before SFE can be performed. Before entering the extractor, the fluid is typically compressed and heated in order to accomplish this. The SCF percolates in the extractor with an ascending or descending flow after being brought to the appropriate pressure and temperature. The SCF is used to extract the solute from the matrix. The solute will be separated from the SCF in the separator, where the SCF will become gaseous and the solute that is no longer solubilized in the SCF will be separated by gravity. As a result, the extracts accumulate in the bottom of the separator. The gas may be recycled by re-injecting it into the system or discharged into the atmosphere, depending on the equipment. For many years, industrial processing using SCF has been a reality.

A large number of industrial units have developed since early patents on coffee decaffeination or hops extraction in the 1970s. Perrut estimated that 300 manufacturing units. The primary uses for supercritical extraction on solid materials are in the food and perfume industries: extraction of smells and tastes. The dispersion of electromagnetic waves in the irradiated material causes microwave heating. The dielectric characteristics of a medium and the local time-averaged electric field strength determine how much power is dissipated. As a result, there is a basic difference between microwave and traditional heating: heat flows from the heating device to the medium in conventional heating, while heat dissipates within the irradiated medium in microwave heating. Microwave heat transmission, unlike traditional heating, is not restricted to thermal conduction or convection currents. In reality, this implies that the temperature may rise considerably more quickly. Furthermore, the maximum temperature of a microwave-heated material is solely determined by the rate of heat loss and the amount of power supplied.

Although microwaves provide volumetric heating, the field distribution over the irradiated object is not uniform. As a result, the energy is not dispersed evenly. The distribution of the electric field is determined by the geometry of the heated item as well as the dielectric characteristics. The depth at which power density is decreased to original intensity may be a limiting issue for material that easily absorb microwaves. If the power dissipation is quicker than the heat transfers to surrounding cooler regions, standing wave patterns will result in hot spots in more transparent material. In general, if multiples of a half wavelength fit in the usual dimension (d) of the irradiated item, a standing wave pattern may emerge. Only dipoles absorb microwaves, converting their energy into heat. Faster energy absorption, decreased thermal gradients, selective heating, and practically limitless ultimate temperature are all benefits of using microwave power, a non-contact energy source, to heat the majority of a material. In the food business, many procedures including as drying, tempering, thawing, blanching, sterilization, pasteurization, baking, and extraction have shown to be effective. Drying is one of the oldest techniques of food preservation, and it is defined as a heat and mass transfer process in which the water activity of a food is reduced by evaporating water into an unsaturated gas stream.

The volumetric heating effect, in which microwave energy passes through the food and is absorbed more in the wet area than in the dry region, is the most significant feature of microwave dehydration. As a result, the center is warmer than the surrounding area, and mass transfer is sped up. When compared to traditional drying, microwave drying has a higher thermal efficiency, a quicker drying time, and enhances the final quality of the dried product. MW drying is also capable of preserving product qualities such as color, fragrance, and texture. Blanching is a heat treatment used before freezing to inactivate enzymes like poly phenol oxidase (PPO) and peroxidase (POD), which are responsible for browning reactions and the formation of off-flavors. Blanching also kills germs on the surface of the product and makes certain veggies compact. Microwave blanching may be a viable option to traditional blanching, since it allows for more accurate process control, faster processing times, and lower energy use, as well as a reduction in product center blanching time. Many studies have shown that using the microwave produces firmer goods with similar or superior nutritional content. Tempering may be thought of as the first step in the thawing process. In the food business, thawing frozen goods is a critical unit activity.

Large amounts of food must be frozen during harvest time in order to be used throughout the year. Without the need of conductors or electrodes, electromagnetic waves are directly absorbed by the product during microwave thawing. As a result, it is a very quick thawing technique, but its use is restricted by the heat stability of the product. The issue is complicated by the fact that the water loss factor is about 12 whereas the ice loss factor is 0.003, implying that ice is virtually insensitive to microwave radiation. Unfrozen water absorbs microwave energy preferentially in a frozen product (-18°C), while the frozen portion is insensitive to microwaves. When opposed to traditional processing, this results in isolated regions of extremely hot water, partial thawing, and thermal runaway contents, as well as comparable hues. Improvements are required to maintain a consistent temperature during microwave thawing. Even when there was no substantial impact on product quality, microwave thawing has the benefit of reducing processing time. Microwave ovens are often used in continuous operations in the food sector. A conveyor transports thin layers of goods through a series of microwave generators. Fish fillets and beef blocks are thawed in microwaves. Microwave tempering lowers the cost of producing prepared meals by allowing frozen raw materials to be tempered as required, with no drip loss, no requirement for tempering facilities, and faster processing times.

Baking is a complicated process that involves both heat and mass transfer. Starch gelatinization, protein denaturation, carbon dioxide release from leavening agents, volume growth, water evaporation, crust development, and non-enzymatic browning are all examples of physical, chemical, and biological changes that occur during baking. Microwave baking saves time and energy, as shown by a comparison of microwave and traditional baking times for a cake. Microwave baking reduced baking time by up to 93 percent as compared to convective baking. Microwave-baked cakes had better textural characteristics including moisture content and stiffness. Microwave baking also offers the benefit of increasing the nutritional content of the finished product. Pasteurization is the process of inactivating harmful microorganisms, such as vegetative cells, yeasts, and molds, by heating them. Microorganisms and their spores, which are usually more thermo-resistant than vegetative cells, are inactivated during sterilization. Microwave food heating is a great way to pasteurize or sterilize goods.

In the past decade, there has been a growing need for novel extraction methods that are automatable, have shorter extraction times, and use less organic solvent, in order to decrease pollution and sample preparation costs. Advances in microwave green extraction have given birth to two types of techniques: Solvent Free Microwave Hydro distillation and Microwave Hydro diffusion and Gravity, all of which are driven by these objectives. The Solvent Free Microwave Hydro distillation (SFME) method was developed for the extraction of essential oils from a variety of aromatic plants and fruits on a laboratory scale. Internal heating of in situ water inside the plant material distorts the plant cells, causing glands and oleiferous receptacles to burst. Ultrasound, microwave, immediate controlled pressure drop, supercritical fluid, and pulsed electric fields are examples of new extraction methods that decrease extraction time, energy consumption, and the amount of water or solvent used. Due to the stiff construction of microbe cell walls, traditional methods are restricted by the diffusion of water or solvent into biomass. The answer may be to increase water or solvent diffusion while also disrupting cell membranes. Ultrasound and electric pulse fields, for example, cause a high degree of cell disruption, allowing mass transfer to be accelerated and processing time to be decreased. Microwave heating, on the other hand, causes simultaneous mass and heating transfer, allowing cells to be destroyed and metabolites to be liberated. A choice tool that allows for the selection of a technology for the first material is a future trend. For example, deciding the method to employ to extract a desired metabolite from a particular plant requires striking a balance between extraction efficiency and repeatability, process simplicity, and cost, time, safety, and automation.

## 3. CONCLUSION

Food processing, including preservation, transformation, and extraction, plays an important role in the manufacturing process and is influenced by a number of factors, including consumer demand for naturally derived ingredients (colors, antioxidants, antimicrobials, aromas, etc.) and the need for standardization. Green Food Processing may be a study topic that includes a complete approach focused on process discovery and design to decrease energy and water usage. It has mostly been studied at the laboratory size by many research teams in Europe, and it offers an excellent chance to rationalize environmentally friendly development and industrial processes. The food business operates in a highly competitive climate, and in order to thrive, it must use efficient procedures and minimize its carbon footprint. The idea of green food processing satisfies the end customer's desire for a greener product; nevertheless, education effort will be required to convey the advantages to the final consumer. This instructional effort will need vulgarization from the scientific community and members of the business, as well as the avoidance of "green washing" shortcuts. For example, to demonstrate how green food processing may be utilized in teaching labs, we employed green processes that utilized ultrasound and microwave radiation as energy sources to teach basic food processing principles like marinating, maceration, and extraction at Avignon University. As an example, we created a novel green method that uses microwave radiation as an energy source to teach the basic principles of essential oil extraction for food aromatization.

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