Gayathri Sanyasi / Afr.J.Bio.Sc. 6(5) (2024). 8947-8963 **ISSN: 2663-2187**

https://doi.org/ 10.48047/AFJBS.6.5.2024. 8947-8963

African Journal of Biological Sciences

A REVIEW OF NON-THERMAL TECHNOLOGIES AS NOVEL PROCESSING METHODS FOR THE FOOD INDUSTRIES' BEVERAGE TREATMENT

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Article History
Volume 6, Issue 5, 2024
Received: 15 May 2024
Accepted: 02 Jun 2024
doi: ***10.48047/AFJBS.6.5.2024. 8947-8963***

Abstract

The main objective of this review is to outline the prevalence of advancing non-thermal technologies in the food processing industry, as well as their efficacy in beverage treatment. Various beverages are treated using non-thermal methods such as pulsed electric fields, cold plasma technology, ultrasonication, and irradiation. As a consequence, they reduced microbial load while retaining sensory characteristics without compromising color and enhancing the product's shelf life. Non-thermal technologies are found to be more effective because the food is processed at room temperature, safeguarding the heat-sensitive nutrients, whereas thermal technologies expose the food to high temperatures, resulting in the formation of chemical toxicants that are carcinogenic to human health. Furthermore, these technologies have the potential to replace traditional thermal processing processes, resulting in clean, safe food. In addition, the uses and effects of different beverages were explored.

Keywords: Emerging non-thermal technologies, beverages, microbial reduction, shelf-life

Introduction

The techniques and processes used in food processing are those that transform raw ingredients into finished products. Due to consumer preferences that raised demand for high quality food products with regards to nutritional physiology and technological excellence, food preservation while maintaining its quality and safety has thus been a top priority for food processors. Processing of food materials, such as sun drying, salting, fermenting, and smoking, has been used to preserve food since the beginning of time in order to make them edible. In fact, techniques for processing food have been developed to inactivate harmful substances including toxins, pathogenic microorganisms, and undesirable components so that the processed food produced can satisfy consumer demands for safety and shelf stability. The two primary categories of food processing (Fig.1) are typically thermal processing and non-thermal processing. The most typical and established method is thermal processing, which effectively inactivates bacteria and spoilage of enzymes. However, food products may undergo chemical and physical alterations as a result of intense heat treatments. These methods even have the potential to produce hazardous chemicals while decreasing the bioavailability of some vital minerals. Furthermore, it has been noted that thermal processing has detrimentaleffect on the sensory qualities of food(Lajnaf, 2023)

Non-thermal technologies in food processing, on the other hand, do not generate high temperatures and have short treatment periods. This entails that, when compared to standard thermal processing, the nutritional components of food are better kept, and the sensory characteristics of foods are less affected(Zhang, 2019).

Materials and Methods

Research Design:

The review methodology proposed for this study is a systematic literature review. This systematic approach ensures a comprehensive and unbiased review of the existing literature related to emerging non-thermal technologies in food industries.

Data Collection:

1. Relevant electronic data bases such as Google Scholar, Web of Science and libraries were used
2. Keywords related to non-thermal technology (‘pulsed electric field,’ ‘ultrasonication,’ ‘cold plasma technology,’ ‘ultraviolet treatment’ as well as ‘irradiation’ combined with keywords related to beverages, were used to identify the potential studies

Inclusive and Exclusive Criteria

Inclusive criteria

1. Studies that primarily focused on non-thermal processing in beverages
2. Peer-reviewed articles published in English

Exclusive criteria

1. Articles not in English
2. Editorials and non-peer-reviewed publications

Researchers have often cited these emerging food processing technologies as an alternative to conventional heat treatments for food processing in order to generate safe food with little harm. (Hernández-Hernández, 2018).Non-thermal treatments also fulfill the needs of the industry by providing enhanced safety margins, new market prospects, and value-added goods (Morris, 2007).

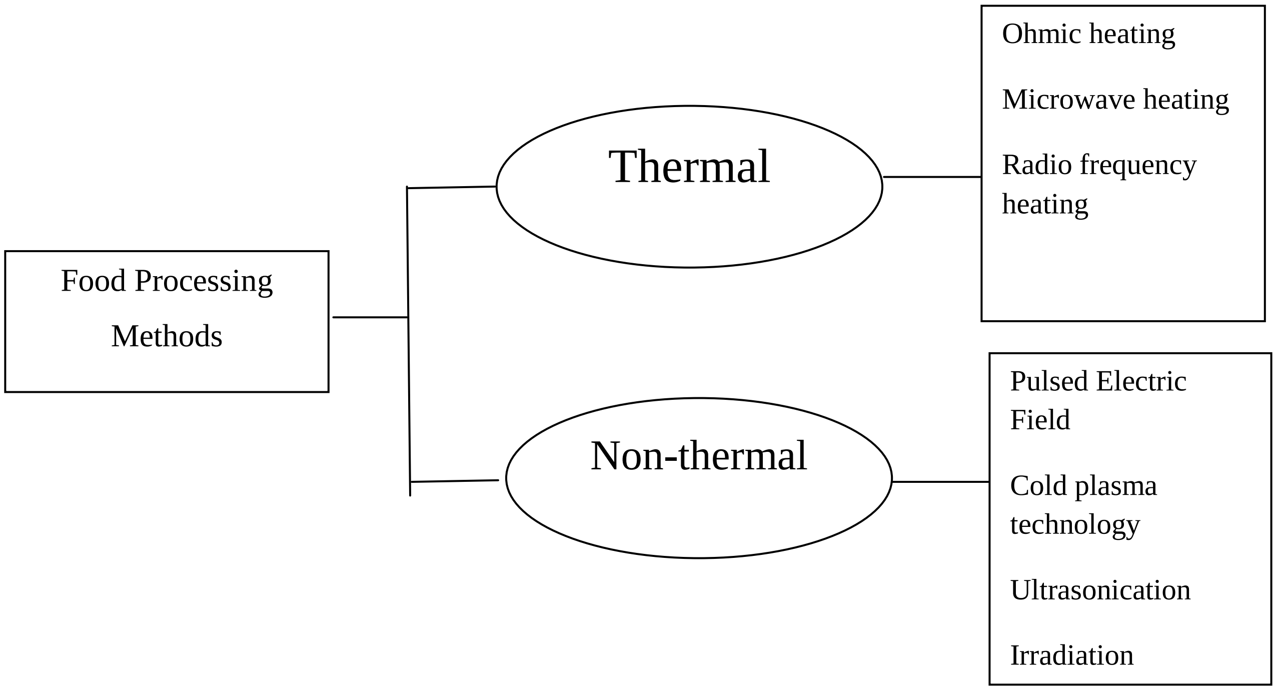

Figure 1. Thermal and non-thermal processing techniques

Source (Lajnaf, 2023)

In addition, they were said to be more economical and environmentally benign than conventional thermal processing methods. Therefore, the purpose of the current review is to emphasize the significance of non-thermal technology.

1. Pulsed Electric Field

One of the prospective ways of non-thermal food preservation, pulsed electric field (PEF) technology, may successfully handle biological hazards. To inactivate microorganisms below thermal processing temperatures, this technique generates a high-intensity electric field with pulse (s) amplitudes ranging from 100-300 V/cm to 20-80 kV/cm between two electrodes and applies it to a product for a short period of time (milliseconds to microseconds). Unlike standard heat treatment, PEF treatment has no effect on the color, texture, taste, or nutrition of food items. (Ghoshal, 2023)

It is largely used for treating liquid food, such as fruit juices, alcoholic beverages, non-alcoholic beverages, etc. The entire fruit may be directly exposed to it. It weakens the cell walls of bacteria, which causes them to die and lowers the microbial load. When food is treated with a pulsed electric field, both the pulse intensity and pulse breadth have a significant impact on the reduction of microorganisms. The activity of enzymes can also be stopped by non-thermal treatment, causing fruits and vegetables to spoil (Jadhav et al., 2021). The impact of PEF on various beverages is shown in Table 1.

Table 1. Impact of PEF treatment on various beverages

Food sample	**Observation**	**Reference**
Orange Juice	Reduction of Salmonella counts and efficacy of bactericidal effect	(Mittal & Griffiths, 2021)
Pomegranate fermented beverage	Mesophilic Aerobic Bacteria (MAB) were reduced	(Rios-Corripio et al., 2021)
Protein fortified fruit-based beverage	Less protein denaturation and lower loss of Vitamin-C	(Sharma et al., 1998)
Fruit juice- soymilk beverage	Colour, soluble solids, pH and acidity values were not affected	(Morales-de la Peña et al., 2010)
Orange juice- milk beverage	The levels of saturated, monounsaturated, and polyunsaturated fatty acids did not alter much. No peroxides or unacceptable quantities of furfurals were found.	(Zulueta et al., 2007)
Orange juice- milk based beverage	Inactivation of Lactobacillus Plantarum	(Sampedro et al., 2007)
Mango and Papaya Juice	Increased content in bioactive compounds and sweetening properties with minimal color changes.	(Carbonell-Capella et al., 2017)
Alcoholic beverage	Inactivation of spoilage microorganism	(Beveridge et al., 2004)
Smoothie type beverage	Shelf life extended up to 21 days	(Walkling-Ribeiro et al.,

(Pineapple, banana, apple, oranges and coconut milk)		2010)
Formulated carrot juice	Did not create any significant change in pH, titratable acidity (TA), Brix, conductivity, color, nonenzymatic browning index (NBI), metal ion, and Vitamin C content	(Akın&Evrendilek, 2009)
Green bean juice	No inactivation of enzymes	(Ghoshal, 2023)
Milk	Extension of two weeks of shelf-life. No apparent change in physic-chemical characteristics	(Datir et al., 2019)
Milk-Juice beverage (Formulated with pectin, citric acid and sugar)	Inactivation of E.coli and salmonella spp.	(Datir et al., 2019)
Yogurt-based beverages	Inactivation of S.cerevisiae and extension of shelf life upto 10 days	(Datir et al., 2019)
Infant milk formula beverages	Inactivation of C. sakazakii	(Datir et al., 2019)

2. Cold plasma technology

Cold plasma (CP) technology has developed as a feasible alternative to traditional food heating methods. Plasma is an ionised gas composed of a variety of charged species (such as electrons, ions, photons, and free radicals, as well as gas atoms and molecules in their fundamental or excited states), which are formed by applying energy to a neutral gas, resulting in the formation of charged carriers. Plasma flows around the treated samples, reducing the shadow effect and guaranteeing that all regions of the product are properly treated. It has a wide range of uses in food and packaging goods. Surface cleaning exposes microorganisms to highly charged reactive species that harm the surface of the bacterial cell wall, causing it to burst. (Coutinho et al., 2019).

Proteins and carbohydrates in food are commonly physiologically enhanced utilizing CP technology, allowing them to be used in a number of food processing applications. It also inactivates the bacteria on the food's surface. The duration of the CP therapy is critical for achieving the desired results(Jadhav et al., 2021). The effect of CP on various beverages is shown in Table 2.

Table 2. Impact of CP treatment on various beverages

Food sample	Observation	Reference
Fruit-based beverages	Inactivation of endogenous enzymes, microorganisms and pathogens	(Waghmare, 2021)
Guava flavoured whey beverage	Provided greater preservation of the bioactive compounds (phenolic compounds, carotenoids, vitamin C, antioxidant activity, and ACE inhibitory activity), and volatile compounds	(Silveira et al., 2019)
Fruit and vegetable juices	Does not affect the texture of treated juices. No change in nutritional composition	(Pohl et al., 2022)
Chocolate milk drink	The drinks treated with cold plasma exhibited particles with larger size, greater consistency, and an altered melting profile	(Coutinho et al., 2019)
Tender Coconut Water (TCW)	TCW remained well for two days at 6°C. TCW combined with orange juice and ascorbic acid had a shelf life of 35 and 18 days when stored at 6°C and 27°C, respectively.	(Chutia& Mahanta, 2021)
TCW treated with 1% of orange juice	Reduced the microbial load of TCW and gave acceptable sensory attributes by masking the chemicalodour	(Chutia et al., 2020)

3. Ultrasonication

Ultrasonication is a non-thermal energy-efficient treatment typically used to speed up operations like food synthesis, extraction, and preservation. Using ultrasonication, it is possible to create food that is both safe and healthy by using the ideal exposure time(Jadhav et al., 2021)

Sonication is a technique that employs sound waves with frequencies greater than 18 kHz to treat and preserve food without affecting its nutritional value. Ultrasound indicates its potential benefits for fresh horticulture products such as drying, fruit juice extraction, detection of foreign bodies, filtration, and microbial contamination management without compromising quality. (Ravikumar, 2017).

In Ultrasound, the particles in the medium undergo compressions and rarefactions (decompressions) when the acoustic waves travel through it. As a result, there is a significant quantity of energy produced because of the increased mass transfer and turbulence. The fundamental idea is that sound waves behave similarly to light waves in terms of reflecting and scattering. Ultrasound, a new sustainable technology, improves the efficiency and speed of a wide range of food processing techniques. It can also be employed in conjunction with pressure (manosonication) and temperature (thermosonication), creating a synergistic consequence that boosts its efficacy (Bhargava et al., 2021). The effect of Ultrasound on various beverages is shown in Table 3.

Table 3. Impact of Ultrasonication on various beverages

Treatment	Food sample	Observation	Reference
Ultrasonication	Tea-based beverages	Microbial inactivation and shelf-life has increased up to 6 days	(Uzuner, 2022)
Ultrasonication,	Tomato-based	Maximum ascorbic acid	(Mehta et al., 2019)

Ultra Violet (UV) and Atmospheric Cold Plasma (ACP)	beverage	retention and considerable influence on bioactive molecules such as chlorogenic acid, sinapic acid, and gallic acid	
Ultrasonication with inulin concentration	Whey-oat beverage	Yielded enhanced bioactive compounds	(Herrera-Ponce et al., 2022)
Ultrasonication and Pulsed light	Lactic acid fermented mulberry juice	The overall phenolic concentration, total flavonoid concentration, total anthocyanin concentration, antiradical activity against 2,2-diphenyl-1-picrylhydrazyl scavenging activity (DPPH-SA), 2,2-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid radical cation scavenging activity (ABTS-SA), and reducing power capacity (RP-CA) everything improved significantly	(Kwaw et al., 2018)
Ultrasonication	Plant-based milk	Generates nano-emulsions with minimal energy consumption	(Sarangapany et al., 2022)

		and decreases the microbial activity	
Ultrasonication	Date-based energy drink	The drink that had been sonicated for 40 minutes had a longer shelf life than the control or thermally treated beverages	(Fikry et al., 2023)
High intensity ultrasound	Whey and oat beverage	A probiotic beverage with 50% whey and 50% oat, ultrasonicated for 3 minutes, produced excellent antioxidant activity and good consumer acceptability	(Herrera-Ponce et al., 2021)

4. Irradiation

Food is sterilised and given a longer shelf life using irradiation, a minimal processing technique that exposes it to several radiation beams. Food irradiation is the process of subjecting food to ionizing radiation by means of accelerated electrons with a maximum energy of 10 MeV, machine-generated X-rays with a maximum energy of 5 MeV, or gamma photons emitted by 60Co (or, less frequently, 137Cs) radioisotopes. (Farkas &Mohácsi-Farkas, 2011). When the radiation source comes into contact with the food, the radiation principle of excitation, ionisation, and food components change. Irradiation is used to make food safer to eat by destroying harmful germs.

Irradiation is similar to pasteurisation but without the use of heat, resulting in changes in freshness and texture. Food irradiation eliminates harmful bacteria, insects, fungus, and pests by using gamma radiation energy sources, electron beams, and X-rays. This method is completely safe and does not result in radioactive food. Irradiated items' chemical, nutritional, microbiological, and toxicological properties are employed as food safety criteria (Indiarto et al., 2020). The effect of Irradiation on various beverages is shown in Table 4.

Table 4. Impact of Irradiation on various beverages

Treatment	Food sample	Observation	Reference
UV-C Irradiation	Cranberry Flavored Water	Microbial inactivation without producing harmful consequences	(Gopisetty et al., 2019)
Irradiation	Ready-to-drink beverage	The anti-oxidant activity and the gingerol/carvacrol content was reduced making the product microbiologically safe up to eight months	(Wadikar et al., 2015)
UV- LEDs	Mixed beverage (carrot, carob, ginger and lemon juice)	Substantial increase in antioxidant capacity and total phenolic substanceSubstantial increase in antioxidant capacity and total phenolic substances	(Baykuş et al., 2021)
UV-C Irradiation	Watermelon Beverage	Escherichia coli and Bacillus Cerius endospores were inactivated	(Pendyala et al., 2020)
UV-C Irradiation	Coconut water	Inactivation of bacteriophage and pathogenic microbes in coconut water	(Bhullar et al., 2018)
Ultrasound,γ-Irradiation Treatment,	Fermented beverage enriched with cricket protein	High digestion of proteins	(Dridi et al., 2021)

enzymatic hydrolysis			

Conclusion

Thermal processing techniques, which are widely used to ensure the nutritional value and microbiological safety of food products, degrade the sensory and nutritional aspects of food. Therefore, novel technologies exhibit interest in the food processing sectors, offer quick turnaround times, and are safe for the environment. Non-thermal technologies have garnered the interest of most global industries throughout the last ten years. They often need greater energy inputs, higher processing costs, higher operational efficiency, and higher initial investment prices as compared to a conventional thermal process with heat recovery capability.

The food industry and consumers alike gain greatly from the numerous, significant advantages that non-thermal food processing methods provide. These methods offer an option to other traditional thermal processes. One of the key advantages of non-thermal food preparation is the preservation of nutritional content. Non-thermal techniques are known to retain more vitamins, minerals, and antioxidants in food than thermal ones.

Customers now have access to superior, higher-nutrient food options, which makes this significant. Additionally, food's sensory qualities are little impacted by non-thermal processing methods. Consequently, the dish retains the desirable characteristics that patrons expect from their food, with flavors, colors, textures, and tastes mostly unaltered or hardly altered. A longer shelf life is another advantage of using non-thermal food processing methods. By using non-thermal technology, food may be prepared and stored securely for extended periods of time without affecting quality.

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