*World Journal of Food Science and Technology*
2025, Vol. 9, No. 4, pp. 78–86
https://doi.org/10.11648/j.wjfst.20250904.12

Research Article

# Novel Technologies: A Review on New Age Food Processing

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## Abstract

Modern lifestyle pattern increased the demand for convenience foods with significant nutritional contribution; bioactive compounds with enhanced sensory properties imposed a challenge towards food processing industries for the evolution of novel and innovative food processing techniques. Conventional thermal food processing technologies such as heat dependant pasteurization and sterilization have the negative impact on the sensory characteristics of food product. Novel technologies have made a place in the food industries due to the wide acceptance by the consumer for the hassle free, flavourful, fresh and mild to moderate processed food products with enhanced keeping quality. Moreover, global food security can be achieved post application these novel technologies due to their effective impact on the extended shelf life without the destruction of organoleptic properties and nutritional content of the processed food product. Ready to use healthy foods are prepared with the application of novel technologies such as High hydrostatic pressure (HHP), Pulse Electrical Field (PEF), Irradiation, application of ultrasonic waves and cold plasma technologies. Mostly food spoilage and food poisoning are caused by the presence of microorganisms, so the main focus of these novel technologies is to destroy the microorganisms and thereby enhance the shelf life of the developed product. Studies proved that there is a trend of using the potentiality of novel heat independent processing technology which can improvise the quality and safety of the processed food products. Restoration of sensory qualities including flavour, texture, colour, appearance and nutritional value are predominantly based on the type of processing techniques applied. Studies also indicated the strong consumer response to High Pressure Processing (HPP), Pulsed Electric field (PEF) and cold plasma (CP) food processing techniques. Moreover, these technologies are providing safe foods to the community and are extensively applied for the mankind. Therefore it can be concluded that in forthcoming year conventional heat dependent processing will be completely replaced by novel food processing techniques as these techniques are predominantly making their place in the global market.

## Keywords

Novel Technology, Food Processing, Nutrient Restoration, Extended Shelf Life, Anti-microbial Activity, Convenience Food

## 1. Introduction

Novel technologies of food processing have made a place in the food industries due to the wide acceptance by the consumer for the healthy and tasty mild processed safe food products with enhanced keeping quality. Modern lifestyle pattern increased the demand for processed products with adequate nutrients; functional and bioactive compounds with

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**Received:** 8 November 2025; **Accepted:** 19 November 2025; **Published:** 11 December 2025

enhanced sensory characteristics imposed a provocation towards food processing sector for the progression of novel and inventive food processing techniques. Ready to use healthy foods are prepared by novel technologies. The sensory qualities including flavour, texture, colour, overall acceptance along with the nutrient content are primarily depends on the type of processing techniques. The predominant cause of food spoilage and food poisoning is the presence of microorganisms, so the food processing technologies target them to destroy and thereby enhance the longevity of the developed food product. Food processing approaches are based on the two different actions such as bacteriostatic and bactericidal [1].

## 2. Evolution of Food Processing Technologies

Conventional thermal food processing technologies such as heat dependant pasteurization and sterilization have the negative impact on the sensory characteristics of food product. Alternative techniques for conventional thermal processing evolved in order to increased consumer demand to obtain safe and beneficial consumer accepted food products. Innovation in food industries helped in the evolution of novel and evident food processing techniques to satisfy the consumer need. High hydrostatic pressure (HHP), Pulse Electrical Field (PEF), Irradiation, application of ultrasonic waves and cold plasma technologies are the predominant innovation in food processing [2].

Moreover, global food security can be achieved post application these novel technologies due to their effective impact on the extended shelf life without the destruction of organoleptic properties and nutritional content of the processed food product. The components responsible for colour, taste and flavour are heat labile; thereby thermal processing can change the attribute of the merchandised food products and affect product acceptability. Thus, the search for alternative approaches for heat dependent food processing which would generate a microbiologically safe product with higher nutrient content and organoleptic characteristics encourage scientists to investigate other deactivation techniques [3].

Thus there is a trend of using heat independent technologies, which faced the challenge by some physical obstacles such as pressure, electromagnetic fields, and sound waves. Researchers also invented some novel heat dependent processing technologies, which primarily use source of energy derived by microwave and electromagnetic radio frequency. Moreover, safety is not only achieved by the application of innovative technology to deactivate microorganisms and their enzymes but also the product should be free from poisonous substances such as adulterants and heavy metals and exposed the food to certain chemicals during processing should be avoided. Post production quality evaluation of the developed products generated by novel technologies is a basic prerequisite before the commercialization [4].

## 3. Heat Independent Novel Food Processing Technologies around the World

In the field of food processing, five basic technologies are widely accepted and implemented. Each processing has specific characteristics and effectivity and impact on the processed food products. The selection of the food processing techniques applied to the food products depends on the nature and the type of food ingredients.

### 3.1. High Pressure Processing (HPP)

HPP is a heat independent technique where the foods are kept at the pressure ranges from 300 and 600 MPa for 10 minutes. This technique involves reduced processing times along with less damage and adequate retention of sensory and nutritional components. However, spores of microorganisms are destroyed during processing which requires this technique to be used in conjunction with another physical obstacle such as reduced pH or low temperature. HPP is potent enough to deactivate pathogens and such spoilage microorganisms but the efficacy is restricted against bacterial spores and their enzymes. Commercial application of HPP is growing worldwide. High capital investment and restricted output are major limitations [5, 6].

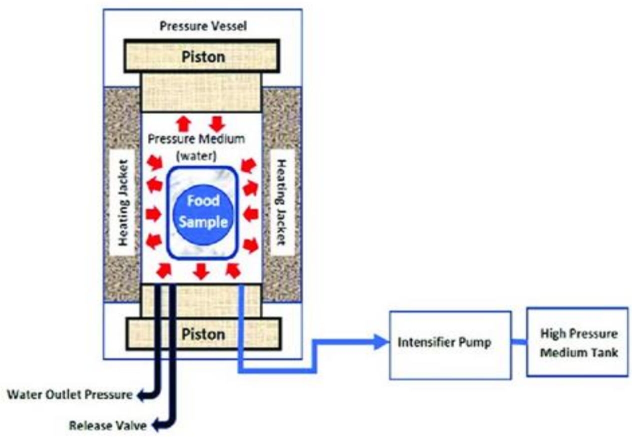


*Figure 1. Schematic diagram of HPP.*

### 3.2. Application of HPP in Food Processing

1) HPP can be applied for various food processing and storage purposes such as heat dependent pasteurization, sterilization etc. This technique increases the thawing and freezing of food and extraction of the functional compounds of food ingredients as shown in Figure 1.
2) This technology is commercially used for fruits and vegetables, juice, jam, jelly, sauce, salad, puree, hummus, smoothies etc. This is also effective for the pro-

cessing of cheese, yoghurt, milk based beverages, meat and poultry products, oyster and ready to eat meals [7].

### 3.3. Pulsed Electric Field (PEF)

PEF is known for its potency to limit bacterial growth in beverages at low temperatures. In this technique, the food is subjected to a pulsed high voltage electrical field for less than 1 second. Researchers indicated that PEF processes helps in the adequate restoration and extended shelf stability of carotenoids, phenolic compounds such as flavones and isoflavones, as compared to heat sensitive processing. This technique can be commercially implemented to generate juices similar to the fresh fruit juice in regards to their aroma profile. It has the ability to replace heat dependent techniques such as pasteurization of beverages due to the restoration of the products nutrient content, sensory characteristics, safety and overall quality attributes at lower operational costs. Potency of PEF towards bacteriostatic action rely on the intensity and depth of the electric field, the pulse range, duration of pulse field exposure, and pulse wavelength and product conductivity as shown in Figure 2. Foods with high conductivity are not assumed to be suitable for treatment with PEF, neither are those with a high salt content or liquid products which contains particulate matters [8, 9].

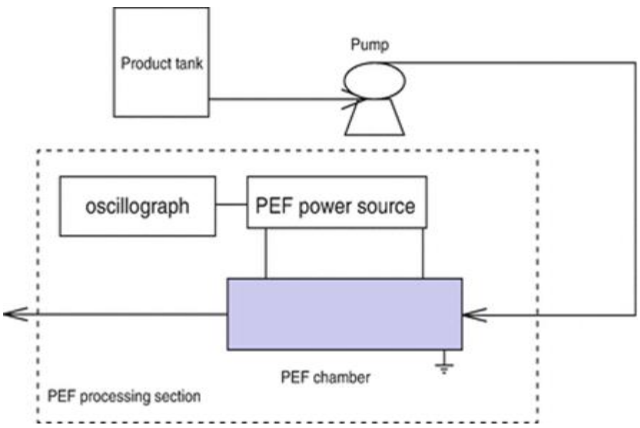


***Figure 2.*** *Schematic diagram of PEF.*

### 3.4. Application of PEF in Food Processing

1) It is generally applied in the processing of beverages such as fruit juice, milk, yoghurt, soup, beer, rice wine, liquid egg, apple cider and so on. It is suitable for those food products which has low electrical conductivity with no air bubble and is easy to pump.
2) It should not be applied in solid foods as the low intensity electrical field damages the texture and appearance of the food as the cells are getting ruptured due to high intensity of the electrical pulse.
3) It can be used as the pre-treatment along with some other processing method for flesh foods. It is also applied for the extraction of bioactive components such as enzymes, fish oil etc. [10].

### 3.5. Cold Plasma

Plasma can be sourced from antimicrobial agents such as charged particles, UV photons and reactive oxygen species (ROS) such as hydroxyl radicals, nitric oxide, superoxide and ozone. Thermal plasmas can be obtained by the application of high pressure, power and temperature. In comparison to thermal plasma, non-thermal plasma requires less power and pressures and may be produced by electric or magnetic discharges. This unexplored cold plasma technology provides its implication in the decontamination and sanitisation of the superficial layers of agricultural produces, beverages as well as surfaces of the equipment used in food processing and food packaging industries as shown in Figure 3. This technique is effectively applied as the alternative to the thermal food processing technique resulting in complete inactivation of pathogens without destroying nutritional components and sensory qualities of the product. Cold plasma technology also proved its potentiality to rupture the cell layers of microorganism's cell wall, reducing the cell density and denaturing the inner content of cell, thereby significantly destroying the pathogenic microorganisms [11, 12].

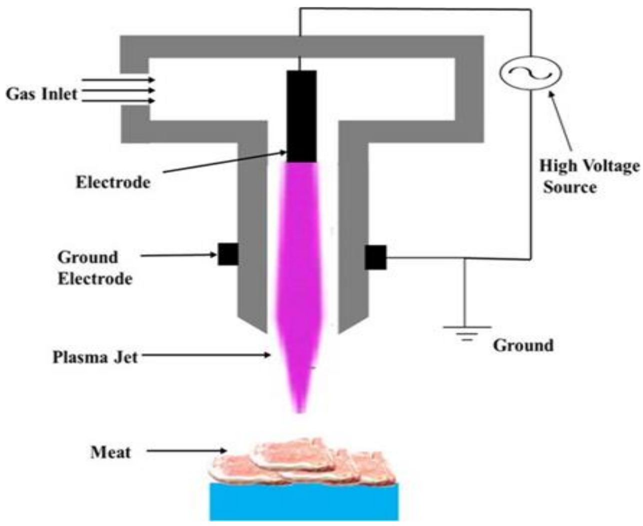


***Figure 3.*** *Schematic diagram of Cold Plasma.*

### 3.6. Applications in Food

1) Non thermal cold plasma technology is useful for the inactivation of enzymes without the loss of their specific characteristics as these are heat sensitive and denatured quickly by thermal processing.
2) It can also be used in the degradation of pesticides and toxins.
3) It is applied in the surface decontamination of food and food processing equipment.

4) This technique is beneficial for the modification of food packaging and waste water treatment in food industry [13, 14].

### 3.7. Ultrasound

Ultra sound is a non-thermal advanced technology alternative to conventional thermal food processing. It is a safe processing method where the sounds having frequency range of more than 20 kHz. Two types of ultra sound technology such as power ultrasound or high intensity ultrasound having low frequency (20-100 kHz) and low-intensity ultrasound with high frequency (2-10 MHz) applied in food industry as shown in Figure 4. Low intensity ultrasound is generally used for non-destructive testing of food and power ultrasound is used for food processing [15, 16].

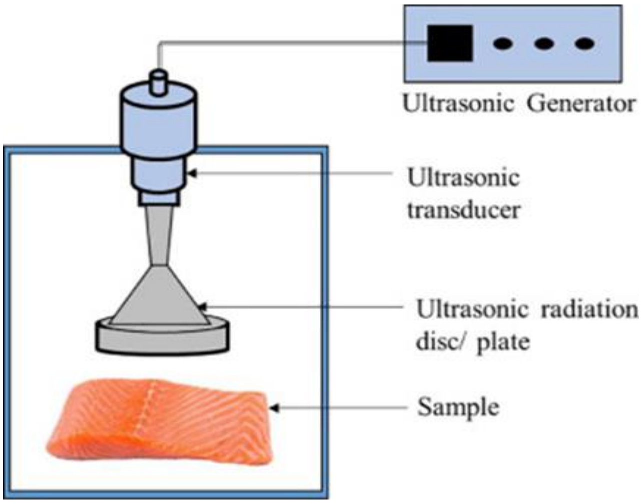


*Figure 4. Schematic diagram of ultra sound.*

### 3.8. Application in Food

1) Ultrasound can be used in the mixing and homogenization of emulsion base of sauce, soup, gravy, ketchup for the processing and preservation.
2) It can also be used in the filtration of fruit extracts and other beverages production along with the degassing of carbonated beverages.
3) Ultrasound technique is associated with the extraction of bioactive components from plants.
4) It can be applied on the meat and milk products for the destruction of spoilage microorganisms [17].

### 3.9. Food Irradiation

Food irradiation is worldwide accepted heat independent processing technology which improves the safety and the shelf life of the food by inactivating the insects and microbes. In this technology the foods and its packaging are exposed to ionizing radiation such as gamma rays, x-rays or electron beams as shown in Figure 5. As per the Food Safety and Standard Regulations, irradiated food should be labelled with logo of "Radura" where the radiation doses should be less than 10 kGray, which is sufficient enough to reduce the number of pathogens and to extend the shelf life [18, 19].

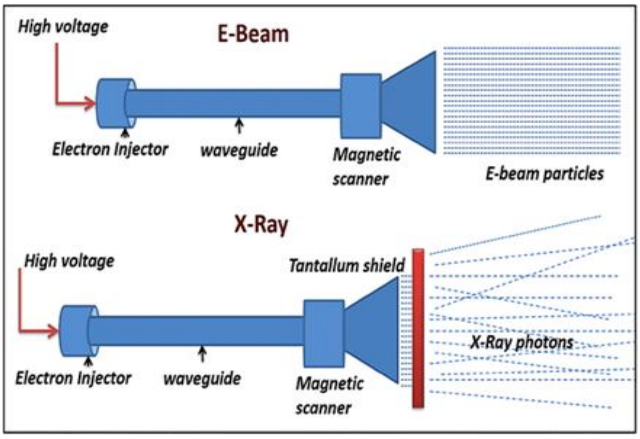


*Figure 5. Schematic diagram of irradiation.*

### 3.10. Application of Irradiation

1) Irradiation is a single process with a multiple uses in the processing of meat, poultry, fish, shell eggs, crustaceans, mollusks, fresh fruits, vegetables, seeds, cereals, pulses, spices and seasonings.
2) It extends the longevity of food by eliminating spoilage organisms resulting in the production of sterilised food.
3) It enhances food safety by reducing food borne pathogens.
4) It delays sprouting of vegetables, pulses and delays ripening of fruits [20, 21].

## 4. Impact of Novel Technologies on Food Quality and Safety

### 4.1. HPP

1) HPP is helpful to extend the longevity of foods by inactivating predominantly the vegetative cells and pathogenic organisms such as bacteria, virus, yeasts and molds. HPP helps to inactivate mostly yeasts and molds as compared to bacteria. Among the bacteria Gram negative are more sensitive as compared to Gram positive bacteria [22, 23].
2) It is effective best against bacterial spores when applied in combination with temperature as shown in Figure 6.
3) HPP also helps in the modification of enzymes resulting in ripening of cheese and prevention of browning of fruits and vegetables.
4) Significant benefits of HPP lies in the retention of nu-

tritional and sensory qualities of food as compared to the conventional thermal pasteurization. However, due to incomplete inactivation of enzymes, it may also lead to some changes in colour, flavour and viscosity of beverages during storage.

5) Another key point of HPP treated foods is that they need to be stored in low temperature in order to retain sensory and nutritional qualities [24-26].

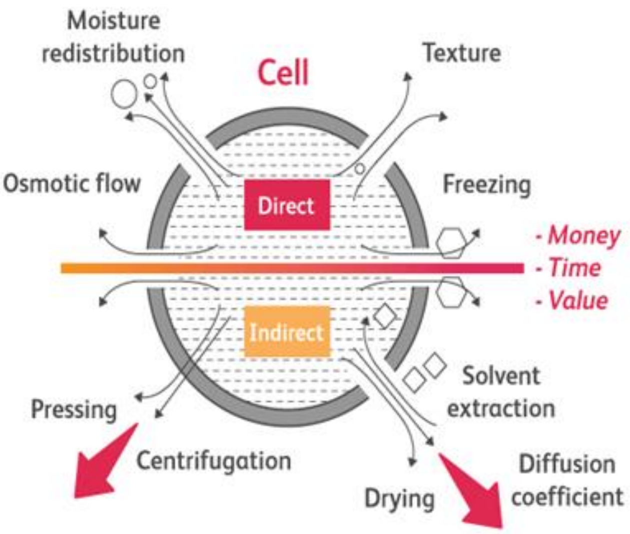


*Figure 6. Effect of HPP on food safety.*

## 4.2. PEF

1) Pulse electric field strength, duration and number of electrical pulses, initial microbial load, microbial growth phase, initial ionic concentration and conductivity of the media affect the efficiency of PEF.
2) In beverage industry, PEF is potential to destroy pathogenic and spoilage microorganisms as the bacterial spores and yeasts are sensitive to PEF as shown in Figure 7.
3) PEF is effective against S. enteritidis, E. coli, S. cerevisiae, B. cereus, L. lactic, Ps. fluorescens etc.
4) Studies have shown the potentiality of PEF by reducing the microbial count in terms of the reduction of cfu (colony forming units) in treated foods and extend the shelf life to one month in refrigerated storage [27-29].
5) It can reduce the activity of enzyme but it varies from one enzyme to another such as pepsin, which can be denatured at lower electrical field strength as compared to lysozyme.
6) PEF treatment rarely affects the sensory qualities of foods. The PEF treated fruit juices restore more ascorbic acid, flavour and colour as compared to thermally processed juice.
7) According to several researches PEF applied in raw egg does not cause denaturation of protein whereas the texture of solid food gets adversely affected by PEF treatment [30, 31].

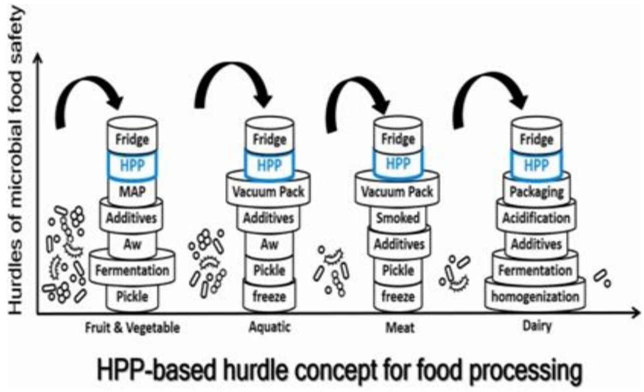


*Figure 7. Effect of PEF on food safety.*

## 4.3. Cold Plasma

1) This technology is potential to inactivate food borne pathogens like *Staphylococcus aureus*, *Escherichia coli*. as well as helps in the degradation of certain food toxins such as mycotoxins, allergens and pesticide residues in food.
2) Predominantly this technique is essential for the processing of heat sensitive substances. Non thermal process helps to restore the standard of the food product by restoring the physical and chemical qualities along with the nutrient and sensory characteristics as shown in Figure 8 [32, 33].

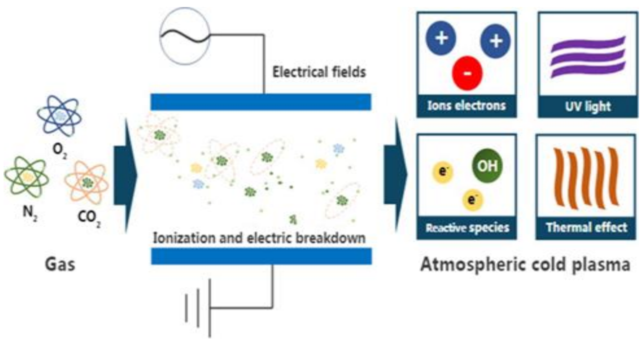


*Figure 8. Effect of cold plasma on food safety.*

## 4.4. Ultrasound

1) Spores of bacteria such as E. coli, P. fluorescens, S. cerevisiae and L. monocytogenes can be killed by ultrasound resulting in the production of microbiologically safe food.
2) 10-40 MHz can be applied to the spores for killing them. Sometimes ultra sound can be applied along with temperature and pressure.

3) The negative impact of ultrasound on the protein rich food is that, it can produce free radicals which in turn can cause the denaturation of protein and enzymes [34].
4) Use of ultrasound in low intensity for short time is helpful for the restoration of nutritional, physicochemical and sensory qualities of food.
5) Studies revealed that ultrasound can enhance the bioavailability of phenols, carotenoids, whereas reduces the ascorbic acid content and the bright colour of fruit juice as shown in Figure 9 [35].
6) Several studies also exhibited that the high intensity ultrasound for longer time or thermosonication affects colour, flavour, functional properties of the food product. Therefore, it is recommended to use low intensity ultrasound for shorter duration [36].


***Figure 9.*** *Effect of ultrasound on food safety.*

### 4.5. Irradiation

1) Irradiation is potential against the pathogenic bacteria such as *Salmonella enteritidis*, *Listeria monocytogenes* as well as viruses such as Norwalk and Hepatitis A virus.
2) Appropriate and adequate doses of radiation helping in the restoration of nutritional and sensory quality of the treated food without making it radioactive. Due to this benefit irradiated foods are well accepted by the consumer as shown in Figure 10.
3) Proteins and enzymes are not denatured at 10 kGy whereas vitamin E, A and B1 are sensitive to irradiation. But the nutrient losses can be prevented by maintaining the vacuum condition during irradiation [37].
4) Fatty foods exposed to high dose of irradiation may produce free radicals leading to rancidity and off flavour of treated food. Moreover, fruits exposed to high doses may also result in softening of texture.
5) Thus, the use of irradiation with the combination of mild heating or modified atmosphere such as vacuum packaging results in better retention of sensory qualities. Specially, high fat food should be irradiated in vacuum package under subfreezing condition [38].

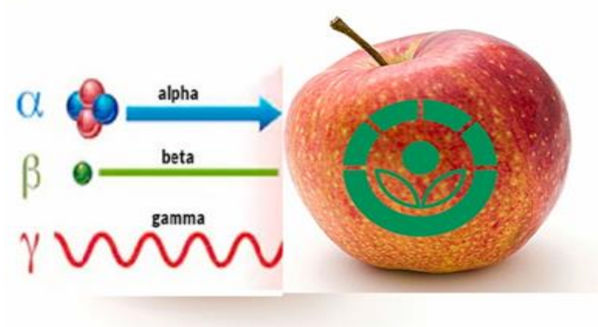


***Figure 10.*** *Effect of irradiation on food safety.*

## 5. Case Studies

### 5.1. Impact of Non-thermal Technologies on the Quality of Grapefruit Juices

In this study the impact of heat independent technologies were applied upon the juices extracted from fruits to determine the microbiological qualities of the juices. Fruits and vegetables are enriched with nutrients which can support microbiological growth which in turn can be the cause of spoilage, deteriorating the quality of the juices. To control the microbial growth instead of thermal processing heat independent technologies such as ultra-sonication, a pulsed electric field, high-pressure processing, and irradiation were used. As the conventional thermal processing negatively impacting on the nutritional and sensory properties of juices, non-thermal processing were applied to determine the changes and it had been noticed that vitamins and the bioactive compounds along with the sensory profiles were restored. The grape juice was exposed to ultrasonic bath at 28 kHz frequency for 0, 30, 60 and 90 min at 20 °C. The result showed the significant increase in total carotenoids, lycopene, sugar contents and phenolic compounds, whereas a decrease in viscosity and micro-organisms were found in all the grapefruit juice samples exposed to non-thermal techniques for 30, 60 and 90 min as compared to thermally exposed grape juices. However, maximum improvement was observed in the sonication treatment for 90 min. Thereby it can be concluded that the non-thermal technologies are potential alternatives to obtain the same storage effect without the negative impact of heat on the standard of juices as well as satisfy consumer need for safe and wholesome products without interrupting the nutritional properties [39].

### 5.2. Consumer Endorsement and Branding Of Irradiated Meat

This study explores the rate of public endorsement and the branding of irradiated meat in USA. Millions of people were undergoing in food borne infection due to hazards of food spoilage. Each year about 76 million Americans become sick from food-related illnesses and among those approximately

325000 are hospitalized. On an average about 5000 Americans die each year from food borne diseases. Existing ancient technologies can reduce but not eliminate harmful bacteria in the food. In this regard researchers found food processing methods to improvise food safety. It had been noticed that use of irradiation on the meat highly reduced the pathogens without the loss of nutritional and sensory properties. Therefore almost 40 countries have already approved food irradiation as a suitable technique for the safety of meat products. It was also observed that consumer endorsement of irradiated meat increased significantly with education [40].

### 5.3. Applications of Modified Atmospheres Commercially for the Storage of Food Commodities

This study was conducted to determine the effect of oxygen depleted atmospheres for the storage of food commodities. Oxygen depleted modified atmospheres (MAs) processing is a non-thermal in nature. It was noticed that Oxygen depleted modified atmospheres processing was successful to replace insecticides to control insects which in turn enhance the quality preservation of stored food commodities. Insecticide residues can cause harm to the human health which can be reduced with the help of adjustable airtight structures suitable for prolonged, large-scale storage of grains by the use of oxygen depleted modified atmospheres preservation technique without the loss of sensory and nutritional properties of the commodities. This technique can be applied for cereal grains, seeds and nuts, dehydrated fruits, cocoa and coffee and other such food commodities [41].

## 6. Conclusion

Studies proved that there is a trend of using the potentiality of novel heat independent processing technology which can improvise the quality and safety of the processed food products. Studies also indicated the strong consumer response to High Pressure Processing (HPP), Pulsed Electric field (PEF) and cold plasma (CP) food processing techniques. These innovative processing technologies contributed the potentiality to achieve the desired standards of the processed foods, safety and bioavailability of functional components. Mostly food spoilage and food poisoning are caused by the presence of microorganisms, so the main focus of these novel technologies is to destroy the microorganisms and thereby enhance the shelf stability of the developed product and reducing the consumer complaints regarding food borne illness and other such health issues. However, these technologies are providing safe foods to the community and are extensively applied for the mankind. Moreover it can be concluded that in forthcoming year conventional heat dependent processing will be completely replaced by novel food processing techniques as these techniques are predominantly making their place in the global market.

## Acknowledgments

No such funding agency is involved in the research. No acknowledgement is required.

## Author Contributions

Uttiya Jana is the sole author. The author read and approved the final manuscript.

## Funding

There is no funding agency involved in this research as it is a review article.

## Data Availability Statement

This is a review article. So all the data used for this article are acknowledged in the bibliography section.

## Conflicts of Interest

The author declares no conflicts of interest.

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