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Recent Developments in Food Preservation Techniques: A Review

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Abstract
Food preservation is a critical issue in the field of food science. One of the most pressing issues in recent years has been food preservation. From the standpoint of safe eating, food preservation's goal is to prevent or postpone food spoilage, loss of quality, and inedibility for a longer period of time. In relation to growing population and depleting natural resources, food waste is a significant problem that affects public health, the environment, and the economy. Waste happens at every stage, from harvest to consumer, necessitating the use of cutting-edge food preservation methods. In this review paper some of the latest food preservation techniques such as Hurdle system, Edible films, Nanotechnology in food preservation, ultrasound, Traditional methods and Modern Methods of food preservation reviewed. This revision aims to provide a current overview on newest preservative techniques related to food. This group of food preservation techniques reviewed in this work.

Keywords
Food preservation, Hurdle system, Nanotechnology, Food spoilage, Natural resources, Food, Safe eating

1. INTRODUCTION

Since prehistoric times, food preservation has been at the forefront of food processing technologies. One of the most pressing concerns in food science is the prevention of microbial spoilage and oxidative deterioration. Food preservation procedures include drying, food additives, and coating application (Kutlu et al., 2021).

Benefits and drawbacks of food preservation (Table 1) On behalf of the different researches there is successfully preserved lots of food with freshness, nutritive value etc. The disadvantages show the health complications, alteration in taste etc.

Microbial metabolism, enzymatic activity, chemical interactions, sensory degradation, and toxin buildup all contribute to food deterioration. However, given the prevalence of various concerns about In order to address the shortcomings of current solutions and ensure the safety of conventional chemical preservatives, it is urgently necessary to research novel materials and methods for food preservation (Yu et al., 2021).

From the standpoint of safe eating, the goal of food preservation is to prevent or postpone food spoilage, loss of quality, and inedibility a longer time span. It entails restricting growth of bacteria, fungi, and other microbes (Hygreeva, et al., 2014; Gutiérrez-del-Río et al., 2021). Food preservation is the process of protecting food products from deterioration and spoilage, increasing shelf life, and assuring consumers that the food is free of pathogenic bacteria. A suitable food preservation method is one that creates hostile environments for bacteria. Heat treatments, lowering storage temperatures, using proper production processes, and adding additives all contribute to food shelf-life and safety. Water activity (aw), temperature, acidity, dehydration, preservatives, and non-thermal methods are the main obstacles (Pernu et al., 2020).

Kurbah & Haorongbam (2023) stated that the Food deterioration also has an effect on nutritional quality. Physical, biological, microbiological, chemical, and metabolic factors can all contribute to food deterioration. In order to apply

preservation techniques as soon as feasible in the food preparation chain, both plant and animal commodities need first undergo the proper postharvest management. In order to ensure continuity of preservation, processing processes typically rely on suitable packing techniques and materials.

Joardder (2019) mentioned the way processed foods are treated throughout storage, transport, retail, and by customers has an impact on how well they are preserved. The product itself, the amount of pathogenic and spoilage microorganisms present, and the cost all have an impact on the technology and methods chosen for food preservation. Product-inherent variables include customary methods of consuming the specific food, sensitivity to heat or other principles used to inactivate microbes, and other physical and chemical properties of the food.

Saleem & Khan (2023) has stated the ancient people had to interact with nature in order to survive. In cold environments, ancient people would freeze seal meat on ice; in warm environments, they would dry their food in the sun. Food preservation entails food processing steps that inhibit yeast-like bacteria growth and slow the rate at which fat oxidizes and becomes rancid. As enzymatic browning rises in an apple after it is sliced during food preparation, food preservation may also include a process that prevents aesthetic degradation.

Food wastes can be reduced considerably by preservation, which is a vital approach for minimizing costs of production and boosting the effectiveness of the food system. Enhanced nutritional status and food safety may support ecological sustainability. It will, for instance, result in a reduction in the ecological impact of food production. More than only food preservation methods are involved in many procedures aimed at keeping food. For example, to preserve fruit by making jam, it should be boiled and sold in an airtight jar to prevent cross-contamination. The quality of foods and food systems are effected differently by distinct techniques of food preservation (Yu et al., 2021).

Sridhar (2020) reported that when compared to more modern approaches, some historical methods of food preservation cost less energy and have lower carbon footprints. Some food preservation procedures are known to produce carcinogens. To survive, ancient man had to rely on nature. He froze seal flesh on the ice in cold climates. In hot climates, he dried food by exposing it to the sun**.**

Food naturally starts to spoil as soon as it is harvested. Ancient man's ability to develop roots, settle down, and create colonies was facilitated by food storage. He may now keep some of the kill or harvest for later use instead of having to devour it right once. Each culture used the same basic food preservation methods to preserve its local food supplies (Tavman et al., 2019).

Table 1 Benefits and Drawbacks of Food Preservation

S. NO.	Benefits	Drawbacks	References
1.	The reduction of autolytic enzymes and microbial growth	Salt and sugar in high amount harmful for health	(Pernu et al., 2020)
2.	Enhances shelf-life of foods	Some methods may destroy nutrient content	(Gokoglu, 2018)
3.	Improves appearance, texture, color & flavor	Alteration in taste	(Hygreeva, et al., 2014)
4.	Provides seasonal foods	Vitamin E is reduced by irradiation	(Sahoo, 2022)
5.	Increased availability of convenience foods	Food can spoil if preserved improperly	(Rahman, 2020)
6.	Foods that spoil quickly and can be carried long distances from the place of manufacture	Preserved foods may taste different than fresh foods	(Sridhar et al., 2021)

1.1 Role and functions of Food Preservation

Despite the fact that some methods work by contaminating the food with beneficial bacteria or fungi, food preservation (Fig. 1) restricts the growth of microorganisms (like yeasts) or other microbes and postpones the oxidation of lipids that results in rancidity**.** Food preservation increases the variety of foods that are available. Preserving food increases its shelf life. Cherries, pineapples, and other fruits and vegetables can all be preserved using a number of techniques for a very long time. Food preservation increases the amount of available food. Preserving food lowers food waste. Food waste is decreased when extra foods that could have otherwise gone bad are prepared and preserved. Preserving food lowers the likelihood of nutrient deficits. With the use of preserved foods, the diet can be varied. For instance, no vegetables are cultivated in a number of Middle Eastern countries due to the arid condition of the soil. Importing fresh and canned fruits and vegetables covers this deficit (Vedantu, 2022).

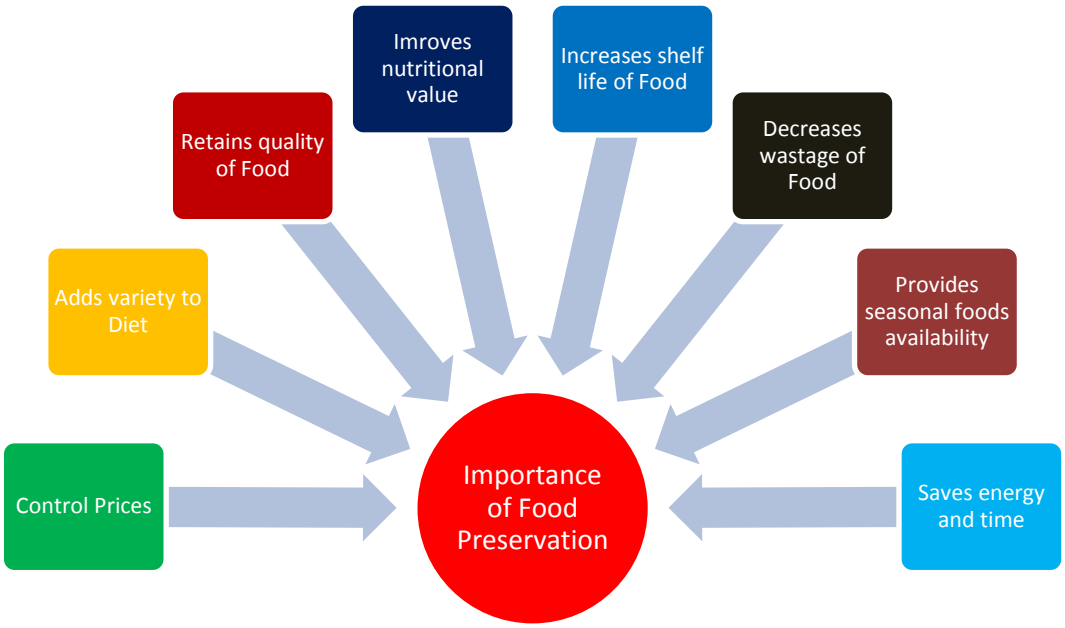
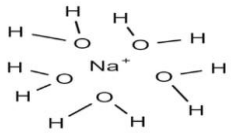
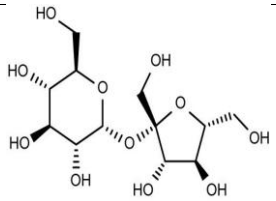
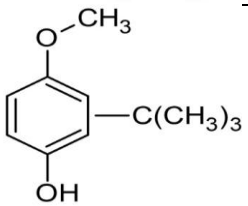
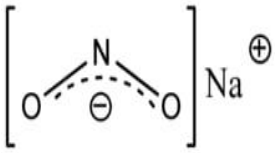
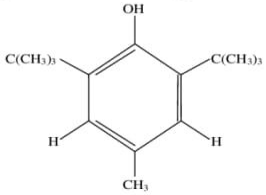


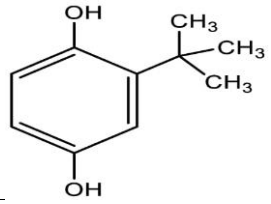
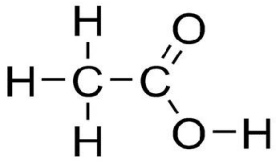
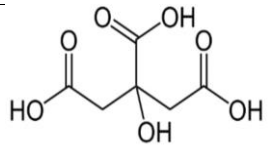
Fig. 1 Importance of Food preservation

1.2 Scope

The current review study's goal is to compile data on food preservation into a single review In order to present a fuller understanding, of current role & prospects for food preservation of common preservatives (Table 2). We discussed the most recent technologies in use at the time in each component in the introduction, highlighting notable developments as well as potential future directions. Information sources such as scientific journals and commercial and Food-related scholarly web pages on the Internet were used to conduct a thorough evaluation of food preservation.

Table 2 Chemical Structures of some common Food Preservatives

S. No.	Preservatives with chemical formula	Structure	Role	References
1.	Salt (NaCl)		Reduces water activity of foods	Albarracín et al. (2011)
2.	Sugar (C12H22O11)		Acts as Humectants	Abdulmumeen et al. (2012)
3.	BHA(Butylated Hydroxyanisole) (C22H32O4)		Acts as antioxidant	Delanghe et al. (2021)
4.	Sodium Nitrite (NO2−)		Used as coloring and antimicrobial agent	Cvetković et al. (2019)
5.	BHT(butylated hydroxytoluene) (C15H24O)		Acts as antioxidant	Anand & Sati (2013)

6.	TBHQ(tert-Butylhydroquinone) ($C_{10}H_{14}O_2$)		Used as synthetic antioxidant	Salmanzadeh et al. (2018)
7.	Vinegar (CH_3COOH)		Antibacterial and antioxidant	Singh (2020)
8.	Citric acid ($C_6H_8O_7$)		Emulsifying agent and for flavoring	Qin (2018)

2. METHODS OF FOOD PRESERVATION

This (Table 3) shows about the application of different types of food preservative methods detailing. Table is divided into two sections namely: Traditional methods & its application and Modern Methods & its applications.

2.1 Physical Methods

a. Drying

Ancient food would have dried naturally as a result of the sun and breeze. Food was actively dried throughout the Middle East and Asia as early as 12,000 B.C., as per evidence. There are more traces of later cultures, and each would have methods and materials that reflect their sources of sustenance, such as fish, wild game, domestic animals, and so on (Ahmad et al., 2017).

Fruits and vegetables have also been dried since ancient times. Ahmed et al. stated that Romans were particularly fond of any type of dried fruit they could produce. In the Middle Ages, "still homes" were purpose-built and used fruits, vegetables, and herbs should be dried in regions with less direct sunlight. A fire provided the heat required to dry and, in some situations, smoke foods (Ahmed et al., 2020).

b. Freezing

In the appropriate temperatures, freezing was an obvious preservation technique. Any location that experienced below-freezing temperatures for even a brief amount of time used the temperature to preserve food. To extend storage times, temperatures below freezing were used. As a result, cellars, caves, and cool streams were all well utilized (Cheng et al., 2015).

Green vegetables and milk products have long been chilled or frozen to maintain their sensory attributes and nutritional value. The most common freezing procedures include air blast, cryogenic, direct contact, and immersion freezing, while novel approaches include high pressure freezing, ultrasound assisted freezing, electromagnetic disturbance freezing, and dehydration freezing (Sridhar et al.,2021; Barbosa de Lima et al., 2020).

c. Canning

Nicolas Appert of France has been dubbed "the father of canning," in early 1800s, fulfilled long-held demands for food that is both fresh and stable. Yet, a method similar to "appertization" was widely used over long time ago (Deák & Farkas, 2013). According to Christensen (2023) they elevate those who can and will commodify, expand, and profit within capitalism institutions, resulting in a self-proclaimed modern corporate hero. By prioritizing "scientific" knowledge above "domestic" these narratives, based on knowledge, lower the costs of universalizing processes while misrepresenting how information is produced and disseminated.

d. Smoking

Rahman (2020) mentioned wood smoke has been used to preserve foods since the days of open-air drying. Smoking's primary goal is to impart desired sensory flavors and colors to foods while also inactivating enzymes and providing an antibiotic impact. Smoked foods are commonly stored in cooled or refrigerated conditions, however they are more dangerous than dry or frozen goods. Fellows (2022) has stated the temperature used in cold smoking is significant and may influence the final characteristics of the smoked product. Smoking contributes to the preservation of Protein-rich meals like meat, fish, and cheese can be enhanced by combining the effects of heat, which kills germs and enzymes, reduced moisture content, and antimicrobial and antioxidant compounds found in smoke.

e. Pasteurization

In the foodservice industry, thermal pasteurization is an essential unit operation for creating high-quality foods with lengthy shelf life in refrigeration or cold storage. Pasteurization treatment attempts to increase food safety by inactivating

viruses and germs found in food. Additionally, thermal pasteurization destroys bacteria that cause spoilage while partially inactivating enzymes. The temperature and duration of thermal pasteurisation are determined by pathogens that must be regulated in each food. Tanks, vats, and heat exchangers can be used to pasteurize food using batch or continuous systems prior to aseptic packaging or prepackaging (Sablani et al., 2023).

As per Cheng (2011) top researchers in the fields have recently begun to investigate an increasing number of non-thermal pasteurization techniques. Among the procedures used to treat water include Ultraviolet (UV) irradiation, ultrasound, high-pressure carbon dioxide, high-pressure homogenization, and microfiltration are all examples of high hydrostatic pressure**.**

2.2 Chemical Methods

a. Salting

One of the oldest known ways of food preservation is salting. The simple strategy typically results in the natural preservation of the community. It is possible to do it both conventionally and naturally. Salting preservation works by lowering the water level, which inhibits germ growth and development. High salt's osmotic qualities can damage microbial cell membranes, and its hygroscopic properties can interfere with proteolytic enzyme function and dissociated Cl ions (Elias, 2020). Because salting is not a stand-alone curing treatment, it is usually used in conjunction with other methods like as desiccation or boiling. Salt is also required for the creation of different flavors, textures, and fragrances. There are two salting processes: wet-dry and wet-dry combinations, as well as a curing process (Indiarto, 2021).

b. Sugaring

According to Dowse (2021) An osmotic effect is induced when sugar is given to fresh foods such as fruits and vegetables. This means that sugar decreases the water activity of food by absorbing water from it (aw). There are fewer free water molecules for bacteria to form and multiply in when there is less water activity (aw) in a foods. Bacteria require water to survive and multiply. It creates circumstances that inhibit germs from growing and surviving.

As per Goldfein (2015) Sugar aids in the creation of other compounds that function as preservatives in some foods, such as alcohol and acids. Fermentative yeasts in fermented foods convert sugar to organic acids such as lactic acid. Yeasts convert sugar to ethanol in wine, beer, and other fermented beverages. In some circumstances, the generated alcohol or acid works as a preservative in and of itself**.**

c. Pickling

Pickling is an ancient method of preserving vegetables, fruits, fish, and meat. Pickling produces distinct and desirable changes in flavors, texture, and colour that occur in fermented pickles over time. Microorganisms (most notably lactic acid bacteria, Micrococcaceae, Bacilli, yeasts, and filamentous fungus) play an important role in food pickling, influencing the final product's quality and safety (Behera et al., 2020).

d. Fermenting

Fermentation was discovered as opposed to invented. The first beer was undoubtedly discovered when a few barley grains were left outside in the rain. The starch-derived sugars were fermented into alcohols by opportunistic bacteria. The same is true for fermented fruits such as wine, cabbage fermented into Kim chi or sauerkraut, and other meals (Montemurro et al., 2019). It's amazing how skilled ancient peoples were at observing, controlling, and promoting fermentations. Some anthropologists believe that around 10,000 BC, humans evolved from wandering nomads to farmers who grew barley for beer. Both the beer and the alcohol were divine. It was considered a divine gift (Pérez-Armendáriz & Cardoso-Ugarte, 2020).

Fermentation was a useful means of preserving food. It has the potential to not only preserve meals, but also to create more nutritious dishes and make less desired elements more appealing. While fermenting, bacteria can generate vitamins. As a result, the ingredients produce a more nutritious finished product (Guerra et al., 2022).

e. Curing

Curing is one of the earliest techniques of food preservation, involving the addition of salt as well as nitrate or nitrite. This processing has undeniable technological value because it aids in the creation of a stable red/pink colour in meat products, protects lipids and proteins from oxidative reactions, enhances product flavors, and, most importantly, has a very unique antimicrobial effect on Clostridium botulinum (Ruiz-Carrascal, 2016).

The application of salt to the surface of complete pieces of meat, frequently in conjunction with nitrite and/or nitrate, is known as dry curing. After salting, the product is dried and matured for months to years before being consumed. Wet curing of complete pieces, such as cooked ham/loin and bacon, often entails injecting brines containing salt, nitrite, ascorbate, and, in certain circumstances, phosphates via a needle. Salt diffusion is accelerated by tumbling, a physical treatment. The product can be smoked and cooked if desired (Geiker et al., 2021).

Table 3 Application of different Methods of Food preservation

Traditional Methods	Application Food Products	Industrial (modern) Methods	Application (food products)	References
Freezing	Cheese, Broccoli, Peas, Curd, Jam & Jelly, Meat, Eggs, Fruits etc.	Pasteurization	Milk & milk products	(Ramesh, 2020); Kaur & Kumar, 2020)
Drying	Jerky, powdered milk, fruits and vegetables, pasta, and rice, etc.	Artificial food additives	Commonly used in all industrial foods	(Akter et al., 2022); (Awuchi et al., 2020)
Cooling	Fruits and vegetables.	Vacuum packing	Cereals, nuts, cured meats, and others.	(Liberty et al., 2013); (Abdulmumeen et al., 2012)
Boiling	Rice, dal, boiled vegetable soup, khichdi, boiled potatoes, boiled chicken, etc.	Irradiation	Meat products, spices and seasonings, Fruits & vegetables etc.	(Bighaghire et al., 2021); (Bisht et al., 2021)
Salting	Salt-cured foods include salted fish, meat, and vegetables	Hurdle system	Seafoods, pickles, sauces, etc.	(Lin et al., 2014); (Pal et al., 2017)
Heating	Baked foods, Boiled and Steamed foods	Bio preservation	Bacteriocins, essential oils, herbs, spices and other substances	(Tavman et al., 2019); (Smid et al., 2020)
Sugaring	Honey, syrup or molasses, etc.	High-pressure food preservation	Beverages, fruit smoothies and ready-to-eat meats.	(Abdel-Aleem, 2020); (Kadam et al., 2012)
Smoking	Meat, poultry and other seafood are available.	Nonthermal plasma	Meat, poultry, spices, herbs, etc.	(Rahman, 2020); (Sonawane et al., 2020)
Pickling	Mango, lemon, tomato, chill, gooseberry, carrot, garlic, etc.	Modified atmosphere	Beef, meat, pork, chicken, and fish	(Ding at al., 2018); (Opara et al., 2019)
Canning	Fruits, preserves, pickled vegetables, etc.	Pulse electric field electroporation	Soups, liquid eggs or fruit juices, etc.	(Sattarova & Saidmakhammadjon, 2022); (Blahovec et al., 2017)

3. NEW TRENDS IN FOOD PRESERVATION

Consumer demand for long-lasting, useful, or health-promoting foods, i.e., foods that not only do not harm people but can also be preserved for a long time with the same nutritional components and treat or prevent diseases such as heart disease, eye disease, cancer, diabetes, skin diseases, and so on, is driving one of today's most significant trends in food preservation.

Those methods that create more nutritious, fresher, less processed, and safer food through various food preservation strategies outlined in this paper will be in high demand in the future.

3.1 Nanotechnology in Food Preservation

Nowadays, the food industry is significantly impacted by nanotechnology. Both during food production and storage, the bioactive components of food commonly degrade or become inactive (Patel et al., 2022). The aforementioned issues can be substantially solved by using nanoencapsulation techniques, such as making nano emulsions. Packaging made of nanocomposite materials is another developing area in food storage and preservation (Brandelli et al., 2019; Patel & Mishra, 2021). The use of nanotechnology in food processing, various nanotechnology-based food preservation techniques, the use of packaging materials for food storage and preservation, nanotechnology applications in food preservation, safety concerns with nanotechnology-based food preservation techniques, and potential future uses of nanotechnology for food preservation were all discussed (Sridhar et al., 2021). Nanotechnology is being used to improve food packaging. Novel nano-based food packaging materials, for example, have outstanding qualities such as antibacterial potential, oxygen scavengers, and gas or moisture barriers, among others. The use of such nanoparticles in food packaging increases the shelf life of food without affecting its quality (Patel & Mishra, 2020).

3.2 Hurdle System

Hurdle innovation is used to preserve goods in both affluent and underdeveloped countries in a mild but effective manner. Many years ago, hurdle technology was invented as a revolutionary technique to producing safe, stable, nutritious, flavorful, and cost-effective foods (Mohammad et al., 2023). Techniques and Strategies for Quality Control in Fruit and Vegetable Processing, 1. Traditionally, hurdle technology was employed empirically with little comprehension of the controlling principles. As the concepts of crucial preservation parameters for foods (e.g., temperature, pH, aw, Eh, competitive flora) and their relationships have been more understood, the intelligent application of hurdle technology has

grown more common (Junaid et al., 2023). In view of the future goal of multi-target food preservation, the current contribution analyses the notion of prospective food obstacles, the hurdle effect, and hurdle technology (Singh & Shalini, 2016).

3.3 Ultrasound

Ultrasonic technology is environmentally safe and rarely causes heat damage to food goods. Ultrasound technology is being utilised to dry food products, including pre-treatments such as ultrasound, osmotic dehydration, and ultrasound-assisted osmotic dehydration. By lowering water activity, dehydration aids food preservation and increases shelf life (Ahmad et al., 2023). Non-thermal techniques such as ultrasound and microwave can be used to prepare and preserve meat and meat products. Combining non-thermal techniques like ultrasound and microwave can now offer superior outcomes (Khalid et al., 2023).

3.4 Edible Films

Biodegradable films derived from food ingredients are being investigated as more environmentally friendly and sustainable alternatives to plastics and other synthetic film-forming materials for food coating and packaging applications. Special emphasis is placed on the creation of active packaging materials based on natural components, particularly those obtained from plants (Gaspar & Braga, 2023). Common food elements used to make film matrices include proteins, polysaccharides, and lipids. To increase the functional qualities of these matrices, active compounds such as antioxidants and antimicrobials might be added. To have the requisite optical, mechanical, barrier, and preservation capabilities for commercial use, edible active films must be appropriately created (Chen et al., 2022).

3.5 Encapsulation

Encapsulation is an important procedure for protecting food components that is frequently used in the food industry. At present, encapsulation is of growing interest in food preservation (Reis et al., 2022). Various encapsulation techniques are spray drying, spray cooling, freeze drying, electro hydro dynamic techniques, fluidized bed coating, extrusion, liposome, and emulsification (Shahidi et al., 2020). These techniques address some of the challenges to incorporating food ingredients, antioxidants, lipids, protein, carbohydrate, minerals, vitamins and bioactive compounds in powder form in food products. Encapsulation achieves excellent preservation, stabilization, and controlled release of bioactive compounds. Encapsulation improves the efficiency of food additives and increases food shelf life, while also cutting food costs (Froiio et al., 2019).

4. CONCLUSION AND FUTURE TRENDS FOR FOOD PRESERVATION

The demand for food grows in lockstep with the world's population. In such cases, food preservation is critical. Many of the revolutionary technologies presented in this paper, including the Hurdle system, edible films, nanotechnology, and ultrasound, have the potential to provide more nutritious, fresher, and minimally processed foods. They are, however, still in the research stage. As a result, their antimicrobial and enzyme inactivation activity must still be demonstrated, and any potential health hazards must be evaluated. As a result, it appears that further research in these areas of food preservation is worthwhile.

Further study is needed to give proof for any novel functional foods' bioavailability and bioactivity. As a result, additional epidemiological study will be needed to prove the influence of nutritious diets or substances. Modern methods preserve food more effectively than traditional methods. However, the nature of food is changing internally. This causes changes in our health, which can be positive or negative.

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