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REVIEW OF BIOCHEMICAL PROCESSES IN FOOD PRESERVATION TECHNIQUES: IMPACT OF FERMENTATION, CANNING, AND FREEZING ON FOOD SAFETY AND SHELF LIFE

Mr. Hemant Kumar Tenginakai* | Dr. Aamarpali Roy**
**Ph.D. Scholar, Himalayan University, Itanagar, Arunachal Pradesh, India.*
***Research Supervisor, Himalayan University, Itanagar, Arunachal Pradesh, India.*

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ABSTRACT:
This review explores the biochemical processes involved in three primary food preservation techniques: fermentation, canning, and freezing. Each method employs distinct mechanisms that enhance food safety and extend shelf life. Fermentation utilizes microorganisms to produce acids and alcohols, creating an environment that inhibits spoilage. Canning involves heating food to eliminate pathogens and sealing it to prevent contamination, while freezing slows enzymatic activity and microbial growth through low temperatures. This review highlights the advantages and challenges associated with each technique, emphasizing their significance in modern food preservation practices and the importance of adhering to safety standards to ensure consumer health.

Keywords: *food preservation, biochemical processes, fermentation, canning, freezing, food safety, shelf life, microorganisms.*

INTRODUCTION

Food preservation is an important aspect of food science that aims to prevent spoilage and extend the shelf life of various products. With the growing global population and increasing food demand, effective preservation methods are essential to ensure food security and reduce waste. This introduction focuses on three prominent techniques: fermentation, canning, and freezing, each utilizing unique biochemical processes to maintain food safety and quality.

Fermentation is one of the oldest preservation methods, harnessing the power of microorganisms to transform food through biochemical reactions. This process not only enhances flavor and nutritional value but also creates conditions that inhibit harmful bacteria. Canning, on the other hand, employs heat treatment to destroy pathogens and enzymes, sealing food in airtight containers to prevent recontamination. Lastly, freezing has become a popular method that slows down microbial growth and enzymatic activity by lowering temperatures, preserving the food's nutritional content and safety.

Understanding the biochemical mechanisms behind these preservation techniques is essential for optimizing their use and ensuring the safety and quality of preserved foods. This review aims to delve into these processes, examining their effectiveness and the implications for food safety and shelf life.

In a literature review on this topic, researcher reviewed and analyze existing research on the biochemical processes in food preservation techniques such as fermentation, canning, and freezing. Looked for studies, articles, and papers that investigate the biochemical processes in food preservation techniques such as fermentation, canning, and freezing and more.

The examination of biochemical processes in food preservation techniques such as fermentation, canning, and freezing plays a pivotal role in ensuring food safety and extending the shelf life of various food products. This literature review delves into the intricate interplay of biochemical reactions involved in these preservation methods and their profound impact on food quality, safety, and longevity.

Fermentation, a time-honored preservation technique, involves the metabolic action of microorganisms like bacteria and yeast on food substrates. This process not only enhances the flavor and texture of foods but also contributes to their preservation by creating an acidic environment that inhibits the growth of harmful

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pathogens. Various biochemical reactions, such as lactic acid fermentation in dairy products and alcohol fermentation in beverages, are fundamental to the preservation and transformation of food matrices.

Fermentation:

Microorganisms, including bacteria, yeasts, and molds, play a vital role in fermentation, a biochemical process that transforms sugars into acids, gases, or alcohol. During fermentation, these microorganisms metabolize carbohydrates, primarily sugars, producing by-products that help preserve food. For instance, yeast converts sugars into alcohol and carbon dioxide during the fermentation of beverages like beer and wine, while lactic acid bacteria convert sugars into lactic acid in products like yogurt and sauerkraut. The production of these by-products lowers the pH of the food, creating an environment that inhibits the growth of spoilage organisms and pathogens.

El Sheikha, A. F., & Hu, D. M. (2020). Fermented foods were likely to have been the first among all types of processed foods consumed by human beings. The role that fermented food plays is not only related to the development of civilizations and cultural relationships between countries but also related to the nutritional importance of its population. Of course, the early manufacturers of fermented foods didn't take into account the advantages of modern sciences, because enzymes and microorganisms were discovered just 150-200 years ago. For that reason, we can conclude why the ancient fermentation techniques were known to philosophers and alchemists, but not to biologists. It demonstrated that the fermentation mechanisms involved many secrets still undiscovered. Recently, applications of molecular techniques for analyzing and study the fermented foods have been explored. In this review, we provide answers with a critical vision to many questions for understanding the role of molecular techniques to discover the secrets of fermented foods such as how to evaluate the traditional fermented foods? Why using molecular techniques to study the fermented foods not else? Is the future will carry to us a boom in molecular technologies contribute to the detection of more secrets of the fermented food?

The paper by Azam, M., Mohsin, M., Ijaz, H., Tulain, U. R., Ashraf, M. A., Fayyaz, A., Abadeen, Z., & Kamran, Q. (2017) highlights the significant roles of lactic acid bacteria in various fermented foods in Asia. It provides an overview of lactic acid fermented foods worldwide and discusses the positive impacts of lactic acid fermentation on food. The study identifies multiple genera of lactic acid bacteria associated with foods, including Carnobacterium, Enterococcus, Lactobacillus, Lactococcus, Leuconostoc, Oenococcus, Pediococcus, Streptococcus, Tetragenococcus, Vagococcus, and Weissella. Lactic acid bacteria are crucial in the fermentation processes of traditional Asian foods, showcasing their profound effects on enhancing food quality and safety. In recent years, there has been an increasing interest in utilizing the antagonistic activities of LAB to extend the shelf life of protein-rich products like meats and fish. The review article outlines various LAB fermentation types and their associated fermented foods such as idli, kishk, sauerkraut, koumiss, Suan-tsai, stinky tofu, Chinese sausage, and kefir, shedding light on the roles of LAB and the reasons for their widespread presence in these food products.

Okazaki, S., Furukawa, S., Ogihara, H., Kawarai, T., Kitada, C., Komenou, A., & Yamasaki, M. (2010).Traditional brewing of Fukuyama pot vinegar is a process that has been continued in Fukuyama, Kagoshima, Japan, for almost 200 years. The entire process proceeds from raw materials, including steamed rice, rice koji (steamed rice grown with a fungus, Aspergillus oryzae) and water, to produce vinegar in roughly capped large pots laid in the open air. No special fermentative manipulation is required, except for scattering dried rice koji (called furi-koji) on the surface of the mash to form a cap-like mat on the surface at the start of brewing. As the biochemical mechanism of the natural transition of the fermentative processes during brewing has not been fully explained, we conducted a microbiological and biochemical study on the transition. Dominant microbial species involved in the three fermentations were identified by denaturing gradient gel electrophoresis analysis using PCR-amplified defined-regions of small rDNA from microorganisms in the brewing mash or colony direct PCR applied to isolated microorganisms from the mash.

The effect of controlled fermentation processes on the microbial association and biochemical profile of Conservolea naturally black olives was studied by Panagou, E. Z., Schillinger, U., Franz, C. M., & Nychas, G. J. (2008). The study compared different treatments: (a) inoculation with a commercial starter culture of Lactobacillus pentosus, (b) inoculation with a strain of Lactobacillus plantarum from a fermented cassava product, and (c) spontaneous fermentation without inoculation. Throughout the fermentation process, microbial growth, pH, titratable acidity, organic acids, and volatile compounds were monitored. The initial microbiota included Gram-negative bacteria, lactic acid bacteria, and yeasts. Inhibition of Gram-negative bacteria was observed in all processes. Both starter cultures accelerated the fermentation process, reducing the survival period of Gram-negative bacteria by 5 days compared to the spontaneous process, thus minimizing spoilage risks. Major volatile compounds identified by gas chromatography included ethanol, methanol, acetaldehyde, and ethyl acetate. The concentrations of these compounds varied among treatments, indicating different levels of microbial activity in the brines. The findings of this study could benefit the Greek table olive industry by enhancing processing methods to improve product consistency and quality, potentially expanding the international market for naturally black olives.

Solomons N. W. (2002). Lactose (milk sugar) is a fermentable substrate. It can be fermented outside of the body to produce cheeses, yoghurts and acidified milks. It can be fermented within the large intestine in those people who have insufficient expression of lactase enzyme on the intestinal mucosa to ferment this disaccharide to its absorbable, simple hexose sugars: glucose and galactose. In this way, the issues of lactose intolerance and of fermented foods are joined. It is only at the extremes of life, in infancy and old age, in which severe and life-threatening consequences from lactose maldigestion may occur. Fermentation as part of food processing can be used for preservation, for liberation of pre-digested nutrients, or to create ethanolic beverages. Almost all cultures and ethnic groups have developed some typical forms of fermented foods. Lessons from fermentation of non-dairy items may be applicable to fermentation of milk, and vice versa.

Caplice, E., & Fitzgerald, G. F. (1999). Preservation of foods by fermentation is a widely practiced and ancient technology. Fermentation ensures not only increased shelf life and microbiological safety of a food but also may also make some foods more digestible and in the case of cassava fermentation reduces toxicity of the substrate. Lactic acid bacteria because of their unique metabolic characteristics are involved in many fermentation processes of milk, meats, cereals and vegetables. Although many fermentations are traditionally dependent on inoculation from a previous batch starter cultures are available for many commercial processes such as cheese manufacture thus ensuring consistency of process and product quality. This review outlines the role of lactic acid bacteria in many such fermentations and the mechanisms of antibiosis with particular reference to bacteriocins and gives a brief description of some important fermented foods from various countries. It is anticipated that the contribution of the advances in lactic acid bacteria research towards improvement of strains for use in food fermentation will benefit both the consumer and the producer.

Research focusing on the biochemical aspects of food preservation techniques is crucial for advancing food science and technology. By elucidating the underlying mechanisms of fermentation, canning, and freezing, scientists can optimize these methods to enhance food safety, quality, and longevity. Moreover, exploring novel approaches to food preservation, such as the use of natural antimicrobial compounds or advanced packaging materials, can further revolutionize the field and address emerging challenges in food security and sustainability.

In conclusion, the examination of biochemical processes in food preservation techniques like fermentation, canning, and freezing is instrumental in safeguarding food safety and extending the shelf life of perishable goods. Through a comprehensive understanding of the biochemical reactions involved in these methods, researchers can innovate and improve food preservation practices, ensuring the availability of safe, nutritious, and high-quality food products for consumers worldwide.

Overall, fermentation not only preserves food but also enhances its safety and nutritional value, making it a crucial process in food production.

Canning:

The canning process is a method of food preservation that involves placing food in airtight containers and subjecting them to heat. This heating process is crucial as it kills microorganisms such as bacteria, yeasts, and molds, while also inactivating enzymes that can cause spoilage. The heat penetrates the food, raising its temperature to a level that destroys harmful pathogens, ensuring that the food remains safe for consumption.

Ţiţa, O., Constantinescu, M. A., Ţiţa, M. A., Bătuşaru, C., & Mironescu, I. (2024) explain that food waste is a significant societal issue globally, causing detrimental environmental impacts. They state that approximately 1.3 billion tonnes of food are wasted annually, as estimated by the Food and Agriculture Organization. The authors aim to develop sustainable, nutritionally rich food products by utilizing food waste, particularly potato and carrot peels, which are cost-effective resources for extracting valuable components like dietary fibers, biopolymers, antioxidants, and food additives. They highlight the nutritional benefits of cheese, a functional dairy product known for aiding in various health conditions such as diabetes, obesity, hypertension, and digestive problems, while providing energy. In their study, the authors prepared control and experimental samples of melted cheese with varying amounts of potato and carrot peels to investigate their nutritional value. They conducted analyses on physicochemical and enzymatic parameters and evaluated consumer acceptability through textural and sensory assessments.

Sridhar, A., Ponnuchamy, M., Kumar, P. S., & Kapoor, A. (2021). Food wastage is a major issue impacting public health, the environment and the economy in the context of rising population and decreasing natural resources. Wastage occurs at all stages from harvesting to the consumer, calling for advanced techniques of food preservation. Wastage is mainly due to presence of moisture and microbial organisms present in food. Microbes can be killed or deactivated, and cross-contamination by microbes such as the coronavirus disease 2019 (COVID-19) should be avoided. Moisture removal may not be feasible in all cases. Preservation methods include thermal, electrical, chemical and radiation techniques. Here, we review the advanced food preservation techniques, with focus on fruits, vegetables, beverages and spices. We emphasize electrothermal, freezing and pulse electric field methods because they allow both pathogen reduction and improvement of nutritional and physicochemical properties. Ultrasound technology and ozone treatment are suitable to preserve heat sensitive foods. Finally, nanotechnology in food preservation is discussed.

The study by Liu, Y., Huang, F., Yang, H., Ibrahim, S. A., Wang, Y. F., & Huang, W. (2014) investigated the proximate composition, free amino acids content, and 5'-nucleotides in frozen, canned, and salted Agaricus bisporus (A. bisporus). The research found that all three types of A. bisporus products are rich sources of protein, with protein content ranging from 16.54 to 24.35g/100g (dry weight). However, the freezing, canning, and salting processes, along with 6 months of storage, led to a notable decrease in free amino acids, particularly tyrosine, alanine, glutamine, and cysteine. Frozen and canned A. bisporus exhibited medium levels of MSG-like amino acids, while salted A. bisporus had lower levels of these amino acids. Additionally, the study discovered that the amount of flavor-enhancing 5'-nucleotides in frozen A. bisporus was higher compared to canned and salted A. bisporus. Overall, the findings suggest that freezing is advantageous for preserving the quality of A. bisporus.

Martínez, S., López, M., González-Raurich, M., & Bernardo Alvarez, A. (2005). Morrón pepper of 'Fresno de la Vega' (Capsicum annuum L.) is a big sweet variety cultivated in the province of León (northwestern Spain). Changes in vitamin C content of this variety of pepper as a function of ripeness, storage and different preservation systems were studied. The ascorbic acid content increases in peppers as they ripen. For green mature, breaker and red peppers values of 107.3+/-1.84, 129.6+/-3.11 and 154.3+/-7.56 mg/100 g edible portion were found. The vitamin C content for green mature and breaker peppers stored at room temperature (20 degrees C) increased up to 10 days of storage, reaching similar values as those obtained for red peppers direct from the plant. However, stored red ripe peppers showed a significant loss in vitamin C content, around 25%. Refrigeration at 4 degrees C for up to 20 days did not change the ascorbic acid content, except for red peppers, which showed losses around 15%. The ascorbic acid content was altered in response to the preservation procedures assayed. Reductions of 12% and 20-25% during the water blanching and canning process,

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respectively, were observed. Ascorbic acid retention during freezing was 60%, increasing when the product was previously blanched (87%). Dehydration of peppers resulted in an 88% decrease in ascorbic acid content, whereas freeze-drying did not cause significant losses.

Korus, A., Lisiewska, Z., & Kmiecik, W. (2002). Seeds of the grass pea (Lathyrus sativus L.) cultivars Derek and Krab, with a dry matter content of about 33%, were used for freezing and for canning. The content of vitamins C, B1, and B2 and of carotenoids, beta-carotene, and chlorophylls was determined in raw and blanched material, in frozen products after 6-month storage before and after cooking to consumption consistency, and in canned products after 6-month storage. In comparison with the cultivar Krab, raw seeds of Derek contained 45% more vitamin C, 14% more total chlorophylls, 13% less thiamine (vitamin B1), and 7% less riboflavin (vitamin B2). The level of carotenoids was similar. Blanching of seeds led to a statistically significant decrease only in the content of vitamin C. Freezing and frozen storage significantly lowered the level of vitamin C and chlorophylls. The cooking of frozen seeds and the production of canned products and their storage resulted in a statistically verified reduction in the content of components analysed in all the samples. Greater losses were found in products prepared from seeds of the cv. Krab. After cooking, frozen seeds contained more of all the analysed components than the canned products.

Cano, M. P., de Ancos, B., Lobo, G., & Monreal, M. (1996). An HPLC study of the carotenoid composition of fresh, frozen and canned papaya fruit slices was done. There were no qualitative differences between the carotenoid patterns of fresh and frozen papaya fruit slices (cultivar Sunrise). The major carotenoids found in papaya extracts were lycopene and carotenol fatty acid esters of beta-cryptoxanthin and beta-cryptoxanthin-5, 6-epoxide. Other xanthophylls detected were beta-cryptoxanthin, trans-zeaxanthin and cryptoflavin. It was possible to determine the quantitative losses of carotenoids in papaya slices as a result of the freezing process and frozen storage, since samples of these fruits were available before processing. The pigment pattern of the canned product showed lycopene as being a major pigment. Thermal treatment induced the degradation of carotenol fatty acid esters of xanthophylls. The freezing and canning processing of papaya slices led to significant decreases in the total carotenoids quantified by HPLC, with frozen female slices and canned samples showing lower amounts of pigments. Hunter colour values of frozen slices were similar to those of fresh papaya fruit slices.

Canning, another prevalent preservation method, relies on heat processing to destroy microorganisms and enzymes that cause food spoilage. The biochemical changes induced by canning involve denaturation of proteins, inactivation of enzymes, and alteration of food structure. Understanding these processes is essential to ensure the safety and quality of canned foods, preventing microbial contamination and maintaining nutritional integrity. Proper canning techniques are essential for food safety, particularly to prevent the growth of Clostridium botulinum, a dangerous bacterium that can produce toxins in low-oxygen environments, such as improperly canned foods. To mitigate this risk, it is vital to follow recommended processing times and temperatures, especially for low-acid foods.

Canning also affects the nutritional quality and shelf life of preserved foods. While some nutrients may be lost during the heating process, canned foods can still retain a significant portion of their vitamins and minerals. The sealed environment created during canning prevents spoilage and extends shelf life, allowing foods to be stored for months or even years without refrigeration. Overall, canning is an effective method for preserving food safety and nutritional quality.

Freezing:

The freezing process involves lowering the temperature of food to below its freezing point, typically around -18°C (0°F). This drastic temperature reduction significantly slows down microbial activity and enzymatic reactions. At low temperatures, the growth of spoilage organisms, including bacteria and molds, is inhibited, effectively halting the spoilage process. This makes freezing an effective method for preserving food quality.

Tomaszewska, M., Bilska, B., & Kołożyn-Krajewska, D. (2022) found that food waste in households is often a result of improper practices by consumers when handling food. In their survey of Polish respondents, they examined the impact of food safety and hygiene practices on food wastage due to spoilage. The study, conducted in 2019 with 1115 Polish respondents aged 18 and above, used synthetic indicators to evaluate the knowledge and behaviors of adults regarding food management and the frequency of discarding food. The analysis showed that most food items were either rarely or never discarded. Regression analysis indicated that the primary factor contributing to food wastage was food spoilage ($\beta = 0.223$). Improper handling of food after purchase, inadequate food storage practices, and inappropriate treatment of uneaten meals, excluding leftovers on the plate, were identified as key practices leading to food waste. The study suggests that raising awareness among consumers about proper food storage practices at home and encouraging the use of freezing uneaten food can help reduce food waste in Polish households.

Cardador, M. J., & Gallego, M. (2018) discussed how the freezing industry commonly utilizes disinfected water and/or disinfectants for various processes like sanitizing, washing, blanching, cooling, and transporting the final products. Consequently, the presence of disinfection by-products (DBPs) in frozen foods is expected. The study specifically focused on examining the occurrence of 14 halogenated DBPs, including four trihalomethanes, seven haloacetic acids, two haloacetonitriles, and trichloronitromethane, in a diverse range of frozen vegetables, meats, and fish. Results revealed that vegetables contained up to seven DBPs, whereas meats and fish had only four DBPs present, at lower concentrations due to less exposure to disinfected water compared to vegetables. Notably, trichloronitromethane, the most prevalent nitrogenous DBP in disinfected water, was detected in foods for the first time. The study concluded that the freezing process can maintain these compounds stable for longer durations compared to other preservation methods like sanitizing or canning. Consequently, frozen foods exhibited higher concentrations of DBPs compared to minimally processed or canned vegetables and meats. Disinfected water and/or disinfectants are commonly used by the freezing industry in such processes as sanitising, washing, blanching, cooling and transporting the final product. For this reason, disinfection by-products (DBPs) can be expected in frozen foods. This study focused on the presence of DBPs in a wide variety of frozen vegetables, meats and fish. For this purpose, the 14 halogenated DBPs more prevalent in disinfected water were selected (four trihalomethanes, seven haloacetic acids, two haloacetonitriles and trichloronitromethane). Up to seven DBPs were found in vegetables, whereas only four DBPs were present in meats and fish, and at lower concentrations, since their contact with disinfected water is lower than in frozen vegetables. It is important to emphasise that trichloronitromethane (the most abundant nitrogenous DBP in disinfected water) was found for the first time in foods. Finally, it was concluded that the freezing process can keep the compounds stable longer than other preservation processes (viz. sanitising, canning) and, therefore, frozen foods present higher DBP concentrations than other food categories (minimally processed vegetables, or canned vegetables and meats).

Domínguez, R., Barba, F. J., Gómez, B., Putnik, P., Bursać Kovačević, D., Pateiro, M., Santos, E. M., & Lorenzo, J. M. (2018) Spoilage of meat products during processing, distribution and exposure in the markets have an important negative impact on meat industry from an economic point of view. Two of the main problems of meat and products during processing and subsequent storage are lipid oxidation and deterioration due to microorganism growth. In this context, several packaging alternatives have been developed by meat industry in order to limit these losses and to extend the meat products´ shelf life. Over the last years, the use of active packaging has been proposed as an alternative to traditional packaging. The principle of active packaging, particularly antioxidant active packaging, consists of including active agents in the packaging which interact with meat and/or its environment, either by trapping pro-oxidant compounds or by releasing antioxidant compounds in order to delay degradation due to lipid oxidation. Therefore, the use of active packaging is presented as a future option to solve the problems derived from oxidative deterioration of meat and meat products. However, its use will depend on the costs involved in the development of this active packaging. Therefore, this review will give an overview about the use of active packaging and natural antioxidants, the active film development techniques, as well as the use of biopolymers as substitutes for synthetic polymers and their direct application in the meat industry.

Martindale and Schiebel (2017) aim to show how the link between food preservation and reducing consumer waste is essential for creating sustainable meal choices. The study provides insights from a consumer survey conducted in the Austrian market on frozen and fresh foods. The survey methods reveal how preservation methods, particularly freezing, can impact meal planning and decrease food waste across different types of food purchases. The findings indicate a significant reduction in food waste, up to six times, when comparing frozen foods to fresh foods. One limitation highlighted is the need for a better understanding of the likelihood of wastage for specific foods based on purchase frequency, an aspect that other researchers have explored. This study identifies varying levels of food waste across different food categories, offering valuable data to shape food product development strategies that minimize consumer waste. The research proposes the use of a decision matrix for guiding new product development, presenting a model that offers tailored food preservation solutions to address consumer needs effectively.

The study by Seminario, D. M., Balaban, M. O., & Rodrick, G. (2011) focused on Vibrio vulnificus (Vv), a pathogen commonly found in raw oysters. Freezing was explored as a method to reduce Vv levels and extend the shelf life of oysters. The research aimed to create predictive models for inactivating Vv in pure cultures under various frozen storage conditions. In the study, Vv was initially diluted in phosphate-buffered saline (PBS) to achieve around 10^7 CFU/mL. Samples were frozen at different temperatures (-10, -35, and -80 °C) with varying freezing rates and stored at different temperatures. The survival of Vv was monitored post-freezing and during storage at -10 °C (0, 3, 6, and 9 days) and at -35 and -80 °C (weekly for 6 weeks). Time-temperature data was collected using thermocouples in empty vials for each treatment. The study found that different freezing temperatures did not significantly impact Vv survival immediately after freezing. However, the combined effect of freezing and 1 week of frozen storage led to substantial reductions in Vv levels: 1.5, 2.6, and 4.9 log10 reductions for samples stored at -80, -35, and -10 °C, respectively. The critical factor influencing Vv survival was the storage temperature. A modified Weibull model was successfully developed to predict Vv survival during frozen storage, represented by the equation: log10 Nt = log10 No - 1.22 - ([t/10^(-1.163-0.0466T)][0.00025T^2 + 0.049325]). Here, N(o) and N(t) represent the initial and time t (days) survival of Vv, respectively.

Freezing, a widely used preservation technique, involves the reduction of temperature to inhibit microbial growth and enzymatic activity. The biochemical processes during freezing include the formation of ice crystals, which can affect the texture and quality of frozen foods. Proper freezing techniques are crucial to minimize cellular damage and preserve the sensory attributes of food products, ensuring their safety and shelf stability.

The pigment principally responsible for the deep-red color of ripe tomato fruits and tomato products is lycopene, as highlighted in the study by Shi, J., & Le Maguer, M. (2000). Lycopene has gained attention due to its biological and physicochemical properties, particularly its role as a natural antioxidant. Despite lacking provitamin A activity, lycopene has a high physical quenching rate constant with singlet oxygen, almost double that of beta-carotene. The degradation of tomato lycopene during processing mainly occurs due to isomerization and oxidation. Isomerization involves converting all-trans isomers to cis-isomers, resulting in an unstable, energy-rich state. Monitoring the degree of lycopene isomerization during processing can offer insights into the potential health benefits of tomato-based foods. Thermal processing methods like bleaching, retorting, and freezing can lead to some lycopene loss in tomato-based foods. Heat triggers the conversion of all-trans to cis forms, with cis-isomers increasing with temperature and processing duration. Dehydrated and powdered tomatoes typically exhibit poor lycopene stability unless processed meticulously and stored promptly in a hermetically sealed, inert atmosphere. Dehydrated tomato samples processed using various dehydration methods show a notable increase in cis-isomers alongside a decrease in all-trans isomers. Frozen foods and heat-sterilized products can also be affected by lycopene degradation during processing.

The impact of these preservation methods on food safety and shelf life is profound. By inhibiting microbial growth, enzymatic reactions, and chemical deterioration, fermentation, canning, and freezing contribute significantly to the prevention of foodborne illnesses and spoilage. However, variations in processing

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parameters, such as temperature, pH, and time, can influence the efficacy of these preservation techniques and their biochemical outcomes.

While freezing can extend the shelf life of foods, it may also alter their quality over time. Some foods, particularly those with high water content, can experience changes in texture upon thawing, becoming mushy or less appealing. Additionally, prolonged storage can lead to nutrient degradation. Therefore, while freezing is an effective preservation method, it's important to consider both food safety and potential changes in quality when storing frozen foods.

CONCLUSION:

In conclusion, the exploration of biochemical processes in food preservation techniques—fermentation, canning, and freezing—reveals their significant roles in enhancing food safety and extending shelf life. Each method employs distinct mechanisms that contribute to the prevention of spoilage and the inhibition of harmful microorganisms. Fermentation not only enhances flavor but also creates an acidic environment that deters pathogens. Canning effectively eliminates bacteria and seals food in a sterile environment, while freezing preserves food by slowing down enzymatic reactions and microbial activity.

As food preservation continues to evolve, understanding these biochemical processes remains crucial for improving techniques and ensuring the safety and quality of food products. By adhering to established safety standards and leveraging the strengths of each method, we can optimize food preservation practices to meet the growing demands of consumers and reduce food waste. Ultimately, these preservation methods play a vital role in sustaining food security and promoting public health.

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ABOUT AUTHORS:

Author Mr. Hemant Kumar Tenginakai is Research Scholar in Himalayan University, Itanagar, Arunachal Pradesh, India.

Author Dr. Aamarpali Roy is Research Supervisor in Himalayan University, Itanagar, Arunachal Pradesh, India.