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Food Processing Technology, Storage and Post Harvest Management

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Introduction

Food items undergo transformations through a range of engineering procedures that make use of scientific principles and methodologies. To make food products that are safe and last a long time, these principles encompass chemistry, microbiology, engineering, and physics. Understanding food composition and processing-related chemical changes, as well as how to preserve nutrients, reduce spoiling reactions, and develop desired flavour profiles, are all made easier with the aid of food chemistry. Microbiology ensures food safety and prolongs shelf life by regulating the growth of pathogenic bacteria. When designing food processing equipment, engineering concepts are used to ensure optimal heat transfer, good sanitation, and efficient operation. Understanding the physical characteristics of food materials, such as heat transfer rates, mass transfer events, and rheological properties, requires a solid understanding of food physics. This information is crucial for preserving the proper texture and consistency of food products, as well as for maximizing heat penetration during sterilization and effective drying during dehydration.

Storage: Safeguarding the quality and safety of food after harvest is equally important as the processing techniques themselves. Storage strategies play a critical role in this endeavour. Different food types require specific environments: fruits and vegetables benefit from controlled atmosphere storage (CAS), where the oxygen and carbon dioxide levels are meticulously controlled to slow down their natural respiration and extend shelf life. Perishables like meat, dairy, and prepared foods rely on refrigeration and freezing to significantly reduce microbial growth and enzymatic activity, thereby preserving their freshness and safety. Grains and other dry commodities require dry, controlled-temperature environments offered by silos and warehouses to prevent spoilage and maintain quality during storage.

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Post-harvest management practices aim to minimize losses and ensure food reaches consumers in the best possible condition. It all starts with proper harvesting techniques: picking fruits and vegetables at the optimal maturity stage and employing methods that minimize mechanical damage. Sorting and grading the produce based on size, maturity, and quality allows for targeted handling and storage practices, further reducing spoilage. Finally, appropriate packaging plays a crucial role in creating a barrier against physical damage, moisture loss, and microbial contamination during transportation and storage. These combined efforts in post-harvest management contribute significantly to minimizing food waste and delivering high-quality food to consumers.

ENERGY SAVING FOOD PROCESSING

Innovative, energy- and environmentally-efficient food processing technologies are being developed rapidly. For instance, cold plasma, pressurized fluids, pulsed electric fields, ohmic heating, radiofrequency electric fields, ultrasonics and mega sonics, high hydrostatic pressure, high pressure homogenization, hyperbaric storage, and negative pressure cavitation extraction are the foundations for the development of modern food processing technologies that limit the thermal degradation of the biologically active compounds and preserve food taste and aroma. In addition to being quick, safe for the environment, and energy-efficient, these procedures can guarantee food safety and a high nutritional content.

Cold plasma technology: Ionized gas made up of atoms, neutral molecules, ions, and electrons is called plasma. Fully ionized plasma has a high temperature; nevertheless, partially ionized plasma that is not thermal can still be employed in biological applications because of its low temperature. The inactivation of microorganisms found in meats and vegetables, the microflora found in milk and dairy products, and the browning enzymes polyphenol oxidase and peroxidases can all be achieved with cold plasma, improving food preservation. It can also be used to decontaminate food packaging materials. Regulatory permission, plasma source design, and process control are some of the remaining obstacles to this technology's use in the food business.

High pressure homogenization: High pressure (HPH, 100–300 MPa) or ultra-high pressure (UHPH, 300–450 MPa) homogenization can be done in batches or continuously. It is caused by a pressurized fluid flowing through a system that causes significant turbulence, cavitation, and temperature rise. Repetition of this procedure five to ten times improves the stability of the emulsion, reduces particle size, boosts nutritional component availability, and inactivates microorganisms. Additionally, it can be applied to food sterilization, modifying the rheological properties of biopolymers, and extracting bioactive chemicals from food or food processing waste. However, the processing rate for a system with a 55 L tank is quite low at about 264 kg/h, while the processing cost for HPH and UHPH is relatively high, ranging from 0.5 to 1.5 €/kg.

Furthermore, according to EU food processing laws (EC No. 258/97), every food processed with HPH or UHPH must be evaluated to see whether it is equal to a food that is currently available in the EU or not.

Pulsed electric field: A novel non-thermal food processing and preservation technique called pulsed electric fields (PEF) works on cells by electroporating their membranes. Food quality is not compromised by this non-thermal approach. In addition to improving food pasteurization, pulsed electric field treatment also improves extraction and drying by lowering drying temperature or shortening freezing time. PEF-assisted cold pasteurization of liquid foods may be a useful food processing method.

Novel food drying technology: Cutting-edge drying techniques like microwave-assisted convective drying, ultrasound-assisted convective drying, and infrared-assisted freeze drying use less energy than traditional convective or freeze-drying methods while also frequently enhancing food quality. Comparing infrared-assisted freeze drying at 45–55°C to conventional freeze drying, it is possible to save up to 19% of energy and 14% of drying time. When comparing ultrasound-assisted convective drying to convective drying of raspberries, the drying time was shortened by up to 64% and the energy consumption was reduced by up to 23%. When compared to convective drying, the energy savings with microwave-assisted convective drying were considerably greater, reaching up to 54%. When combined with artificial intelligence technologies, biomimetic technologies like computer vision and electronic nose can greatly enhance various drying methods.

Disinfection of equipment: Equipment used in the food processing industry needs to be cleaned, washed, disinfected, and rinsed in that order. Three novel physical cleaning techniques for equipment are ultrasonic vibration to clean filtering membranes, dry-ice cleaning, and ice-pigging (using an ice-water mixture to remove and take off particles from the equipment). Equipment used in food processing can be cleaned and disinfected using either electrolyzed water or a 5% solution of hydrogen peroxide. In addition to heating, other methods for sterilizing equipment include the use of various liquids, primarily phenolic or quaternary ammonium compounds, and gaseous chemicals like hydrogen peroxide vapor and ethylene oxide.

BIOTECHNOLOGICAL FOOD PROCESSING

Use of enzyme for food technology: Over the past 60 years, food processing has changed dramatically due to the emergence of new enzymatic applications. In food technology, microbial enzymes—specifically, hydrolases and proteinases—are essential. To make "calf rennet," for example, proteinases that are present in the stomachs of calves were used to make milk coagulant. Enzymes from psychrophilic bacteria, like Bacillus stearothermophilus, may hydrolyze flesh from shrimp, pork, and fish at 0°C. The food sector can also use commercial proteases such as Flavour enzyme and Thermolysin.

Transglutaminases are utilized in the production of cheese, meat products, and edible milk protein films. They improve food products' firmness, viscosity, elasticity, and capacity to hold water. For example, they can give minced meat a texture, generate low-calorie foods with good elasticity and texture from gelatin, and make fish paste harder.

Lactose in milk is hydrolysed by microbial β-galactosidase to produce lactose-based sweeteners and to treat hot or cold milk. α-galactosidase hydrolyzes galacto-oligosaccharides found in food products, such as raffinose, melibiose, stachyose, galactomannans, and galacto-glucomannans, in soymilk. In the wine and juice industries, pectinases are mostly employed to increase juice quality and yield, while bacterial and fungal amylases are utilized to hydrolyze starch for juice, alcohol fermentation, and baked goods.

Validation of food processing wastes: More and more green food processing techniques, such as mushroom farming and nutraceuticals, are using food leftovers. Grape pomace can be utilized to cultivate mushrooms and generate antioxidant-containing nutraceuticals, and whey proteins can yield bioactive peptides with advantages for the nervous system, gastrointestinal tract, heart, and immune system. Vegetable seeds and peels are examples of industrial biowastes that might enhance macaroni quality. Processing plants emit a lot of waste, yet its byproducts can be turned into food, medicine, and cosmetics. Food gelatine can be made from dry waste by enzymes and chicken feet, and waste from the processing of potatoes can be turned into proteins, lipids, enzymes, and organic acids using biotechnological methods.

PERSONALIZED FOOD PROCESSING

Computerized food processing and consumption: Mobile apps are rapidly transforming how we manage our nutrition. These tools, currently focused on calorie counting for weight control, have the potential to become even more sophisticated. A study in China revealed that most dietary guidance apps prioritize calorie intake over a balanced diet. However, the future of these apps looks far more comprehensive. Imagine a scenario where your nutrition app seamlessly integrates with your health data, fitness tracker, and grocery store loyalty program.

The app could analyze your individual needs, dietary goals, and past eating habits to generate personalized meal plans. It could then suggest recipes, create shopping lists optimized for your specific needs, and even connect directly to online grocery stores for convenient, customized food orders. This digital revolution in food consumption could fundamentally change the way food is produced and retailed, with a shift towards short-term and long-term personalization based on individual needs. Grocery stores could stock shelves based on real-time customer data, allowing for more targeted product placement and reduced food waste. Food manufacturers could develop personalized food items based on consumer preferences and health profiles. Ultimately, this data-driven approach to food consumption holds the promise of a more efficient, sustainable, and individualized food system.

3-D printing: One strategy for individualized food designs, streamlining food supply chains, and personalizing nutrients could be food 3D printing. It may cost more than traditional food items, but it will fulfill individual preferences for flavour, texture, scent, diet elements, food perception, culinary art, and eating habits. Thus, it is utilized as nourishment for the military, space exploration, and certain diets.

Food made with protein, starch, and fiber-rich components can be 3-D printed, demonstrating the accuracy and stability of the printed design in addition to uniform extrusion. A paste based on semi-skimmed milk powder demonstrated the best printing accuracy, shape stability after printing, and oven drying after post-printing. However, because the safety and benefits of 3D-printed food are still unknown, customers' attitudes about it are unclear. Food technology is only now beginning to go in this direction.

STORAGE

Novel food packaging technologies: These days, the development of logistics packaging systems is a necessary component of each final product manufacturing process. Product packaging transforms it into a commodity. For high-quality packaging operations, there must be a synergistic relationship between three systems: products, packaging materials, and packaging machinery. While each of these systems grows on its own, other systems' features and development stages are taken into account when packaging. Many cutting-edge food packaging materials are created with the goal of maintaining the high quality of the items while being easy to pack and distribute. For food goods to be stored for an extended period of time, oxygen absorption in the pack is crucial. Extended shelf life also depends on disinfecting the packaged food and packaging materials, such as with cold plasma or dielectric barrier discharge plasma.

Many tasks that depend on packing must be completed in order for logistics to be efficient. Important characteristics consist of:

[a] Operational feature provides protection of packaged products from mechanical and physico-chemical damages;

[b] Technological feature ensures rational, with minimal losses production, storage and transportation of packaged products;

[c] Ecological feature provides the use of cheap, environmentally friendly, fast renewable and affordable packaging materials;

[d] Special feature depends on the properties of the product, its physical condition, shelf life, consumption conditions;

[e] Sanitary and hygienic features provide neutrality and safety of packaging for the products.

Smart Packaging: Major trend in food storage technology is the rise of **smart packaging**. This innovative approach goes beyond simply containing food; it actively enhances safety, transparency, and consumer experience. The way we engage with food is being revolutionized by RFID technology, which also lowers waste and promotes cooking. Using RFID and embedded codes, smart packaging tells consumers about a product's origin, production details, nutritional value, and sustainability policies. Customers are better equipped to make educated purchases thanks to this transparency. Freshness indications are another feature of smart packaging that enables customers to evaluate product quality and save waste. This technology promotes culinary experimentation in addition to decreasing food waste.

Examples: The regulated release of ethylene gas, a natural ripening agent, is made possible by self-venting packaging with a bio-based film. This prolongs shelf life and lowers food waste. Oxygen-sensor-equipped smart lids have the ability to alter colour in response to oxygen concentrations, giving customers a visual indicator of how fresh meat items are. The proper cooking temperature can also be indicated by these lids. Customers can get information about the sustainable practices of the vineyard or recommend recipes by interacting with wine bottles that have NFC chips embedded in them. When food is no longer safe to eat, smart labels equipped with biosensors can identify rotting signs and alert customers. Food within will be safeguarded by antimicrobial packaging that has the ability to mend itself even in the event of small rips or punctures.

Smart Food Storage Systems: Internet of Things (IoT) enabled refrigerators can adjust temperature and humidity based on the type of food stored, optimizing shelf life. The rise of the Internet of Things (IoT) is revolutionizing how we manage food storage within our homes. Smart refrigerators, equipped with various sensors and internet connectivity, are no longer a futuristic fantasy. These intelligent appliances can actively adjust temperature and humidity levels based on the type of food stored. Imagine placing a container of fresh berries in your fridge, and the appliance automatically creates a microclimate with slightly higher humidity to prolong their freshness. This not only reduces food waste but also ensures optimal flavour and texture for your favorite fruits and vegetables. Smart food containers with built-in sensors can track expiration dates and even suggest recipes based on the contents. Beyond smart refrigerators, the concept extends to individual food containers. Imagine a pantry or crisper drawer filled with smart containers that keep track of their contents. These containers, equipped with built-in weight sensors and cameras, can identify the type and quantity of food stored. They can then connect to a smartphone app, providing real-time information about expiration dates and even suggesting recipes based on the available ingredients. This level of integration between food storage and meal planning can significantly reduce food waste and promote a more resourceful approach to home cooking.

POST HARVEST MANAGEMENT

Loss reduction: More than 40% of food (cereals, roots and tubers, pulses and oil crops, vegetables and fruit, fish, meat, and dairy) is lost during the trade and customer stages in developed countries, whereas more than 40% is lost during the post-harvest stage and processing point in developing countries (FAO, 2019). Microorganism attack can cause recently harvested high moisture yields that have not been maintained to swiftly degrade. Nanotechnology is one of the most recent and sophisticated technologies that can aid in reducing post-harvest losses. By creating functional packaging materials with the fewest amounts of bioactive components, better gas and mechanical qualities, and less of an impact on the sensing qualities of fruits and vegetables, nanotechnology can be used to reduce post-harvest losses.

Edible coatings are a class of structural media that improve the texture and flavour of food while preventing it from deteriorating. The shelf life of synthetic meals is extended by these coatings, which are frequently composed of proteins, lipids, carbohydrates, or combinations. They act as a barrier against the exchange of gases and moisture. They are frequently used in horticultural products.

Precision Harvesting: The practice of harvesting fruits and vegetables is being revolutionized by precision harvesting, a data-driven approach to modern agriculture. It is based on advanced sensors that gather data about specific fruits and vegetables, including size, sugar content, firmness, and colour changes. The best harvest time for each item is determined by using sophisticated algorithms to examine real-time data that is uploaded to a cloud-based system or wirelessly transferred to a central processing unit. Produce quality is raised as a result of this precise harvesting, guaranteeing the best possible flavour, texture, and nutritional content. It also reduces post-harvest losses, which lowers spoilage and boosts farmer profitability while providing consumers with a more consistent supply of food.

Internet of things: With its ability to provide real-time data on temperature, humidity, and gas emissions from storage facilities, the Internet of Things (IoT) is transforming the food business. This information is essential for preserving ideal storage conditions and spotting possible spoiling. Based on this information, farmers, distributors, and retailers may make well-informed decisions that will increase the accuracy of their shelf-life predictions, cut waste, and enhance inventory control. By automating operations and establishing the ideal atmosphere for each variety of product, AI and IoT can increase shelf life and decrease spoilage. Additionally, IoT improves real-time tracking across the supply chain, maximizing traceability and transportation to guarantee timely and fresh produce. As a result, the food system becomes more sustainable and effective, lowering food waste, raising quality, and giving consumers a consistent supply.

ROLE OF NANO TECHNOLOGY

Food manufacturing and processing are being revolutionized by nanotechnology, which also improves food's nutritional content, safety, and qualities. Applications in the pharmaceutical, healthcare, and smart distribution systems domains include nano-based additives, nano-encapsulation, nano-sensors, and nano-packaging. Encapsulation formation, biopolymer matrices, emulsions, and delivery methods are the main areas of focus for food nanotechnology. Because of its special qualities, it can be used in sensor technologies, food characterization, microfluidic instruments, and nanocomposite coatings.

Nano emulsions, nanomaterials, and nanotubes are used in the quickly developing sector of food processing to improve the quality and safety of food products. Minimal droplets at the nanoscale create nano emulsions, which are employed in beverage production, flavour improvement, and salad dressing. In order to increase the value and security of food, nanomaterials are also utilized in food additives, anti-caking agents, nutrient delivery systems, antibacterial agents, and filling agents.

Proteins, carbs, and fats are just a few of the food components that naturally include nanoparticles. Nanotechnology is being used in the food and beverage business, which generates substantial incomes, to enhance food safety, nutritional qualities, and manufacturing efficiency. The application of nanoparticles in meat and packaging offers several advantages, including as improved sensory characteristics, directed administration of chemicals with superior bioactivity, and greater bioavailability and antibacterial capabilities.

Low-calorie food and drink goods, clever nano-packaging, and ecologically friendly operations are all made possible by nanotechnology. Using nano-sensors, nanotechnology can also be used to find missing ingredients and find infections in food. Nanofiltration, nanoencapsulation, heat and mass transfer, nanoscale enzyme-based reactors, and nanofabrication are some of the multipurpose uses of nanotechnology in food processing. While heat and mass transfer nanofabrication increase the heat resistance of packages, nanofiltration is used to clean medications. Metal oxides such as SiO2 and TiO2 are utilized as food colouring or flow components, while nanoencapsulation enhances flavour, preservation, and cooking balance.

Food packaging and storage is essential for shielding food from deterioration in quality and physical damage. Because of their antibacterial qualities, nanomaterials like silver (Ag) and titanium dioxide (TiO2) have found extensive application in active packing applications. Because of its enhanced optical, electrical, and photosensitive properties, TiO2 is frequently employed as an adsorbent, stain, or catalytic substrate. Benefits of nanoparticles include oxygen transfer, enzyme mobilization, antibacterial activity, and degradation resistance. Combined with zinc oxide nanoparticles, nano-polymers have produced food packaging that is incredibly useful. Modified nanocomposite films containing nano-chitosan and nano-cellulose have demonstrated improved food protection properties, elongation to breakage, and tensile force. Because of their innate antibacterial properties, chitosan films with nanoscale thickness are highly concentrated and frequently utilized in food packaging. Coatings of chitosan-Ag and chitosan-Au nanocomposites are promising antibacterial options that work against fungus, yeast, gram-positive, and gram-negative bacteria.

To improve post-harvest quality, food coatings are increasingly using nanoparticles, especially silver nanoparticles. The antibacterial qualities of these coatings prolong the shelf life of fruits and vegetables. It has been discovered that silver nanoparticles inhibit skin colour changes, limit weight loss, and delay the growth of microorganisms. Other coatings, like those made of gelatin and cellulose nanocrystal, have also demonstrated encouraging outcomes in terms of keeping fruits' post-harvest value. Through the use of nano-sensors that react to changes in the storage environment, degradation products, and microbial contamination, nanotechnology can also be utilized to control grain quality. By identifying the existence of fungi or insects in grains that have been stored, these sensors help guarantee the food's safety and quality.

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