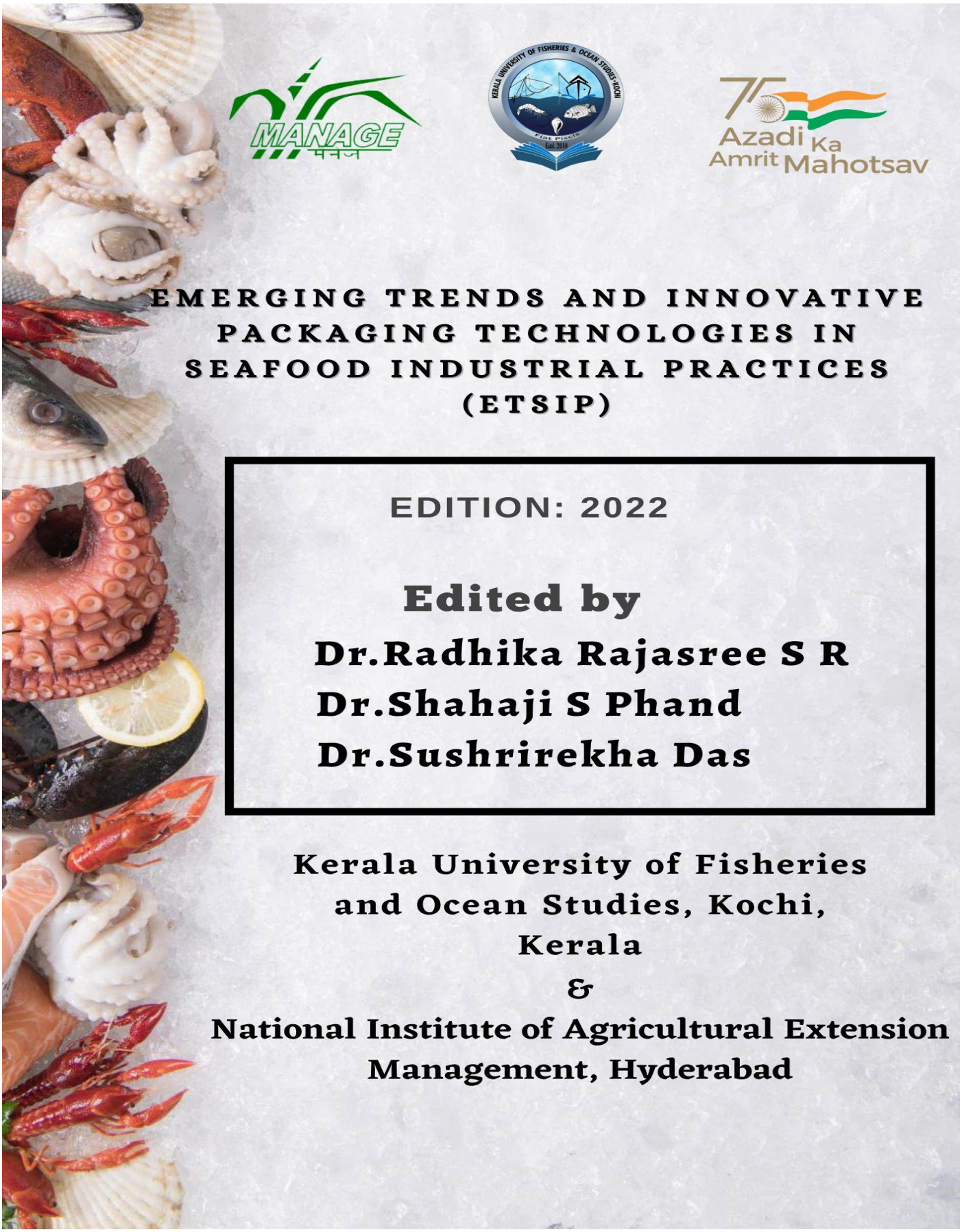

EMERGING TRENDS AND INNOVATIVE PACKAGING TECHNOLOGIES IN SEAFOOD INDUSTRIAL PRACTICES (ETSIP)

EDITION: 2022

Edited by

Dr.Radhika Rajasree S R

Dr.Shahaji S Phand

Dr.Sushrirekha Das

Kerala University of Fisheries and Ocean Studies, Kochi, Kerala

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National Institute of Agricultural Extension Management, Hyderabad

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This e-book is a compilation of lecture notes obtained from the resource persons of the training programme "Emerging trends and innovative packaging technologies in seafood industrial practices (ETSIP)" jointly organized by KUFOS Business Incubation Centre, Directorate of extension, KUFOS & National Institute of Agricultural ExtensionManagement, Hyderabad, India. This e-book is designed to educate extension professional from fisheries, industries, students, research scholars, farmers, entrepreneurs and academicians in fisheries and allied sectors about the emerging and innovative trends in seafood and practice. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas contained in the e-book.

Published for Dr. P. Chandra Shekara, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr. Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication.

MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

The global fish industry is arguably the most intricate in the entire food industry. More species (about 1,000 commercial species) and processing technologies are used in it than in any other food business. The seafood sector is increasingly focusing on developing new products and using cutting-edge processing techniques. This book gives an overview of the latest developments in active and intelligent packaging (IP) that are being used in the fish and seafood industries.

It is a pleasure to note that, Kerala University of Fisheries and Ocean Studies (KUFOS) and MANAGE, Hyderabad, Telangana is organizing a collaborative training program on “Emerging trends and innovative packaging technologies in seafood industrial practices” from 12-14th September, 2022 and coming up with a joint publication as e-book on “Emerging trends and innovative packaging technologies in seafood industrial practices” as immediate outcome of the training program.

I wish the program be very purposeful and meaningful to the participants and also the e-book will be useful for stakeholders across the country. I extend my best wishes for success of the program and also I wish Kerala University of Fisheries and Ocean Studies (KUFOS), many more glorious years in service of Indian agriculture and allied sector ultimately benefitting the farmers. I would like to compliment the efforts of Dr. Shahaji Phand, Center Head- EAAS, MANAGE, Hyderabad and the Vice – Chancellor, KUFOS, Kerala for this valuable publication.

Dr. P. Chandra Shekara
Director General, MANAGE

FORWARD

It is a well-known fact that food from aquatic sources is one of the healthiest sources of nutrients with their rich complement of healthy proteins, high quality lipids rich in polyunsaturated fatty acids and vitamins. Fisheries is one of the fastest growing sectors of the global economy, supporting not only the nutrient needs of millions but livelihoods of the people involved in the varied processes from capture to consumption. For many maritime nations, fisheries represent a very important factor for economic growth.

As the demand for good quality fishery products with extended shelf life rises, the fish-processing industry is faced with the challenge of developing alternative methods of preservation of seafood that are economically viable, environmentally safe and sustainable. High perishability, fast nutritional degradation, and preference for very fresh products from consumers make the maintenance of the seafood supply chain prohibitive in terms of economic and ecological costs. It has become the need of the day to explore innovations in packaging that can provide extended keeping quality at low cost and minimal impact on the environment.

In this context, it gives me great pleasure to present this E-book of lectures which is a compilation of the presentations made during a recent online training program organized jointly by the Kerala University of Fisheries and Ocean Studies (KUFOS) and the National Institute of Agricultural Extension Management (MANAGE), Hyderabad. This training program on "Emerging Trends and Innovative Packaging Technologies in Seafood Industrial Practices" which was conducted during 14^{th} -16^{th} September, 2022 brought together a team of the most eminent researchers, academicians and entrepreneurs who delivered lectures on a variety of topics comprehensively addressing the technical as well as business aspects of modern trends in the field of seafood packaging technology. Going through the contents of this compendium I realize its contents shall remain relevant for many years to come and shall be an invaluable reference for students, academics, technicians as well as business leaders who are engaged in the field of fish processing and packaging technology.

Prof. (Dr.) K. Riji John
Vice – Chancellor
Kerala University of Fisheries and
Ocean Studies (KUFOS)

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Chapter-1

CURRENT TRENDS OF FISH PACKAGING

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Introduction:

Food packaging, a crucial tool of food preservation from storage to distribution, is considered as an important component of the manufacturing process which act as a linkage between the producer and end customer in today's consumer- focused industry. The initial notions of food packaging, which was to act as a passive means of safeguarding the food product against the effect of moisture, oxygen, biological contamination and light, has led to the more complex function, such as product-package interaction in the form of different principles and technologies of packaging. Among them, vacuum packaging and Modified Atmospheric Packaging have a great commercial acceptance, while smart packaging such as intelligent and active packaging are yet to be investigated more before they turns to commercial.

In addition, more recently, compostable packaging, biodegradable packaging, nano packaging, and sustainable packaging have all been developed and used, helping to manage environmental pollution issues that are endangering many ecosystems. Today's consumers are very aware of their right to purchase products of the right quality and quantity at a fair price in aesthetically pleasing and hygienic packaging. Therefore, the primary purpose of food packaging is to safeguard the product from microbiological decomposition as well as physical damage and pollutants. Due to their high water activity, close to neutral pH, and high amount of unsaturated fats and non-protein nitrogenous substances, seafood items are very perishable.

The three main elements influencing the global food sector are health, nutrition, and convenience. Fish products are a significant source of protein, vitamins, minerals, and lipids. They also rank third among the food categories with the fastest global growth. Fish quality is maintained by adequate processing and packaging because fish is highly perishable. Around the

world, a variety of preservation methods are used, from straightforward chilled or ice storage to modern and sophisticated high pressure and electromagnetic field application. The information in this document provides an overview of recent developments in the packaging and processing of fish and marine products.

Basic Function of Packaging for Fish and Marine Product

Packaging is desirable to facilitate handling and to enhance the presentation. As fish is a perishable commodity, it must always be handled carefully to prevent the growth of microorganisms. If fish are handled and stored in an improper way, their quality get deteoriate and the shelf life become shortened. In order to maintain the quality of fish, it is crucial to consider the type and quality of packaging materials as well as the storage and packaging techniques. The diverse types of marine products come under different category such as fresh fish, canned fish, frozen fish, processed fish etc which requires special packaging requirements and hence varying packaging materials.

Fresh fish packaging:

Due to the lack proper facilities in packaging and transportation, mainly in tropical areas causes the wastage of more than 20% of the fish that get caught. The fish will remain its freshness only for a restricted period, i.e., 4-6hrs, which depends upon the intrinsic nature and environmental condition of the fish. The freshly caught fish in landing centers which are placed far away from the processed areas of fish requires an advanced harvest and post-harvest techniques. In order to prevent the microbial deterioration, the fish must be kept in cooled condition even after the landing immediately due to the fact that with every 5.5°C increment in temperature doubles the rate of spoilage. The mixture of fish and ice, chilling is regarded as a cheapest method for fresh fish preservation and it must ensure the insulating properties of containers used for the transportation of fish, to prevent the melting of ice. Indeed, reduction of lipid oxidation, lessen the chemical and bacterial spoilage, reduce dehydration, eliminate drip and restrict odour permeation are considered to be a major requirement of an efficient fresh fish package.

Battered and breaded fishery products:

One of the significant classes of value-added products are battered and breaded products, which is having a huge demand in both internal and exports markets. A number of products such as fish fillets, squid rings, fish cutlet, breaded peeled shrimps etc can be prepared from fish minced meat, shrimp, squids, cattle fish etc. For the retardation of various problems such as

discoloration, desiccation, rancidity development etc. requires a better packaging application. Since, no suitability of stand-alone conventional packaging materials, thermoformed containers are widely used which provide mechanical protection to the products. Food grade materials are used for the formation of thermoformed trays, includes HIPS, HDPE, PVC which are not affected by low frozen storage temperature and assure protection to the food content.

Packaging of dried fishery products:

For internal consumption, a sizable chunk of the fish catch is salted and dried. Due to its high hygroscopicity, dried fish will collect moisture in humid environments. It quickly deteriorates as a result of oxidation when exposed to air or oxygen. Insects like to prey on dried fish. The most crucial requirements for a dried fish/product package are inertness, leak-proofness, permeability to oxygen and moisture, and less transparency. Additionally mechanical resistant and puncture is also required.

Cans and Canning:

The processing and packaging of heat-sterilized items typically uses cans. Standard tin plates, light weight tin plates, double reduced tin plates, tin free steel (TFS) cans, vacuum deposited aluminium on steel, and polymer coated tin free steel cans are some of the options available today. To obtain desirable qualities like acid and sulphur resistance, the cans employed for fisheries goods are internally coated. However, caution must be exercised to prevent lacquer tainting. The advantages of metal cans as packaging include their superior strength, quick production, and simple filling and dosing. Metal cans' drawbacks are their weight, difficulty in closing, and disposal.

R**etort pouches:**

The flexible laminated materials known as retort pouches are necessary required for the packaging of fisheries products that are thermally processed. An exterior polyester layer and a central layer of aluminium make up the three- or four-layer retort pouches.

Recent trends in harvest and post-harvest technologies in fisheries

Even though the seafood packaging industry is developing quickly, a lot of seafood is still delivered to institutional and retail markets unpackaged. Fish and some shellfish are sold in bulk containers, either whole or dressed, and wrapped in ice. On a bed of ice, the goods are displayed at the market and put up for sale still unpackaged. The only packaging innovation in many cases has been the transfer from wooden to waxed or plastic corrugated boxes, as well as

the use of metal or plastic tubs as bulk shipment containers. In the meantime, pre-packaged meats and poultry have taken over the self-service meat counters, which are mostly fish-free.

Accordingly, a wide range of nicely packaged products found in supermarket frozen food areas, frozen fish products have advanced in packaging more than fresh ones. Unfortunately, some packaging seems better than it can actually safeguard the quality of the goods. The continued expansion of farmed seafood sales will require the movement of product through longer and more-complex distribution chains to reach consumers. As a result, packaging will be more and more crucial to ensuring excellent quality, positive sales appeal, and satisfied customers.

Protecting and Cushioning

Fishery items are among the most perishable of all goods, even when kept refrigerated. The rapid deterioration in quality is caused by three biochemical and biological processes. Since fishing products are a great source of nutrients for bacterial growth, bacteria are the main contributing component. Numerous natural ingredients are changed by bacteria into unpleasant flavours or odours, and they occasionally even produce dangerous substances. Second, compared to other muscle meals, the lipids in fishing products are extremely unsaturated and readily degrade into rancid chemicals. Third, a number of digestive and muscle enzymes actively metabolise the proteins in muscles, which can provide mushy, squishy textures. The only way to control an enzyme's activity is to keep the product at extremely low temperatures. Except for acting as an insulator during distribution, packaging does not prevent enzyme degradation. Packaging serves as a defence against product contamination and helps delay lipid oxidation by acting as a barrier to oxygen. Packaging can also aid in preventing or reducing freezer burn. The chemical makeup of packing material affects how easily gases and water can pass through it. Today, high-barrier films are made of two or more layers of variously formulated materials and can be laminated or coextruded. This allows for the incorporation of many qualities, like gas permeability, heat sealing prowess, and flexibility at low temperatures, into a single film to satisfy packaging requirements.

Characteristics of freezer packaging materials

Table 1

Material	**Permeability Water**	**Permeability Air**	**Tightness of Fit**	**Strength**	**Cost**
Polyvinylidene chloride (saran)	Low	Very low	Very good	Medium low	Low
Polyvinyl chloride	Low	Very low	Very good	Medium	Low
Polyester bags, sleeves	Very low	Low	Good	Very high	Low
Ice glaze	Low	Low	Excellent	Very low	Low
Polyethylene wrap, bags	Medium	High	Poor	High	Low
Aluminum foil	Low	Low	Fair	Very low	High
Cellophane Waxed paper, cartons	Very high	Medium	Fair	Low	Low

Conclusions and Future Outlook

Since seafood is one of the most traded commodities in the global food industry, it is anticipated that seafood packaging will continue to develop in the years to come. Examples of this development include the introduction of new bio-based eco-friendly packaging materials with or without natural additives and improved functional properties, new packaging technologies that result in the maintenance of food product quality and safety with extended product shelf lives, and these technologies will have an impact once they are used. Such developments must meet two requirements: I the sensory/consumer acceptance properties must not be impacted; and (ii) all raw materials and additives utilised in particular applications must adhere to the applicable laws already in effect or any upcoming new laws.

Chapter-2

RECENT ADVANCES IN FISH PRODUCT PRESERVATION AND PACKAGING

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Aquatic foods occupy third position among the food products and are considered as the fastest growing sectors all over the world. Fish considered as one of the healthiest foods due to the availability of important nutrients, protein, vitamins etc. Fish is also great source of omega-3 fatty acids which are essentials for optimal body and brain functions and strongly related in reducing risks of many diseases. Fishes are grouped in to finishes and shell fishes and are being utilized for the production of various value-added food products and by-products. The annual supply of fishes for human consumption is 20.5 Kg per capita protein with a rise in fish consumption recorded 122% in the last four decades. Based on this huge demand, the global fish production is also grown and estimated at 179 million tonnes with a total first sale value estimated at US$ 401 billion. There is a visible rise in global capture fisheries over the years (1990-2020) with 16% whereas Aquaculture sector shown a multifold increase in production (527%) during the above period. At present this sector occupies 48% of production 114 million tonnes, 263 US$ (2020). Among the countries in fish production, China ranks first in capture and culture fisheries with 15 and 35 % respectively. This was followed by India as the 2^{nd} largest producer of aquaculture and 6^{th} largest producer of culture fisheries in the world. The contribution of the fisheries sector to agriculture is nearly 20% and to total GDP is nearly 1%.

Freshly caught fish undergoes nutritional and sensory quality changes as a result of faster rigor mortis, oxidative spoilage, autolysis and microbial activity. Due to increased demand for fish products with enhanced shelf life and high expenditure towards freezing and frozen storage, the seafood processing industry is in search of alternative and other green technologies to

enhance preservation with increased time for marketing at the same time economizing the electricity costs. In order to process larger volumes of fishes India has about 625 processing plants with a total capacity of 36410MT. Of these, there are 387 European Union approved fish processing plants with a production capacity of 22495 MT per day and Individually Quick-Frozen plant with a production capacity of 1729 MT per day (MPEDA, with a cold storage capacity of 273,056 MT, India exports 43000crores worth fishery products all around the globe. Item wise exports of fishery products from India is given in Figure 1.

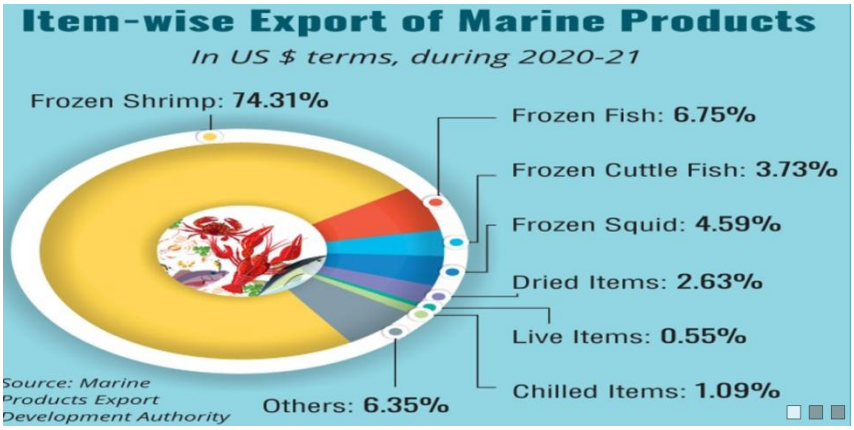

Figure1. Item-wise exports of fish products from India (Source, MPEDA)

Among the valued added products export, shrimp products in various forms viz. battered and breaded, IQF, stretched , AFD , Blanched/cooked, IQF head on /IQF peeled tail on , tray packs Vannemei Pulled Veined (Pvpd) Eazy peel are the most preferred items. Cephalopod items like Double Skinned Cuttlefish, IQF Sashmi Grade, IQF Cooked/ Blanched squid/ Cuttlefish fillets, strips blanched, strips blanched, Pine Cut/ Diamond Cut, Stuffed Squid IQF Tray Pack, Tube Tray Pack, Ring Blanched IQF, Skewers, vacuum Skin Packed Products, AFD are the major cephalopod export products.

In order to maintain the availability of fishery products throughout the production process it is necessary to extend the shelf life of fishes from harvesting to consumption. Also to extend the shelf life, maintain and improve sensory and nutritive properties, reduction of wastes and ensure safety proper preservation techniques are very much necessary. This will enable the producers to increase the economic value and facilitate exports as well as cross boundary trade.

The traditional methods for seafood fish preservation are chilling, freezing, drying, smoking, curing, pickling, salting, smoking, and canning. Various novel processing technologies are being explored and implemented to provide safe, fresh-tasting, nutritive foods without the use of heat or chemical preservatives along with reducing the undesirable changes during processing (Ahvenainen, 2003). Recent developments have improved techniques in handling, product development, packaging, preservation and storage.

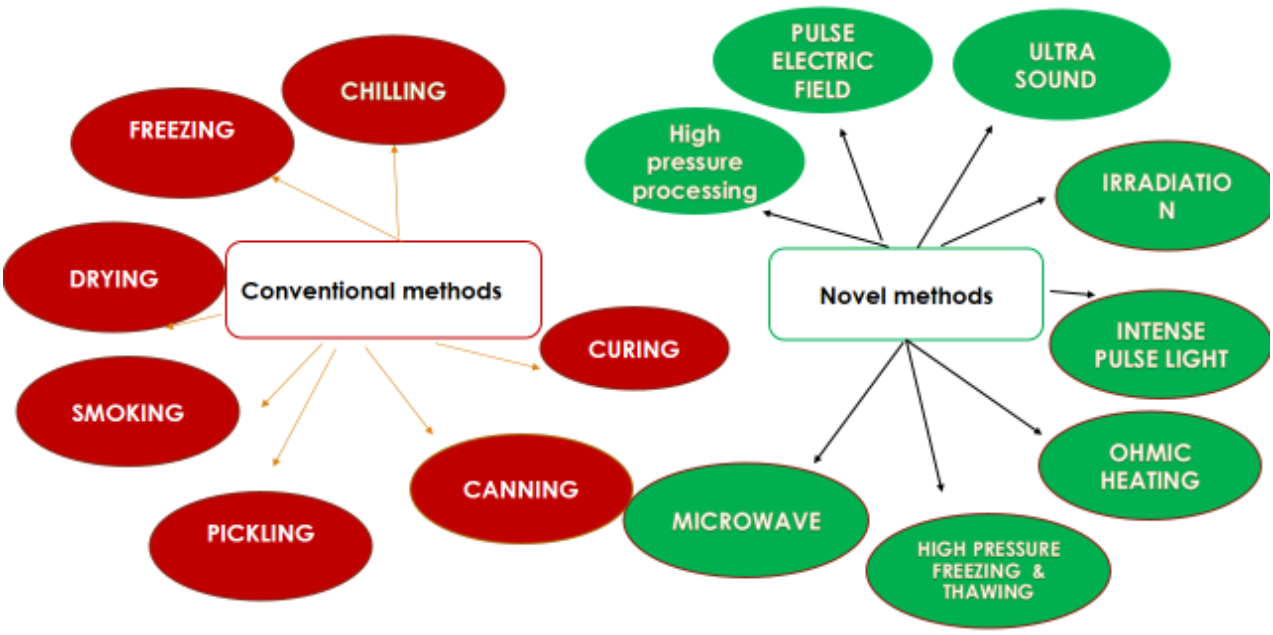

Figure 2. Conventional and emerging methods in fish processing and preservation

Preservation of Fishes is also classified as thermal and nonthermal methods based on the application of heat in preservation of foods. However, the emerging technologies that have wider application in future food processing are high pressure processing, high pressure freezing and thawing , pressure shift freezing , pulsed electric field, high intensity pulsed light technology, ohmic heating , irradiation , microwave processing etc (Figure 2).

High pressuring processing or high hydrostatic pressure (HHP) or ultra-high pressure (UHL) is an emerging non thermal cold pasteurization technique used for the preservation of food products. . High level hydrostatic pressure 100-600MPa (87000 psi) is used in high pressure equipment which includes high pressure vessel and their closures, pressure generator system, temperature control unit and material handling systems. HPP is carried out at chilled or mild

process temperatures (<45^{0}C) and it was proven that the foods to be preserved were observed to have minimal effects on taste, texture, appearance or nutritional values.

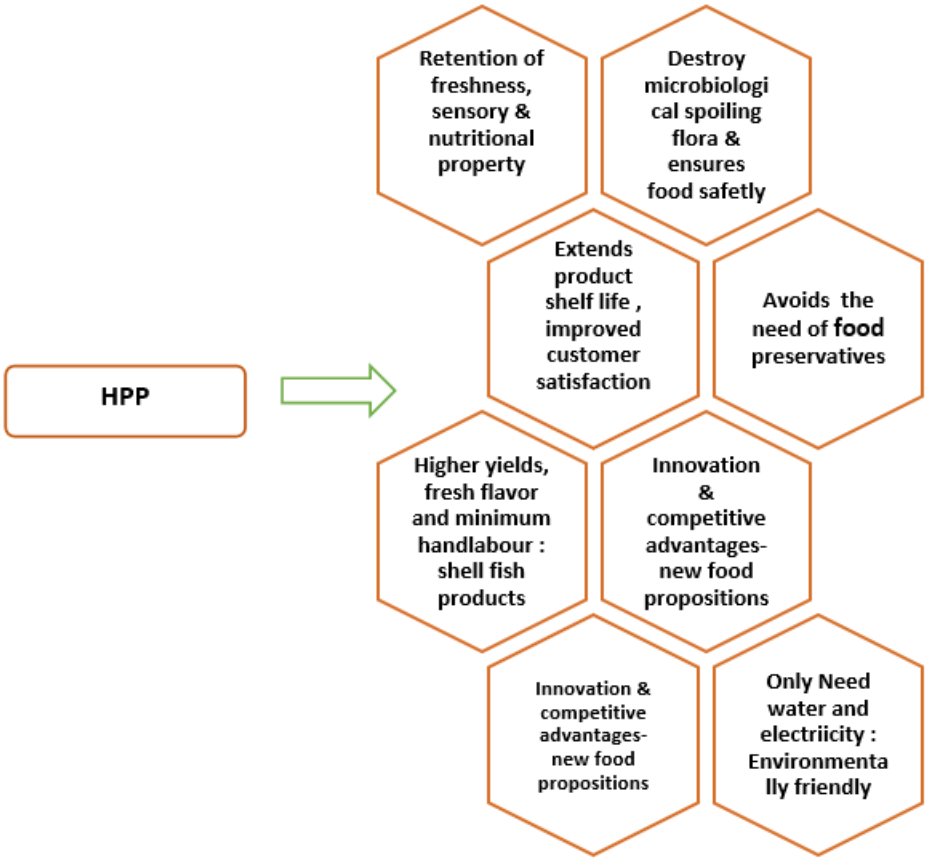

Figure 3. Advantage of High-pressure processing

In the processing sector HPP utilization is mainly takes place in the shell fish industry where oysters, clams, mussels, lobsters, crab, shrimp, and similar ready to eat seafood meals are shucked or extracted the meat at pressures below 4,000 bar / 400 MPa / 58,000 psi (Figure 3).

In high pressure assisted freezing, samples are cooled under 200 MPa to -20^{0}C without the formation of Ice. At high pressure up to 210 MPa, water can remain in liquid state down to about -22 ^{0}C .This allows rapid freezing and thawing. Impact pressure shift freezing is employed in salmon products .In the smoked salmon mince inoculated with *Lysteria* and *Micrococcu*s spp. A pressure of 207MPa and −21°C by further freezing to −25°C at 0.1MPa , pressure shift freezing with pressure release in 18min enhanced reduction to 2 and 2.5 log cycles for *L. innocua*

and *M. luteus* (Elzade et al.,2016) . In Asian seabass, the accelerated freeze-dried sample at -15 and -250C showed shrunken and gray muscle tissue with larger white ice crystals whereas the samples stored after pressure shift freezing in similar temperature showed intact muscle tissues without any deformation and lesser , smaller ice crystals.

Pulsed Electric Field (PEF) fish processing is another emerging non-thermal technique and foods processed through this method show excellent sensory, nutritional quality and shell life. With the help of a high voltage pulse generator in a treatment chamber a high intensity pulsed electric field (HIPEF) is created having voltages typically between 30-80kV/cm. The pulse frequency time is fixed anywhere between 10 to 10000 µs depending upon the products to be processed. A control system maintains the frequency time as well as the voltage intensity. Fish products such as fresh fish fillets, dried and salted fishes, marinated fish products etc processed through this method. A high voltage electric field (upto 25kv) inactivates pathogenic strains of microorganisms such as *E.coli S.aureus, B.cereus, C.welchii* etc. PEF method is shown to inactivate parasitic nematods in fish fillets and enhanced drying in fishery products. In marinades PEF showed improved micro diffusion of brine and increased water binding due to the interaction between protein, salt and phosphates.

High intensity Pulsed Light Technology (PLT) is an innovative technological concept for preserving the foods without heat treatment. This uses intense and short duration pulses of broad spectrum 'white light' such as pulsed UV light, where each pulse or flash of light lasta fraction of a second and the intensity is 20,000 times that of sunlight at sea level. PLT acts as a sterilization method for packaging materials, pharmaceutical products & products with uniform surface and shown to reduce levels of spoilage & pathogenic microorganisms. This method helps to rreduce the need for chemical disinfectants & preservatives as well as helps in maintaining the sensory and nutritive quality. The main light sources used are ultraviolet (UV), visible (VL), and infrared (IR) light (200–1000 nm). PLT increases the shelf life of lightly preserved cold smoked fish products by effective penetration to depths in foods. This method is also used as a source to control microorganisms on the surface of foods.

Ultrasound assisted technology is a recently emerged food products preservation method which helps to reduce processing, thawing and rehydration times thereby reducing the usage of water. Here in ultrasound technology, mechanical waves at a certain frequency are employed, in which

the frequency range is fixed based on the energy output. In order to inhibit various pathogens and for effective pasteurization as well as retention of flavour and colours, this technology is widely applied. In the dried fish products, in order to rehydrate the fishes as well as echinoderms such as sea cucumbers, the technology is being applied. Rehydration ratio and water holding capacity were found to increase when ultrasound power was increased from 100 W to 300 W @ (28, 35, and 45 KHz) up to 12 folds (Longtao Zhang et al., 2016). The technology is expanding rapidly in EU and USA, due to safeguarding of product quality and found to be highly beneficial for seafood processing companies due to increasing capacity of production by about 35% and profits (50%) as well as margin (2%) (https://cordis.europa.eu/article/id/248607). Some of the chemical and biochemical effects of ultrasound include increased bactericidal action, sterilization of processing equipment, alterations in the enzyme activities etc. Similarly, homogenization, tenderization and flavour extractions viz. mechanical effects also

Ohmic heating is a direct resistance heating by the flow of an electric current through foods, heating by internal heat generation. In the cooking process, Ohmic heating helps to generate heat rapidly there by t product cooking is accelerated. This method is also used for thawing the frozen fishery products at a faster rate thereby reducing microbial growth, prevention of nutrient loss through leaching, and saving of larger volume of water. Ohmic heating is also used for uniform heating by electro conductive blanching as well as an alternative method for vacuum evaporation. For the preparation of surimi products from pacific whiting, catfish, pollocks etc., Ohmic heating is employed which has significantly improved their gel values and color by Ohmic cooking.

Food irradiation is an emerging technique used for the treatment of food using ionizing radiations from gamma rays, electron beams and X-rays mainly used in fishery products like raw, frozen, cooked, partially cooked, shelled or dried crustaceans cooked or ready-to-cook (6KGy), mussels and oysters etc. Irradiation breaks chemical bonds killing microorganisms, insects without generating heat in crabs, substantial shelf-life extension was observed in irradiated meat which was found effective against non-spore forming pathogenic strains *Listeria, Vibrio and E. coli*. Similar results were observed in Crystal Sea Oysters against *V. vulinificus, V. parahemolytics* with a reduction in initial microbial content by 1to 3 log cycles (2013). *A radicidation dose of* 4–6 kGy is effective in Packaged, frozen, ready-to-export fish

treated just before shipment. Improvement of hygienic quality of frozen materials for export such as frozen shrimp, cuttlefish, squid, finfish, fillets, and IQF items were also observed in samples treated with radiation. It was observed that the product quality of chilled marine and freshwater fishery products extends 2-3 times whereas in dried products elimination of eggs and larvae of insects were totally avoided due to radiation processes.

Proper packaging is very essential in the prevention of spoilage of fish and other food products. The conventional packaging material used for fish products packaging includes, ice, refrigerated cans, corrugated boxes, shrink packages, vacuum packages, Modified atmospheric packages, flexible films etc. Novel packaging technologies such as active packaging, intelligent packaging and biodegradable edible films have important roles in fish preservation and enhance shelf-life (Da-Wen, 2005). Intelligent packaging can be prepared by nano encapsulation technique for pH sensor materials to evaluate fresh fish quality tools. Duplex laminated packages with a nano-encapsulated pH monitoring label for fresh fish will be printed. A quick response code to check the cooking and fish quality, particle size, zeta potential and surface area will be measured with the nano encapsulated indicators (Saber et al. 2021). In the case of edible and active packaging materials for fishery products, single or a combination of polymers such as gelatin, chitosan, chitosan-gelatin/alginate, carrageenan, whey protein concentrate etc. are used. The active agents like clove Essential Oils (EO), Cinnamon EO, Oregano EO, Thyme EO, Lemon EO, Glycerol monolaurate, α-tocopherol, citric acid, tea polyphenols , grape seed extracts etc. will be used to enhance the degradable films antimicrobial and antioxidative properties.

As seafoods play a pivotal role in addressing the nutritional security of the nation, emerging technologies in thermal and non-thermal processing will help to extend the shelf life, sensory and nutritive properties, and safety, increase convenience, reduce wastage, facilitate expansion of export and in turn boost economic value.

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Chapter-3

MICROBIAL ASPECTS IN SEAFOOD PROCESSING AND PACKAGING

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Seafood is a major animal protein source in diet. Consumption of seafood is increasing due to its health benefits over red meat. Catch can be collected from seas, rivers and lakes, the waters of which can range from pristine to pollute. Contamination is often from humans and animals. Geographic region, time of year and, for fish, whether it is a pelagic (surface to mid-water) or benthic (bottom) feeding ground influence the number and type of microorganisms present in freshly caught seafood. The presence of microorganisms depends on the preservation technique. The details of microorganisms related to preservation technology are as follows.

1. CHILLED AND FROZEN RAW FISH

Chilled fish is fish that has been refrigerated and maintained at a temperature of at least 7°C and not less than 3°C during storage, transportation and sale. Underground meat from live healthy fish should be considered sterile and free from bacteria and other microorganisms. The number and type of microbes associated with fish vary with geographic location, season, and harvesting method. Bacteria pathogenic to humans may be part of the major fish microbiome, raising concerns about fish borne diseases. These pathogens can be divided into two groups. Organisms that occur naturally in fish (Table 1). It is not endemic to the aquatic environment, but is present as a result of contamination (anthropomorphism or otherwise) or is incorporated by fish during harvest, processing or storage (Table 1).

Table 1. Indigenous bacterial pathogens typically present in fish

Organism	Temperature range	Estimated Minimum Infective Dose
Clostridium botulinum - non-proteolytic type E	3 - 26 °C	00.1 - 1 µg toxin lethal dose
Pathogenic *Vibrio* spp. *Vibrio cholerae* *Vibrio parahaemolyticus* *Vibrio vulnificus* other vibrios	10 - 37 °C	High for most species, 10^5 - 10^6 cells/g (exception: *V. vulnificus*)
Aeromonas spp.	5 - 35 °C	Unknown
Plesiomonas shigelloides	8 - 37 °C	Unknown

Table 2. Non-indigenous bacterial pathogens frequently present in fish

Organism	Primary habitat	Minimum Infective Dose
*Listeria monocytogenes**	Soil, birds, sewage, stream water, estuarine environments, and mud	Variable depending on the strain (>10^2 cells/g)
Staphylococcus aureus	Ubiquitous, human origin	10^5 - 10^6 cells/g. Toxin levels 0.14 - 0.19 µg/kg bodyweight
Salmonella spp.	Intestinal track of terrestrial vertebrates	from < 10^2 - >10^6
Shigella spp.	Human origin	10^1 - 10^2
Escherichia coli	Fecal contamination	10^1 - 10^3
Yersinia enterocolitica	Ubiquitous in environment	High (10^7 - 10^9 cells/g)

1.1 Pathogens: Growth and Survival

There are several human bacterial pathogens that can cause primary infection or illness and can persist in aquatic environments. It cannot grow on fresh fish. The remaining few bacteria pose major risks associated with eating raw seafood such as sushi and oysters, but these risks are greatly reduced when properly cooked. These pathogens include:

- ***C. botulinum***, diverse bacterial species that poses potential risks. Consumer risk from Clostridium botulinum from fresh fish whether stored aerobically or in a modified atmosphere. Regardless, high. Proper temperature control (below 3.3°C) eliminates all risks. Proper cooking, i.e. boiling for 1 minute or cooking at 80°C for 5 minutes significantly reduces the risk.
- ***V. parahaemolyticus*** is a marine organism that can cause gastroenteritis in humans. It is not normally detected in seawater below 19°C, but can be cultured as cold as 5°C and grown in food at 10°C. Appropriate refrigeration, application of post-harvest treatments, and/or preparation of fresh seafood mitigate risk
- The genus Aeromonas, in particular Aeromonas hydrophila, has been implicated in diarrheal disease in humans. Most cases are sporadic, not associated with large outbreaks. Refrigeration does not prevent growth, but proper cooking can greatly reduce the risk of infection.
- ***L. monocytogenes*** has been well documented as a foodborne human pathogen. Organisms pose a serious risk to refrigerated products that are not cooked prior to consumption, but proper cooking reduces the risk.Cod has a reported D60 of 1.98 minutes and salmon a D60 of 4.48 minutes.

Table 3. IFST Guidelines for processed foods - fish products, ready meals

Storage: Frozen/chilled
Use: Re-heated prior to consumption

Pathogens and toxins

Organism	**GMP***	**Maximum**
Salmonella spp.	Not detected in 25 g	Not detected in 25 g
L. monocytogenes	Not detected in 25 g	10^3
B. cereus	$<10^2$	10^4
Staph. aureus	<20	10^3
V. parahaemolyticus (warm-water fish)	Not detected in 25 g	10^2
Histamine (scrombroid fish)	<50 ppm (<5 mg/100 g)	<50 ppm (<5 mg/100 g)

Indicators and spoilage organisms

Organism	**GMP***	**Maximum**
APC (heat treated)	$<10^4$	Product-dependent
Enterobacteriaceae	$<10^2$	10^4
E. coli	<10	10^3

*GMP = Values found immediately after production under good manufacturing conditions.
Maximum= Levels at end of stated shelf life

2. CURED, SMOKED AND DRIED FISH

Curing is the preservation of fish by preventing the growth of microorganisms and removing or replacing existing moisture in fish meat before serious spoilage occurs. This includes salting, drying, smoking, combinations and/or variations thereof. Curing is the preservation of fish by evaporating the moisture contained in the meat, rendering the product unsuitable for microbial growth. The product can be dried in three ways.

• **Air drying:** Heat is transferred from heated air or heated surfaces to the fish and steam is removed by air movement. This is a common way to dry fish. Traditionally, this was done naturally by aerating the fish.

• **Vacuum drying:** The product is dried by contact with a heated surface or radiation. Evaporated water is removed with a vacuum pump. It is not commonly used in fish products.

• **Sublimation:** The fish freezes when it hits the cooling plate, the ice sublimes and a vacuum pump removes the steam from the fish. After the freeze-drying process, the product quickly rehydrates, but does not retain the reabsorbed moisture during cooking. Limited use for fish.

2.1. Initial Microflora

The initial microbiome is that of the raw fish from which the product is made. However, the salts used in the process may contain halophilic bacteria, spore-forming bacteria, or systemic molds. Additionally, the sugar used in some products may contain yeast, mold and spore-forming bacteria. Various spices used in soaking brines are also potential sources of microorganisms, including pathogens. The smoke itself may contain mold spores**.**

2.2 Pathogens: Growth and Survival

- ***C. botulinum:*** The presence of salt in cured products has a significant effect on bacterial growth, but the salt concentration in smoked salmon or trout (usually 1-4% salinity) is not high enough to prevent growth. Concentrations required to prevent growth at room temperature range from 3.5% to 5%, while approximately 10% salt in the aqueous phase is required for complete inhibition of mesophilic A and B strains of Clostridium botulinum. The FDA has specified that hot or cold smoked fish should contain at least 3.5% salinity in the water phase, but if the water phase contains 100 ppm or more of sodium nitrite, the water phase must contain 3.0% or more salinity.
- ***Staphylococcus aureus*****:** Although a ubiquitous organism, its main reservoir and habitat are animals and more importantly the human nose, throat and skin. So if the person dealing with the product is Staph. aureus organisms may contaminate the product. Human carrier levels can be as high as 60% of healthy individuals, with an average of 25-30% of the population being positive for enterotoxin-producing strains. The organism is mesophilic with a minimum growth temperature of 7 ℃, but requires higher temperatures (>10 ℃) for toxin production.
- **Enterobacteriaceae:** Salmonella, Shigella and *E. coli* pathogens occur in fish products as a result of animal/human contamination. As with other organisms, the risk of infection can be eliminated with proper preparation.

- ***Listeria monocytogenes*:**

The *Listeria monocytogenes* is a ubiquitous organism that has been identified in fresh fish skins, gills, and intestines, as well as lightly preserved fish products such as cold-smoked fish, marinades (ceviche), and gravado fish. Their growth boundary conditions are 0–45 °C, 8–12% salinity, pH 4.8–9.6, and water activity below 0.92–0.95.

Table 4. Guidelines for the microbiological quality of ready-to-eat smoked fish, taramasalata and cooked shellfish sampled at the point of sale

Criterion	Satisfactory (cfu/g unless stated)	Borderline - limit of acceptability (cfu/g unless stated)	Unsatisfactory (cfu/g unless stated)	Unacceptable/ potential hazard* (cfu/g unless stated)
Aerobic plate count† (30 °C, 48h ± 2h)	$<10^6$	10^6 - $<10^7$	$\geq 10^7$	N/A
Indicator organisms‡ Enterobacteriaceae	<100	100 - $<10^4$	$>10^4$	N/A
E. coli (total)	<20	20 - <100	>100	N/A
Listeria spp. (not *L. monocytogenes*)	<20	20 - 100	>100	N/A
Pathogens *Salmonella* spp. *Campylobacter* spp. *E. coli* O157 & other VTEC *Vibrio. cholerae*	not detected in 25 g			present in 25 g
Vibrio parahaemolyticus	<20	20 - <100	200 - $<10^3$	$\geq 10^3$
L. monocytogenes	<20**	20 - <100	N/A	>100
Staph. aureus	<20	20 - <100	100 - $<10^4$	$\geq 10^4$
C. perfringens	<10	10 - <100	100 - $<10^4$	$\geq 10^4$
B. cereus and *Bacillus subtilis*#	$<10^3$	10^3 - $<10^4$	10^4 - $<10^5$	$\geq 10^5$

Table 5.US Food and Drug Administration (FDA) guidelines related to ready-to-eat fishery products

Product	Organisms and/or toxins	Limit of tolerance
Ready-to-eat fishery products (minimal cooking by consumer)	Enterotoxigenic *E. coli* (ETEC)	1x 10^3 ETEC/g, LT or ST positive
	L. monocytogenes	Presence of the organism
	Salmonella spp. *	Presence of the organism
	Staph. aureus *	Positive for enterotoxin or $\geq 10^4$ (Most Probable Number)
	Vibrio cholerae	Presence of toxigenic 01 or non-01
	V. parahaemolyticus	$\geq$ 1 x10^4 (Kanagawa positive or negative)
	Vibrio vulnificus	Presence of the organism
	C. botulinum *	Presence of viable spores or vegetative cells in products that will support their growth; or presence of toxin
	Paralytic shellfish poisoning*	0.8 ppm (saxitoxin equivalent)
	Amnesic shellfish poisoning *	20 ppm domoic acid, except in the viscera of dungeness crab, where 30 ppm is permitted

3. FERMENTED FISH

The term 'fermentation' describes a range of processes, from the autolytic degradation of most fish proteins to processes in which the activity of lactic acid bacteria (LAB) which plays an important role. The relative importance of these two activities depends on the product formulation. The one with only salt added tend to be predominantly self-degrading and produce fish sauces and pastes, while those with carbohydrate sources such as rice and sugar added, lactic acid fermentation plays an important role. Fish fermentation Products are mostly confined to East and Southeast Asia, but some are made elsewhere.

3.1. Initial microflora

Normally fish used for fermentation are gutless, especially in fish/salt products, and in these cases the initial microbiota can be very large (Philippines and Thailand), preparations such as Lucpan (Thailand). is available as is or as partly saccharified rice produced. Contains a mixed flora of mold and yeast, species of the genus Saccharomyces. These microbes play an important role in the production process, but they can also contribute to the final spoilage of the product.

3.2 Pathogens: Growth and Survival

Fermented fish products are typically stored at ambient temperatures and can be consumed without heating. Safety is therefore depends on the raw material quality used and the inhibitory effect of the fermentation process.

> *Vibrio parahaemolyticus* has been reported to grow to pH 4.8 and salinity to 10%, but these limits apply when all other factors are optimal. The combination of salt and pH in many fermented products is completely to prevent microbial growth, and hostile growth conditions and high ambient temperature storage can lead to a fairly rapid reduction in viable counts.

> *C. botulinum*: Botulism is also associated with many traditional foods of the peoples of Greenland, Northern Canada, and Alaska. Wider modern use of glass and plastic containers, is thought to contribute to this. Salt concentrations are not low enough to prevent the growth of *Clostridium botulinum*. A warm climate can lead to rapid growth of *Clostridium botulinum*. The production of *Clostridium botulinum* and toxins that remain in products commonly consumed raw.

4. IRRADIATED SEAFOOD

Food irradiation is recognized as a successful technique for ensuring the safety and extending the shelf life of foods such as fresh meat, but consumer confidence in this method is lacking. Highly effective at inactivating pathogenic microorganisms without affecting product quality. Food is usually irradiated with gamma rays originating from a radioactive isotope source. However, X-rays or electrons produced by electron accelerators can also be used. According to the Joint Expert Panel on Food Irradiation (Anon., 1981), foods irradiated with 1 kGy are subject to what is known as extinction ("rad" by irradiation, Latin for "hard" or "permanent"). When the radiation dose emitted is in the range of 1-10 kGy, the food undergoes a process called radicalization ("rad" in radiation and "cid" from Latin "kill"). After Appert, a French scientist who invented aseptic canning. Radappertization results in complete sterilization of food as all bacteria are removed.

Table 5. USFDA approved year and acceptable dose of a variety of food

Food	Dose (kGy)	Purpose	Approval year
Wheat flour	0.2–0.5	Mould control	1963
White potatoes	0.05–0.15	Reduce sprouting	1964
Pork	0.3–1.0	Inactivate Trichina parasites	1986
Fruit and vegetables	1.0	Pest control, increase shelf life	1986
Herbs and spices	30	Sterilization	1986
Poultry	3	Reduce bacteria	1990
Poultry	1.5–3.0	Reduce bacteria	1992
Meat	4.5	Reduce bacteria	1997
Meat	4.5	Reduce bacteria	1999

Source: US government (Center for Contagious Diseases).

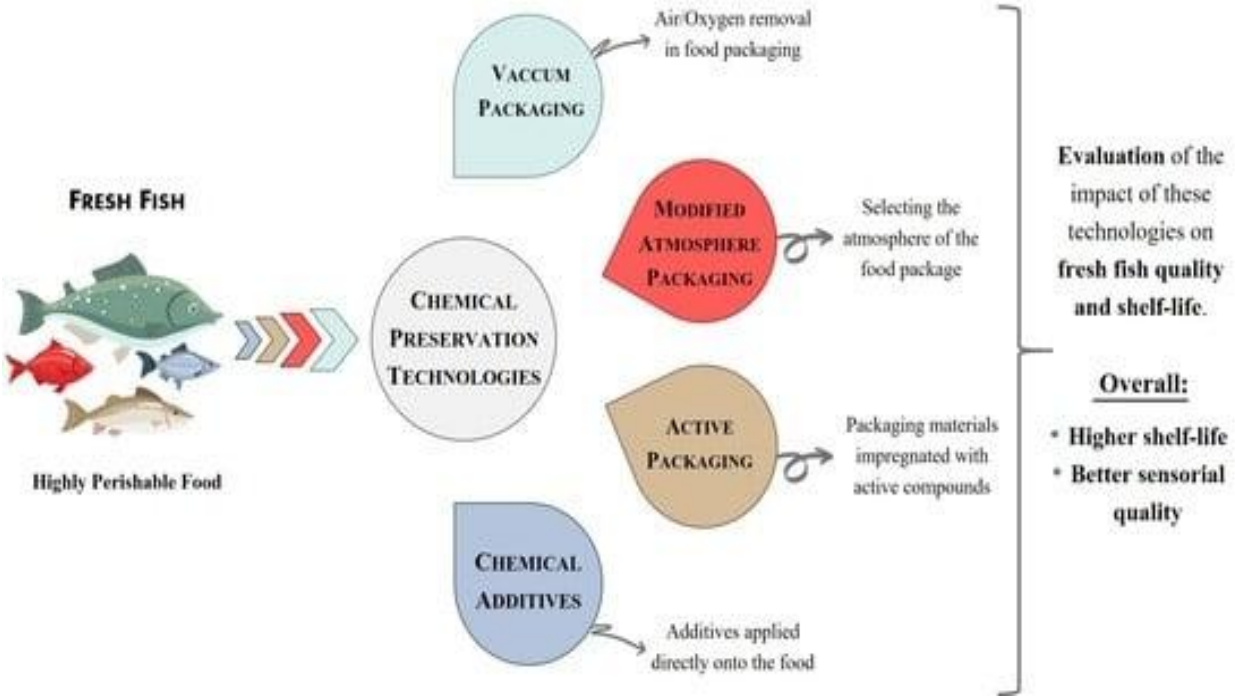
Table 6. The microflora of irradiated shellfish.

Species	Irradiation type/dose (kGy)	Temperature (°C)	Shelf life	Organoleptic changes	Results	Refs
Live oysters (*Crassostrea brasiliana*)	1 kGy gamma irradiation	–	–	The highest irradiation dose did not kill the oysters or affect their sensory attributes.	6-log10 reduction of V. *parahaemolyticus*	Jakabi et al., 2003
Live oysters (*Crassostrea brasiliana*)	3 kGy gamma irradiation	–	–		Reduction of *Salmonella* serotypes by 5 to 6 log10 units	
Live oysters (*Crassostrea virginica*)	0.75–1.0 kGy gamma irradation	–	–	Sensory panellists, were unable to distinguish non-irradiated from irradiated oysters	*Vibrio vulnificus* (MO-624) was reduced from 10^6 cfu/g oyster meat to non detectable levels (<3 mpn/g oyster meat)	Andrews et al., 2003
Live oysters (*Crassostrea virginica*)	1.0–1.5 kGy gamma irradation	–	–	–	*Vibrio parahaemolyticus*, 03:K6 (TX-2103), was reduced to non detectable levels.	
Eastern Oysters (*Crassostrea virginica*)	2 kGy electron beam irradiation.	–	–	No negative effect of visual appearance	Complete elimination of *C. parvum* infectivity	Collins et al., 2005
Pacific oysters (*Crassostrea gigas*)	–	7°C	2 days	–	A large percentage of Lactobacillus was detected in oysters (55.0%)	Shiflett et al., 1966
Pacific oysters (*Crassostrea gigas*)	1 kGy gamma irradiation	7°C	–	–	The Lactobacillus species were the predominant survivors (92.4%)	
Pacific oysters (*Crassostrea gigas*)	4 kGy gamma irradiation	7°C	–	–	The predominant survivors were Achromobacter species (99.3 %).	

Microbial aspects of food packaging

Advances in food packaging systems over the years have revolutionized how food is stored, distribution trends, improved quality and extended shelf life for consumer health and safety. Proper packaging techniques are essential to maintain the quality of seafood during storage and bulk or retail distribution. The latest active packaging, smart packaging, modified atmosphere packaging (MAP) and insulated packaging designs maximize durability while limiting degradation factors. Packaging is primarily intended to protect the necessary water and gas barriers, mechanical, optical and thermal. It helps protect the product with its physical and physical properties. Seafood packaging is designed to preserve the quality of the product. Active packaging inhibits microbial growth in fish products. To prevent oxidation of lipids and proteins, we use high barrier vacuum packaging and high CO2 packaging. An intelligent seafood freshness monitoring package was developed to monitor pH changes, biogenic amines, and ammonia production. Insulated packaging is mainly designed to maintain low temperatures during seafood distribution.

Figure 1: Distinctive types of Food Packaging Source



Conclusion

This chapter reviews recent advances in polymer packaging technology, focusing on the microbiota associated with different processing techniques. New technologies related to macromolecular MAP, intelligent packaging, rigid insulation packaging and active packaging for aquatic products have been developed and patented. The research works on biodegradable insulation packaging for seafood is progressing. Based on the recent results, sustainable and biodegradable polymers are increasingly being investigated in packaging applications to prevent microbial degradation.

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Chapter-4

APPLICATIONS OF SMART AND INTELLIGENT PACKAGING

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Globally, fisheries production announced to 178.5 mmt in 2018 in which capture and culture fisheries accounted to 96.4 and 82.1 mmt, respectively (FAO, 2020). Fish is recognized as a very perishable foods, needs a proper precaution for maintain the freshness and spoil free. To achieve this, a number of preservation techniques have been implemented. Amongst these, preservation by chilling and refrigeration is the most preferred one due to its ability to keep food fresh-tasting and the prolongation of bacterial lag phase in chilled condition, the deterioration rate can be reduced. Being one of the most perishable foods, fish loses its freshness quickly even when stored in a refrigerator. In order to preserve the flavours and qualities of the fish, consumers also require that it be as fresh as possible. Fish storage quality can be enhanced by using proper packaging. For products to have a longer shelf life and be more marketable, packaging is crucial. Packaging makes a product more appealing to consumers and hence more likely to be sold. Food packaging has historically served as a means of containment, protection, and communication. The purpose of the package is to shield the product from environmental factors that can cause it to degrade, such as heat, light, pressure, moisture or lack of it, bacteria, and gaseous emissions.

Packaging contributes to the conservation of natural resources by preventing waste and product deterioration and by shielding goods until they have served their purpose. Good marketing properties, a fair pricing, technical viability, utility for food contact, low environmental stress, and recycling adaptability are the fundamental requirements for a package. Depending on the kind of fish, simply packaging fish will extend the shelf life of chilled and refrigerated fish to 7 to 15 days. The presence of O2 in standard air packing, however, will cause the spoiling process to proceed more quickly in regular packaging. By using vacuum packaging or packaging with a changed atmosphere, it is possible to overcome the issue of shelf life.

VACUUM PACKAGING

The consumer acceptability of a fish and fishery products depend on some quality attributes such as its appearance, flavour and texture. Myoglobin, a major pigment exists in of the three chemical forms in red meat fishes; deoymyoglobin (purple) which get oxygenated to oxymyoglobin (red) and again oxidised to metmyoglobin (brown colour) which is responsible for freshness loss. By the reduction of oxygen level to below 0.05% or at saturation level can minimize the formation of myoglobin formation in fresh meat. Apart from this, lipid oxidation is also considered as a quality deteriorative process responsible for the development of undesirable off -odours and flavours. In order to limit the rate of quality deterioration and spoilage, it is necessary to control the level of oxygen in food package. One such method is vacuum packaging, otherwise known as skin packaging which involves the complete exclusion of air entrapped inside the package by the application of vacuum and keeping the product in vacuum conditions, reduces the problem of freezer burn and can arrest the microbial growth by the removal of oxygen. The usage of material with good barrier property is a significant parameter in vacuum packaging application. For example, nylon and polyester possess good oxygen barrier and has good strength, while polyethylene provides water transmission resistant and excellent heat-sealing property.

The advantages of vacuum packaging comprise depletion of fat oxidation and survival of aerobic organisms, decrement in evaporation rate and thereby dryness and freezer burn in frozen products and broaden the shelf life. In contrast to this, the need of high barrier material and maintenance of aerobic condition for product with sharp edge and sensitive crispy products, which otherwise promote the growth of *Clostridium botulinum* and the growth of *Listeria monocytogenes* limits its applications. Indeed, additional barriers required to switch these microorganisms, which is capital intensive. With the incorporation of oxygen scavengers in vacuum packaging promotes an active packaging system, thus reduced the oxygen content to <0.01% within 24 h, act as a preservative option.

MODIFIED ATMOSPHERE PACKAGING (MAP)

With the rising demand of consumers for fresh food with prolonged shelf-life leads to the widespread interest of modified atmosphere packaged food (MAP). It employs the principle that alteration of normal air composition (78% nitrogen, 21% oxygen, 0.03% carbon dioxide and traces of noble gases) takes place to deliver an optimum atmosphere to enhance the storage period and food quality. However, the safety, cost and regulatory measured limits its application commercially. The combination of gases such as oxygen, nitrogen and carbon dioxide are used in MAP in three ways; inert blanketing using N_2, semi-reactive blanketing using CO_2: N_2 or O_2: CO_2: N_2 or fully reactive blanketing using CO_2 or CO_2: O_2.

Inhibiting the growth of spoilage bacteria is the primary purpose of carbon dioxide in MAP. Since carbon dioxide (CO2) is a lipid and water soluble gas, it possesses antibacterial and antifungal effects and lowers the tissue pH, including that of microbes. It has an impact on membrane potential and on the balance of microorganisms' decarboxylating enzymes. In the logarithmic phase, CO2 causes microorganisms to grow more slowly and with a longer lag phase. Generally speaking, carbon dioxide works best to preserve food when the typical spoilage organisms are aerobic, Gram-negative psychrotropic bacteria. By purging the air and injecting the proper gas combination into the modified atmosphere package before closing, the CO2 is flushed into the container. The generation of CO2 and/or the removal of O2 from a package after packaging, or the incorporation of CO2 into the product itself, are two more methods of altering the environment around a product. With a lower gas/product ratio, both approaches can deliver the right packages. Since CO2 becomes less soluble as temperature rises, MAP products should be stored at lower temperatures to maximise their antibacterial impact. Additionally, the positive benefits of CO2 are typically eliminated by temperature changes. The amount of moisture and fat in the product affects how quickly CO2 is absorbed. The volume of the entire package will decrease if the product absorbs too much CO2, creating a vacuum-like appearance known as "pack collapse." The decline in water holding capacity and "pack collapse" caused by excessive CO2 absorption cause further drip loss to the products.

Oxygen in MA-packages of fresh fish will inhibit the formation of metmyoglobin and reduction of TMAO to TMA. Nitrogen (N_2), used as a filler in MAP, prevent the packaging

collapse occurs due to CO_2 dissolution and also reduce oxygen, leads to the inhibition of growth of aerobic microorganisms. The gas ratio normally used are 60% CO_2 and 40% N_2, for fatty fishes and 40% CO_2, 30% O_2 and 30% N_2 for lean variety fishes and the exact combination get varied on the basis of packaging materials, type of product and storage temperature.

SMART PACKAGING TECHNOLOGIES

The capital investment and requirement of good grade fish for the application of MAP, build up the researchers to invent advanced methods for keeping quality of food. Smart packaging such as active and intelligent packaging technologies, is considered as an innovative packaging technique for the development of wide variety of products with competitive cost and achieved a great position in the preservation of different food systems. It is a fast-growing technology with a market demand projected to reach $28 billion by 2024, which will outgrowth superior market acceptance for varieties of product types. Some of the smart packaging technologies and their applications are highlighted in Table 1.

Active Packaging

Active packaging is a pioneering concept that can be stated as ‘a packaging type that alters the packaging condition and keep these conditions all over the storage period to extend shelf-life or to improve safety or sensory properties while maintaining the quality of packaged food’. It performs some anticipated role rather than functioning as an inert barrier and merges advances in bio-technology, material science, food technology and packaging. It acts as either emitting or scavenging system or removal agent’s gases during its application. The main active packaging methods are concerned with ethylene, moisture, carbon dioxide, flavours and odours, and compounds that release carbon dioxide, such as antimicrobials, antioxidants, and flavours.

Antimicrobial packaging

A significant portion of fish deterioration is related to microbial contamination and development, which shortens food shelf life and raises the possibility of food borne illness. The use of antimicrobial chemicals or salts as well as heat processing, drying, freezing, refrigeration, irradiation, and MAP are traditional means of protecting fish from the effects of microbial

development. However, some of these methods can't be used on products made from fresh fish because they change the freshness of the fish. A rapidly growing active packaging, particularly for fish and poultry items, is antimicrobial packaging.

Antimicrobial films primarily work by releasing antimicrobial substances into food, which prolongs the lagged phase and shortens the growth phase of microbes, hence extending shelf life and maintaining product quality and safety. Antimicrobial agents may be surface modified, immobilised, coated, integrated, or immobilised onto packaging materials to give antimicrobial activity. In order to prevent the growth of bacteria on food surfaces, promising active packaging solutions include antimicrobial agents into the materials used to package food. The preservative is liberated from the active substance and acts directly when it comes into touch with a moist food or a food that has a liquid-like consistency. In both situations, the system's goal is to prolong the packed food's shelf life by preventing microbial development and maintaining its qualities. Acid anhydride, alcohol, bacteriocins, chelators, enzymes, organic acids, and polysaccharides are only a few of the classes of antimicrobials. In addition to these, chitosan and other derivatives from plants and fishing waste can be used in the packaging system as antimicrobials.

Antioxidant release

Antioxidants are frequently employed as food additives to enhance lipid oxidation stability and extend shelf life, mostly for dried goods and O2-sensitive foods like fish due to their high content of unsaturated fatty acids. Antioxidants can also be combined into plastic films to stabilise the polymer and prevent deterioration. BHT, a butylated hydroxytoluene, is frequently used in packaging films as an antioxidant. BHT's propensity to accumulate in human adipose tissue, however, has raised some questions about the physiological implications of use. As a result, less artificial antioxidants are being used in interaction with food. Therefore, it is preferable to use natural antioxidants that are safe. The most prevalent natural antioxidants are vitamins E and C, and researchers are still exploring how to incorporate them into polymer films to have antioxidative benefits. Vitamin E has great solubility in polyolefins and is stable during processing. In addition to these, research is being done on the use of natural antioxidants derived from plant and animal sources as packaging for antioxidants.

Active packaging systems with dual functionality

The employment of multiple function active systems is a more advanced method of increasing the life stability of packaged goods utilising active packaging systems. For instance, the storage of packaged foods is greatly increased when oxygen scavengers are combined with carbon dioxide and/or antibacterial / antioxidant releasing systems. When oxygen is removed from packages using an O2 scavenger alone, a partial vacuum is created, which could cause flexible packaging to collapse**.** In addition, when a package is flushed with a gaseous mixture that includes carbon dioxide, the CO2 dissolves in the product, creating a partial vacuum, causes the permeation of CO2 through the packaging film. However, in order to prevent the growth of surface microbes and increase shelf life, high CO2 levels are required. The self-working devices, which absorb O2 and generate enough CO2, will be promising in such situations for increasing the shelf life of goods, particularly fishery items. In order to extend the shelf-life of various food systems, ICAR-CIFT has developed the technology for these active packaging systems.

Intelligent Packaging

Intelligent packaging detects certain characteristics of food it contains or the environmental conditions in which it is placed and notifies the people of the state of these properties. The attributes of intelligent packaging could be employed to check the efficiency and reliability of active packaging systems. Intelligent packaging has been described as ‘packaging technology that can monitor the state of packaged foods to issue details about the quality of the packaged food during transport and storage’. A variety of indicators such as temperature, time-temperature, pack integrity, microbial growth, product authenticity and freshness are of interest to the fish packaging industry.

Future aspects

Smart packaging systems proved to be an effective mechanism to improve the food safety and shelf-life extension of the packaged foods. However, these technologies are in development stage in the seafood sector and needs ongoing researches and continued innovations to anticipate future advancement in food quality, safety and stability.

Table 1. Examples of some currently known smart packaging systems and their applications in different fish products

Smart packaging system	Substances used	Applications
O_2 absorbing	Chemical systems (powdered iron oxide, catechol, ferrous carbonate, iron-sulfur, sulfite salt-copper sulfate, photosensitive dye oxidation, ascorbic acid oxidation, catalytic conversion of oxygen by platinum catalyst) Enzymatic systems (glucose oxidase-glucose, alcohol oxidase-ethanol vapour)	Fresh and dry fish, sausages, smoked and cured fish
CO_2 emitting	Ascorbic acid, ferrous carbonate, metal halide	Fresh fish and shellfish
Moisture regulator	Silica gel, propylene glycol, polyvinyl alcohol, diatomaceous earth	Fresh and dry fishery products
Ethanol emitting	Encapsulated ethanol	Fresh and Semi dry Fish products
Antimicrobial releasing	Sorbates, benzoates, propionates, ethanol, ozone, peroxide, sulfur dioxide, antibiotics, silver-zeolite, quaternary ammonium salts	Fresh fish and value added products
Antioxidant releasing	BHA, BHT, TBHQ, ascorbic acid, tocopherol	Fresh fish, dry fish, smoked fish, fish oil,
Flavour absorbing	Baking soda, active charcoal	Fresh and dry fish and shell fish
Flavour releasing	Many food flavours	Fresh and heat processed fish products
Colour containing	Various food colours	Surimi, smoked fish, red

		meat fish, shrimps
Anti-fogging and anti-sticking	Biaxially oriented vinylon, compression rolled oriented HDPE	Fresh chilled / refrigerated fishery products
Light absorbing / regulating	UV blocking agents, hydroxybenzophenone	Dry fish and fish oil
Microwave susceptors	Metalized thermoplastics	Ready to eat fish meals
Insect repellant	Low toxicity fumigants (pyrethrins, permethrin)	Dry fish, smoked fish and fried fish
Temperature indicator	Metal Nanoparticles, nanocomposites from biomaterials, enzymes	Refrigerated & frozen food and pharmaceutical products
Freshness indicator	Sensors, modified gels, indicators	Freshness of fish and meat products
Leakage indicator	Dye based, biobased materials, enzymes	Vacuum & modified atmosphere packed food
Pathogen indicator	Antigen-antibody based system	Fresh, chilled and refrigerated fish and other Food products

Chapter-5

SAFETY EVALUATION OF FOOD PACKAGING MATERIALS

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Food packaging is synonymous with food preservation. As methods for preserving foods against spoilage evolved, so did food packaging materials evolved through the centuries. Food is packaged to preserve its quality and freshness, appeal to consumers and facilitate storage and distribution. The primary functions of a package are;

i) Contain the product

ii) Protect the product

iii) Sell the product

iv) The cost must be in commensuration with the cost of the food product.

Packaging materials:

- Various packaging materials have been used, as given below
- Wood and wood products like reeds and vines.
- Animal products – Hides, cured hides and intestines.
- Ceramics – Pottery has been used since pre-historictimes.
- Glass – Used for about 4000years.
- Paper – believed to have originated in China around 200BC.
- Metals – Tin, tin-free steel and aluminium.
- Plastics (Petroleum-based) – polyethylene (low, high-density), polypropylene, polyethylene terephthalate, polystyrene and their laminates.

The words “package”, “packing”, and “packaging” have noteworthy differences. A package is a physical entity containing the product. The Food Safety and Standards Authority of India characterizes a package (container) as a pre-packaged box, bottle, casket, tin, barrel, case, pouch, receptacle, sack, bag, wrapper or other things in which an article of food is packed. The

verb “packing” can be delineated as the enclosure of an individual or numerous items in a container or package. Packaging, as already defined, is a social-scientific principle encompassing the enclosure of products in a package and facilitates its protection, presentation, transport, and identification (Robertson et al., 2016). The packaging can be disparate into different “levels”, viz. primary packaging, secondary packaging, tertiary packaging, and quaternary packaging. Primary packaging is the layer of packaging that is in direct contact with the food being contained and is of prime importance as it makes a major protective barrier for the food and should be food grade. Most food products on the shelf are available in their primary packaging; these include plastic pouches and containers, glass, containers, and metal cans. Multiple primary packages contained in the package make a secondary package. An example of a secondary package can be a corrugated fibre board case or box specifically designed to carry shelf-ready primary packages. A tertiary package holds multiple secondary packages that aid their handling and facilitate interstate and international trade of products.

Consideration of the requirements of a package:

1. **It must contain the product**

- Adequate size to hold thecontents
- Proper constructional features – non-leaky, no spoilage anddiffusion.
- Adequate strength to withstand handling and internalstresses.
- Compatible with theproduct.

2. **To protect the product**

- Against physical damages through strength and cushioning against handling and transportation hazards.
- Against storage hazards stacking, warehousing resulting in compression, crushing, spillage and contamination.

i) External relative humidity and moisture–resulting in physical, chemical and biological deterioration. They are protected by water and water-vapour barriers and in-package desiccants.

ii) Oxygen within the package and fromoutside.

- Results in loss of vitamins, oxidation, loss of colour and flavour.
- Protected by oxygen barriers, removal of oxygen by vacuum or gas flushing, and use of anti-oxidants and oxygenabsorbers.

iii) Light source – visible and ultravioletradiations.

- Resulting in the destruction of essential ingredients and acceleration of deteriorativechanges.
- Protected by coloured or opaque materials.

iv) Temperature of the environment – High-temperature detrimentalchanges.

- Results in a change of state and rate of deteriorativechanges.
- Protected by insulators, reflective packages and cold storageconditions.

The advent of petroleum-based polymers in food packaging has benefitted consumers in terms of convenience; tamper proof, better display of product information and high retention of nutritional and sensory characteristics of the food. The low-molecular weight chemical compounds incorporated into the packaging material, such as plasticisers, stabilisers, UV-absorbers, adhesives etc., may react with the food during processing or storage and migrate into food. Hence, safety evaluation of food packaging materials is paramount and carried out by overall and specific migration tests.

Overall migration

The overall migration analysis gravimetrically determines the amount of migrants transferred from the packaging material to the foods. Since food is also a complex chemical, simulants (solvents) that mimic the actual food are being employed for migration testing (table1). The overall migration tests are performed as per BIS (IS 9845:1998:2020), which consists of five test methods depending upon the shape/construction of the packaging material. Among these are the methodologies for rigid/semi-rigid containers, sealable single/multi-layered flexible films and non-sealable homogeneous single-layered flexible films. The selection of food stimulant based on the nature of foods is given in table

Once the packaging material is exposed to the suitable food stimulant under a particular time/temperature condition (table 3), the final extractive value should be below the specified limits (10 mg/dm^2& 60 ppm as per BIS). Pigments/colorants are also added to the packaging materials to get attractive products. Suppose there is any visible color migration into the food

simulant; that packaging material is unsuitable for food contact applications even if the extractive value is below the prescribed limits as per BIS.

Table 1: Classification of Food Stimulants

Sl .No	Types of Food	Stimulants
1	Aqueous, non-acidic foods (pH>5) without fat	Water (A)
2	Aqueous acidic foods (pH<5) without fat	3% acetic acid (B)
3	Alcoholic beverages Alcohol concentration less than10%	10% Ethanol (C_1)
4	Alcoholic beverages Alcohol concentration more than 10%	50% Ethanol (C_2)
5	Oils, fats and processed dry foods with surface fats or volatile oils	n-heptane (D)
6	Non-acidic foods (pH>5) or high fat and having high moisture content	A & D
7	Acidic foods (pH<5) or high fat and having high moisture content	B & D
8	Dry processed foods without fat	A

Table 2: Classification of Foods and Selection of Food Simulants for Migration Tests

Sl. No	Type	Description	Example	Simulants
1	I	Aqueous, non-acidic foods (pH>5) without fat	Honey, mineral water, sugar syrups, molasses, skimmed milk, rasgulla, infusions, murabba, yeast paste etc	Distilled water
2	II	Aqueous, acidic foods (pH<5) without fat	Fruit juices, squashes, fruit chunks or puree or paste, vinegar, jams, jellies, carbonated beverages, lemonade, processed vegetables, rennet, preparations of soups, broths sauces, RTS beverages etc.	3% Glacial Acetic acid (v/v)
3	III	Alcoholic beverages: i) Alcohol concentration less than 10% ii) Alcohol concentration above 10%	Beer and some pharmaceutical syrups Wine, brandy, whiskey, arrack and other alcoholic drinks	10% Ethanol (v/v) 50% Ethanol (v/v)
4	IV	Oils, fats and processed dry foods with surface fat or volatile oils	Vegetable oils, ghee, vanaspati, cocoa butter, lard, biscuits, spice powder, snacks and savoury, chocolate, caramels, malted foods, egg powder, tea coffee powder confectionery, fried and roasted nuts etc	n-Heptane
5	V	Non-acidic foods (pH>5) or high fat and having high moisture content	Butter, bread, pastry, shrikhand with low cakes, milk-based sweets, ice-cream, moist and fatty confectionery products	Distilled waterand n-Heptane

6	VI	Acidic foods (pH<5) or high fat and having high moisture content	Pickles, ketchup, cheese, fresh and processed meat and fish products, sauces having fat, frozen foods, mayonnaise etc.	3% Glacial Acetic acid (v/v) and n-Heptane
7	VII	Dry processed foods without fat	Cereals and pulses, dehydrated vegetables and fruits, dried yeast, corn flakes, salt, sugar, milled products, barley powder, oats, vermicelli, spaghetti etc.	Distilled water

Sl. No	**Conditions of use**	**Type of Food**	**Migration test with food simulants-Time conditions (□C/h)**				
			Water (A)	**3% acetic acid (B)**	**10% alcohol (C^1)**	**50% Alcohol (C^2)**	**n-Heptane (D)**
1	High temperature heat sterilised (Retorting)	I, II, IV, V and VI	121 °C/2h	121 °C/2h	-	-	66 °C/2h
2	Hot filled or pasteurised Above 66°C, below100°	I, II, IV, V and VI	100 °C/2h	100 °C/2h	-	-	49 °C /0.5h
3	Hot filled or pasteurised below 66°C	I to VI	70 °C /2h	70 °C /2h	70 °C /2h	70 °C /2h	38 °C/0.5h
4	Room temperature filled and stored and also in refrigerated	do	40°C/ 10days	40°C/ 10days	40°C/ 10days	40°C/ 10days	38°C/0.5 h

	and frozen condition (no thermal treatment in container)						
* a) Heptane simulant not to be used of wax lied containers b) Heptane extractive results must be divided by a factor of five to arrive at the extractive of a food product							

Specific migration:

Since over all migration does not identify the chemical compounds that are migrating into the food stimulant from the packaging material, a specific migration analysis is essential. Both methodologies are similar, the difference being that the final residue/extractive obtained from overall migration analysis is introduced into GC-MS or HPLC to identify the migrated compounds that include: unreacted monomers, reaction intermediates, oligomers etc. Monomers such as vinyl chloride or bisphenol A are highly toxic; theformerisacarcinogen,andthelatteranendocrinedisruptor.Hencebothspecificmigrationandoverall migration analysis are essential to ensure that any food packaging materials out in the market are safe for food contact applications.

References:

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Chapter-6

TESTING OF PACKAGING MATERIALS

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Testing of packaging materials is an important component of the total packaging activities. The test results decidedly influence the selection of packaging materials and the design of the package. A test can generally be defined as the act of determining a given property or characteristics of a product (packaging material or package) by taking one or more measurement qualitatively or quantitatively according to prescribed procedure. Tests on packaging materials and packages are performed mainly for comparison with competitive material to compare the offers, current checks over the uniformity of new supplies of packaging materials i.e to check for changes in quality if any from batch to batch, quality checks during the production of packaging materials or packaged commodities and evaluation of suitability of packaging materials for certain purpose (e.g. protection against mechanical or climatic hazards)

1. Paper and Paper Boards

Conditioning Condition the samples in accordance with IS: 196-1950 and perform all tests with conditioned samples. For conditioning, expose the samples at 64% RH and 27°C for at least 24 hours for bringing the moisture level at 8-10%. Saturated solution of Sodium Nitrite in a desiccators gives 64% RH

Determination of Thickness (IS: 1060-part I- 1966)

Thickness or Calliper is the perpendicular distance between the two principal surfaces of the paper. Calliper of Kraft liner for a particular grammage should be uniform across the sheet.

Apparatus **:** Micrometer Screw Gauge

Report **:** Corrected values of average, minimum and maximum obtained on each test specimen. The thickness of paper and paper board is measured in mm

or mils of points.

(1 mil = 1 point = 1/1000'').

ii. Determination of Grammage or Basis Weight (IS: 1060-part I- 1966)

The weight per unit area of paper is defined as basis weight in g/m^2, or grammage.

Apparatus **:** Substance Indicator.

Method **:** A specimen cut into a size of 10x10 cm after conditioning the sample and kept in the substance indicator. Weight of the paper is expressed as gram per square meter.

iii. Determination of Bursting Strength (IS: 1060-part I- 1966)

Bursting strength is the hydrostatic pressure in Kg/cm^2 or $pound/inch^2$, required to produce rupture of material when kinds of paper. It gives an indication of tensile strength and stretch of paper.

Apparatus: Bursting Strength Tester.

Method: Clamp the sample of approximate size 12x12 cms after conditioning in position, apply hydrostatic pr3ssure with the instrument until the specimen ruptures and record the maximum registered by the pressure gauge. Make at least 10 acceptable tests to each side of the samples. The pressure is increased at a controlled constant rate through a rubber diaphragm of 1.20 inch in diameter. Bursting strength is widely used as measure of resistance to rupture in many

Report: The values are a measure of pressure and are reported in lbs/sq.inch or kg/cm^2.

Determination of Burst Factor

$$\text{Burst factor (BF)} = \frac{\text{Bursting strength } (Kg/cm^2) \times 1000}{\text{Grammage (GSM) of papers}}$$

Kraft paper is graded according to the BF.

Grades of Paper	BF
A	> 30
B	20 - 30
C	< 20

Type of Flutes in Corrugated Fibre Boards

Type of flute (mm)	No. of flutes/30 cm	Flute Height,
A flute	32-38	4.5-4.7
B flute	50-56	2.1-2.8
C flute	38-44	3.6-3.8

iv. Determination of Puncture Resistance: IS: 4006 (Part II) – 1972

The resistance of paper boards to puncture is of extreme importance in manufacture of shipping containers, because of the hazards involved in transportation, handling and storing, containers frequently are punctured by corners of the other containers, lumber, fork trucks etc. The beach puncture test gives an indication of the ability of container components or combined board to resist the damage caused by these various objects. The puncture test gives better assessment of the combined board strength than the burst and also appears to have better correlation with the package performance against impacts.

Equipment: Puncture Resistance Tester

Procedure: Place sample in clamping jaw, the sample should be placed in the machine with the outside surface down. Release the pendulum so as the pointer puncture the sample completely.

Report: Puncture test results as inch - ounces per inch of tear as shown pm the scale or beach units.

v. Determination of Water Absorptiveness or Cobb's Test: IS 4006 (Part I)- 1966

This test intended to find the penetration of aqueous liquids into paper and paper boards. In addition to indicating the extend of sizing in papers, the test is particularly useful in assessing the suitability of corrugated and solid fibre boards to be used for shipping containers, which have been the likelihood of being exposed to water spray.

The test specifies the amount of water absorbed by a specified area of paper in a given length of time.

Equipment: Cobb's test apparatus

Procedure**:** The specimen holder consists of a metal cylinder of 11.30 cms inside diameter. This cylinder clamped tightly over the specimen, which in turn is supported underneath by a rubber mat placed over a flat metal plate. With this set up, a water column of 0.6 to 1 cm height (usually100 ml) is allowed to stand on the specimen for a specific time (for paper 1 and for paper board 30!). The weight of water absorbed is found out after wiping of the adherent water with blotting paper. From this, the weight of water absorbed by one m^2 of the sample is computed.

Precaution: Printed areas should be avoided as also deformed of cracked surfaces for test. Weight should be performed quickly since evaporation of water at this stay may cause serious error.

vi. Determination of Tearing Resistance for paper:

The papers are tested for their tearing strength by this method. Papers tear almost straight along the grain or MD and somewhat irregular across the grain or CD.

Tearing strength serves to indicate resistance to wear in paper and it will also show whether the paper is made from strong or brittle fibrous material. This method is intended to measure the resistance of packaging papers against tearing forces that they can encounter during packaging operations, printing and handling.

Apparatus: Tearing strength tester

Procedure: The conditioned sample is clamped in the jaws and a pre-cut is made using the knife attached to the equipment. The pendulum is then released when it swings, continuing the tear along the guideline made by precut. Depending on the resistance offered by the sample for tear, the indicator needle moves along the scales and gives the force.

When no weight is used, multiply the reading by 16 (1600 gm - wt of pendulum) and express the tearing force in gm.

Higher fixing weights of 3200 and 6400 can also be used, multiply the reading by 32 in first case and by 64 in the second case. Perform the test in two directions.

Calculation of tear factor

$$\text{Tear Factor} = \frac{\text{Tearing strength in g (MD \& CD)} \times 100}{\text{GSM}}$$

Flexible Packaging Materials (Plastics)

i) Determination of yield: (IS: 2508-1984)

Yield is the amount of area provided by a given mass of a film of specified thickness.

The actual yield, Ya shall be calculated as, Ya, cm^2/kg = $\frac{A \text{ (Area in } cm^2)}{M \text{ (Mass in Kg)}}$

The nominal yield, Yn shall be calculated as, Yn, cm^2/kg = $\frac{1000}{dt}$

d = density in g/ml

t = nominal thickness in cm.

ii) Determination of Density: (IS: 2508-1984)

Specimen shall be conditioned by submerging it in boiling water for 30 minutes followed by conditioning at 27±2ºC for at least 24 hrs. to make it bubble free.

Procedure

Pipette 100ml of dilute alcohol (having density 0.8-0.82g/ml at 27ºC) into a clean Drechsel bottle kept immersed in a water bath maintained at 27±0.1ºC. After temp. equilibrium has been attained; lower one test specimen carefully into the dilute alcohol avoiding any adhering air bubbles. Add from burette, distilled water, 0.2ml at a time, with stirring. When the specimen remains just suspended in the solution well away from the glass surface, the density of the solution and the specimen is taken to be the same. Density of the solution may determine with a pyknometre, or specific gravity bottle at 27±0.1ºC.

iii. Determination of Tensile Strength and Elongation at break: (IS: 2508-1984)

Tensile strength has been defined as the force parallel to the plane of the specimen required to produce failure in a specimen of specified width and length under specified condition of loading.

Apparatus: Tensile Strength Machine

The machine used should be able to maintain a constant rate of traverse of one grip. The load scale should be accurate to within 1% or 0.1 N whichever is less. The load range should be such that the breaking load of the test pieces should fall between 15% and 85% of the full-scale reading.

Preparation of samples:

Gauge length of the Specimens: Plastics - 50±1mm length x 15mm width

Paper - 180±1mm length x 15mm width

Traverse speed of machine: Plastics- 500 mm/min

Paper - 150 mm/min

Samples shall be cut in lengthwise and crosswise direction, five numbers each. Total length should be at least 50mm longer than the gauge length. The thickness should be measured using a micrometer. The conditioned specimen is clamped between the grips of the machine. Machine is then switched on at the pre adjusted speed. The load and elongation at break are recorded.

Calculation

The tensile strength at break calculated in Kg/cm^2 from the original area of cross section i.e., kgf/cross section area in cm^2. The mean of five results is expressed for the lengthwise and crosswise samples (MD and CD).

Cross Section area = width x thickness in cm.

Elongation at break is expressed as percentage of the original length between the reference lines. The mean value of the five results is expressed from MD & CD samples.

$$\% \text{ E-B} = \frac{L_2 - L_1 \times 100}{L_1}$$

Breaking Length for paper

$$\text{Breaking length (in meters)} = \frac{\text{Tensile strength in Kgs X Length of the strip in meters}}{\text{Wt. of strip in Kgs}}$$

Usually, Tensile Strength is more in MD and Elongation is less in MD.

iv. Determination of Impact Resistance: (IS: 2508-1984)

This test is designed to measure the ability of the film to withstand the fracture by shock. It is the measure of toughness of the material. It is a combination of deformation and breaking properties.

In this test, the film is held flat and tight and a dart is dropped vertically at the centre of the film using an electro-magnetised holder. The weight of the dart can be increased using attached weight. The dart weight for which 50% of the specimen fails is reported as impact failure weight.

Apparatus **:** Impact Resistance Tester with vacuum clamp.

Adapter **:** An electro-mechanical or similar suitable device for use in supporting and

instantaneously releasing the dart so that it will fall freely on to the centre of test specimen in the specimen holder.

Dart : Consisting of a 3.81 cm diameter hemispherical head fitted with 0.64 cm diameter shaft 11.5 cm long, to accommodate removable mass. The head shall be constructed of aluminium, phenolic plastic or other low density material of similar hardness. The shaft shall be attached to the centre of the flat surface of the head with its longitudinal axis at 90ºC. The shaft shall be made of aluminium with a 1.27 cm long steel tip at the end for supporting it in the adapter.

Masses : Stainless steel detachable masses are suggested as follows:

a) Twenty four masses of 15.0±0.1 g each having approx. dimensions of 3cm in diameter, with a hole in the centre 0.61cm in diameter and 0.25cm thickness, and b) Five masses of 5.0±0.1g each, similar in construction, specified in (a), except that the thickness shall be altered to obtain the specified mass.

Positioning device

Means shall be provided for positioning the dart at the following drop heights from the impinging surface of the dart head to the surface of the test specimen.

1. Low Impact resistant film - 220 mm
2. Normal Impact resistant film - 660 mm
3. High Impact resistant film - 1524 mm

Test specimens shall be large enough to extend outside the specimen clamp gasket at all points. Specimens shall be free from pinholes, wrinkles, folds or other obvious imperfections.

Procedure

Place the specimen over the specimen clamp, making certain that it is uniformly flat, free of folds and that it covers the gasket at all points. Apply vacuum. Position the dart vertically with the shaft tip inserted in the adapter and the impinging surface of the dart at the appropriate height from the film surface. Release the dart.

Examine the specimen to determine whether it has failed or not. Failure is defined as any break through the film. Such a break may be readily observed by using the specimen under back lighting. Use a new specimen for each impact.

A few trial runs shall be made to establish approximately the working range of masses, which will break the film. Then for at least three dart masses selected to give percentage failure between 20 and 80, a minimum of ten specimens at each dart mass shall be tested.

v. Determination of Impact Failure Load

Plot the percentage of failure against total mass of the falling dart on a graph paper and determine the results graphically. The dart mass at which 50% of the specimens fail shall be read from the graph and will give value for impact failure load.

vi. Determination of Water Vapour Transmission Rate (ASTM E96-66)

This is an important property of the packaging material under 3 mm thickness, to be considered in the selection of barrier materials for hygroscopic foods. It is measured as the quantity of water vapour in gms that will transmit from one side to the other of the film of an area of one sq. meter in 24 hrs. when the relative humidity difference between the two sides is maintained at 90±2% at 37°C.

Apparatus: Test Dishes

Shallow aluminium dishes of as large a diameter as a can should be used. A wax seal between the test piece and the dish is given so as to prevent the transmission of water vapour at or through the edges of the sheet.

Method

WVTR is determined by sealing the open end of the dish containing the desiccant (fused Calcium Chloride) by the test specimen and exposing the dish to the desired RH and temperature conditions. For standard test this condition is 37°C and 92% RH, when the desiccant used exerts 2% RH. Increase in weight of the desiccant after a known period of time gives the amount of water vapour transmitted by the specimen.

$$\text{WVTR} = \frac{Q \times 24 \times 90}{A\ t\ (H_1 - H_2)} \quad g/m^2/24hrs.\ \text{at } 90\pm2\%\ \text{RH \& } 37°C.$$

Q - Quantity of water vapour pass through the test material of area **A** m^2 for **t** hours when the relative humidity on either side maintained at H_1 and H_2.

94% RH - Saturated solution of Potassium Nitrate

Sealing Wax - Combination of microcrystalline wax and paraffin wax in 60:40 ratio

2% RH - Fused Calcium Chloride or Magnesium perchlorate

Area of test specimen - 50 cm^2

vi. Determination of Gas Transmission Rate: (ASTM D 1434 & BS 2782 Method 514 A procedure 2)

The permeability of plastic films by gases is described as the volumetric rate of transmission of the gas, under known pressure differential, through a known area of film and is usually expressed as the transmission rate in ml per square meter per 24 hrs per atmosphere ($ml/m^2/24$ hrs. atoms). The permeability of plastic materials to different gases is of considerable significance in many applications. It can often be desirable to achieve a certain degree of permeability to certain gases, rather than to produce an entirely impermeable pack.

The phenomenon of gas permeability is dependent on the physical nature of the film, its density, degree of crystallinity and thickness and on the other the size and mobility of the gas molecules. The degree of polarity of both plastic materials and gas molecules as well as their tendency to be either hydrophobic or hydrophilic do influence the permeability of films with respect to particular gases.

Apparatus

Gas Permeability Apparatus (Davenport-designed in general accordance with B.S.2782, method 514A, Procedure 2 and ASTM D 1434)

Procedure

Unscrew the bolts holding down the upper half of the permeability cell and remove it. As supplied, the apparatus will have the 'X' volume controlling insert correctly fitted in the lower half of the cell. A dried circular filter paper (Whatmann No.1) is placed on the top of the insert and the sample of film spread over the filter paper. The upper part of the film permeability cell is then replaced. The bolts are then reinserted and tightened up with the box spanner.

The test gas is now turned on and the cell 'flushed out ' with a brisk stream of gas for a few seconds, after the flow may be reduced to a slow rate, to ensure that no air can diffuse back in to the cell (1 bubble/second through liquid paraffin). The lower part of the cell is then evacuated (using vacuum pump capable of giving a vacuum at least as low as 0.2 mm Hg. A vacuum gauge also be connected between the apparatus and the vacuum pump- Tipping Mc Leod gauge) as rapid as possible and as soon as the gauge indicates that the pressure is 0.2 mm Hg or lower. The apparatus is tilted to the left until the mercury runs out of the reservoir into the manometer, partially filling it. Return the apparatus to the normal position and immediately set the movable scale to a convenient starting point, start a stopwatch and begin to take readings, at suitable time intervals.

Repeat the test with other samples.

Calculation

GTR = $\frac{273xpVx24x10^4}{A \times T \times P}$

where,

GTR = Gas transmission rate in ml/m^2/24 hrs at 1 atmosphere pressure difference.

p = Rate of pressure change in capillary in cm Hg per hour.

V = Total volume in ml of the space between the lower surface of the film and the top of the mercury column in the capillary.

This total volume expressed as,

(a) The volume of cell cavity (i.e. 5,10,15 or 20)

(b) The volume of capillary tube above the mercury level half way through test; as the area of cross section of the capillary is 0.018 cm^2, this volume will be 0.018 X, when X is the length of the capillary above the mercury at the half way point in cm.

(c) The 'free space' volume of filter paper - can be taken as 0.24 ml.

A = Area of the specimen - 23.77cm^2

T = Temp. in ºK (273+ºC)

P = Pressure difference =1 atmosphere (76cm Hg)

i.e., = $\frac{273 \times pV \times 24 \times 10^4}{23.77 \times 76 (273+^oC)}$

vii. Determination of Overall Migration Residue

Migration is mass transfer of materials from plastics to foods under specified conditions. Migrants are materials thus transferred from plastics to food. In order to assess the toxic effects of the plastic packaging materials, the specification laid by various countries prescribe short-term extraction test called the global migration tests for quantifying the migrants. It is difficult to estimate quantitatively the amount of migrants in actual foodstuffs because of the complex nature of the food and diverse food categories. Accordingly, global migration tests, measure gravimetrically the amount of migrants from plastics to different food Simulating Solvents (FSS), which are based on the Categorisation of foods.

Food Categorisation**:** As per IS: 9845 - 1998

I	Non-acid (above pH 5, aqueous products, may contain salt or sugar or both.
II	Acidic (pH below 5), aqueous products may contain salt or sugar or both including oil-in-water emulsions of low or high fat content.
III	Aqueous, acid at non-acid products containing free oil or fat, may contain salt and including water-in-oil emulsions of low or high fat content.
IV	Dairy products and modifications a. Water-in-oil emulsion, high or low-fat b. Oil-in-water emulsion, high or low fat.
V	Low moisture fats and oils.
VI	Beverages: a) Containing alcohol; b) Non-alcoholic
VII	Bakery products.
VIII	Dry solids

Simulating solvents for different types of foods and time-temperature conditions for GMT

Conditions of use	Type of food	Temperature and Time				
		Water	3% Acetic acid	10% Alcohol	50% Alcohol	n-heptane
High temp, heat sterilised (retorting)	III,II,IV,V &VI	121°c, 2 hrs.	121°c, 2 hrs.			66°c, 2 hrs.
Hot filled or pasteurised above 66°C, below 100°C	I,II,IV,V& VI	100°c, 2 hrs.	100°c, 2 hrs.			38°c, 30 min.
Hot filled or pasteurised below 66°C	I to VI	70°c, 2 hrs.	70°c, 2 hrs.	70°c, 2 hrs.	70°c, 2 hrs.	38°c, 30 min.
Room temperature filled & stored and also in refrigerated and frozen condition	I to VI	40°c, 2 hrs.	40°c, 2 hrs.	40°c, 2 hrs.		38°c, 30 min.

US FDA 176.170: Components of Paper and Paper Board in Contact with Aqueous and Fatty Foods

Table 6.1 Types of Raw and Processed Foods

I	Non-acid, aqueous products, may contain salt or sugar or both (pH above 5.0)	**V**	Low moisture fats and oils.
II	Acid, aqueous products, may contain salt or sugar or both including oil-in-water emulsions of low or high fat content (pH below 5.0)	**VI**	**Beverages:** Containing upto 8% alcohol Non-alcoholic Containing more than 8% alcohol
III	Aqueous, acid or non-acid products containing free oil or fat may contain salt and including water-in-oil emulsions of low or high fat content.	**VII**	Bakery products other than those included under Types VIII or IX of this Table Moist bakery products with surface containing free fat or oil Moist bakery products with surface containing no free fat or oil
IV	Dairy products and modifications: Water-in-oil emulsions, high or low fat Oil-in-water emulsions, high or low fat	**VIII** **IX**	Dry solids with the surface containing no free fat or oil (no end test required) Dry solids with the surface containing free fat or oil

Method

Fill the container/pouch to their filled capacity with pre-heated simulant at test temperature and close it (1 ml/cm^2 of contact area). Expose to specified temperature maintained for the specified duration of time. After exposure for the specified duration, remove the container/pouch and quickly transfer the extractant into clean glass beaker with three washing with stimulant.

Evaporate the extractant to about 50-60 ml and transfer into a clean tared stainless-steel dish along with three washings and further evaporate to dryness in an oven at 100ºC. Cool this in a dessicator for 30 minutes and weigh.

Calculate the extractives in milligrams/dm^2 and mg/litre.

$$OMR = \frac{\text{Mass of residue in mg X 100 mg/dm}^2}{\text{(A) Area exposed in cm}^2} \quad \text{or}$$

$$= \frac{\text{Mass of Residue in mg X 1000}}{\text{(V) Volume of simulant in ml.}} \quad \text{mg/litre (ppm)}$$

Maximum limit value = 60 mg/litre or 10 mg/dm^2

viii. Determination of Tear Resistance

(By initiation method BS: 2782 Part- 3)

Method 360 C: 1991 or ASTM D 1004 - 94a (1995)

Principle: Tension is applied to ends of a test specimen so shaped that it tears across its width, by the extension of a right angled discontinuity in one of its long edges to the opposite edge. The tear strength is recorded as the maximum recorded tension in Newton divided by the thickness of the test piece in millimetres.

Apparatus: Tensile strength tester, with a rate of grip separation of 250±25mm/min.

Specimen: Die 'C'

Procedure

Determine the thickness of the test piece. Clamp the ends of the test piece symmetrically in the grips, such that the initial grip separation is 65±5mm, than separate the grips at 250±25mm/min., and record the maximum force registered.

Calculation:

$$\text{Tear Resistance} = \frac{\text{Maximum force in Newton, (N)}}{\text{Thickness in mm, (mm)}}$$

ix. Determination of Tear Resistance by the Trouser Tear Method

BS: 2782: Part 3: Method 360 B: 1991

Definition

Tearing force is the average force required to propagate a tear at a constant tearing speed across a test specimen.

Tear resistance

The tearing force divided by the specimen thickness.

Principle

A rectangular test specimen having a longitudinal slit extending over half its length is subjected to a tensile test on the "trouser legs" formed by the slit. The average force required to tear the specimen completely along its length is used to calculate the tear resistance of the material.

Procedure

Measure the thickness of the material. Set the initial separation of the grips to 75 mm, carefully clamp and align the test specimen legs in the grips so that its major axis coincides with an imaginary time joining the centre of the grips. The speed of the testing shall be 250 mm/min. Start the machine and record the load necessary to propagate the tear through the entire unslit length of the specimen.

Result

Disregarding the loads recorded in tearing the first 20 mm and the last 5 mm of the unslit length, determine the approximate mean value of the tearing load over the remaining 50 mm of the unslit length.

Calculate the tear resistance of the specimen from the formula, Ft/d

Where Ft is the tearing force in newtons and d is the thickness in mm.

Test speed : 250 mm/min. Initial separation : 75 mm

x. Determination of Puncture Resistance (ASTM: D 120-94 a, 1995)

The puncture resistance test shall be performed to determine the ability of the material to withstand puncture.

Method

A specimen shall be cut to fit between the opposing faces of two flat metal plates having concentric openings. The thickness of specimen shall be measured at its approximate centre. One of the plates shall have a circular opening 6 mm in diameter to allow the passage of a stainless-steel needle. The other plate (lower) shall have an opening 25 mm in diameter to provide a fixed free area through which the specimen can elongate while being subject to the pressure of the needle point. (Stainless steel needle having 5 mm diameter and machined at one and to produce a taper with an inclined angle of 12ºC with the tip of the end

rounded to a radius of 0.8 mm. The needle shall be positioned perpendicularly to the specimen so that the point contacts the specimen through the small whole in the plate. The needle shall be at a continuous rate of approximately 500 mm/min. The maximum force required to perform the puncturing operation shall be measured to the nearest 2N. The puncture resistance shall be calculated by dividing the puncturing force by the specimen thickness and recorded in units of Newton/meter.

$$\text{Puncture Resistance} = \frac{\text{Force in N}}{\text{Thickness in M}}$$

Test Speed = 500mm/min.

xi. Determination of Seal Strength [ASTM: F88-68: 1973]

Heat sealability of a packaging film is one of the most important properties when considering its use on retort pouch equipment and of course, the integrity of the seal is of tremendous importance to the ultimate package. After the seal is made, the strength is determined by measuring the force required to pull apart the pieces of film, which have been sealed together.

Method B: Dynamic Load Test

Unsealed samples of sealable flexible barrier materials shall be heat sealed and prepared for test with dimensions, according to 'fin' and 'lap' seals respectively. Edges of test specimens shall be clean cut and perpendicular to the direction of the seal.

Clamp each leg of the specimen in the testing instrument (tensile strength tester). The sealed area of the specimen should be equidistant between the clamps with at least 50 mm leg between the seal and clamp. Align the specimen in the clamps and allow sufficient slack so that the seal is not stressed prior to the initiation of the test. The rate of loading shall be such that the lower clamp moves at a rate 300 mm/min. Record the maximum stress applied to the specimen at yield or breakage.

Chapter-7

RETORT POUCH PROCESSING OF FISH AND OTHER VALUE-ADDED PRODUCTS

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Retort pouch processing is a mode of thermal processing technology applied to produce long/term shelf stable ready-to-eat (RTE) food products. The technology is an extension of the canning preservation methodology invented by Nicholas Appert, during the Napoleon era. The thermal sterilization method developed by Appert was heavily dependent on the container and as the time progressed, more inputs in the form of the container material, design and manufacturing were introduced by the industry. The retort pouch was such an invention collaboratively made by the United States Army Natick R&D Command, Reynolds Metals Company, and Continental Flexible Packaging, mutually acquiring the Food Technology Industrial Achievement Award for its discovery in 1978. Retortable pouches are still widely utilized by the U.S. and other militaries worldwide for combat rations, popularly known as *Meals, Ready-to-Eat*, or *MREs*. The core aspect of the retort pouch processing technology is the retort pouch itself, in which the food ingredients are packed. It consists of generally 3 to 4 layers consisting of an outer polyester, Nylon, a middle barrier layer of aluminium and an inner food contact layer of polypropylene (PP). On some occasions the aluminium layer is replaced with a silicon dioxide layer for making transparent pouches. The pouches according to their capacity, the pouches are filled with food solids and liquid media and hermetically sealed using heat sealing technology making sure that a vacuum is maintained inside by means of mechanical exhaustion, steam injection or heat filling methodology. The perfectly vacuumized and sealed pouches are then loaded to pressure cookers or retorts to be processed at a heat/pressure combination of 121.1^{o}C and 120 psi. Several retort systems such as still retorts, hydrostatic retorts, and rotary retorts, agitating retorts, steam/air retort and water immersion retort are popularly used. The heat transferring media used in such retort systems include steam (moist heat), steam/air (moist heat), water

spray (spraying super-heated water), water immersion (immersion in super-heated water), in which, steam and steam/air are considered as direct steam processing, while water spray, water immersion are considered as indirect steam processing. Retort pouch processing has many advantages compared to its counterparts such as metal containers. Its thin profile facilitates reduced space requirements, faster heat transfer, resulting in shorter processing time which intern generates energy savings as well as reduced nutritional loss and preservation of natural flavor and texture. The only disadvantage it processes is regarding the cost of the container since being a flexible packaging; it requires secondary packaging to protect against handling during transit. Almost all food varieties except heat labile ingredients could be preserved using retort pouch preservation technique and could be stored under room temperature with a commercial shelf life of at least 18 months. Seafood is also a popular raw material currently utilized for preserving in retort pouches. The demand for ethnic seafood recipes among the world populations, seasonal availability of raw material and susceptibility towards spoilage makes seafood an ideal candidate for retort pouch processing. Popular seafood items such as tuna, sardine, mackerel, salmon, tilapia, shrimp, squid etc. are widely packed in retort pouches with standard or regional gravy and marketed worldwide. The multilaminate nature of the retort pouch has been a constant challenge for the industry while addressing the recyclability of the discarded packing materials. The industry is currently trying to address the issue by introducing single laminate PP pouches which facilitates recycling and through reusable zip pouches which encourage storage by consumers. Various interventions are also being made in the heating equipment department as well. Advanced technologies such as microwave assisted thermal sterilization (MATS), and pressure assisted thermal sterilization (PATS) are currently being experimented by the industry.

Over pressure water spray retort

Steam air retort

Water Immersion retort

RTE Canned foods

Ready – To- Eat retort pouch processed foods

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Chapter-8

INNOVATIONS AND FUTURE PROSPECTS OF BIOPLASTICS

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Petrochemical based conventional plastics are not sustainable because of their high content of carbon footprint (Boonniteewanich J. *et al,* 2014*).* Plastics exhibit superior characteristics such as durability; lightness and cheapness make it more valuable than the metals, wood, papers, glass etc. These are widely provided in every industrial sector and their products. But the high demand of plastics created an alarming issue to the environment and from the statistical analysis about 34 million tonns of plastics are producing worldwide. Recycling is not much effective in most of the plastics and these are dumped into landfills or seas (Sushmitha BS *et al,* 2016). Various waste disposal methods are available right now. Toxic emissions will create more hazardous issues while on burning and affect the ecosystem as well as climate worldwide (Barker T, 2007). The chemical additives are incorporated during the synthesis of plastic products, are highly carcinogenic and deadly toxic to humans. On careful examinations, Scientists are required an alternative option.

Origin of Bioplastics

Bioplastics are biodegradable plastics. It is obtained from renewable sources such as cassava (Souza AC *et al*, 2012), jute, hemp, banana stems, citrus waste (Batori V *et al*, 2017) etc. Bio-based plastics can be degraded by the help of algae, fungi and bacteria (Ali S *et a*l, 2017, Das SK *et al*, 2018, Momani B *et al*, 2009). Nowadays bioplastics are receiving much more attention due to its remarkable properties. It is used in various sectors like packaging, catering products, consumer electronics, automotive, agriculture/horticulture, and toys to textiles and several other segments.

Classification of bioplastics

Bioplastics can be divided into three types

1. Biodegradable and Bio-based.
2. Biodegradable and fossil-based.

3. Non-biodegradable and petroleum based called as plastics (Izathul Shafina Sidek *et al*, 2019).

Examples of biodegradable biobased are Starch, Cellulose, Polyhydroxy alkanoates, Polylactic acid and biodegradable petroleum based are Polycaprolactone, Polybutylene succinate, Polybutylene adipate Terephthalate. Non-biodegradable bioplastics are Bio-polyethylene, Biopolypropylene and nonbiodegaradable conventional plastics are PVC, Polypropylene, polyethylene.

Cellulose and starh can be converted to its corresponding plastic by fermentation process (Misra M *et al*, 2009) or suitable polymer technology such as casting (Indriyati*et al*, 2012), mixing, extrusion (Wang B, 2009), injection molding, etc. (Salleh MSN, 2012). Bio-based ethylene and propylene are originated from renewable sources and showing similar characteristics like petrochemical based plastics (Jovanoviæ S. *et al*, 2013).

Production of some of the important bioplastics

1. Starch

Starch is produced from green plants. Commercially, starch and its derivatives are formed from different raw materials such as, potato & its peel, corn, wheat, pea etc. Starch shows typical properties due to its natural abundance, high carbohydrate ratio and it is considered as biodegradable plastic (Gáspár M, 2005). Starch contains amylose and amylopectin units, the high concentration of amylose shows its high tensile properties in bioplastics (Ceseracciu L *et al*, 2015).

Starch based plastics are an alternative material for petroleum based. One of the prominent factor of this plastic is its origin. It is produced from corn, potato etc and are degraded naturally. Many European Countries are implementing starch basd plastics. Recycling and reuse are effective for this plastic. Most of our bioplastics are created large-scale from various starches (Gadhave RV, et al, 2018, Abidin MZAZ et al., 2015).

2. Chitin/Chitosan

After the wide production of cellulose, chitin/chitosan is the second abundant biopolymer occurring in the nature (Shahidi F *et al*, 1999). Chitosan is prepared by deacetylation process of chitin. Chitosan films are one the remarkable product and shows better quality and storage life (Ribeiro C *et al*, 2007).

3. Cellulose & its Derivatives

Glucose units linked together by glycosidic linkages to form the natural polymer cellulose. It is one of the most abundant biomaterial on earth. Cellulose exhibit unlimited economic

importance, treated to generate papers, fibres and chemically modified material to yield substances used in the manufacture of such items as plastics, photographic films, and rayon. Hydroxypropyl cellulose, Hydroxypropyl methylcellulose, Carboxymethylcellulose and Methylcellulose are used for the preparation of films and coatings.

4. Polylactide Acid (PLA) Plastics

In the packaging sector, polylacticacid (PLA) is widely used due to its superior characteristic properties. It is considered as the first biobased polymer cpmmercially and can be converted to various products (Rasal RM *et al*, 2010). It is a better alternative to synthetic polymers like High density polyethyne, Low density polyethylene, Polyethyneterepl thalate and Polystyrene in packaging sector.

5. Polyhydroxy alkonate (PHA)

Polyhydroxyalkanoates (PHAs) are naturally occurring biodegradable polymers. Recent times, PHA has of great interest because of its in-built biodegradability. It shows biocompatible also. It is used for various medical applications such as drug carriers, biodegradable implants, tissue engineering, memory enhancers, and anticancer agents.

Existence of Bioplastics

1. **Raw Materials :** Starts with plants such as corn, sugar cane and potatoes
2. **Extraction & Isolation**: Materials are processed suitably
3. **Purification**: Processed materials are refined for suitable applications.
4. **Production:** Various kinds of bioplastics in the form of pellets, granules, films can be manufactured for the production of utensils, cups, plates etc.
5. **Disposal:** Biodegardable plastics can be completely decompose within three to six months.
6. **Reuse:** Bioplastics are converted to compost and return to earth that will help to grow new crops and plants.

Future scope and market importance of bioplastics

Nowadays scientists and researchers have adopted a new method to support for the selection of plastics, known as “plastic spectrum” (Kaith BS *et al*, 2010,Iles A *et al*, 2013). According to this specturm, bio-based plastics have raised much attention due to its biodegradable and compostable nature (Alvarez-Chavez CR *et al*, 2011). Many European countries and companies widely manufacturing biodegradable materils for packaging application (Krzan A *et al*, 2006).

Adavantages Vs Disadvantages

Bioplastics exhibits remarkable properties compared to synthetic plastics. Biodegradable bioplastics have high demand in commercial sectors and more advantageous than conventional ones.

Some of the advantages are depicted below:

1. Low carbon foot print (Chen YJ, 2014 ,Shamsuddin IM *et al*, 2017, Reddy RL *et al*, 2013)
2. Eco-friendly (Yu J *et al*, 2008)
3. Based on natural raw materials (Arikan EB *et al*, 2015)

Disadvantages are highlighted below:

1. High processing cost (Shivam P, 2016)
2. Numerous recycling issues

Applications of Bioplastics

Bioplastics are widely used as a packaging material because of its superior properties. Cellulose can be used in electronic devices (Kumar S *et al*, 2017, Mehta Varda *et al*, 2014, Sabbah M *et al*, 2017, Barker M *et al*, 2009), starch is used in textile, construction and food packaging sectors. PLA is commonly used in films and packaging of foods (Khosravi-DaraniK*et al*, 2015, Beucker S *et al*, 2007). PHA is one of the important bioplastic, produced from natural sources can be used for the packaging segment.

Conclusion

The review paper focused on the importance, advantages, disadvantages and future scope of bioplastics. Consumption of renewable resources for the fabrication of bioplastics rather than other synthetic plastics are more valuable for our ecosystem and our lives because petrochemical based plastics creates many drawbacks such as environmental pollution, formation of toxic gases etc. Coming generation will follow and use bioplastics due to its exceptional characteristics as well as biodegradable and sustainable nature. In future, research and development in the area of bioplastics will enlighten much more heights compared to petroleum-based plastics.

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Chapter-9

SEAWEED BASED EDIBLE FILMS AND COATINGS FOR FISH PRODUCTS PACKAGING: AN ECOFRIENDLY SOLUTION TO POLLUTION

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Introduction

Food packaging is essential for guaranteeing the quality and safety of food items packed within it and also endures shipping, material handling and storage. Improper maintenance of packaging integrity can lead to safety compromises a lot, in terms of contamination, physical damage and much more. Humans are addicted to using petroleum-based materials because of their versatility, which are used in the majority of traditional food packaging. Globally, the amount of packaging is growing every year, yet strangely, recycling rates are declining. The inability of plastics to biodegrade and their production from non-renewable natural resources are two major barriers to their increased use. Thus, the high accumulation of plastics has generated drastic effect on the environment considering the adverse effect on the ecosystem. The longevity of these non-degradable materials causes gradual accumulation in the landfill or natural environment. Hence in order to overcome the shortcomings of traditional plastics, it is necessary to develop packaging materials from innovative natural derived polymers.

Many biomaterials like starch, chitosan, cellulose etc. are currently using to formulate different films and coatings. These biobased systems can be employed as active ingredient carriers because they can transport antioxidants, antimicrobials, nutraceuticals, flavouring agents, and other additives to enhance the mechanical integrity, handling, and quality of food products. The edibility and biodegradability of bio-functional films and coatings are their finest features in packaging application. To make films and coatings to be edible, the

biopolymers, plasticizers, and other additives employed in preparation should be of food-grade nature. Also, before being labelled as edible and biodegradable, the developed films and coatings must first undergo toxicological and environmental safety testing by means of analytical techniques for broad applications. Design and development of such novel seaweed-based composites thus can contribute to the recent advancements in the field of active packaging, drug delivery systems, biomedical scaffolds, tissue engineering and cell encapsulations etc.

Edible films and coatings

Even the idea of using edible films and coatings for foods is quite old, the technology still remains as emerging which is attributable to the potential to reduce biochemical and microbial contamination, prevention of moisture loss, sensorial enhancement etc. The known methods of wax coating and similar methods are better moisture barriers, as well as restrict the transmission of oxygen and carbon dioxide. However, the inclusion of water-soluble hydrocolloids like polysaccharides and proteins can impart better mechanical properties to edible films and coatings than do other lipids and hydrophobic substances. Additionally, they can be employed to increase the shelf-life of foods by arresting the dehydration, oxidative rancidity, and surface-browning reactions. Also, the seaweed hydrocolloids can serve as nutrient-dense food components with some health advantages, such as lowering risk factors for heart diseases and boosting immune system performance.

Solvent casting and extrusion are two key production methods for edible films. The solvent casting, also known as wet process, involves spreading edible material dispersions over a suitable base material and followed by drying. As a result, the solubility of the polymer lowers due to solvent evaporation, and eventually the polymer chains align themselves to form films through subsequent chemical bonding or interactions. Both drying rate and environmental factors must be carefully managed since they have significant impact on the physical parameters (like thickness, appearance etc) and structural qualities of the final film obtained. The kind of base material will determine how easily the film may be removed without breaking or wrinkling.

The two basic methods used to produce edible coatings are spraying and dipping. In spraying method, low viscosity coating solutions, which are easy to spray at high pressure,

can be applied. Other factors like drying time, temperature, technique, and so forth can have an impact on how polymeric coatings are created by spraying systems. Fruits, vegetables, and animal items can develop extremely thick coatings during the dipping process. A knowledge on rheological and chemical nature of coating solutions including density, viscosity, and surface tension can give an idea on final coating thickness and stability. Foam application is another mode employed by applying emulsions, where the foam will break by tumbling actions, and causes even distribution of the coating solution over the surface of the product.

Seaweed polysaccharide as the raw material

Seaweeds, are richest class of marine bio-resources that humans have been used since the dawn of civilization. It includes members of the red, brown, and green algae and are the most abundant sources of polysaccharides like alginate, agar, fucoidan, agarose, carrageenan, and ulvan. Marine macroalgae have a long history of use in the food industry as additives, emulsifiers, gelling agents, and stabilizers. The industrial utilization of macroalgae is mainly confined to the extraction of phycocolloids and bioactive compounds for direct food and pharmaceutical applications.

However, in recent years seaweeds have gained a great deal of interest in the search for developing biopolymer films and coatings with the increasing of consumers concern on high-quality and long shelf-life of different food products and their awareness of environmental issues. In addition, the antioxidant, antimicrobial and nutraceutical properties of the seaweed show a potential effect on the consumer health and product quality. Edible seaweeds are rich in dietary fibers, high quality protein, essential fatty acids, minerals, carotenoids etc. Utilization of such seaweed species for the extraction of valuable polysaccharides has valid significance in terms of low cost, bio-mass availability, cultivation requirements etc. compared to other available sources for developing ecofriendly packaging formulations like edible sachets, biodegradable pouches, sheets and films etc. Agar, alginate, and carrageenan are the most commonly used seaweed polymers due to their biocompatibility, availability, gelling ability, and film forming ability in edible formulations. The conditions of polymers' extraction and manufacturing processes have a significant impact on the developed films and coatings. Different reinforcing materials like essential oils, biopolymers (such as starch, cellulose, and chitosan), and nanoparticles (organically modified and unmodified inorganic nanoclays, nano-cellulose, and carbon nanotubes) are generally being used today to make up for the shortcomings in the lower mechanical, barrier, and other functional properties of seaweed only packaging formulations. In addition, the renewability

and sustainability on developing edible composites based on seaweed polysaccharides encourage current researchers for extending its applications to food packaging.

Seaweed based composite films and coatings in food applications

Composites are hybrid materials, of which their properties are quite different from their individual components of which they are made of. The technological properties of bio-based edible films and coatings made of single component can be done by means of chemical (eg: cross linking) or physical treatments (eg: ultrasound, heat or radiation). For achieving a synergistic effect of combined features of single components involved, a proper designing on composite films and coatings should be done by combining different proteins, polysaccharides, lipids, as well as synthetic polymers. The mechanical and barrier properties of such composite films and coatings depend on properties of chosen components and their compatibility and combined interactions.

Some recent reports on seaweed polysaccharides- based packaging showed that the alginate- and carrageenan-based film or coating for meat and meat products can prevent the shrinkage, microbial contamination, oxidative changes and surface discoloration by delaying the moisture and oxygen transport and are found to be effective for maintain postharvest quality of fruits such as tomato, cherries, berries etc., by delaying the ripening and storage life. Alginate along with starch/cellulose was processed into films having excellent mechanical and barrier properties with proper packaging measurements. Alginate/essential oil preservative coatings could prevent the quality deterioration in fresh cut fruits and processed meat varieties with water repellent and gas barrier nature. Carrageenan/fruit seed extract and Carrageenan/ organically modified nanoclay combinations were developed for effecting

shelf-life extension and retention of quality attributes. Agar/Nanocrystalline cellulose/konjac Glucomannan had beneficial antibactericidal effect by reducing the growth of spoilage and pathogenic microbes in aquatic products, such as *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella anatum* and *Escherichia coli*. The addition of crude and purified extracts to different base materials also had a positive result on the flexibility and use for effective food preservation. Since more findings gave different set of packaging formulations, a thorough validation and perfect combination of components is essential for successful commercialization of seaweed-based coatings and films.

Legal aspects, health concerns and future prospects

Despite of many advantages on consumption of seaweeds, its gradual intake can result in accumulation of some undesirable compounds and toxic metals such as mercury, lead etc in our body. It might be due to the industrialization over the coastal belts where the seaweed is growing. Legislations are marked in the European Union as European Commission Regulation for setting guidelines to the application of seaweed as a food supplement. However, there is still lack of proper legislation in developing and developed parts of the world covering Asia and USA. Also, a thorough analysis and explanation on the release rate and the diffusivity of the seaweed based active agent incorporated in film matrices is necessary for shifting consuming beliefs and behaviour from use and throw plastic to edible packaging concepts. Primarily for this, control over the release of the ingredient component is neither too rapid, causing migration to the internal part of the food, nor too slow, meaning the inhibitory concentration cannot be reached, within the designed edible formulations and food item. Also, to extend the application of seaweed derived films and coatings to wide class of foods, future research on incorporating water repellant, high tensile imparting agents is required but without affecting the biodegradability or edibility status. Scale up issues can be

resolved by addressing the availability of bulk algal biomass, changes in cultivation system and subsequent composition and the overall production cost involved. Finally, the green synthesis methods of packaging can successfully lower the manufacturing cost and as sure safety parameters for contributing to the eco friendly approaches required in current scenario.

Conclusion

Considering the increasing consumer awareness for sustainable packaging materials, the popularization of seaweed polymers possesses great potential in the development of food packaging sector. Even though it lowers the quantity of plastic consumption and subsequent pollution, it demands further work on determining the effect of the seaweed on preserving the quality and in maintaining the shelf life of different kind of food products. The physical, structural, mechanical, barrier and functional abilities of the fabricated film/ coating can be modified with the inclusion of blend of polymers, natural plasticizer and other reinforcing agents of less or no harmful impact. For an extensive commercialization of seaweed based edible films/coatings into foodstuffs and packaging, an overall improvement in the legislation and health facts related to the safe and risk free for consumption of seaweed as well as developed packaging forms should be addressed. Altogether, the seaweed biodegradable packaging is more feasible and valid research towards the optimization of the processes and designing can make it a possible competitor on the market in future.

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