Major Challenges for Seafood Packaging

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Seafood is a highly economical product worldwide. Primary modes of deterioration include autolysis, oxidation of protein and lipids, formation of biogenic amines and melanosis, and microbial deterioration. These post-harvest losses can be properly handled if the appropriate packaging technology has been applied. Therefore, it is necessary for packaging deterioration relevance to be clearly understood.

food packaging active packaging seafood

1. Introduction

In 2021, world fishery market trade was forecast to increase by 12% in value and 3.7% in volume, with production projected to increase by 4 million tons from 2020 to 2022 [1]. Fishery product prices, especially shrimp, remained stable until July 2021 and then increased from August 2021 due to high freight costs of US$ 0.70–0.80 per kg for products exported from Asia to North America and Europe. Processed seafood is popular as ready-to-eat meals or snacks equipped with detailed serving instructions that normally involve reheating using a microwave oven [2]. Consumption of frozen packaged foods had predicted a CAGR of 5.98% from 2021 to 2028, while average year-on-year growth of 15.35% in 2020 was attributed to consumer panic buying behavior during the COVID-19 outbreak. Cold chain distribution requires high maintenance of both containers and packaging systems to maintain product quality. Seafood is a rich source of nutrients with specific aromas and tastes, while increasing global seafood production reflects consumer demand for packaged seafood products.

Packaging technology has been introduced to improve the quality with many beneficial solutions that offer interaction between food, packaging, and the environment. Finally, the shelf-life can be prolonged. Numerous types of research have investigated the efficacy of active and intelligent packaging, modified atmosphere packaging, as well as insulator packaging with various functions, forms, and materials/sources to preserve seafood quality. Active packaging focuses on inhibiting seafood deterioration, such as microbial growth and chemical oxidation. Intelligent packaging is designed to monitor the freshness of seafood products by detecting acidity, ammonia, or biogenic amine. Insulator packaging is for maintaining the temperatures in cold chain distribution. Active packaging is starting to be commercially developed. In the United States, active packaging contributed to 1% of the total packaging. This lower industrial scale of production relates to safety and legislative concerns [3].

Recent reviews relating to seafood technology include edible films and coating [4], spoilage and microbiota [5], and indicators for freshness [6].

2. Major Challenges for Seafood Packaging

2.1. Seafood Quality and Freshness

Seafood products (fish, crustaceans, bivalves, and cephalopods) are categorized as perishable, with high water content promoting rapid deterioration, especially by microorganisms. Improper handling during pre- and post-harvest accelerates the growth of indigenous microorganisms that trigger chemical and biochemical reactions that lead to deterioration. Water activity, the packaging system, storage temperature, and hygiene are the main external factors that influence seafood quality. Appropriate packaging technology is required to preserve the quality of seafood products during storage and bulk or retail distribution. Recent designs of active packaging, intelligent packaging, and modified atmosphere packaging (MAP), as well as thermal insulated packaging, maximize shelf-life while inhibiting factors of deterioration.

Packaging mainly functions to protect the product from undesirable environmental conditions such as heat, oxygen, light, or contamination (biological, chemical, and physical) with the required water and gas barrier, mechanical, optical, thermal, and physical properties. Seafood packaging is designed to preserve product quality. Active packaging inhibits microbial growth in seafood products. High barrier packaging/vacuum or high CO_2 packaging is used to prevent lipid and protein oxidation. Intelligent packaging is designed to monitor seafood freshness according to biogenic amines, pH changes, and ammonia production. Insulator packaging is designed to maintain low temperatures during seafood distribution.

2.2. Fishery Smell in Seafoods

The fishy aroma of seafood is the major factor impacting consumer acceptance. The aroma of seafood depends on the habitat, origin, type of nutrition content, breed, and processing method [7]. Freshwater fish have a mud-like aroma due to the presence of geosmin, while oct-1-en-3-ol, hexanal, and heptanal are chemical compounds responsible for the fishy odor [8]. Volatile organic compounds responsible for the seafood-like aroma include alcohols, aldehydes, ketones, esters, and sulfur, which are found in *Ruditapes phillipinarum* (Manila clam) [7]. The fishy aroma of seafood products is also related to polyunsaturated fatty acids (PUFAs) as the dominant fatty acid content in seafood. PUFAs can be converted into derivatives of unsaturated aldehydes including 1,6-nonadienal, 2,4-decadienal, and 2,4,7-decatrienal with a low odor threshold concentration [9]. Trimethylamine is the major source of the fishy smell in seawater fish, which gets stronger during storage due to post-harvest metabolism.

Managing the fishy-like aroma is challenging during transportation and storage. Oxidation of proteins and lipids in fish results in undesirable odors that need to be contained by high gas barrier packaging, or MAP. PVOH and nylon block the diffusion of fishy smells from inside to outside the packaging, thereby preventing odor pollution and product oxidation. Kimbuathong et al. (2020) [10] reported that MAP with a high CO_2 concentration reduced shrimp

TMA production. The fishy-like aroma originating from some volatile compounds may also react with the packaging, limiting the reuse and recycling of Styrofoam box-based thermal insulators. Ishida (2020) [11] reported that trimethylamine sticks to Styrofoam after use and can be dissolved in vegetable oil to improve its recycling potential.

The application of bio-based packaging for seafood products needs to be improved to contain the fishy aroma of seafood because the barrier properties are relatively lower than conventional packaging. Ortega-Toro et al. (2016) [12] improved the barrier properties of thermoplastic starch by blending with poly(ε-caprolactone), while Bang and Kim (2012) [13] improved the barrier properties of poly(lactic acid) (PLA) by insertion into an inorganic silica network as a hybrid coating material via the sol-gel method. Dong et al. 2022 [14] synthesized poly(butylene glycolate-*co*-furan dicarboxylate) with excellent barrier properties 68.6 times higher than poly(butylene adipate-*co*-terephthalate) (PBAT), while Katekhong et al. (2022) [15] improved the gas barrier properties of thermoplastic starch/PBAT based film by adding nitrite as a plasticizer and active agent. The permeability of thermoplastic starch/PBAT blends depends on the hydrophobicity of starch, and octenyl-succinated starch reduced the barrier properties more than acetylated starch [16].

Incorporation of essential oils with highly desirable smells such as lime, ginger, garlic, or oregano into the packaging also reduces the fishy aroma of seafood. Essential oils are aromatic organic compounds extracted from plants that exist in various forms, including aldehydes, alcohols, ethers, ketones, acids, amines, and other volatiles. Seafood products contain high amounts of fat and moisture that increase the release of phenolic compounds from essential oils such as aliphatic hydrocarbons (8–10 carbon atoms) in citrus oil, aliphatic molecules (6 carbon atoms) in leafy-green scented floral oils, or octanal aldehyde in orange oil, which are responsible for odor migration from packaging to seafood [17]. The patent for removing the fishy smell of salted mackerel using peanut sprouts was listed by Yun Hee and Kgeong Su (2018) [18]. They claimed that salted mackerel treated with peanut sprout extract had a lower fishy smell and trimethylamine content (0.21 Mg%) than untreated salted mackerel (1.91 Mg%). Another patent listed by Yoo (2014) [19] involved the use of garlic pickle and tangerine peel to remove the fishy smell of mackerel and hairtail stew. The fishy smell is an issue regarding consumer acceptance and air pollution. Nevertheless, it can be controlled via packaging with a desirable smell and prevented by high barrier packaging.

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