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Oxygen Scavenger Packaging for Seafood Preservation

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Abstract

Presence of oxygen inside the package leads to fast degradation of quality of fish due to oxidative deterioration and microbial spoilage. In active packaging systems, the food, the package and the environment surrounding the food interact to preserve the quality and to extend the shelf life of the packaged food. Oxygen (O_2) scavengers, the most commercially significant sub-group of active packaging, are very effective in reducing the residual levels of oxygen within the package to less than 100 ppm, thereby retaining the original quality and extending the storage life. Various studies have shown that the use of O_2 scavengers, also known as O_2 absorbers, have effectively controlled fat oxidation and inhibited the growth of microorganisms, which ultimately enhanced the storage life of fish. It is also observed that O_2 scavengers inhibited the growth of aerobic bacteria such as *Pseudomonas spp*. in fish stored in chilled environment and altered the dominant bacterial flora from Gram-negative to Gram-positive *Brochothrix thermosphacta* and *Lactobacillus spp*. In addition to extension of shelf life of fishes, the use of O_2 scavenger also proves economically beneficial for the seafood industry, since it is a simple, cost-effective means of generating low-oxygen atmosphere eliminating the cost of equipments.

Keywords: O_2 absorber, Fish preservation, Active packaging, Reduced oxygen packaging

Introduction

Fish has gained a lot of acceptance as a source of vital nutrients including prime quality protein, essential minerals, vitamins and most importantly the polyunsaturated fatty acids (PUFAs) (Ashie. et al., 1996). The presence of high moisture content, protein and PUFAs make fish highly susceptible to spoilage due to bio-chemical and microbiological quality deterioration (Mohan et al., 2010b). As a result, the freshness and storage life of fish predominantly rest on the effective control of spoilage bacteria (Gram & Huss, 1996) and lipid oxidation, particularly in semi fatty and fatty fishes. The rising demand for fresh fish among the customers has necessitated implementation of novel strategies and technologies, which can be coupled with low temperature storage to improve the shelf life, safety, and quality of fresh fish (Manju et al., 2007). There has been an increasing attention and effort over the last few years for developing innovative packaging concepts as novel food preservation methods. Packaging has an important role in extending the shelf-life of food by retarding food product deterioration because of protection from microbial and chemical contamination, oxygen, water vapour, and light (Lo´pez-Rubio et al., 2002). In the presence of atmospheric oxygen, the keeping quality of fish is limited due to the undesirable chemical changes like lipid oxidation and growth of aerobic spoilage microorganisms (Ozogul et al., 2004). Different preservation methods have been adopted by the industry to minimize these unwanted effects. Among those, currently, active packaging is leading the revolution of fresh and minimally processed food preservation method.

Active packaging

Active packaging, the new generation of food packaging, has begun to gain the attention of industry and researchers owing to its ability to offer quality and safety benefits to food. Conventionally, the packages safeguard the contents from physical, chemical, and microbiological contamination passively. Compared to traditional packages, the active packages deliver extra functions other than just physically protecting the packaged food from external influences (Vermeiren et al., 2002). In other

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words, packaging may be labelled as active, when it undertakes an additional preferred role in food preservation than acting as an inactive fence to exterior conditions (Hutton, 2003). Active packaging is defined as packaging, which alters the form of the packaged food product to enhance shelf-life and/or manage microbial food safety and/or improve sensorial properties while retaining the quality of food (Ahvenainen, 2003). The package is made active to interact with the food and/or the nearby environment (Pereira De Abreu et al., 2012) by incorporating certain additives into packaging systems. The earlier designs in active packaging included a sachet/small pouch holding the active ingredients, which was introduced into a permeable package. The substitute, which is being widely researched at present, is incorporation of the active substance within the package material wall. Active packaging systems can be grouped into releasing and scavenging systems. Some examples include oxygen (O_2) scavengers, carbon dioxide (CO_2) scavengers and emitters, humidity adsorbers or controllers, ethylene scavengers, aroma emitters/absorbers, enzymatically active systems, and antimicrobial systems. Among these, O_2 scavenger is the most commonly used and antimicrobial packaging is the most promising version of active packaging (Biji et al., 2015). Moisture absorbers are the most popular active packaging method for all applications. But, oxygen scavengers/absorbers are commercially more valuable due to their use in food applications. The main focus of this review is to provide an outline of those oxygen scavengers that have already been successfully applied to seafood, and highlighting their role in seafood preservation.

Oxygen (O_2) scavenger/absorber

Packaged foods contain some amount of headspace gases and entrained O_2. The presence of oxygen in packages triggers many chemical reactions and impacts food quality like off-flavour development (e.g., rancidity due to lipid oxidation), colour changes (e.g., pigment oxidation), nutrient losses (e.g., oxidation of vitamin C) and microbial growth thereby reducing the shelf life of foods significantly (Mohan et al., 2019). Hence, reducing the concentration of oxygen in the package headspace assumes great significance in controlling oxidative and microbial spoilage in food. Though O_2-sensitive food can be suitably packaged in materials with high barrier properties including multilayer films of ethylene-vinyl alcohol copolymers or aluminium foil along with other oxygen reduction techniques such as vacuum or modified atmosphere packaging (MAP), these methods cannot fully remove the O_2 inside the package (Lagaron et al., 2004). Oxygen scavengers, also known as oxygen absorbers create a micro/reduced oxygen atmosphere by decreasing and actively controlling the residual levels of O_2 within the package to <100 ppm (0.01 %), which is not achievable in the case of other packaging systems. Structurally, the O_2 scavengers vary, which can be in the form of a sachet, label, film, card, closure liner or concentrate (Suppakul et al., 2003). In that way, oxygen absorbers have eased the method of gas reduction within the food package.

Mechanism of action

The typical O_2 scavengers work on the principle of oxidation of iron powder through chemical means or absorption of O_2 using enzymes. The various mechanisms of action of O_2 scavengers are following;

a) Oxidation of iron and iron salts
b) Oxidation of photosensitive dyes
c) Oxidation of ascorbic acid
d) Oxidation of unsaturated fatty acids
e) Oxidation of rice extract
f) Oxidation of immobilized yeast on a solid substrate (Rooney, 1995).

Oxygen scavengers based on the principle of iron oxidation

Most of the studies in seafood were executed using O_2 absorbing sachets containing iron powder, since the ferrous iron-based oxygen scavengers are most widely used in the preservation of packaged foods. The O_2 scavengers were first prepared and presented in the food packaging market in 1976 by the Mitsubishi Gas Chemical Co. Ltd. in Japan under the brand name Ageless™. Subsequently, many other companies like Toppan Printing Co. Ltd. and Toyo Seikan Kaisha Ltd. introduced O_2 scavengers in the Japanese market but, Mitsubishi still leads the oxygen scavenger business in Japan. The scavenging action in Ageless™ is based on iron oxidation (Suppakul et al., 2003). It is widely employed in the food industry in Japan as an alternative to nitrogen and vacuum packaging techniques for preserving processed foods. It is promoted as a non-toxic~ residue-free method of preserving foodstuffs against mould~ aerobic bacterial growth and insect attack. Ageless™ is manufactured in the form of small sachets containing an oxygen absorbent sealed in a gas-permeable, water-impermeable film, which controls the flow of oxygen and moisture to the absorbent (Grattan & Gilberg, 1994). According to the manufacturer, Ageless™ is capable of reducing the oxygen concentration in an airtight container or package to less than 0.0001% (1 ppm) and can maintain this level for long periods depending upon the oxygen permeability of the packaging material. Different types of Ageless™ have been developed for the preservation of foods possessing a wide range of water activities. Ageless™ is also available in different sizes depending upon the amount of oxygen to be absorbed, which is indicated by the Ageless™ type number. For example, Ageless™ Z-200 is capable of absorbing 200ml of oxygen, which is the approximate oxygen content of one litre of air.

The names of other major commercially available O_2 scavengers are given in Table 1. A significant number of commercial O_2 scavengers in the market are based on the mechanism of iron oxidation (Smith et al., 1990), which works efficiently with diverse packaging materials. It reduces and maintains the O_2 level to < 0.01 % or 100 ppm inside the food package. These kinds of O_2 scavengers are available as labels, sachets, cards or films and the de-oxygenation time is usually ~ 1 to 4 days. Other examples of commercial O_2 scavengers in sachet form include ATCO® (Emco Packaging Systems, UK; Standa Industrie, France), FreshPax® (Multisorb Technologies Inc., USA) and Oxysorb® (Pillsbury Co., USA). In O_2 scavengers based on iron oxidation, the iron powder is kept separated from the food by placing it in a small, highly oxygen permeable sachet that is marked 'Do not eat'. The scavenger molecule, ferrous iron powder along with activated carbon and salt is presented as small, highly oxygen-permeable sachets that can be packed separately from the food product. The packaging of the absorber generally consists of paper and polyethylene (Cichello, 2015). These O_2 absorbers are based on the principle of oxidation in the presence of moisture or Lewis acids like $FeCl_3$ or $AlCl_3$ (Cruz et al., 2006). These chemical systems usually react with water existing in the food to yield a reactive hydrated metallic reducing agent that absorbs O_2 within the food package and irreversibly changes it to a stable oxide.

$$Fe \rightarrow Fe_2^{+} + 2e^{-}$$
$$\tfrac{1}{2}O_2 + H_2O + 2e^{-} \rightarrow 2OH^{-}$$
$$Fe_2^{+} + 2OH^{-} \rightarrow Fe(OH)_2$$
$$Fe(OH)_2 + \tfrac{1}{4}O_2 + \tfrac{1}{2}H_2O \rightarrow Fe(OH)_3$$

O_2 absorbers reacts quickly in foods with high water activity (a_w) in comparison to O_2 absorbers for dry foods. O_2 absorbers based on ferrous iron depend on the existence of moistness for activation. A minimum a_w of 0.7 is essential for acting O_2 scavengers based on iron oxidation and a_w of 0.85–0.9 is preferred (Brody, 2001). It was observed that nano-iron conversely presented O_2 absorbing efficiency in presence of both moisture and anhydrous environment (Dey & Neogi, 2019). In iron-based O_2 absorbers, the O_2 is eliminated by oxidation/rusting of powdered iron leading to formation of non-toxic iron oxide. It was also found that O_2 scavenging action enhanced with the rise in temperature (Gibis & Rieblinger, 2011). Instead of expensive materials with superior barrier properties, inexpensive or bio-based and environmentally friendly packages with low oxygen barrier efficiency can be used in combination with an O_2 scavenger, for making oxygen free atmosphere in the headspace, which will scavenge residual O_2 and O_2 infused through the packaging material during storage.

Oxygen scavenging films

Oxygen scavenging films have been developed as an alternative to sachets/labels, which incorporates O_2 scavenger into the packaging structure. An example is the commercial O_2 absorbing film, AGELESS OMAC®. In general, the rapidity and efficiency of O_2 absorbing plastic packaging films and laminated trays are substantially inferior to iron based O_2 scavenger sachets or labels. Cryovac® OS2000™ is a UV light-activated polymer-based oxygen scavenging film, which has been developed by Cryovac Division, Sealed Air Corporation, USA. Structurally, this includes an O_2 absorber layer extruded into a multi-layered film, which can decrease the amount of headspace O_2 from 1 % to ppm level in 4–10 days. $ZERO_2$™ is another light-activated O_2 scavenger film developed by CSIRO, Division of Food Science Australia in collaboration with VisyPak Food Packaging. $ZerO_2$® is the registered brand name for a number of O_2 absorbing plastic packaging materials, which are passive till triggered and hence can be subjected to traditional extrusion-based transforming methods for making films, sheet, coatings, adhesives, lacquers, bottles, closure liners and can coatings. Multilayer packaging, in which an oxygen scavenging layer is sandwiched between inert layers, could overcome some concerns of incorporated active films, but their costs are high (Gaikwad et al., 2018).

Oxygen scavengers in fish preservation and shelf life extension

The quality degradation of fresh fish is typically microbial. So, inhibiting the growth of microorganisms is generally the most significant parameter for an active packaging technology to be effective.

Table 1. Commercially available oxygen scavengers

Trade name	Manufacturer	Country	Product form	Scavenging Mechanism
Ageless™	Mitsubishi Gas Chemical Co.	Japan	Sachet/Label	Iron/Non-Iron based
FreshPax®, FreshCard™ and FreshMax®	Multisorb Technologies Inc.	USA	Sachet/Label	Iron oxidation
Oxysorb®	Pillsbury Co.	USA	Sachet	Iron powder oxidation
O_2™	O_2 Zero	UK	Sachet	Iron oxidation
Oxyfree® and Oxylabel™	Sorbtech International	USA	Sachet	Iron oxidation
Freshilizer® series	Toppan Printing Co.	Japan	Sachet	Iron oxidation
ATCO®	Emco Packaging Systems; Standa Industrie	UK; France	Sachet/Label	Iron/Organic based
Bioka®	Bioka	Finland	Sachet/Laminates	Enzyme based
Vitalon	Toagosei Chemicals Industry Co.	Japan	Sachet	Iron oxidation
Oxy-Catch	Kyodo Printing Co. Ltd.	Japan	Sachet	Cerium oxide
O-Buster	Dessicare Ltd.	USA	Sachet	Iron powder + Zeolites
Sanso-Cut®	Finetec Co.	Japan	Sachet	Iron oxidation
Keplon™	Keplon Co.	Japan	Sachet	Iron based
Oxy-Guard™	Toyo Seikan Kaisha	Japan	Plastic trays	Iron based
Darex Pure Seal®	W. R. Grace & Co.	USA	Bottle Crown/ Bottle	Ascorbate/Sulphite/ Metallic salts
Oxbar®	Carnaud Metal Box (CMB) Technologies	France	Plastic bottle	Cobalt catalyst
Amsorb®	Amoco Chemicals	USA	Film	Photo sensitive dye
Cryovac® OS2000™	Cryovac Division, Sealed Air Corporation	USA	Film	UV activated scavenger
$ZERO_2$™	CSIRO, Division of Food Science; VisyPak Food Packaging	Australia	Film	Photo sensitive dye
SHELFPLUS® O2	Albis Plastic GmbH	Germany	Film	Iron based
Activ-Film™	Aptar CSP Technologies	USA	Film	UV activated scavenger

Elimination of oxygen from the package interiors by O_2 scavengers enhances the shelf-life of fish by sub-optimizing the atmosphere for aerobic microbiological growth, which are thus particularly efficient in inhibiting the growth of moulds and aerobic bacteria. Nevertheless, the oxygen free environment created by the O_2 absorbers may lead to the growth of anaerobic pathogenic microorganisms such as *Clostridium botulinum* inside the package, especially when the food has a_w >0.92 and accordingly can cause health issues unless the storage temperature is not maintained below 3 ºC (Mexis et al., 2009). During chilled storage, there is a shift in the bacterial types. When a fish or fishery product is spoiled microbiologically, the microbiota will generally include a group of bacteria, in which many organisms may be absolutely innocuous in terms of its ability to cause any health issues or off-odour/ off-flavour production. The bacterial group causing significant chemical changes in fish during spoilage are referred as specific spoilage organisms (SSOs) (Gram & Huss, 1996). For several fishes stored under aerobic conditions in ice, *Shewanella putrefaciens* have been identified as the main spoilage bacteria. Under anaerobic conditions (MAP, vacuum packaging, active packaging technologies), the spoilage microbiota is mostly constituted by Lactic acid bacteria and *Brochothrix thermosphacta*. The commercial use of O_2 absorbers in case of fish products is largely restricted to the Japanese market and to dried or smoked fish products (Ashie et al., 1996). Those products have low water activity (aW<0.85) and are generally stored at ambient temperature. Hence, the microbial action is not shelf-life limiting and hence the purpose of the use of O_2 scavengers is to control oxidative reaction and discolouration alone. There are also other products like fresh yellowtail, salmon roe, and sea urchin stored at superchilling conditions packaged with O_2 absorber mainly to control oxidation and discolouration and to prevent bacterial growth to a lesser degree.

Studies on application of oxygen scavengers for fish preservation are limited (Table 2). Recently, Monteiro et al. (2020) reported that O_2 absorber alone or in combination with UV-C radiation extended the shelf life of tilapia fillets stored at 4±1°C and reduced the negative impacts of UV-C radiation. Previously, Johnson et al. (2018) reported that the commercial O_2 absorber pouch (Ageless OMAC®) could prevent primary and secondary products of fat oxidation (lipid hydroperoxides and thiobarbituric acid reactive substances) in fish oil-in-water emulsions. Remya et al. (2018) reported that an active reduced oxygen packaging atmosphere created by O_2 scavenger enhanced the shelf life of barracuda (*Sphyraena jello*) fish steaks stored at 0-2ºC to 20 days in comparison to 12 days for aerobically packed control sample. The count of total mesophilic and psychrotrophic bacteria increased significantly ($p<0.01$) in aerobically stored fish steaks. The total mesophilic count of fish steaks packed without and with O_2 scavenger crossed 7 log cfu g^{-1} on 12th and 20th days of storage, which coincided with the sensory rejection of the samples. It was also observed that the thiobarbituric acid value surpassed 2 mg malonaldehyde kg^{-1} in air packed barracuda fish steaks on 12th day of ice storage while for steaks packed with O_2 scavenger, this value never exceeded until completion of storage trial. In another work, Remya et al. (2017) observed that the combined use of O_2 scavenger and chitosan-ginger essential oil antimicrobial ûlm could lengthen the shelf life of chilled stored cobia (*Rachycentron canadum*) ûsh steaks up to 30 days, in comparison to 15 days for aerobically packed control samples. The use of O_2 absorber considerably inhibited the aerobic bacteria like *Pseudomonas spp.* and O_2 scavenger coupled with antimicrobial ûlm resulted in a 5-days lag phase for aerobic mesophilic bacterial count. Also, fat oxidation as revealed by thiobarbituric acid reactive substances (TBARS) was significantly lowered by O_2 absorber in cobia fish steaks indicating that O_2 absorber considerably limited the availability of O_2 within the package.

Mohan et al. (2010a) reported that O_2 absorber was efficient in scavenging the amount of O_2 inside the package up to 99.95 % within a day and it extended the post-harvest life of seer fish (*Scomberomorus commerson*) steaks up to 20 days compared to 12 days for air packs during chilled storage. Sodium acetate application and the micro aerobic environment influenced the spoilage microflora of seer ûsh (*Scomberomorus commerson*) steaks during chilled storage. For fish steaks packed with O_2 scavenger and pre-treated with sodium acetate, *B. thermosphacta* and *Lactobacillus spp.* were the major microbiota. The use of O_2 scavenger repressed the growth of *Pseudomonas spp*., and total *Enterobacteriaceae*. Mexis et al. (2009) investigated the combined effect of O_2 scavenger and 0.4 % (v/w) essential oil extracted from oregano on keeping quality of refrigerated stored rainbow trout fillets (*Onchorynchus mykiss*).

Table 2. Oxygen scavengers for fish preservation

Fish/Fishery product	Key findings	Reference
Tilapia (*Oreochromis niloticus*) fillets	O_2 scavenger singly or in combination with UV-C radiation extended the shelf life of refrigerated stored tilapia fillets by inhibiting bacterial growth, which also had lower amounts of free amino acids, biogenic amines and lipid oxidation products, compared to control.	Monteiro et al. (2020)
Indian oil sardine (*Sardinella longiceps*)	O_2 scavenger significantly inhibited lipid oxidation in Indian oil sardine, a fatty fish and hence extended the shelf life by 6-7 days.	Mohan et al. (2019)
Fish oil-in-water (O/W) emulsion	O_2 scavenger displayed protective effects against fat oxidation and vitamin degradation avoiding the use of antioxidants in fish oil-in-water emulsion.	Johnson et al. (2018)
Barracuda (*Sphyraena jello*) fish steaks	During chilled storage, the values for free fatty acid (FFA), peroxide value (PV) and thiobarbituric acid reactive substances (TBARS) of aerobically packed fish steak sample was higher compared with samples packed under reduced oxygen atmosphere indicating the protective effect of O_2 scavenger.	Remya et al. (2018)
Cobia (*Rachycentron canadum*) fish steaks	Unlike in air packed sample, where the dominant spoilage bacteria were *Pseudomonas spp*. and H_2S producers, the anaerobic LAB and *Brochothrix thermosphacta* were the dominant spoilage microorganisms in fish steaks packed with O_2 absorber during chilled storage.	Remya et al. (2017)
Seer (*Scomberomorus commerson*) fish steaks	O_2 scavenger altered the spoilage microbiota of chilled stored seer fish from Gram negative, particularly *Pseudomonas* and H_2S producing bacteria to Gram positive mainly *Brochothrix thermosphacta* and *Lactobacillus spp*.	Mohan et al. (2010a)
Rainbow trout (*Onchorynchus mykiss*) fillets	Ageless® oxygen absorber extended the shelf life of refrigerated stored fish fillets to 13-14 days, compared to 4 days for air packed control,	Mexis et al. (2009)
Seer fish (*Scomberomorus commerson*) steaks	The biogenic amine content was considerably high in air packed fish steaks compared to ice stored steaks packed with O_2 absorber. Production of agmatine was prevented by O_2 scavenger.	Mohan et al. (2009b)
Seer fish (*Scomberomorus commerson*) steaks	Relatively faster degradation of ATP and presence of its degradation products was reported for seer fish packed in control air packs compared to samples packed with O_2 absorber. Freshness (as K and related values) of fish samples packed with O_2 absorber was retained for longer period in ice in comparison to air packed sample.	Mohan et al. (2009a)
Catfish (*Pangasius sutchi*) steaks	Sensory score, mesophilic bacterial count, psychrotrophic bacterial count, total volatile base nitrogen (TVB-N), thiobarbituric acid value (TBA) and peroxide value (PV) of catfish steaks during chilled storage was positively influenced by O_2 scavenger, resulting in a shelf life extension of 10 days, compared to control samples packed under air.	Mohan et al. (2008)
Scaled and gutted seabream (*Sparus aurata*)	Lipid oxidation was significantly reduced and sensory score, particularly appearance was considerably higher in scaled and gutted seabream packed with O_2 scavenger.	Gonçalves et al. (2004)
Fishcakes, fish pudding, salmon and mackerel fillets	Quality was retained by preventing lipid oxidation as revealed by the difference in malonaldehyde formation in salmon and mackerel fillets packed with and without O_2 absorber.	Sivertsvik (1997)
Sardine oil	No quality degradation of w-3 PUFAs in sardine oil during storage at 22 °C for 1 month with O_2 scavenger, which also positively impacted on the loss of EPA and DHA in sardine oil.	Suzuki et al. (1985)

Based on organoleptic properties, shelf life was decided as 4 days for the control fillet samples, 7–8 days for fillets treated with oregano essential oil, 13–14 days for fillets packed with O_2 scavenger and 17 days for fillets samples containing both the O_2 scavenger plus oregano essential oil. The grouping of O_2 scavenger and oregano essential oil (0.4 % v/w) pre-treatment displayed an additive effect and had a strong positive impact on prevention of bacterial growth in rainbow trout ûllets leading to lengthening of the keeping quality. The O_2 scavengers maintained the peroxide value, the primary lipid oxidation product, below 20 meq O_2/kg oil even after 21 days of storage leading to a marked influence on the organoleptic acceptability of trout fillets. Mohan et al. (2009b) found that O_2 scavenger together with maintenance of appropriate temperature during chilled storage helped in decreasing the generation of biogenic amines to a larger extent in seer fish samples compared to control air packed sample. Mohan et al. (2009a) observed that degradation of nucleotides especially Inosine monophosphate (IMP) and Hypoxanthine (Hx) was delayed in chilled stored seer fish sample with O_2 scavenger compared to air packed sample. Mohan et al. (2008) reported an extension of storage life of 10 days for catfish steaks in O_2 absorber packs as compared to control air packs. There were substantial differences in the lipid oxidation products (PV and TBA value) in cat fish steaks packed with and without O_2 absorber after 8 days of chilled storage indicating that O_2 absorber can effectively manage the chemical spoilage problem due to lipid oxidation in fatty fishes. Gonçalves et al. (2004) studied the ability of O_2 scavenger in enhancing the keeping quality of scaled and gutted seabream (*Spratus aurata*) packed under air during chilled storage. They observed that O_2 absorber was very effective in decreasing oxygen concentration inside the packages. Lipid oxidation and sensory acceptability of scaled and gutted seabream was positively influenced by O_2 scavenger. However, its efficiency in prolonging the storage life of seabream was not very evident though it was reported that lipid oxidation considerably decreased in seabream packed with O_2 scavenger. In an unpublished work, Sivertsvik (1997) assessed the influence of iron-based O_2 scavenger on some fish and fishery products and found that the commercial O_2 scavenger had only a marginal impact on the growth of bacteria in fishcakes, fish pudding and mackerel fillets, while a significant effect was observed on salmon fillets. He conveyed that O_2 scavengers retained the lipid quality by prohibiting lipid oxidation and rancidity indicated by low TBARS value in mackerel and salmon fillets, which was comparable to oxygen free MAP. Suzuki et al. (1985) declared that n-3 PUFA of sardine oil packed with O_2 absorber didn't degrade during one month of storage at 22°C.

Merits and demerits of oxygen scavengers

O_2 scavengers offer itself as a substitute to vacuum packing (VP) and gas flushing technologies. Though MAP or vacuum packaging can be used for preservation of oxygen sensitive foods, which may not aid in complete elimination of oxygen. The O_2 infused through the packaging material or which is locked within the food can't be removed by these methods. In such cases, use of O_2 absorbers can reduce the alterations in quality of O_2 sensitive foods by efficiently scavenging the residual O_2 inside the package. One of the key benefits of using O_2 absorbers is that they are able to lessen the levels of O_2 in the packages to <100 ppm, which is much lesser than the 3000-30,000 ppm residual oxygen concentration attainable by MAP. O_2 absorbers can be used alone or jointly with VP or MAP. The use of O_2 absorbers unaccompanied by VP/MAP excludes the requirement for VP/MAP machinery leading to lower cost and could enhance the packaging efficiency. Nevertheless, commercially it is more usual to eliminate most of the atmospheric O_2 by MAP and then use a comparatively small and low-cost O_2 absorber to scavenge the remaining O_2 inside the package.

The demerits include concerns regarding the growth of anaerobic pathogens inside the package, moisture dependent activation of iron based O_2 scavenger sachet, chance of leakage of sachet or accidental consumption by the customers and the development of a partial vacuum inside the pack or pack collapse. This can be solved by incorporating O_2 scavenger into the packaging structure instead of placing it separately within a sachet. This can minimize the negative consumer perception regarding O_2 absorbers and can offer a possible monetary benefit through increased output. It also avoids the risk of inadvertent breakage of the sachet and accidental consumption of its content. Non-metallic O_2 absorbers were prepared to lessen the chance for metallic taints being imparted to food products due to the use of metal based O_2 scavengers and for easing the difficulty due to accidentally setting off in-line metal detectors. Currently, there are advanced detectors, which can be adjusted to phase out the absorber signal while retaining high sensitivity for ferrous and non-ferrous metallic contaminants.

Conclusion

Packaging has a very important role in protecting and preserving the food packed in it. Recently, the packaging industry has diverted its attention from the conventional packages to the new generation active packaging systems, since it satisfies the requirements of the green consumers, who demand safe, minimally processed, and fresher foods. Oxygen absorber is an improved active packaging method designed to reduce oxygen levels to less than 100 ppm in package headspace. O_2 absorbers are much superior in terms of O_2 scavenging ability, compared to other reduced oxygen packaging techniques such as VP or MAP and hence can be used as a better cost-effective alternative for shelf life enhancement of fish and fishery products.

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