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Microporous Modified Atmosphere Packaging of food stuffs

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ABSTRACT

MAP is broadly used globally to withhold the quality and to prolong the shelf-life of vegetables and fruits. It also helps in lowering processing cost and adaptable air permeability. By the progress and growing demand of fresh foods industry, the partial porousness of film in MAP can't encounter the fresh-keeping desires of foods, specially vegetables and fruits. Microporous film can adaptably regulate the gas absorptivity in line with metabolic physiological characteristics of foods stuffs, which has slowly become a prominent fresh-keeping technology in the field of food industry. Various methods used to prepare microporous films. This paper is especially targeting the applying of environmentally friendly degradable film materials in fruits and vegetables preservation. Investigation has revealed that the bio-degradable material can upsurge the fresh-keeping outcome of microporous modified atmosphere packaging. Broad range of application of microporous modified atmosphere packaging is used in various foodstuff packages. Current and future trends of microporous MAP are briefly discussed.

Keywords— *Microporous MAP, shelf-life, packaging, and biodegradable*

1. INTRODUCTION

As living standards increase, people are gradually chasing the nutrition, diversification of diet and health. The demand for fresh foods comprising fruits, vegetables, meat, aquatic products, etc. is increasing. The freshness of fresh foods is a key display for customers. Typical fresh foods are some unrefined primary products. It faces not only the hazard of microbes, but also the loss of deterioration and corruption, causing a small shelf life; This causes great economic losses and waste of products (Huang and Zhang 2012) (Jiang et al. 2018) (More et al. 2020) and (Zhang, Zhang et al., 2017). Therefore, it is domineering to develop suitable preservation methods for fresh foods to hold the sustaining quality and achieve longer shelf-life (Islam et al. 2014; Meng, Zhang, and Adhikari 2012). At present, modified atmosphere packaging method has been largely used in food stuffs preservation field to lengthen shelf life of food and preserve quality. By uniting diverse proportions of gas components (usually N2, O2, CO2) (Sandhya 2010). MAP can adjust the gas environment and inhibit the decline in food quality to prolong its shelf life. Compared with usual atmosphere, MAP can offer an environment with high CO2 and low O2 levels, which can hinder oxidation reaction, food shrinkage, and microbial spoilage of food and keep better sensory quality.

The key to prolonging shelf life is to match the respiratory rates of the products and film permeability and slow down to feeble aerobic respiration. Aimed at the non-porous film, the diffusion rate of CO2 is 2–8 times quicker than that of O2 (Hussein, Caleb, and Opara 2015). Such a permeability of high CO2 and low O2 is not appropriate for food items with high respiratory rate, such as strawberry, mushroom, tomatoes, cherries etc. (Hussein, Caleb, and Opara 2015; Kim and Seo 2018).

Table 1: Suggested gas compositions for various fruits and vegetables.

Name of the product	O2 (%)	CO2 (%)
Corn	2-4	10-20
Grape	2-5	1-3
Cabbage	2-3	3-6
Kiwi	1-2	3-5
Spinach	21	10-20
Tomatoes	2-5	0
Apple	1-2	1-3

The gas transmission rate is partially focused to the thickness of packaging materials. The lessening thickness can advance film permeability, but its strength will fall accordingly, which is tough to satisfy the desires of transportation and commodity storage (Wang et al. 2019). In order to resolve this inconsistency, microporous MAP is used to keep the foodstuffs fresh, in which the micro-perforated film plays a vital role to regulate gas permeability rate. The permeability rate of CO_2/O_2 is much subordinate, close to a ratio of 1 (Gonzalez et al. 2008). Micro holes help control the equilibrium levels of CO_2 and O_2 and relative humidity (RH) (Giannoulis, Mistriotis, and Briassoulis 2017). The usage of micro-perforated films helps to reduce the curiosity of developing synthetic or costly materials packaging for fresh foodstuffs, which may be a pointless investment at the moment. Also, it is easy to be believed and trusted by consumers as a clean and safe preservation method. Microperforated films are a well-behaved choice to attain the suitable gas component in MAP for high respiration products (Cai et al. 2017; Hussein, Caleb, and Opara 2015; Joshi et al. 2018).

There are numerous factors distressing postharvest characters of foodstuffs. Among them, the, transpiration, ethylene synthesis and respiration of products are more significant. Anaerobic respiration of vegetables and fruits is not expected, as it not only causes more flavor and quality (sweetness) loss of vegetables and fruits, but also produces, acetaldehyde, ethyl acetate, ethanol etc., following undesirable smell. Frequently-used continuous films in MAP simply lead to anaerobic bacteria proliferation and fermentation products, which can be evade by using microporous modified atmosphere packaging (Bovi et al. 2016);

2. MICROPOROUS MODIFIED ATMOSPHERE PACKAGING

The technique is to make micropores with detailed diameter, density and quantity on the packaging film, so as to augment the overall air permeability of the packaging. The permeability of microporous film is adjusted and controlled by the area, number, length, pore diameter and pore distribution (pore density). The key preparation technology of microporous films comprises:

- Physical perforation technology
- Inorganic filler polymer drawing technology
- Semi crystalline polymer drawing technology and
- Chemical foaming technology.

Physical perforation technology is the most appropriate preparation method of microporous membrane among them. It includes cold needle or hot needle drilling, electric spark drilling and Laser technique (Kim and Seo 2018).

2.1 Cold needle or hot needle drilling (pin perforation)

It is a mechanical technique to advance perforations in packaging material by using semi-automatic or manual tools. Actually, the difference among cold and hot needle perforations is the kind of the applied mechanical method. To simplify, hot needle creates holes by melting the plastic material while cold needle creates holes by punching the plyometric film. Both hot and cold needle perforations creating large pores, which are greater than 1 mm in diameter.

2.2 Electric spark drilling

The main principle behind this method is to make pores by either vaporizing or by melting the plyometric material using electrical ejection machine. The machines are prepared of two electrodes, and are parted by oil or water to create electrical ejection. Thus, the type of electrodes used and with few operating conditions the shape and the size of the developed perforations.

2.3 Laser technique

The technique is categorized by its capability to produce a well determined hole bounded by specific edges. Laser system is made up of power source for energy generation and laser beam. Despite the cost competence of laser techniques, regulatory the pore size is also hard because it is reliant on the heat conductivity of the plyometric material. Thus, laser technique was customary by using different kinds of laser beams such as ultraviolet, Co2, Nd:YLF (neodymium-doped yttrium lithium fluoride) and Nd:YAG (neodymium-doped yttrium Aluminum garnet) Mohamed, M. (2019).

Table 2: The comparison of three physical perforations technique.

Physical perforation techniques	Cold or hot needle perforation	Electric spark perforation	Laser perforation
Perforations method	Semi-automatic or manual mechanical perforation	Electrode discharge	Laser energy
Advantages	Low processing cost, Flexibility; easy to work	Suitable for making small holes with large depth diameter ratio, Faster than hot and cold needle.	Clean holes, minimum mechanical and thermal deformation, microporous structures (small size, high spatial accuracy, high aspect ratios.
Disadvantages	Speed slowly, irregular shape, large holes, difficult to calculate the accurate area.	Unpractical for most plastic materials, difficult to obtain the required number of holes.	The absorption of laser energy by film material disturbs the perforation efficiency; heating the film to produce microporous marginal residue can affect the outcomes.

3. BIODEGRADABLE POLYMERS IN FOOD PACKAGING

3.1 Polylactic acid

Eco-friendly polymers have lately grown a momentous importance due to their benefits above the polymers, which cause undesirable environmental effects. The monomer used in PLA production is Lactic acid and it is obtained from natural resources such as corn, other starch rich products and sugar beet (Mohamed, M. 2019). According to the investigation carried out by FDA, it was verified that the migration of components such as lactide, lactoyl lactic acid and lactic acid from PLA does not cause risk on food stuffs, because the immigration is irrelevant. PLA is referred 'Generally Recognized as Safe' for food stuff packaging applications. PLA is used as, lamination films, cups and food centenaries. Also, PLA grew high courtesy for fragile food products packaging such as vegetables and fruits (Tai, H. 2012, Conn, R. E. 1995)

3.2 Polycaprolactone

Polycaprolctone (PCL) is an eco-friendly polymer that has been exploited in various extensive applications for its characteristic properties. PCL is totally degraded by the effect of fungal, lipase and bacterial enzymes. Ɛ-caprolactone is the monomer usually used to synthesize PCL (Mohamed, M. 2019). PCL is used extensively as decomposable polymer for food stuff packaging because of its flexibility property (Labet, M, 2009).

3.3 Polyethylene oxide

It is a hydrophilic, semi-crystalline and thermoplastic polymer. Ethylene oxide (EO) is the monomer used to synthesize PEO. It is also used as hole forming agent in scaffold design and porous polymer. Hence it is used in food packaging industry.

4. APPLICATION

- Microporous packaging hasn't adverse effects on the health components Chaudhary et al. (2015). Perforated packaging was more superior to non-porous MAP in refining the level of antioxidant activity and plant compounds (Opara, Hussein, and Caleb (2017)). Microporous modified atmosphere packaging can avoid anaerobic respiration of fresh foods and the proliferation of anaerobic bacteria. Microporous MAP can accomplish better fresh-keeping effect than traditional MAP. On the one hand, it can regulate respiratory rate and evade anaerobic respiration. On the other hand, low O2 levels can hinder aerobic microbial growth to some extent. Facing the problem of microbial invasion, we can associate other fresh-keeping technologies to play the benefits of microporous modified atmosphere packaging by weakening the role of microorganisms. For example, ozone is used to inhibit gray mold. The permeability of ozone on microporous film also needs to be considered (Liguori et al. 2015)
- Hussein, Jacobs, Caleb et al. (2015) investigated effects of storing time and perforation number on the microbial pollution and physio-chemical properties of pomegranate arils. Perforation packaging can confine the growth of mold, yeast and mesophilic aerobic bacteria during 15 days storing (5 degree Celsius). Paralleled with no perforation and higher perforation number, average perforation can better preserve the quality of pomegranate owing to its suitable permeability.
- Microporous modified atmosphere packaging united with other technologies can advance the fresh-keeping effect. Microorganisms can be controlled by uniting pre-treatments (such as UV-C and ozone) or some natural antibacterial substances (Villalobos et al. 2016a). Citric acid or ascorbic acid can be used to inhibit oxidation or browning (Cefola et al. 2014; Jayathunge et al. 2014).
- Acting on ethylene can also improve the preservation effect. On the base of microporous modified atmosphere packaging, adding ethylene adsorbent might progress microbial and organoleptic quality and prolong shelf life by 3 days (Danza et al. 2015)
- PLA perforated film is an effective practice in the study of biodegradable film materials. Briassoulis et al. (2013) enhanced the packaging materials by using laser perforation technology, PLA film and air permeable film technology.
- In reflection of evaporative mass loss at low RH throughout chilled storage of fresh meat and the economic losses caused, Lee, Choi, and Yoon (2004) took gain of micro-perforated film to control and advance the exchange of water vapour and gas, dipping evaporative mass loss and microbial contamination. Therefore, it is proved to be effective on the preservation of desired characteristics of meat and its shelf-life extension by using the micro-perforated film.

5. DEVELOPMENT TRENDS

Many investigations have established the significant benefits of microporous MAP in prolonging the shelf life of garden-fresh food stuffs, but its present application is restricted to fruits and vegetables with high respiratory rate. To be sure, this is a technology worth emerging to inflate its application or improve its effects in the target products. Some directions and trends are as follows:

- Microporous modified atmosphere packaging combined with 1-MCP, can figure synergies and play an improved fresh-keeping effect (Li et al. 2017). 1-MCP, as ethylene antagonist, has the benefits of being nontoxic, applied in lower amounts and having high stability and efficiency. It can fix to the ethylene receptors (Lv et al. 2020), so as to successfully prevent the synthesis of endogenous ethylene and the induction of exogenous ethylene.
- To lessen the pollution and problem on the environment, we need to further develop and utilize eco- friendly films. Numerous biodegradable or edible packaging film materials are being tested. Edible films and coatings, which are on the base of polysaccharides, lipids, proteins, or their combinations, are being developed (Galus and Lenart 2019; Kumar 2019).
- Starch has boundless potential in evolving edible/biodegradable films to extend shelf-life of garden-fresh foods, especially fruits, due to its excellent antioxidant properties (Zhou et al. 2019). Polylactic acid can be used as raw material of food packaging for its thermoplastic enactment (Zhou et al. 2019). (Min et al. 2020) primed a new type of quaternary ammonium salt chitosan composite material by using the chitosan and polyvinyl alcohol, strong hygroscopicity of quaternary ammonium salt, which was used as a high-efficiency antibiotic and anti-fog food packaging film.
- Nano-TiO2 is degradable (photodegradable) and can lessen the environmental burden (Khalaj et al. 2016). In count, Jeevahan and Chandrasekaran (2019) concised use of nano materials in edible packing film. These materials are worthy choices for microporous packaging films.
- The freshness index of the wrapped food items that consumers can perceive before purchase, such as gloss, colour, maturity, hardness etc., people pay more and more attention to its flavour quality. Biosensors can be used to indicate the freshness through naturally extracted colour.

- Developing more operative and easier-to-use computer software to aid the choice of the most suitable packaging materials for different parameters (humidity, temperature, etc.) can cut the research cycle, save manpower and advance efficiency.

6. CONCLUSION

Microporous modified atmosphere packaging can considerably improve the gas exchange through the wrapping film, which can well adjust to the fresh-keeping chucks of postharvest vegetables and fruits with high respiratory rate. Related research showed that it also has probable in fresh animal foods preservation. At current, the research is mostly about the choice of traditional plastic packaging and its pore parameters. Diverse methods of microporous preparation will affect the establishment microporous membrane. Currently most of them are made by laser drilling. The expansion trends of microporous modified atmosphere packaging have been introduced in former part. It is worth highlighting that new materials used in microporous modified atmosphere packaging, as an environmental protection packaging method, have greater fresh-keeping potential than using non-biodegradable plastic for packing food stuffs.

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