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Isharyadi, Febrian
Research Center for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, South Tangerang, Indonesia

Kristiningrum, Ellia
Research Center for Testing Technology and Standards, National Research and Innovation Agency, South Tangerang, Indonesia

Nur Tjahyo Eka Darmayanti
Research Center for Testing Technology and Standards, National Research and Innovation Agency, South Tangerang, Indonesia

Supono, Ihsan
Research Center for Testing Technology and Standards, National Research and Innovation Agency, South Tangerang, Indonesia

他

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Modified Atmosphere Packaging Technology for Indonesian Food Products: The Latest Developments and Potentials

Febrian Isharyadi[1,*], Ellia Kristiningrum[2], Nur Tjahyo Eka Darmayanti[2], Ihsan Supono[2], Nur Muhamad Fuad[3], Muhammad Ghozali[4], Khairu Rezqi[5], Sari Andarwati Kunharyanto[6], Isnaini Rahmadi[7], Sri Peni Wijayanti[1]

[1]Research Center for Sustainable Production System and Life Cycle Assessment, National Research and Innovation Agency, South Tangerang, Indonesia

[2]Research Center for Testing Technology and Standards, National Research and Innovation Agency, South Tangerang, Indonesia

[3]Research Center for Energy Conversion and Conservation, National Research and Innovation Agency, South Tangerang, Indonesia

[4]Research Center for Advanced Chemical, National Research and Innovation Agency, South Tangerang, Indonesia

[5]Research Center for Structural Strength Technology, National Research and Innovation Agency, South Tangerang, Indonesia

[6]Center for Data and Information, National Research and Innovation Agency, South Tangerang, Indonesia

[7]Study Program for Food Technology, Sumatra Institute of Technology, Lampung, Indonesia

*E-mail: febr012@brin.go.id

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Abstract: Modified atmosphere packaging (MAP) is a food product packaging technology that modifies atmospheric conditions inside the packaging, aiming to increase shelf life while maintaining product quality and safety. This study aims to explore the development of MAP technology and identify opportunities for its application to food products in Indonesia. The work is conducted by exploring and analyzing the effect of MAP that has been carried out to date and its application opportunities, especially for leading Indonesian food products. The results show that MAP technology has the potential to be used as an alternative packaging method to improve competitiveness further.

Keywords: modified atmosphere packaging; food product; Indonesian food; shelf life.

1. Introduction

Food is the primary need for human life. In the current era, there is a condition that the distribution flow of food products is speedy and broad[1–3]. This condition is caused by consumer demand for food products which are increasing in variety and quantity. The factors that cause an increase in food demand are the world population, the development of the food industry, the openness of global markets and the level of urbanization[4]. In addition, there is also demand from consumers for diverse and exotic products that may not be locally available. Globalization and advances in transportation and logistics have made it more cost-effective and efficient to transport food over long distances, enabling access to a wider range of ingredients and cuisines from around the world. As a result, the flow and distribution of food products have become wider, ensuring that food availability for consumers can be fulfilled. Moreover, each consumer has several preferences for the food to be consumed[5], among others are price, taste (sensory quality), packaging, safety, best before time, shelf-life, and other factors[6,7]. Food safety is one of food products' main concerns and issues[8]. On food products, the main goal is to ensure that the quality and safety of food are maintained until it is consumed. One of the ways to maintain the quality of food products is to use appropriate packaging. The main function of product packaging has been categorized as follows: protection, communication, convenience, and containment. The packaging technology must follow the characteristics and the requirement of the products[9–12].

Many studies have investigated the interactions that occur in food packaging. In a package, there are potential interactions between food product, packaging, and the environment around[13,14] (intrinsic or extrinsic factors) (Fig. 1), which will lead to changes in food quality. The interactions will cause a decrease in the quality of food products and the potential to cause contaminants in food[15]. For example, high humidity will cause the growth of microorganisms and bacteria that will contaminate food[16,17]. In fresh food products, changes in colour, aroma, and flavor also signal deterioration in quality[18,19]. These conditions have an impact on degradation of nutrients in fresh food[20].

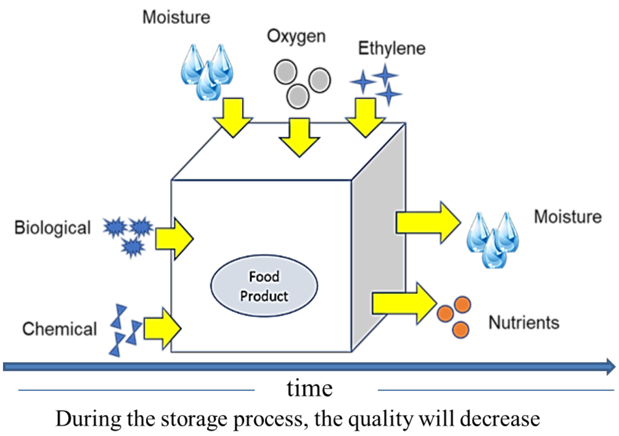

Fig. 1: An illustration of the potential interactions between food, packaging, and environment around.

To overcome this condition, several food packaging technologies are currently being developed. There is active packaging, intelligent packaging, smart packaging, nano-packaging, and modified atmosphere packaging. Some of these technologies certainly have different principles. The insertion of specific additives into packaging systems with the goal of maintaining or enhancing product quality and shelf-life is referred to as active packaging. Oxygen scavengers, carbon dioxide scavengers/emitters, ethylene scavengers, preservative releasers, ethanol emitters, moisture absorbers, flavor/odor absorbers, and temperature control packaging are examples of popular active packaging applications used in the food sector[21–23]. Intelligent packaging is defined as a packaging system capable of performing intelligent functions such as sensing, detecting, tracing, recording, monitoring, and communicating to facilitate decision-making to extend shelf life, improve quality, increase safety, provide information, and warn about potential problems[23–25]. Intelligent packaging systems consist of hardware components such as time temperature indicators (TTI)[22], gas detectors, freshness and/or ripening indicators and radio frequency identification (RFID)[23], and chemical or biological indicators including integrity indicators[26] and a component that allows for the monitoring of the state of packaged food or the environment in which the food is transported and stored[27]. Intelligent packaging and active packaging can work together to generate smart packaging, which is defined as a whole package concept that incorporates the benefits of active and intelligent technologies[21]. Smart or responsive packaging is defined as any container that communicates in response to a specific trigger or change in the food product, food package headspace, or the outside environment. Sensors and indicators are the two primary types of responsive packaging systems[28]. Smart packaging can monitor changing conditions in a food product and then is able to respond using external communication interfaces (electrical or optical)[29,30]. Smart packaging enables tracking and tracing of a product throughout its lifecycle, as well as the analysis and control of the environment inside or outside the package, to inform the product's maker, retailer, or consumer of the product's status at any given time[23]. Nano-packaging refers to the use of nanotechnology in the packaging industry. Nanosensors used in food packaging plants include nanoparticle-based sensors, array biosensors, nanocantilevers, nano-test strips, nanoparticles in solution, and electronic noses. Nanomaterials such as nano-titanium dioxide, titanium nitride nanoparticles, silver nanoparticles, nanoclay, and nano-zinc are now being used as functional additions in food packaging[22]. Nanosensors in packaging are critical for tracking the conditions of containers and products. They can detect gases in food and changes in package colour if there is food spoilage[22]. Nanoparticle combined with edible film can act as antimicrobials which inhibits bacterial growth[31,32]. Incorporated nanoparticles and polymers such as polyethylene, polypropylene, polyurethane, and polyamide, with several other supporting components such as silver (Ag), titanium dioxide (TiO_2) and zinc oxide (ZnO) can also function as antimicrobials[33]. Another application of nanotechnology in food packaging has been reported in the literature[34–36].

Modified Atmosphere Packaging (MAP) is a well-developed food product packaging technology. The forerunner of MAP technology began in the 1930s when apples were stored in a storage warehouse under conditions with minimal oxygen resulting in a longer shelf life[37]. Over time, the development of the treatment became more widespread. MAP is a method of creating the mix gas atmosphere in a package before sealing it with a preset mixture of gases[38]. MAP modifies atmosphere (air) conditions (Fig. 2) inside food packaging[39–42]. So, the composition of gases inside the packaging differs from the general air conditions[43]. Once the package is sealed, no further control over the composition of the in-package atmosphere is exercised. However, its composition may vary during storage due to the contents' respiration and/or the solution of part of the gas in the product. In contrast, vacuum packaging requires removing air from the package prior to sealing, but no other gases are introduced. As a result, this process is not commonly classified as a type of MAP but has been utilized for many years in food products such as cured meats and cheese. Generally, gases such as nitrogen, carbon dioxide, and oxygen are used in modified atmosphere packaging[22]. MAP technology aims to maintain food quality by minimizing the factors causing damage, spoilage, and contamination. Environmental condition (extrinsic factor) may cause deterioration of food quality, such as oxidation and rancidity of fat and oil[44], rapid ripening due to respiring activity[45], or accelerated growth of microorganisms that cause contamination of food products[41,46]. This concept can also be called the principle of food preservation so that the shelf-life is longer[47]. Until now, some studies have reported the applications of MAP technology, including fresh fruit and vegetable products[48,49], fresh meat and processed meat products[50–53], mushrooms[54,55], fish and shellfish products[56,57], cheese[46,58,59], bread and cake[60,61], and herbs and spices[62,63].

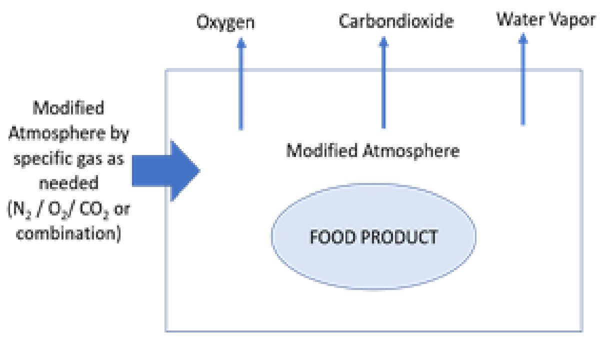

Fig. 2: A condition of modified atmosphere packaging.

Indonesia is rich in natural resources[64] in agriculture, plantations, animal husbandry, and fisheries. The abundance of natural resources has the potential to produce various types of food, both in the form of fresh and processed foods. Besides abundant natural resources, differences in geographical conditions, environment, and culture, cause variations in Indonesian food products[65,66]. Apart from being used for national consumption, these various types of food have the potential to be used as export commodities to other countries. This potential should be supported with quality assurance of food products[67] to enhance competitiveness against food products from other countries.

MAP technology can potentially be an alternative way to maintain the quality of food products. Thus, shelf life can be extended, and food waste can be minimized [68]. Distribution of food products to a remote location will undoubtedly increase the consideration of the storage time of a product. It needs an effort to avoid food products being damaged and become waste. Based on the application of MAP technology, it can be beneficial for the food industry. This study aims to explore the development of MAP technology and identify opportunities for its application to Indonesian food products. The use of MAP technology will increase the competitiveness of national products in the global market.

2. Methodology

This study was conducted with a descriptive method approach in 2 (two) steps. The first step, bibliometric analysis was performed on the development of MAP technology that has been carried out to date. Bibliometric analysis is a quantitative review technique for uncovering emerging trends in a particular research field[69]. In this study, the research area to be explored is MAP technology. Data exploration was carried out from Scopus and Web of Science (WoS) database sources as an indexing publication with coverage of a global reputation in scientific papers in all fields of sciences[70–73]. The metadata was taken with the timeframe 1987 – July 2023. Data search was conducted using the keywords modified AND atmosphere AND packaging, by limiting the type of document in the form of articles and proceeding papers. The data obtained is analyzed using VOSviewer 1.6.19 software, with keywords as the unit of analysis and the kind of analysis is co-occurrence. The thematic cluster results will be interpreted according to the keywords in each cluster formed. In the second stage, the work will focus on identifying data on trade in Indonesian food products, the data used is export trade data in 2022 under the 2-digit Harmonized System (HS) category. The categories of Indonesian food products obtained from these total exports then identified as leading products in each category and the potential use of MAP technology in these food products is also identified.

3. Result and Discussion

3.1 MAP Technology Development

Based on an exploration of the Scopus and WoS database, from the Scopus database, 812 articles were obtained. From the WoS database, 660 articles were obtained. The same articles in both databases were merged into 1 (one) article, so that the total of 995 articles was obtained. The publication has increased from year to year in the period 1987 – July 2023 (Fig. 3). Based on keywords analysis using VOSviewer, it shows that the development of MAP technology has 5 (five) main focuses area (Fig. 4). The focuses include (1) combination application of MAP technology with other technology i.e., active packaging, edible coating, use of appropriate packaging materials by considering the permeability of each packaging material which will later affect food products, and food storage that can prevent damage of physical condition, deterioration of nutrient, and oxidation of fats, oils, proteins in food product, (2) minimizing damage and contamination of food products due to microorganisms especially in fresh product i.e., fishery, poultry, and meat products, so that the decay process will be minimize that causes the product to be fresher and the nutrients content to be better (not reduce), if stored in normal or cold conditions, (3) extending the shelf life by maintaining the quality of fresh products, especially beef and fishery products, by minimizing lipid oxidation which will be able to maintain product quality in a longer time, (4) application to postharvest products (vegetable and fruit), so that it will minimize the process and the product keep fresher and the available content obtained is better, if stored in normal or cold conditions, and (5) Combination MAP with controlled atmosphere packaging and irradiation to maintain food quality as a food preservation. Some of these focuses reflect the current state of demand for food products. Fresh food products generally do not have a long shelf life (perishable). That is due to contamination by microorganisms and natural processes of fresh products (especially fruits and vegetables), such as ripening and respiration[19,45]. Food distribution from producers to consumers is consists of a long process and journey along the supply chain. If a food product is perishable, it will come to the consumer in poor quality [74], and food waste will increase. Several methods of preservation during the distribution and storage process have been performed to overcome this impact, including dry and cold processes[75–77]. Extending the shelf life can be supported by adding antioxidants, especially in food products that are easily oxidized, to prevent damage and rancidity to the product[78,79]. However, due to the geographical conditions, further development of methods in safe food preserving is a necessity. The goal is to extend the shelf life, so that product quality is maintained until it comes to the hands of consumers.

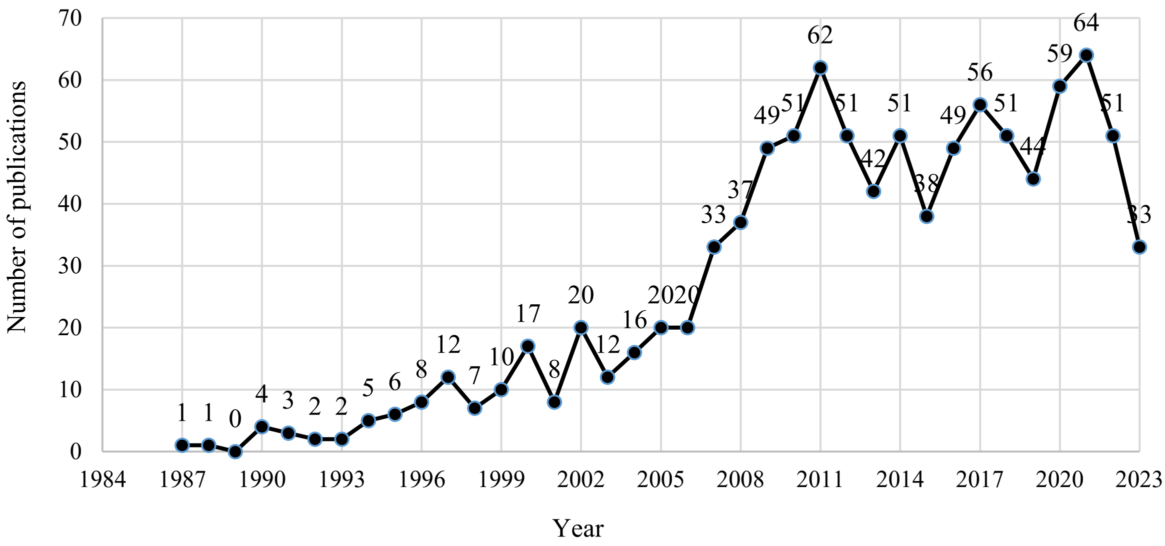

Fig. 3: The scientific publications related to development of MAP technology (1987 – July 2023).

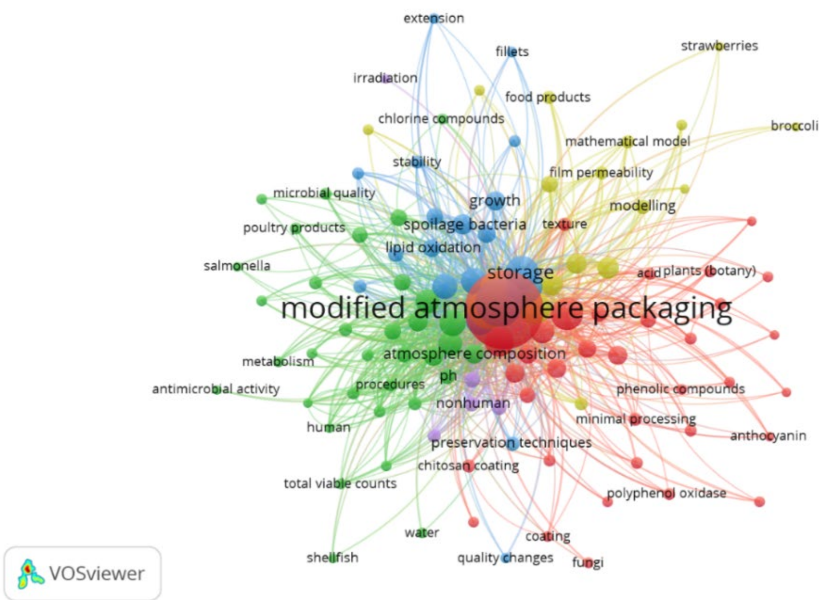

Fig. 4: The results of the analysis of the focus on MAP technology development based on reported scientific publications.

Development of MAP technology is still being carried out, so that it can be applied to a various product. In addition, several current MAP technology developments have been combined with other treatment, substances, and techniques to maintain quality and extend shelf life of food product. The combination that has been done with MAP technology in food products are vacuum treatment, ultrasound treatment, edible coating, high-voltage electrostatic field, and substances (calcium ascorbate,1-methylcyclopropene) which acts as an active packaging. Several studies have reported combination treatments carried out with MAP technology; among others, combination of MAP with vacuum has been reported to be able to inhibit the enzymatic browning reaction, which can prolong the shelf life of vegetable products for 3-9 days, compared by using MAP independently[80]. The combination of MAP with ultrasound treatment is able to increase the preservation ability for meat products compared to individual treatments by inhibiting the growth of *Pseudomonas* and *Carnobacterium* bacteria and also maintaining the flavor of the meat[81]. In fruit products such as pineapples and apples, the combination of MAP and edible coating film can inhibit metabolism, which causes enzymatic browning[82,83]. In addition, edible coating film can also be used as an anti-microbial which will inhibit the growth of Gram-positive and Gram-negative bacteria[31,32]. Using high-voltage electrostatic fields with MAP can inhibit the rate of respiration in vegetables which can slow down deterioration quality[84]. Substances that act as active packaging is also able to maintain quality longer in combination with MAP[85,86], active packaging increases shelf life and enhances safety by preventing contaminants. The use of active packaging is based on the presence of critical components and the intrinsic properties used in the packaging process. Several combinations that have been reported are generally able to maintain the quality of food products longer than the use of single-treatment packaging technologies.

3.2 Application of MAP Technology in Food Products

MAP technology, in principle, is the technology to modify the atmosphere inside the packaging of a food product according to the needs so that the quality of the food product will be maintained in the long term. MAP can be accomplished in several ways (Table 2), there are (1) vacuum packaging, (2) passive MAP, and (3) controlled atmosphere packaging (CAP). Vacuum packaging involves removing all the air from the package[87], and sealing it hermetically. The essence of vacuum packaging is to create an unfavorable environment for the growth of aerobic microorganisms, prevent oxidation and discoloration of foods as well as protect its nutrients. Vacuum packaging is a widely used technique in the food industry due to its ability to extend the shelf life of food products. Passive MAP involves modifying the atmosphere of the air inside the package with certain gases based on the product's characteristics[41]. The technique consists of removing air from the package and replacing it with a mixture of gases that are tailored to the specific needs of the product[47]. MAP is created in the headspace that retards chemical deterioration while simultaneously retarding the growth of spoilage organisms[79]. CAP is similar to the passive MAP technique, but in CAP the gas concentration in the packaging is controlled so that the environmental conditions on the packaging can be known and the quality of packaged food products can be maintained. Using CAP, the atmosphere in packaging is controlled as desired. That can be accomplished by adding components that can be used to controlled atmosphere conditions, such as a water absorber and oxygen scavenger which is supported the function[47,79]. The principle behind CAP is to reduce the concentration of oxygen and increase the concentration of carbon dioxide and nitrogen in the package. This can be achieved by using a variety of methods, including flushing the package with nitrogen or carbon dioxide gas, or by using special films that are impermeable to gases. CAP useful to extend the shelf-life of fresh agricultural and horticultural product[88].

Several aspects must be examined before implementing MAP technology on a food product to ensure its success. There are include selection of suitable gas, selection suitable gas compositions, and selection of packaging materials.

3.2.1 Selection of Suitable Gas

In the type of MAP, the selection of gas becomes crucial. Differences in product characteristics will have implications for the use of gas[89]. The gases commonly used in this MAP technology application are Nitrogen (N_2), Carbon dioxide (CO_2), and Oxygen (O_2).

Nitrogen is an inert gas with low solubility in water and fat[47]. The inert nature of nitrogen prevents the gas from reacting with food products. Therefore, nitrogen is commonly used to prevent the oxidation process and the growth of aerobic bacteria. When nitrogen is filled into a package that previously contained oxygen and CO_2, it replaces (displaces) the existing atmosphere. Nitrogen also exhibits low permeability to polymer packaging materials. The relative value of nitrogen permeability varies in several commonly used polymers as packaging materials. However, for the same packaging material, oxygen has a permeability 3.5 times higher than nitrogen, and CO_2 has a permeability 13 times higher than nitrogen[90]. The characteristic of nitrogen provides a stable and consistent headspace volume of the package during storage or refrigeration environments[47]. CO_2 is a gas with high solubility in water and fat[47]. Solubility CO_2 in fat depends on fat content, fatty acid composition and temperature[91]. CO_2 has high permeability in plastic packaging. However, carbon dioxide can slow down the respiration process in fresh produce. Therefore, CO_2 is more utilized in fresh fruit products, so the metabolism of these products can be slowed, which will impact fruit maturity. However, the use of CO_2 should be done in minimal quantities because CO_2 is one of the gases that contribute highly to greenhouse gas[92,93].

Table 1. Gas composition in packaging with MAP technology on some products.

Product	**Modified Atmosphere (%)**			**Source**
	N_2	**O_2**	**CO_2**	
Fruit				
Apple		1-2	1-3	[47]
Avocado		2-5	3-10	[47]
Banana		2-5	2-5	[47]
Grape		2-5	3-1	[47]
Mango		3-7	5-8	[47]
Orange		5-10	0-5	[47]
Papaya		2-5	5-8	[47]
Strawberry		5-10	15-20	[47]
Pineapple		50	50	[94]
Dragon Fruit		5-21		[95]
Guava		2-5	2-5	[96]
Lemon		5-10	0-10	[96]
Vegetable				
Broccoli		1-2	5-10	[47]
Cabbage		3-5	3-6	[47]
Carrot		5	3-4	[47]
Cauliflower		2-5	2-5	[47]
Corn (sweet)		2-4	10-18	[47]
Cucumber		3-5	0	[47]
Mushroom		1-3	10-15	[47]
Spinach		7-10	5-10	[47]
Tomato		3-5	0	[47]
Potato		1-3	6-9	[68]
Meat				
Chicken leg meat			60	[97]
Beef ham	40		60	[50]
Fresh beef	10	70	20	[50]
Chicken breast	5	65	30	[50]
Red meat		70-85	15-30	[68]
Poultry	70-80		20-30	[68]
Fish and shellfish				
Oily fish	40-60		40-60	[68]
Whitefish		40	60	[68]
Crustacea			80-100	[68]
Chub mackerel	30	0-20	50-70	[57]
Salmon slices			100	[57]
Sardine fillets	50		50	[57]
Tuna		60	40	[98]
Prawn			40	[98]
Others				
Bakery and pasta	20-50		50-80	[68]
Cheese	30-100		0-70	[68]
Coffee bean			40 - 60	[47]
The potato chips	100			[68]
Tofu	70		30	[99]

Oxygen has moderate solubility in water and fat, but oxygen is generally avoided in food products containing fat and oil[100,101]. That is because it will accelerate the oxidation reaction and impact food quality. For example, an oxidation reaction causes rancidity in food; moreover, oxygen will increase the growth of aerobic bacteria that can damage food. Generally, on the MAP, oxygen is applied to meat products. Its function is to suppress destructive anaerobic bacteria and to maintain the red colour of meat by maintaining the oxymyoglobin content of fresh meat[47]. In addition, high oxygen can also inhibit the growth of certain bacteria and fungi, prevent anaerobic fermentation reactions, and reduce spoilage[102].

There are several other gases currently being developed, namely Argon (Ar), Helium (He), Carbon monoxide (CO), Hydrogen (H), and Nitrous oxide (N_2O). The use of these gases is still very minimal. Each of these gases has a different function[47,103,104]. Ar and He are inert gases, similiar with N_2. The function of Ar and He in MAP is to prevent the oxidation process, the growth of aerobic bacteria, and slow down the respiration rate of fruits and vegetables[103,104]. CO has been used to preserve the colour of meat and seafood. However, the use of CO in food packaging is controversial and not allowed in most countries due to potential toxic effects and concerns about misleading consumer[105]. In comparison, Hydrogen and N_2O have their respective functions, Hydrogen is a preventer of oxygen in packages combined with an oxygen scavenging system. Whereas N_2O has a similar function as a substitute for oxygen in packaging which will prevent oxidation and growth of aerobic bacteria, it can also be used as a propellant gas applied to whipping cream[47].

3.2.2 Suitable Gas Composition

Several studies have reported the application of MAP technology in food products packaging. The objective of MAP is to obtain the maximum food product shelf life. Table 1 shows different types and compositions of gases for various applications. The gas composition is under the needs of contaminants which must be minimized to prevent food spoilage. In fruits and vegetables, the gas composition is oxygen and carbon dioxide, following the aim of maintaining the freshness of vegetables and the functional components of vegetables and fruit. Oxygen gas is dominant for red meat, according to the purpose of preserving oxymyoglobin in meat. In fresh fish, the composition of each fish has several differences according to its function, including preventing spoilage and keeping the colour of the fish bright.

3.2.3 Selection of Packaging Materials

Packaging materials in the application of MAP technology have an important role. Each type of packaging material has its characteristics, including transparency, specific gravity, melting point, water-vapour transmission rate, and gas transmission rate (Table 2). The packaging material must be adjusted to the needs, acceptable, and appropriate to the functions[106]. The function as a barrier of gas transmission inside and outside the packaging is the most significant[107]. Transmission rate characteristics of packaging materials to some gases and water vapour are critical to maintaining the optimal internal atmosphere condition that prevents contamination that cause increased food spoilage. Some packaging materials that are generally used include polyvinyl chloride (PVC), light-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), and polyethylene terephthalate (PET)[39,47,57]. Based on the packaging material characteristics (Table 2), the packaging material that is more suitable for use with MAP technology is PET. This is because PET has the better gas permeability compared with PVC, LDPE, HDPE, and PP[108]. Those characteristics cause atmosphere modifications carried out in the packaging are more stable[109,110].

Table 2. The characteristics packaging material commonly used on MAP [39,47,111,112].

Packaging Material	**Permeabilities (mmol µm d-1 m-2 kPa-1) at 25 ^{0}C**			**Melting Point (^{0}C)**	**Spesific Gravity (g/cm^3)**	**Transparency**
	O_2	**CO_2**	**H_2O**			
PVC	54	328	81000	158	1.3 – 1.58	Yes
LDPE	81	508	2600	98 – 115	0.910 – 0.940	Translucent
HDPE	25	148	350	130	0,940 – 0.970	Translucent
PP	28	94	1960	168 – 175	0.89 – 0.92	Yes – film
PET	0.98	3.57	3800	245	1.29	Yes - APET

Note: APET (Amorphous-Polyethylene Terephthalate)

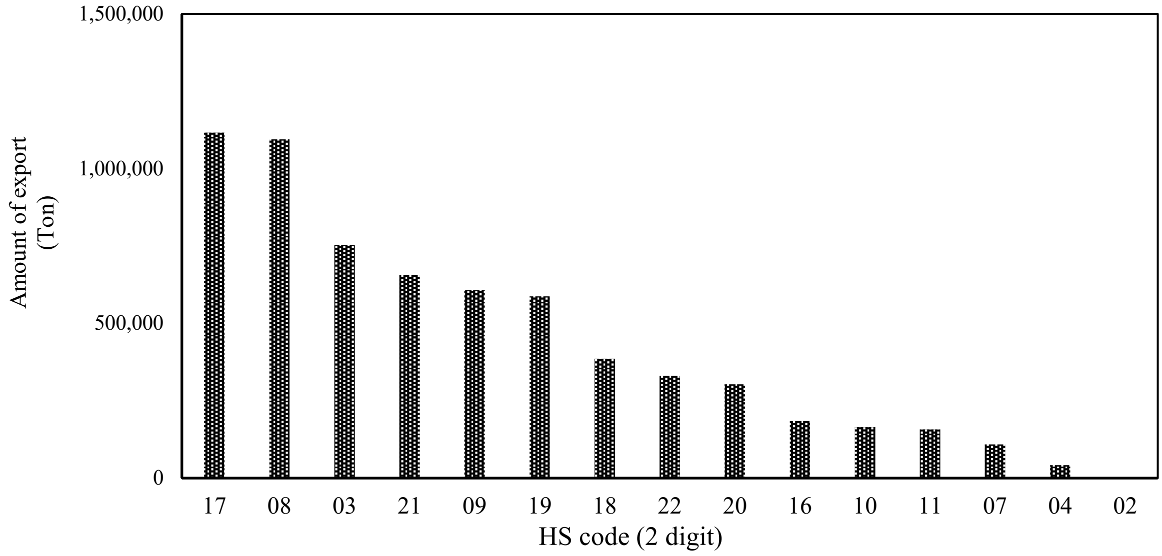

Fig. 5: Amount of export Indonesia food product (January – December 2022)[113].

3.3 Potential Use of MAP Technology for Indonesian Food Products

The number of food products produced in Indonesia is very diverse, both in the form of fresh and processed food products. Data trade (Fig. 5) shows that the number of exports of each category of Indonesian food product in 2022 is based on the 2-digit Harmonized System (HS). The 2-digit HS category includes HS code 02 (meat and edible meat offal); 03 (fish and crustaceans, molluscs and other aquatic invertebrates); 04 (dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere specified or included); 07 (vegetables and certain roots and tubers; edible); 08 (fruit and nuts, edible; peel of citrus fruit or melons); 09 (coffee, tea, mate and spices); 10 (cereals); 11 (products of the milling industry; malt, starches, inulin, wheat gluten); 16 (meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof); 17 (sugars and sugar confectionery); 18 (cocoa and cocoa preparations); 19 (preparations of cereals, flour, starch or milk; pastrycooks' products); 20 (preparations of vegetables, fruit, nuts or other parts of plants); 21 (miscellaneous edible preparations); 22 (beverages, spirits and vinegar). In Figure 5, it is shown several Indonesian food products with high export value and the potential to become a source of foreign exchange. Based on the export value, excluding vegetable oil and sugar, the potential food products that include on the top 5 categories and can use MAP technology are on the HS code 08 (fruit and nuts, edible; peel of citrus fruit or melons), 03 (fish and crustaceans, mollusks and other aquatic invertebrates), 21 (miscellaneous edible preparations), 09 (coffee, tea, mate and spices), and 19 (preparations of cereals, flour, starch or milk; pastrycooks' products).

Tropical fruits are the main commodity in demand by other countries. In 2022, this commodity export contributed 20.58% of the total annual agricultural crop exports. Annual fruit and vegetable commodities that have a major contribution to horticultural production are bananas, durians, oranges, mangoes, pineapples, and mangosteens[114]. Besides being delicious, these fruits have active components that benefit the body[115]. To be able to obtain these benefits, consumption in fresh form is highly recommended. However, reaching areas with remote geographical locations will undoubtedly cause these tropical fruits to become easily damaged or rotten and will become food waste[116]. In several countries, food waste is a problem that is of grave concern[117], as well as in Indonesia[118].

Indonesian fishery products (HS code 03) also have a high number of exports, this is because most of Indonesia's territory is a water area that rich in water resources and biodiversity that can be used as a food source. Tuna and skipjack are Indonesia's leading fish species[119]. Besides that, shrimp is a fishery product that is competitive in the international market[120]. Processed food products are also one that has the potential to have high export value. In Indonesia, frying is used to prepare various traditional foods, such as some chips with different constituent materials. In addition, many traditional Indonesian processed food products can be encouraged as superior export products, such as tempeh, *dodol* and sugar palm fruit. The coffee commodity is the agricultural product with the largest export value in 2022. During 2018–2022, this commodity has an average contribution of 39.38 % to the annual crop agricultural sector exports[114]. Some of Indonesia's leading food products can increase their competitiveness in the international market, one of which is by maintaining quality over a long period (extending shelf life).

Table 3. Recommendation MAP condition for Indonesia leading food product.

HS code	HS code name	Potential Product	MAP condition			Temparature Storage	Packaging Material	Estimated Shelf Life
			N_2	CO_2	O_2			
08	Fruit and nuts, edible; peel of citrus fruit or melons	Banana[47,121]		4 – 12 %	2- 4 %	12 ± 1 ^{0}C	PE	49 days
		Durians[122]		5 %	3 %	5 ^{0}C	PE	15 days
		Orange[47,123]		0 - 5 %	5 - 10 %	7 ^{0}C	PP	16 days
		Mango[124]		5 -10 %	3 -5 %	10 ^{0}C	PE	28 days
		Pineapple[94]		50 %	50 %	7 ^{0}C	PP	7 days
		Mangosteen[125]		9 %	5 %	13 ^{0}C	LDPE	25 – 30 days
03	Fish and crustaceans, mollusks, and other aquatic invertebrates	Fish (tuna and skipjack)[98]		40 %	60 %	2 ^{0}C	LDPE	more than 14 days
		Shrimp /prawn[126]	15 %	80 %	5 %	4 ^{0}C	not available	10 days
21	Miscellaneous edible preparations	Tempeh[127]	55 %	30 %	15 %	20 - 25 ^{0}C	PE	4 days
		Snack/chips[128]	100 %			20 - 25 ^{0}C	PET / LDPE	184 days
09	Coffee, tea, mate, and spices	Coffee bean[47]		40 – 60 %		20 - 25 ^{0}C	PE/PVC	360 days
19	Preparations of cereals, flour, starch, or milk; pastrycooks' products	Bakery product[129]		30 %		20 - 25 ^{0}C	PE	7 days

For Indonesian leading food products, MAP technology has the potential to be applied. Several studies have been conducted on applying MAP to authentic Indonesian food products. Most of the development carried out is the implementation of fresh products, including pineapple[130,131], banana[121,132,133], carrot[134], snake fruit[135,136], rambutan[137], citrus[138], chili[139], fresh fish[56], and other tropical fruits[140,141]. Other than that, several processed products have been developed using MAP packaging, *dodol*[142], tempeh[127], and sugar palm fruit[143]. MAP technology can be applied to those are Indonesian leading food products. The optimal conditions and requirements for using MAP, including storage temperature and packaging materials used, are given in Table 3. Each of those food products have different optimal conditions due to different characteristics. This implementation has the potential to maintain quality and extend shelf life.

The application of MAP technology on some of those products will undoubtedly allow reaching of a broader market. Appropriate packaging technology will have an overall impact on Indonesian food products. However, MAP technology has advantages and disadvantages in its application. The advantage is that it is practical in use and is able to maintain food safety for a longer period of time compared to the use of packaging without treatment. However, the drawback is that this technology requires several supporting instruments as part of the MAP application, among others are cylinders or tank for storing gas connected by line to supply gas to the packaging material and gas mixing instrument if using a combination of several gases[47]. With this process, food producers' capability is needed to implement MAP. However, the fact is that the food production in Indonesia is not entirely performed by an industry. Even most food producers in Indonesia are small and medium-sized enterprises (SMEs)[144]. The food industry and SMEs certainly differ in their ability to implement MAP. SMEs are a business category that has several limitations in its operations; among these limitations are limited resources, technological skills and management, markets, and networks[145]. These conditions can cause the implementation of MAP become obstructed. Some developments in applying MAP technology to food products, especially traditional Indonesian food, are still minimal. So, the implementation of MAP potentially has several obstacles, including requiring more specialized and expensive equipment and requiring training of the production staff[41]. The characteristics of SMEs will undoubtedly determine the development of MAP technology, while maintaining the quality of the products produced following standards[146,147]. In dealing with these potential obstacles, it is necessary to develop MAP technology on a micro-scale in future research. The goal is to overcome SMEs' limitations as many food producers, especially in Indonesia. Apart from that, it is also possible to identify the potential utilization of MAP and the challenges, especially in the SME business category, so that the development is more appropriate according to needs.

4. Conclusion

The development of MAP technology is still being carried out to obtain ideal and practical conditions in maintaining food quality and safety in the long term so that the shelf life of products is getting longer. The MAP application can be more optimal if supported by several other treatments such as storage temperature and suitable packaging materials. Future trends in MAP development are implementation on new and more diverse food products, supported by combining MAP technology with other packaging techniques such as active packaging, edible coating, vacuum, and several others. The hope is that the shelf life of food products can be longer and has the potential to be able to overcome the problem of food waste. This development is certainly a good opportunity to be applied to various food products in Indonesia. Especially for Indonesia's leading food products such as fruits, fishery products, processed food products, coffee and processed flour products, this MAP technology is an alternative way of packaging products that will be able to maintain product quality and safety. However, as the majority of food producers in Indonesia, SMEs have limitations that become obstacles in implementing MAP technology. The main problem is the price of equipment, which is still relatively expensive; the other is limited knowledge in MAP technology applications. Therefore, developing MAP technology on a micro-scale is recommended, hoping the required costs will be lower. Furthermore, the development carried out can be initiated by identifying the type of food products and packaging technology that is currently used, so that the challenges faced and development of MAP technology design that appropriate can be identified. The result of affordable MAP technology will provide more comprehensive benefits. In addition to extending the shelf life of products, market access will be broader and more competitive with other products in the global market.

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References

1) X. Li, M. Zang, D. Li, K. Zhang, Z. Zhang, and S. Wang, "Meat food fraud risk in chinese markets 2012–2021," *NPJ Sci Food*, **7** (*1*) (2023). doi:10.1038/s41538-023-00189-z.
2) R. Teasley, J. Bemley, L.B. Davis, A. Erera, and Y. Chang, "A markov chain model for quantifying consumer risk in food supply chains," *Health Systems*, **5** (*2*) 149–161 (2016). doi:10.1057/hs.2015.16.
3) L. van Wassenaer, C. Verdouw, A. Kassahun, M. van Hilten, K. van der Meij, and B. Tekinerdogan, "Tokenizing circularity in agri-food systems: a conceptual framework and exploratory study," *J Clean Prod*, **413** (2023). doi:10.1016/j.jclepro.2023.137527.
4) B.L. Bodirsky, S. Rolinski, A. Biewald, I. Weindl, A. Popp, and H. Lotze-Campen, "Global food demand scenarios for the 21st century," *PLoS One*, **10** (*11*) (2015). doi:10.1371/journal.pone.0139201.
5) B.B. Louhenapessy, W.C. Anggundari, B. Prasetya, Y. Yopi, E. Kristiningrum, N.T.E. Darmayanti, F. Isharyadi, B.D. Tampubolon, L. Khairiyati, and P. Anggraeni, "Consumer preferences towards the selection of products market with the national standard of Indonesian (SNI)," in: 2022: p. 040009. doi:10.1063/5.0109967.
6) T.J. Rennie, and P.S. Sunjka, "Modified atmosphere for storage, transportation, and packaging," in: Novel Postharvest Treatments of Fresh Produce, CRC Press, 2017: pp. 433–480.
7) E.J. Alice, M. Amanullah, M.A. Karim, M.A. Hossain, and M.T. Islam, "Effects of vacuum and modified atmosphere packaging on the biochemical and microbiological quality of sliced goonch fish (bagarius bagarius) stored at refrigerated condition," *Food Res*, **4** (*6*) 2256–2264 (2020). doi:10.26656/fr.2017.4(6).287.
8) K. Flynn, B.P. Villarreal, A. Barranco, N. Belc, B. Björnsdóttir, V. Fusco, S. Rainieri, S.E. Smaradóttir, I. Smeu, P. Teixeira, and H.Ó. Jörundsdóttir, "An introduction to current food safety needs," *Trends Food Sci Technol*, **84** 1–3 (2019). doi:10.1016/j.tifs.2018.09.012.
9) Q.A. Al-Maqtari, T.A.A. Alkawry, K. Odjo, A.A.S. Al-Gheethi, M. Ghamry, A.A. Mahdi, W. Al-Ansi, and W. Yao, "Improving the shelf life of tofu using chitosan/gelatin-based films incorporated with pulicaria jaubertii extract microcapsules," *Prog Org Coat*, **183** (2023). doi:10.1016/j.porgcoat.2023.107722.
10) Z.-C. Wang, Y.-X. Yin, H.-P. Ao, H. Yin, D.-F. Ren, and J. Lu, "The shelf-life of chestnut rose beverage packaged in pen/pet bottles under long term storage: a comparison to packaging in ordinary pet bottles," *Food Chem*, **370** (2022). doi:10.1016/j.foodchem.2021.131044.
11) U. Siripatrawan, V. Hwansena, K. Ornrootee, P. Chuesiang, A. Ruengdech, S. Keratimanoch, and P. Jaturontrasame, "Effect of packaging systems on dried shrimp quality and storage stability as visualized using pattern recognition," *Agriculture and Natural Resources*, **56** (*5*) 987–996 (2022). doi:10.34044/j.anres.2022.56.5.13.
12) A. Wilczyńska, A. Kukułowicz, and A. Lewandowska, "Effect of packaging on microbial quality of edible flowers during refrigerated storage," *Pol J Food Nutr Sci*, **73** (*1*) 32–38 (2023).

doi:10.31883/pjfns/159037.
13) G. Altieri, F. Genovese, A. Matera, A. Tauriello, and G.C. Di Renzo, "Characterization of an innovative device controlling gaseous exchange in packages for food products," *Postharvest Biol Technol*, **138** 64–73 (2018). doi:10.1016/J.POSTHARVBIO.2017.12.012.
14) I.A. Ciobotaru, I.E. Ciobotaru, D.I. Vaireanu, and F.M. Benga, "Food-packaging interactions investigated by electrochemical impedance spectroscopy," *J Food Process Eng*, **41** (*1*) (2018). doi:10.1111/jfpe.12615.
15) M. Raicopol, and L. Pilan, "The role of aryldiazonium chemistry in designing electrochemical aptasensors for the detection of food contaminants," *Materials*, **14** (*14*) (2021). doi:10.3390/ma14143857.
16) A.F. Ridassepri, F. Rahmawati, K.R. Heliani, Chairunnisa, J. Miyawaki, and A.T. Wijayanta, "Activated carbon from bagasse and its application for water vapor adsorption," *Evergreen*, **7**(*3*) 409–416 (2020). doi:10.5109/4068621.
17) K. Ito, "Micro- and macro-scale measurement of fungal growth under various temperature and humidity conditions," *Evergreen*, **1**(*1*) 32–39 (2014). doi:10.5109/1440974.
18) T.G. Patil, and S.P. Shekhawat, "Artificial neural based quality assessment of guava fruit," *Evergreen*, **9**(*2*) 389–395 (2022). doi:10.5109/4794164.
19) M.H. Mahmood, M. Sultan, and T. Miyazaki, "Study on water-vapor adsorption onto polymer and carbon based adsorbents for air-conditioning applications," *Evergreen*, **6**(*3*) 215–224 (2019). doi:10.5109/2349297.
20) D.H. Wardhani, F.D. Hapsari, K.M. Suryana, N. Aryanti, and H. Cahyono, "Physicochemical properties of glucomannan-alginate as vitamin c excipient," *Evergreen*, **5**(*2*) 6–10 (2018). doi:10.5109/1936211.
21) M. Latos-Brozio, and A. Masek, "The application of natural food colorants as indicator substances in intelligent biodegradable packaging materials," *Food and Chemical Toxicology*, **135** 110975 (2020). doi:10.1016/J.FCT.2019.110975.
22) M. Pal, M. Devrani, and A. Hadush, "Recent developments in food packaging technologies," *Beverage Food World*, **46** (*1*) 21–25 (2019).
23) D. Schaefer, and W.M. Cheung, "Smart packaging: opportunities and challenges," *Procedia CIRP*, **72** 1022–1027 (2018). doi:10.1016/J.PROCIR.2018.03.240.
24) S. Kalpana, S.R. Priyadarshini, M. Maria Leena, J.A. Moses, and C. Anandharamakrishnan, "Intelligent packaging: trends and applications in food systems," *Trends Food Sci Technol*, **93** 145–157 (2019). doi:10.1016/J.TIFS.2019.09.008.
25) C. Medina-Jaramillo, O. Ochoa-Yepes, … C.B.-C., and undefined 2017, "Active and smart biodegradable packaging based on starch and natural extracts," *Elsevier*, (n.d.). https://www.sciencedirect.com/science/article/pii/S0144861717309554 (accessed July 18, 2023).
26) P. Lu, Y. Yang, R. Liu, X. Liu, J. Ma, M. Wu, S.W.-C. Polymers, and undefined 2020, "Preparation of sugarcane bagasse nanocellulose hydrogel as a colourimetric freshness indicator for intelligent food packaging," *Elsevier*, (n.d.). https://www.sciencedirect.com/science/article/pii/S0144861720310043 (accessed July 18, 2023).
27) V. Shukla, G. Kandeepan, M.R. Vishnuraj, and A. Soni, "Anthocyanins based indicator sensor for intelligent packaging application," *Agricultural Research*, **5** (*2*) 205–209 (2016). doi:10.1007/S40003-016-0211-0/FIGURES/4.
28) S. Purkayastha, • Agni, K. Biswal, and S. Saha, "Responsive systems in food packaging," *Journal of Packaging Technology and Research 2017 1:1*, **1** (*1*) 53–64 (2017). doi:10.1007/S41783-017-0007-0.
29) S. Chen, S. Brahma, J. Mackay, C. Cao, and B. Aliakbarian, "The role of smart packaging system in food supply chain," *J Food Sci*, **85** (*3*) 517–525 (2020). doi:10.1111/1750-3841.15046.
30) M. Soltani Firouz, K. Mohi-Alden, and M. Omid, "A critical review on intelligent and active packaging in the food industry: research and development," *Food Research International*, **141** 110113 (2021). doi:10.1016/J.FOODRES.2021.110113.
31) L. Motelica, D. Ficai, O. Oprea, A. Ficai, R.D. Trusca, E. Andronescu, and A.M. Holban, "Biodegradable alginate films with zno nanoparticles and citronella essential oil-a novel antimicrobial structure," *Pharmaceutics*, **13** (*7*) (2021). doi:10.3390/pharmaceutics13071020.
32) L. Motelica, D. Ficai, O.C. Oprea, A. Ficai, V.L. Ene, B.S. Vasile, E. Andronescu, and A.M. Holban, "Antibacterial biodegradable films based on alginate with silver nanoparticles and lemongrass essential oil–innovative packaging for cheese," *Nanomaterials*, **11** (*9*) (2021). doi:10.3390/nano11092377.
33) M. Rossi, D. Passeri, A. Sinibaldi, M. Angjellari, E. Tamburri, A. Sorbo, E. Carata, and L. Dini, "Nanotechnology for food packaging and food quality assessment," *Adv Food Nutr Res*, **82** 149–204 (2017). doi:10.1016/BS.AFNR.2017.01.002.
34) F. Mustafa, and S. Andreescu, "Nanotechnology-based approaches for food sensing and packaging applications," *RSC Adv*, **10** (*33*) 19309–19336 (2020). doi:10.1039/D0RA01084G.
35) S.A. Ntim, and G.O. Noonan, "Nanotechnology in food packaging," *RSC Nanoscience and Nanotechnology*, **2017-January** (*42*) 118–142 (2017). doi:10.1039/9781782626879-00118.
36) D. Enescu, M.A. Cerqueira, P. Fucinos, and L.M.

Pastrana, "Recent advances and challenges on applications of nanotechnology in food packaging. a literature review," *Food and Chemical Toxicology*, **134** 110814 (2019). doi:10.1016/J.FCT.2019.110814.
37) R. Priyadarshi, F. Deeba, Sauraj, and Y.S. Negi, "Modified atmosphere packaging development," *Processing and Development of Polysaccharide-Based Biopolymers for Packaging Applications*, 261–280 (2020). doi:10.1016/B978-0-12-818795-1.00011-3.
38) M. Rashvand, A. Matera, G. Altieri, F. Genovese, T. Fadiji, U. Linus Opara, M.A. Mohamadifar, A.H. Feyissa, and G. Carlo Di Renzo, "Recent advances in the potential of modeling and simulation to assess the performance of modified atmosphere packaging (map) systems for the fresh agricultural product: challenges and development," *Trends Food Sci Technol*, **136** 48–63 (2023). doi:10.1016/j.tifs.2023.04.012.
39) A. Embleni, "Modified atmosphere packaging and other active packaging systems for food, beverages and other fast-moving consumer goods," in: Trends in Packaging of Food, Beverages and Other Fast-Moving Consumer Goods (FMCG), Elsevier, 2013: pp. 22–34. doi:10.1533/9780857098979.22.
40) Z.A. Belay, O.J. Caleb, and U.L. Opara, "Modelling approaches for designing and evaluating the performance of modified atmosphere packaging (map) systems for fresh produce: a review," *Food Packag Shelf Life*, **10** 1–15 (2016). doi:10.1016/j.fpsl.2016.08.001.
41) R. Rodriguez-Aguilera, and J.C. Oliveira, "Review of design engineering methods and applications of active and modified atmosphere packaging systems," *Food Engineering Reviews*, **1** (*1*) 66–83 (2009). doi:10.1007/s12393-009-9001-9.
42) L.G.M. Gorris, and H.W. Peppelenbos, "Modified-Atmosphere Packaging of Produce," in: Handbook of Food Preservation, 3rd ed., CRC Press, 2020.
43) D.M. Abouelella, S.E.K. Fateen, and M.M.K. Fouad, "Multiscale modeling study of the adsorption of co2 using different capture materials," *Evergreen*, **5**(*1*) 43–51 (2018). doi:10.5109/1929729.
44) K. Czerwiński, T. Rydzkowski, J. Wróblewska-Krepsztul, and V.K. Thakur, "Towards impact of modified atmosphere packaging (map) on shelf-life of polymer-film-packed food products: challenges and sustainable developments," *Coatings*, **11** (*12*) 1504 (2021). doi:10.3390/coatings11121504.
45) M.H. Mahmood, M. Sultan, T. Miyazaki, and S. Koyama, "Desiccant air-conditioning system for storage of fruits and vegetables: pakistan preview," *Evergreen*, **3**(*1*) 12–17 (2016). doi:10.5109/1657381.
46) S.R.B. Brown, E.C. Forauer, and D.J. D'Amico, "Effect of modified atmosphere packaging on the growth of spoilage microorganisms and listeria monocytogenes on fresh cheese," *J Dairy Sci*, **101** (*9*) 7768–7779 (2018). doi:10.3168/jds.2017-14217.
47) D.S. Lee, "Modified atmosphere packaging of foods: Principles and applications. John Wiley & Sons, 2021.," John Wiley & Sons, 2021.
48) M.D. Wilson, R.A. Stanley, A. Eyles, and T. Ross, "Innovative processes and technologies for modified atmosphere packaging of fresh and fresh-cut fruits and vegetables," *Crit Rev Food Sci Nutr*, **59** (*3*) 411–422 (2019). doi:10.1080/10408398.2017.1375892.
49) M.A. Shah, S.M. Wani, S.A. Ganai, S.A. Mir, T. Ahmad, and B.N. Dar, "Modified Atmosphere Packaging as a Tool to Improve the Shelf Life of Fruits," in: Emerging Technologies for Shelf-Life Enhancement of Fruits, 1st ed., Apple Academic Press, 2020.
50) I.S. Arvanitoyannis, and A.C. Stratakos, "Application of modified atmosphere packaging and active/smart technologies to red meat and poultry: a review," *Food Bioproc Tech*, **5** (*5*) 1423–1446 (2012). doi:10.1007/s11947-012-0803-z.
51) Y. Guo, J. Huang, X. Sun, Q. Lu, M. Huang, and G. Zhou, "Effect of normal and modified atmosphere packaging on shelf life of roast chicken meat," *J Food Saf*, **38** (*5*) e12493 (2018). doi:10.1111/JFS.12493.
52) J.G. Sebranek, and T.A. Houser, "Modified atmosphere packaging," *Advanced Technologies for Meat Processing*, 615–646 (2017). doi:10.1201/9781315152752-20.
53) X. Yang, J. Wang, B.W.B. Holman, R. Liang, X. Chen, X. Luo, L. Zhu, D.L. Hopkins, and Y. Zhang, "Investigation of the physicochemical, bacteriological, and sensory quality of beef steaks held under modified atmosphere packaging and representative of different ultimate ph values," *Meat Sci*, **174** 108416 (2021). doi:10.1016/J.MEATSCI.2020.108416.
54) R. Gholami, E. Ahmadi, and S. Farris, "Shelf life extension of white mushrooms (agaricus bisporus) by low temperatures conditioning, modified atmosphere, and nanocomposite packaging material," *Food Packag Shelf Life*, **14** 88–95 (2017). doi:10.1016/j.fpsl.2017.09.001.
55) W. Wei, P. Lv, Q. Xia, F. Tan, F. Sun, W. Yu, L. Jia, and J. Cheng, "Fresh-keeping effects of three types of modified atmosphere packaging of pine-mushrooms," *Postharvest Biol Technol*, **132** 62–70 (2017). doi:10.1016/j.postharvbio.2017.05.020.
56) A.D. Bouletis, I.S. Arvanitoyannis, and C. Hadjichristodoulou, "Application of modified atmosphere packaging on aquacultured fish and fish products: a review," *Crit Rev Food Sci Nutr*, **57** (*11*) 2263–2285 (2017). doi:10.1080/10408398.2013.862202.
57) J. Babic Milijasevic, M. Milijasevic, and V. Djordjevic, "Modified atmosphere packaging of fish – an impact on shelf life," *IOP Conf Ser Earth*

Environ Sci, **333** (*1*) 012028 (2019). doi:10.1088/1755-1315/333/1/012028.

58) A.A. Atallah, A.M. El-Deeb, and E.N. Mohamed, "Shelf-life of domiati cheese under modified atmosphere packaging," *J Dairy Sci*, **104** (*8*) 8568–8581 (2021). doi:10.3168/jds.2020-19956.
59) I. Barukčić, M. Ščetar, I. Marasović, K. Lisak Jakopović, K. Galić, and R. Božanić, "Evaluation of quality parameters and shelf life of fresh cheese packed under modified atmosphere," *J Food Sci Technol*, **57** (*7*) 2722–2731 (2020). doi:10.1007/S13197-020-04308-6/FIGURES/5.
60) M.A. Kurek, J. Wyrwisz, S. Karp, and A. Wierzbicka, "Effect of modified atmosphere packaging on the quality of wheat bread fortified with soy flour and oat fibre," *Journal of Food Measurement and Characterization*, **13** (*3*) 1864–1872 (2019). doi:10.1007/s11694-019-00105-8.
61) R. Chawla, S. Sivakumar, S.K. Mishra, H. Kaur, and R.K. Anurag, "Modified atmosphere packaging for milk cake: assessment of ideal gas composition for extending shelf life," *British Food Journal*, **123** (*8*) 2893–2906 (2021). doi:10.1108/BFJ-09-2020-0785.
62) C. Kirkin, and G. Gunes, "Modified atmosphere packaging and gamma-irradiation of some herbs and spices: effects on antioxidant and antimicrobial properties," *J Food Process Preserv*, **42** (*8*) e13678 (2018). doi:10.1111/jfpp.13678.
63) X. Fang, H. Chen, H. Gao, H. Yang, Y. Li, P. Mao, and T.Z. Jin, "Effect of modified atmosphere packaging on microbial growth, quality and enzymatic defence of sanitiser washed fresh coriander," *Int J Food Sci Technol*, **51** (*12*) 2654–2662 (2016). doi:10.1111/ijfs.13254.
64) A.T. Nugraha, G. Prayitno, A.W. Hasyim, and F. Roziqin, "Social capital, collective action, and the development of agritourism for sustainable agriculture in rural indonesia," *Evergreen*, **8**(*1*) 1–12 (2021). doi:10.5109/4372255.
65) S. Wijaya, B. King, A. Morrison, and T.-H. Nguyen, "Destination encounters with local food: the experience of international visitors in indonesia," *Tourism Culture & Communication*, **17** (*2*) 79–91 (2017). doi:10.3727/109830417X14966810027526.
66) S. Fatimah, D. Syafrini, Wasino, and R. Zainul, "Rendang lokan: history, symbol of cultural identity, and food adaptation of minangkabau tribe in west sumatra, indonesia," *Journal of Ethnic Foods*, **8** (*1*) 12 (2021). doi:10.1186/s42779-021-00088-2.
67) F. Isharyadi, and E. Kristiningrum, "Profile of system and product certification as quality infrastructure in indonesia," *Open Engineering*, **11** (*1*) 556–569 (2021). doi:10.1515/eng-2021-0054.
68) U.L. Opara, and A. Mditshwa, "A review on the role of packaging in securing food system: adding value to food products and reducing losses and waste," *Afr J Agric Res*, **8** (*22*) 2621–2630 (2013).
69) N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W.M. Lim, "How to conduct a bibliometric analysis: an overview and guidelines," *J Bus Res*, **133** 285–296 (2021). doi:10.1016/J.JBUSRES.2021.04.070.
70) A. Perianes-Rodriguez, L. Waltman, and N.J. van Eck, "Constructing bibliometric networks: a comparison between full and fractional counting," *J Informetr*, **10** (*4*) 1178–1195 (2016). doi:10.1016/j.joi.2016.10.006.
71) J. Murillo, L.M. Villegas, L.M. Ulloa-Murillo, and A.R. Rodríguez, "Recent trends on omics and bioinformatics approaches to study sars-cov-2: a bibliometric analysis and mini-review," *Comput Biol Med*, **128** 104162 (2021). doi:10.1016/j.compbiomed.2020.104162.
72) P.R. Phulwani, D. Kumar, and P. Goyal, "From systematic literature review to a conceptual framework for consumer disposal behavior towards personal communication devices," *Journal of Consumer Behaviour*, **20** (*5*) 1353–1370 (2021). doi:10.1002/cb.1940.
73) E. Kristiningrum, R. Nurcahyo, D. Susanto, F. Isharyadi, A. Budi Mulyono, P. Anggraeni, B. Dulbert Tampubolon, S. Harjanto, B. Wahyu Hapsari, and M. Yusuf, "Aflatoxin in rice: a publication review," *IOP Conf Ser Earth Environ Sci*, **1133** (*1*) 012035 (2023). doi:10.1088/1755-1315/1133/1/012035.
74) N.S. Zulkefly, H. Hishamuddin, F.A.A. Rashid, N. Razali, N. Saibani, and M.N.A. Rahman, "The effect of transportation disruptions on cold chain sustainability," *Evergreen*, **8**(*2*) 262–270 (2021). doi:10.5109/4480702.
75) M.A. Islam, A. Pal, K. Thu, and B.B. Saha, "Study on performance and environmental impact of supermarket refrigeration system in japan," *Evergreen*, **6**(*2*) 168–176 (2019). doi:10.5109/2321014.
76) S. Hanif, M. Sultan, T. Miyazaki, and S. Koyama, "Steady-state investigation of desiccant drying system for agricultural applications," *Evergreen*, **5**(*1*) 33–42 (2018). doi:10.5109/1929728.
77) M. Soltani Firouz, R. Alimardani, H. Mobli, and S.S. Mohtasebi, "Effect of modified atmosphere packaging on the mechanical properties of lettuce during shelf life in cold storage," *Information Processing in Agriculture*, **8** (*4*) 485–493 (2021). doi:10.1016/j.inpa.2020.12.005.
78) D. Daud, S.C. Yang, C.C. Balaja, F. Ja'afar, H.M. Yasin, E. Kusrini, W.W. Prihandini, and A. Usman, "Radical scavenging activity assay and red fluorescence microscopy studies: antioxidant properties of selected young and mature leaves for application in pharmaceutical industry," *Evergreen*, **7**(*2*) 216–220 (2020). doi:10.5109/4055222.
79) K.W. McMillin, "Modified Atmosphere Packaging," in: 2020: pp. 693–718. doi:10.1007/978-3-030-

42660-6_26.
80) W. Wanakamol, P. Kongwong, C. Chuamuangphan, D. Bundhurat, D. Boonyakiat, and P. Poonlarp, "Hurdle approach for control of enzymatic browning and extension of shelf life of fresh-cut leafy vegetables using vacuum precooling and modified atmosphere packaging: commercial application," *Horticulturae*, **8** (*8*) (2022). doi:10.3390 /horticulturae8080745.
81) T. Mao, C. Xia, T. Zeng, Q. Xia, C. Zhou, J. Cao, J. He, D. Pan, and D. Wang, "The joint effects of ultrasound and modified atmosphere packaging on the storage of sauced ducks," *LWT*, **177** (2023). doi:10.1016/j.lwt.2023.114561.
82) N. Tabassum, and M.A. Khan, "Modified atmosphere packaging of fresh-cut papaya using alginate based edible coating: quality evaluation and shelf life study," *Sci Hortic*, **259** (2020). doi:10.1016/j.scienta.2019.108853.
83) X. Liao, Y. Xing, X. Fan, Y. Qiu, Q. Xu, and X. Liu, "Effect of composite edible coatings combined with modified atmosphere packaging on the storage quality and microbiological properties of fresh-cut pineapple," *Foods*, **12** (*6*) (2023). doi:10.3390/foods12061344.
84) X. jia Zhang, M. Zhang, C.L. Law, and Z. Guo, "High-voltage electrostatic field-assisted modified atmosphere packaging for long-term storage of pakchoi and avoidance of off-flavors," *Innovative Food Science and Emerging Technologies*, **79** (2022). doi:10.1016/j.ifset.2022.103032.
85) J. Shin, B. Xiang, K.M. Solval, and Y.S. Lee, "Combined effects of calcium ascorbate treatment and modified atmosphere packaging to improve quality retention of fresh-cut cantaloupes," *Journal of Applied Packaging Research*, **11** (*1*) 70–87 (2019).
86) J. Wyrwisz, S. Karp, M.A. Kurek, and M. Moczkowska-Wyrwisz, "Evaluation of modified atmosphere packaging in combination with active packaging to increase shelf life of high-in beta-glucan gluten free cake," *Foods*, **11** (*6*) (2022). doi:10.3390/foods11060872.
87) E.J. Alice, M. Amanullah, M.A. Karim, M.A. Hossain, and M.T. Islam, "Effects of vacuum and modified atmosphere packaging on the biochemical and microbiological quality of sliced goonch fish (bagarius bagarius) stored at refrigerated condition," *Food Res*, **4** (*6*) 2256–2264 (2020). doi:10. 26656/fr.2017.4(6).287.
88) L. de Siqueira Oliveira, K.S. Eça, A.C. de Aquino, and L.M.R. da Silva, "Modified and controlled atmosphere packaging," in: Fresh-Cut Fruits and Vegetables: Technologies and Mechanisms for Safety Control, Elsevier Inc., 2019: pp. 151–164. doi:10.1016/B978-0-12-816184-5.00007-0.
89) Z.A. Belay, O.J. Caleb, and U.L. Opara, "Influence of initial gas modification on physicochemical quality attributes and molecular changes in fresh and fresh-cut fruit during modified atmosphere packaging," *Food Packag Shelf Life*, **21** (2019). doi:10.1016/j.fpsl.2019.100359.
90) V. Siracusa, "Food packaging permeability behaviour: a report," *Int J Polym Sci*, **2012** 11 (2012). doi:10.1155/2012/302029.
91) M. Jakobsen, and G. Bertelsen, "Solubility of carbon dioxide in fat and muscle tissue," *Journal of Muscle Foods*, **17** (*1*) 9–19 (2006). doi:10.1111/J.1745-4573.2006.00029.X.
92) D. Supramono, and J. Edgar, "Characteristics of non-polar bio-oil produced by co-pyrolysis of corn cobs and polypropylene using co2 as carrier gas," *Evergreen*, **6**(*1*) 78–84 (2019). doi:10.5109/2328407.
93) N.A. Lestari, "Reduction of co2 emission by integrated biomass gasific ation-solid oxide fuel cell combined with heat recovery and in-situ co2 utilization," *Evergreen*, **6**(*3*) 254–261 (2019). doi:10.5109/2349302.
94) B.Y. Zhang, S. Samapundo, V. Pothakos, I. de Baenst, G. Sürengil, B. Noseda, and F. Devlieghere, "Effect of atmospheres combining high oxygen and carbon dioxide levels on microbial spoilage and sensory quality of fresh-cut pineapple," *Postharvest Biol Technol*, **86** 73–84 (2013). doi:10.1016/J.POSTHARVBIO.2013.06.019.
95) Y. Fang, and M. Wakisaka, "A review on the modified atmosphere preservation of fruits and vegetables with cutting-edge technologies," *Agriculture*, **11** (*10*) 992 (2021). doi:10.3390/agriculture11100992.
96) R. Kargwal, M. Garg, V. Singh, R. Garg, and N. Kumar, "Principles of modified atmosphere packaging for shelf life extension of fruits and vegetables: an overview of storage conditions," *Int J Chem Stud*, **8** (*3*) 2245–2252 (2020). doi:10.22271/chemi.2020.v8.i3af.9545.
97) Q. Wang, Q. Chen, J. Xu, F. Sun, H. Liu, and B. Kong, "Effects of modified atmosphere packaging with various co2 concentrations on the bacterial community and shelf-life of smoked chicken legs," *Foods*, **11** (*4*) (2022). doi:10.3390/foods11040559.
98) U.L. Opara, O.J. Caleb, and Z.A. Belay, "Modified atmosphere packaging for food preservation," in: Food Quality and Shelf Life, Elsevier, 2019: pp. 235–259. doi:10.1016/B978-0-12-817190-5.00007-0.
99) L. van Campenhout, P. Maes, and J. Claes, "Modified atmosphere packaging of tofu: headspace gas profiles and microflora during storage," *J Food Process Preserv*, **37** (*1*) 46–56 (2013). doi:10.1111/j. 1745-4549.2011.00612.x.
100) F. Esfarjani, K. Khoshtinat, A. Zargaraan, F. Mohammadi-Nasrabadi, Y. Salmani, Z. Saghafi, H. Hosseini, and M. Bahmaei, "Evaluating the rancidity and quality of discarded oils in fast food restaurants,"

Food Sci Nutr, **7** (*7*) 2302–2311 (2019). doi:10.1002/fsn3.1072.

101) M.A. Varas Condori, G.J. Pascual Chagman, M. Barriga-Sanchez, L.F. Villegas Vilchez, S. Ursetta, A. Guevara Pérez, and A. Hidalgo, "Effect of tomato (solanum lycopersicum l.) lycopene-rich extract on the kinetics of rancidity and shelf-life of linseed (linum usitatissimum l.) oil," *Food Chem*, **302** 125327 (2020). doi:10.1016/j.foodchem.2019.125327.
102) Z.A. Belay, O.J. Caleb, and U.L. Opara, "Influence of initial gas modification on physicochemical quality attributes and molecular changes in fresh and fresh-cut fruit during modified atmosphere packaging," *Food Packag Shelf Life*, **21** (2019). doi:10.1016/j.fpsl.2019.100359.
103) V. Heinrich, M. Zunabovic, L. Nehm, J. Bergmair, and W. Kneifel, "Influence of argon modified atmosphere packaging on the growth potential of strains of listeria monocytogenes and escherichia coli," *Food Control*, **59** 513–523 (2016). doi:10.1016/j.foodcont.2015.06.010.
104) J.-J. Park, J.-J. Lee, I.F. Olawuyi, and W. Lee, "Effect of argon- and nitrogen-based modified atmosphere packaging on shiitake mushroom quality," *Korean Journal of Food Preservation*, **26** (*4*) 391–398 (2019). doi:10.11002/kjfp.2019.26.4.391.
105) D. Djenane, and P. Roncalés, "Carbon monoxide in meat and fish packaging: advantages and limits," *Foods 2018, Vol. 7, Page 12*, **7** (*2*) 12 (2018). doi:10.3390/FOODS7020012.
106) D. Ariawan, Wahyu Purwo Raharjo, K. Diharjo, Wijang Wisnu Raharjo, and B. Kusharjanta, "Influence of tropical climate exposure on the mechanical properties of rhdpe composites reinforced by zalacca midrib fibers," *Evergreen*, **9**(*3*) 662–672 (2022). doi:10.5109/4842526.
107) Z.A. Belay, O.J. Caleb, and U.L. Opara, "Modelling approaches for designing and evaluating the performance of modified atmosphere packaging (map) systems for fresh produce: a review," *Food Packag Shelf Life*, **10** 1–15 (2016). doi:10.1016/j.fpsl.2016.08.001.
108) H.-C. Langowski, "Shelf life of packed food and packaging functionality," *Food Packaging Materials*, 11–66 (2017). doi:10.1201/9781315374390-2.
109) R.W.G. Van Willige, J.P.H. Linssen, M.B.J. Meinders, H.J. Van der Stege, and A.G.J. Voragen, "Influence of flavour absorption on oxygen permeation through ldpe, pe, pc, and pet plastics food packaging," *Food Addit Contam*, **19** (*3*) 303–313 (2002). doi:10.1080/02652030110081146.
110) R. Nisticò, "Polyethylene terephthalate (pet) in the packaging industry," *Polym Test*, **90** (2020). doi:10.1016/j.polymertesting.2020.106707.
111) Y. Teck Kim, B. Min, and K. Won Kim, "General Characteristics of Packaging Materials for Food System," in: Innovations in Food Packaging: Second Edition, Elsevier Ltd., 2013: pp. 13–35. doi:10.1016/B978-0-12-394601-0.00002-3.
112) M. Milijasevic, J. Babic Milijasevic, B. Lakicevic, M. Lukic, B. Borovic, S. Veskovic, and B. Baltic, "Food packaging and modified atmosphere - Roles, materials and benefits," in: IOP Conf Ser Earth Environ Sci, Institute of Physics Publishing, 2019. doi:10.1088/1755-1315/333/1/012078.
113) Ministry of Trade Republic of Indonesia, "Monthly Report: Developments in Indonesian Foreign Trade & Commodity Prices in International Markets," Ministry of Trade, Republic of Indonesia, Jakarta, 2023.
114) Statistic Indonesia, "Statistic of Horticulture," Statistic Indonesia, Jakarta, 2022.
115) T. Sarkar, M. Salauddin, A. Roy, N. Sharma, A. Sharma, S. Yadav, V. Jha, M. Rebezov, M. Khayrullin, M. Thiruvengadam, I.-M. Chung, M.A. Shariati, and J. Simal-Gandara, "Minor tropical fruits as a potential source of bioactive and functional foods," *Crit Rev Food Sci Nutr*, 1–45 (2022). doi:10.1080/10408398.2022.2033953.
116) C.Y. Cheok, N. Mohd Adzahan, R. Abdul Rahman, N.H. Zainal Abedin, N. Hussain, R. Sulaiman, and G.H. Chong, "Current trends of tropical fruit waste utilization," *Crit Rev Food Sci Nutr*, 1–27 (2016). doi:10.1080/10408398.2016.1176009.
117) N. Angie, E.M. Tokit, N.A. Rahman, F. al Zahrah Mohamad Saat, F.S. Anuar, and N.M.M. Mitan, "A preliminary conceptual design approach of food waste composter design," *Evergreen*, **8**(*2*) 397–407 (2021). doi:10.5109/4480721.
118) K. Ibadurrohman, I. Gusniani, D.M. Hartono, and N. Suwartha, "The potential analysis of food waste management using bioconversion of the organic waste by the black soldier fly (hermetia illucens) larvae in the cafeteria of the faculty of engineering, universitas indonesia," *Evergreen*, **7**(*1*) 61–66 (2020). doi:10.5109/2740946.
119) M. Firdaus, "The profile of tuna and cakalang fishery in indonesia," *Buletin Ilmiah "MARINA" Sosial Ekonomi Kelautan Dan Perikanan*, **4** (*1*) 23–32 (2018).
120) S. Oktavilia, Firmansyah, F.X. Sugiyanto, and M.A. Rachman, "Competitiveness of Indonesian fishery commodities," in: IOP Conf Ser Earth Environ Sci, Institute of Physics Publishing, 2019. doi:10.1088/1755-1315/246/1/012006.
121) V.B. Kudachikar, S.G. Kulkarni, and M.N.K. Prakash, "Effect of modified atmosphere packaging on quality and shelf life of 'Robusta' banana (musa sp.) stored at low temperature," *J Food Sci Technol*, **48** (*3*) 319–324 (2011). doi:10.1007/S13197-011-0238-Y.
122) N. Phuoc Minh, "Investigation of Map for Durian Preservation," 2017. http://www.ripublication.com.

123) S. Barrios, A. De Aceredo, G. Chao, V. De Armas, G. Ares, A. Martín, M. Soubes, and P. Lema, "Passive modified atmosphere packaging extends shelf life of enzymatically and vacuum-peeled ready-to-eat valencia orange segments," *J Food Qual*, **37** (*2*) 135–147 (2014). doi:10.1111/JFQ.12074.

124) X. Liu, Y. Fu, P. Guo, … W.X.P.P. of 2017 49th, and undefined 2018, "Modified atmosphere packaging and postharvest treatments on mango preservation: a review," *SpringerX Liu, Y Fu, P Guo, W XuApplied Sciences in Graphic Communication and Packaging: Proceedings of 2017, 2018•Springer*, (n.d.). https://link.springer.com/chapter/10.1007/978-981-10-7629-9_63 (accessed July 19, 2023).

125) C. Palakawong, and P. Delaquis, "Mangosteen processing: a review," *J Food Process Preserv*, **42** (*10*) (2018). doi:10.1111/JFPP.13744.

126) Y.F. Qian, J. Xie, S.P. Yang, W.H. Wu, Q. Xiong, Z.L. Gao, and J.B. Shi, "Effect of co2 on chemical and microbial changes of pacific white shrimp during modified atmosphere packaging," *Http://Dx.Doi.Org/10.1080/ 10498850.2014.914117*, **25** (*5*) 644–655 (2016). doi:10.1080/10498850. 2014.914117.

127) S. Muslikhah, C. Anam, and M.A.M. Andriani, "Tempe storage by a method of modification atmosphere to maintaining quality and shelf life," *Jurnal Teknosains Pangan*, **2** (*3*) 51–61 (2014).

128) L. Marangoni Júnior, D. Ito, S.M.L. Ribeiro, M.G. da Silva, and R.M.V. Alves, "Stability of β-carotene rich sweet potato chips packed in different packaging systems," *LWT*, **92** 442–450 (2018). doi:10.1016/J.LWT.2018.02.066.

129) M. Kurek, A.K.-F.S. and Technology, and undefined 2020, "Effect of modified atmosphere packaging on quality of bread with amaranth flour addition," *Journals.Sagepub.ComMA Kurek, A KrzemińskaFood Science and Technology International, 2020•journals.Sagepub.Com*, **26** (*1*) 44–52 (2020). doi:10.1177/1082013219864197.

130) I. Prabasari, C.K. Setiawan, A.P. Andani, D.L. Kurniawansyah, W.N. Achsan, and N.A.U. Hasanah, "Modified atmosphere packaging and heat treatment for maintaining the quality of fresh-cut pineapple (ananas comosus)," *IOP Conf Ser Earth Environ Sci*, **752** (*1*) 012024 (2021). doi:10.1088/1755-1315/752/1/012024.

131) E. Warsiki, and K. Manan, "Application of modified atmosphere packaging to extend pineapple (ananas comosus l.) shelf life," *IOP Conf Ser Earth Environ Sci*, **1034** (*1*) 012025 (2022). doi:10.1088/1755-1315/1034/1/012025.

132) N.A. Utama, "Usage of heat treatment and modified atmosphere packaging to maintain fruit firmness of fresh cut cavendish banana (musa cavendishii)," *Planta Tropika : Jurnal Agrosains (Journal of Agro Science)*, **8** (*2*) (2020). doi:10.18196/pt.2020.122. 126-132.

133) X. Li, T. Xiong, Q. Zhu, Y. Zhou, Q. Lei, H. Lu, W. Chen, X. Li, and X. Zhu, "Combination of 1-mcp and modified atmosphere packaging (map) maintains banana fruit quality under high temperature storage by improving antioxidant system and cell wall structure," *Postharvest Biol Technol*, **198** 112265 (2023). doi:10.1016/J.POSTHARVBIO.2023.112265.

134) I.S. Wardatullatifah, A.F. Amalia, and D. Santoso, "Disinfectants Effect Of Fresh Cut Carrot (Daucus carota L) During Cold Storage In Modified Atmosphere Packaging (MAP)," in: Proceeding of The Ist International Conference On Indigenous Knowledge For Sustainable Agriculture 2022, Universitas Borneo, Tarakan, 2022.

135) I. Mulyawanti, S.M. Widayanti, K.T. Dewandari, and D.A. Setyabudi, "Study of the quality of zalacca fruit on control atmosphere storage (cas) and modified atmosphere packaging (map)," *IOP Conf Ser Earth Environ Sci*, **803** (*1*) 012035 (2021). doi:10.1088/1755-1315/803/1/012035.

136) A.S. Arlikah, S.Z. Al Ghifari, N.M. Prasetyo, and W.B. Sediawan, "Mathematical modeling of degradation quality on snake fruit (salacca edulis) quality during storage in modified atmosphere packaging," *AIP Conf Proc*, **2616** (*1*) (2023). doi:10.1063/5.0135760/2892757.

137) A.G. Sanches, A.G. Silveira, M.B. da Silva, E.G.S. Moreira, and C.A.M. Cordeiro, "Postharvest storage of rambutan (nephelium lappaceum l.) under passive modified atmosphere," *Amazonian Journal of Plant Research*, **2** (*1*) 117–126 (2018). doi:10.26545/AJPR.2018.B00016X.

138) A. Dirpan, "Combining an analytic hierarchy process and topsis for selecting postharvest technology method for selayar citrus in indonesia," *IOP Conf Ser Earth Environ Sci*, **156** 012031 (2018). doi:10.1088/1755-1315/156/1/012031.

139) H. Marni, K. Fahmy, A. Hasan, and Ifmalinda, "Modelling respiration rate of chili for development of modified atmosphere packaging," *IOP Conf Ser Earth Environ Sci*, **515** (*1*) 012032 (2020). doi:10.1088/1755-1315/515/1/012032.

140) H.K. Purwadaria, "Research and development for quality and safety of fresh and fresh cut produce in indonesia," *Acta Hortic*, (*875*) 243–250 (2010). doi:10.17660/ActaHortic.2010.875.30.

141) D. Saputra, and F. Pratama, "Quality changes of exotic tropical fruits during storage in semi-passive modified atmosphere," *Acta Hortic*, (*1011*) 243–249 (2013). doi:10.17660/ActaHortic.2013.1011.29.

142) R.P. Tanhindarto, "Preservation of ethnic food dodol combination of irradiation and atmosphere modified packaging," *Penelitian Dan Pengembangan Aplikasi Isotop Dan Radiasi*, 161–167 (1998).

143) A. Fatharani, N. Bintoro, and A.D. Saputro,

"Respiration rate modeling of sugar palm fruit (arenga pinnata) in modified atmospheric packaging (map)," *AgriTECH*, **40** (*2*) 124–132 (2020).

144) S. Hasibuan, "SMEs development strategy for competitive and sustainable typical local snacks of banten province," *International Journal on Advance Science Engineering Information Technology*, **5** (*6*) (2015).

145) A. Setyawan Agus, M. Isa, W.F.M. Wajdi, Syamsudin, and S. Nugroho Permono, "An assessment of sme competitiveness in indonesia," *Journal of Competitiveness*, **7** (*2*) 60–74 (2015). doi:10.7441/joc.2015.02.04.

146) D.A. Susanto, F. Isharyadi, and N. Aliyah, "The factors are affecting small and medium enterprises on applying standards consistently," *Jurnal Standardisasi*, **18** (*2*) 129–138 (2018).

147) D.A. Susanto, "Implementation of standards in international trade: benefit or barrier? a case study from indonesia," *Evergreen*, **9**(*3*) 619–628 (2022). doi:10.5109/4842518.