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

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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 broad¹⁻³. 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 urbanization⁴. 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 consumed⁵, 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 issues⁸. 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 products⁹⁻¹².

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 food¹⁵. 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 food²⁰.

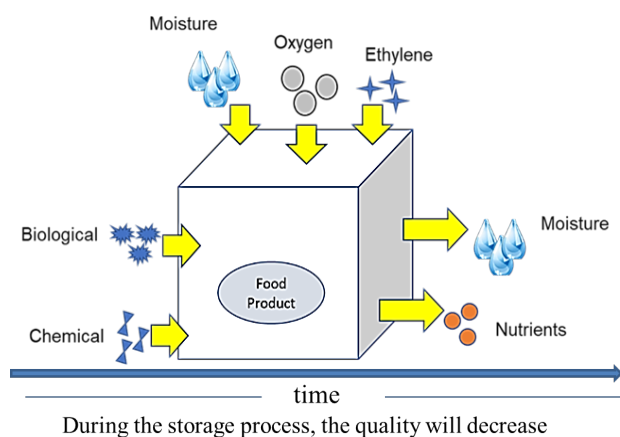


Fig. 1: An illustration of the potential interactions between food, packaging, and environment around.

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 sector²¹⁻²³. 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 problems²³⁻²⁵. 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 indicators²⁶ and a component that allows for the monitoring of the state of packaged food or the environment in which the food is transported and stored²⁷. 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 technologies²¹. 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 systems²⁸. 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 time²³. 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 nanotitanium dioxide, titanium nitride nanoparticles, silver nanoparticles, nanoclay, and nano-zinc are now being used as functional additions in food packaging²². 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 spoilage²². 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 (TiO₂) and zinc oxide (ZnO) can also function as antimicrobials³³. Another application of nanotechnology in food packaging has been reported in the literature³⁴⁻³⁶.

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 life³⁷. 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 gases³⁸. MAP modifies atmosphere (air) conditions (Fig. 2) inside food packaging³⁹⁻⁴². So, the composition of gases inside the packaging differs from the general air conditions⁴³. 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 packaging²². 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 oil⁴⁴), rapid ripening due to respiring activity⁴⁵), 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 longer⁴⁷). Until now, some studies have reported the applications of MAP technology, including fresh fruit and vegetable products^{48,49}), fresh meat and processed meat products⁵⁰⁻⁵³), mushrooms^{54,55}), fish and shellfish products^{56,57}), cheese^{46,58,59}), bread and cake^{60,61}), and herbs and spices^{62,63}).

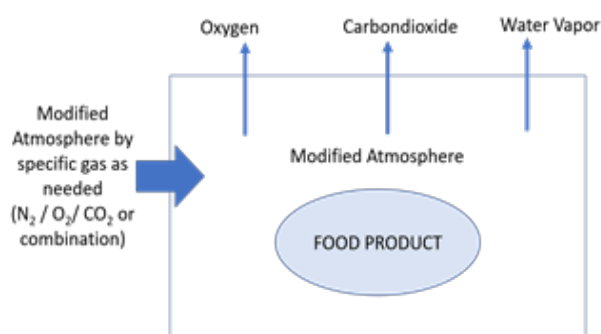


Fig. 2: A condition of modified atmosphere packaging.

Indonesia is rich in natural resources⁶⁴) 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 products⁶⁷) 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 minimized⁶⁸). 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 field⁶⁹). 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 sciences⁷⁰⁻⁷³). 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 quality⁷⁴, 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 processes⁷⁵⁻⁷⁷. 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.

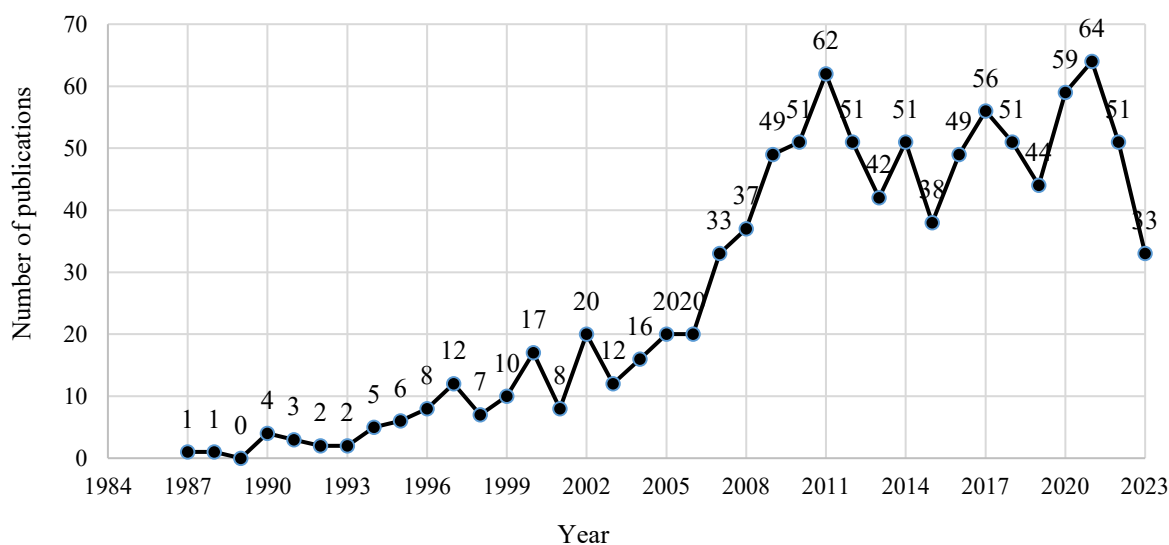


Fig. 3: The scientific publications related to development of MAP technology (1987 – July 2023).

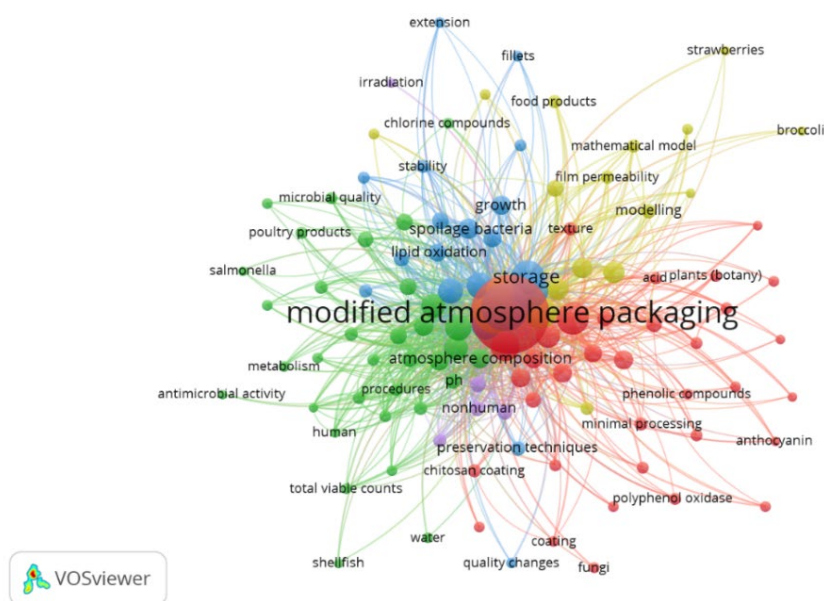


Fig. 4: The results of the analysis of the focus on MAP technology development based on reported scientific publications.

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 independently⁸⁰. 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 meat⁸¹. 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 quality⁸⁴. 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 package⁸⁷, 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 characteristics⁴¹. 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 product⁴⁷. MAP is created in the headspace that retards chemical deterioration while

simultaneously retarding the growth of spoilage organisms⁷⁹. 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 product⁸⁸.

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 gas⁸⁹. The gases commonly used in this MAP technology application are Nitrogen (N₂), Carbon dioxide (CO₂), and Oxygen (O₂).

Nitrogen is an inert gas with low solubility in water and fat⁴⁷. 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 CO₂, 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 CO₂ has a permeability 13 times higher than nitrogen⁹⁰. The characteristic of nitrogen provides a stable and consistent headspace volume of the package during storage or refrigeration environments⁴⁷. CO₂ is a gas with high solubility in water and fat⁴⁷. Solubility CO₂ in fat depends on fat content, fatty acid composition and temperature⁹¹. CO₂ has high permeability in plastic packaging. However, carbon dioxide can slow down the respiration process in fresh produce. Therefore, CO₂ 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 CO₂ should be done in minimal quantities because CO₂ 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 meat⁴⁷). In addition, high oxygen can also inhibit the growth of certain bacteria and fungi, prevent anaerobic fermentation reactions, and reduce spoilage¹⁰².

There are several other gases currently being developed, namely Argon (Ar), Helium (He), Carbon monoxide (CO), Hydrogen (H), and Nitrous oxide (N₂O). 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, similar with N₂. 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 consumer¹⁰⁵. In comparison, Hydrogen and N₂O have their respective functions, Hydrogen is a preventer of oxygen in packages combined with an oxygen scavenging system. Whereas N₂O 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 cream⁴⁷.

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 functions¹⁰⁶. The function as a barrier of gas transmission inside and outside the packaging is the most significant¹⁰⁷. 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 PP¹⁰⁸. 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 μ m d-1 m-2 kPa-1) at 25 °C			Melting Point (°C)	Specific Gravity (g/cm ³)	Transparency
	O ₂	CO ₂	H ₂ O			
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)

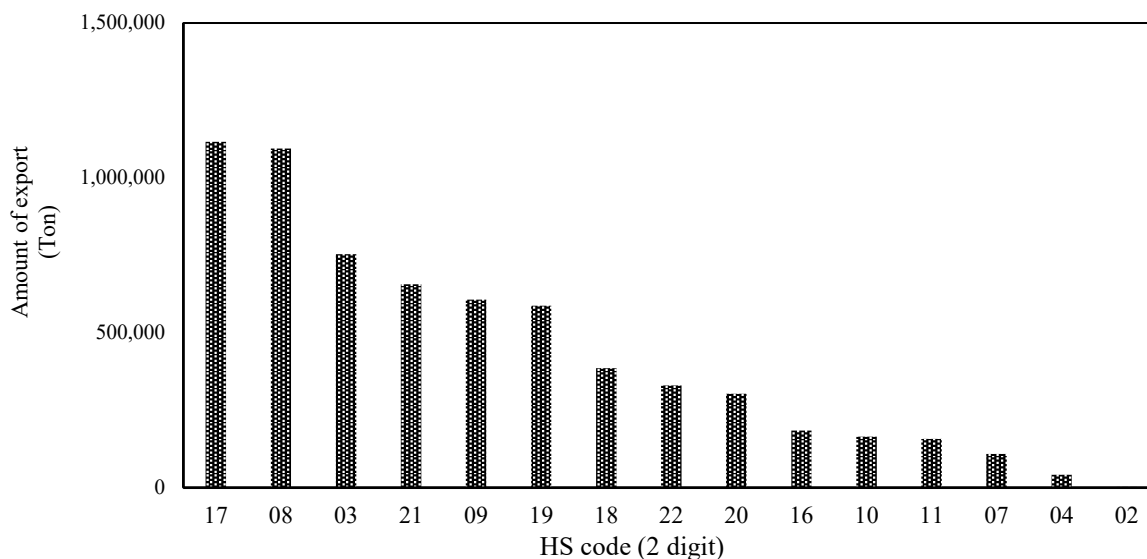


Fig. 5: Amount of export Indonesia food product (January – December 2022)¹¹³.

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 mangosteens¹¹⁴. Besides being delicious, these fruits have active components that benefit the body¹¹⁵. 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 waste¹¹⁶. In several countries, food waste is a problem that is of grave concern¹¹⁷, as well as in Indonesia¹¹⁸.

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 species¹¹⁹. Besides that, shrimp is a fishery product that is competitive in the international market¹²⁰. 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 exports¹¹⁴. 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			Temperature 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 °C	PE	49 days
		Durians ¹²²⁾		5 %	3 %	5 °C	PE	15 days
		Orange ^{47,123)}		0 - 5 %	5 - 10 %	7 °C	PP	16 days
		Mango ¹²⁴⁾		5 - 10 %	3 - 5 %	10 °C	PE	28 days
		Pineapple ⁹⁴⁾		50 %	50 %	7 °C	PP	7 days
		Mangosteen ¹²⁵⁾		9 %	5 %	13 °C	LDPE	25 – 30 days
03	Fish and crustaceans, mollusks, and other aquatic invertebrates	Fish (tuna and skipjack) ⁹⁸⁾		40 %	60 %	2 °C	LDPE	more than 14 days
		Shrimp /prawn ¹²⁶⁾	15 %	80 %	5 %	4 °C	not available	10 days
21	Miscellaneous edible preparations	Tempeh ¹²⁷⁾	55 %	30 %	15 %	20 - 25 °C	PE	4 days
		Snack/chips ¹²⁸⁾	100 %			20 - 25 °C	PET / LDPE	184 days
09	Coffee, tea, mate, and spices	Coffee bean ⁴⁷⁾		40 – 60 %		20 - 25 °C	PE/PVC	360 days
19	Preparations of cereals, flour, starch, or milk; pastrycooks' products	Bakery product ¹²⁹⁾		30 %		20 - 25 °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)}, carrot¹³⁴⁾, snake fruit^{135,136)}, rambutan¹³⁷⁾, citrus¹³⁸⁾, chili¹³⁹⁾, fresh fish⁵⁶⁾, and other tropical fruits^{140,141)}. Other than that, several processed products have been developed using MAP packaging, *dodol*¹⁴²⁾, tempeh¹²⁷⁾, and sugar palm fruit¹⁴³⁾. 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 gases⁴⁷⁾. 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 networks¹⁴⁵⁾. 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 staff⁴¹⁾. 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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