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Kimchi Packaging Technology: An Overview

Suyeon Jeong and SeungRan Yoo*

World Institute of Kimchi, 86 Kimchi-ro, Gwangju, Korea

Abstract This paper provides an overview of kimchi packaging technology, focusing on packaging materials, package design, and active/intelligent packaging technology for kimchi. From a packaging-material standpoint, although various materials have been used to ensure customer satisfaction and convenience, plastic is the most widely used material, in the form of bags, trays, pouches, and rigid containers. Additionally, recent efforts in the kimchi packaging industry have allowed companies to differentiate their products by using different packaging materials and technologies, while simultaneously improving product safety and quality. On the other hand, the biggest problem in kimchi packaging is excess CO_2 production, leading to package expansion and leakage. To alleviate this problem, the use of CO_2 absorbers, high CO_2-permeable films, and degassing valves, in addition to the use of different packaging systems, has been investigated. Active and/or intelligent packaging systems have been developed, to include active functions beyond simply inert, passive containment and protection of the kimchi product. However, most such approaches are not yet adequately effective to be useful on a commercial scale. Therefore, further studies are needed to resolve the limitations of each technology.

Keywords Kimchi, Fermentation, Packaging, Technology

Introduction

Kimchi is the most well-known, traditional Korean food prepared from lactic acid fermentation of brined vegetables with the addition of various kinds of seasoning, giving it a unique flavor that is sour, spicy, salty, and carbonic. Kimchi has recently been demonstrated to promote health, by enhancing immunity as well as exhibiting anti-carcinogenic and antioxidative activities. Kimchi was listed among the "World's Healthiest Foods" in 2006[1), resulting in a rapid increase in kimchi popularity and consumption worldwide[2).

Preparing kimchi involves several complicated processes as shown in Fig. 1, including salting in brine for a couple of hours. Of note, the scarcity of ingredients in winter poses a challenge to the preparation of kimchi during this season. Therefore, a large amount of kimchi is prepared before the onset of winter and stored in kimchi jars buried in the ground, which is the traditional method for its long-term storage.

The concept of kimchi packaging and distribution began with its commercialization. The first commercial kimchi appeared in local grocery stores in the mid-1980s and quickly became a favorite of consumers because, despite its place as an essential part of the cuisine in Korean households, preparation of high-quality kimchi requires significant effort, time, and good quality ingredients. Since 2010, Korea annually exports approximately 100 million USD worth of kimchi to over 60 countries. With the growth of the commercial kimchi market, kimchi packaging has gained importance. Today, commercial kimchi is packaged in plastic film bags or rigid plastic trays with a film lid for domestic consumption and export.

Fermentation of kimchi is brought about by various microorganisms and enzymes associated with the ingredients/raw materials, producing a unique, fresh sour flavor by generating various organic acids[3). Thus, the taste and texture of kimchi are affected over time by microorganisms during storage[4). Additionally, these microbiological and enzymatic activities continue even in well-aged kimchi, producing excess acid that results in a sour and bitter taste, offensive odor, and softening due to the deterioration of kimchi[3,5). Excess acid production also leads to CO_2 accumulation in the packaging headspace, as shown in Fig. 2[4), which may cause damage owing to bloating and result in leakage[6). Therefore, in addition to its limited shelf life, the number one priority for kimchi manufacturers is a quick turnover to prevent kimchi package damage from CO_2 accumulation[3). Hence, the control of metabolic processes is key to preserving the quality of kimchi and extending its shelf life.

To solve the leakage problem, various processing methods such as canning, bottling, pasteurization, adding preservatives, use of food additives, irradiation, pinhole packaging systems,

*Corresponding Author : SeungRan Yoo
World Institute of Kimchi, 86 Kimchi-ro, Gwangju, Korea
Tel : +82-62-610-1738, Fax: +82-62-610-1850
E-mail : sryoo@wikim.re.kr

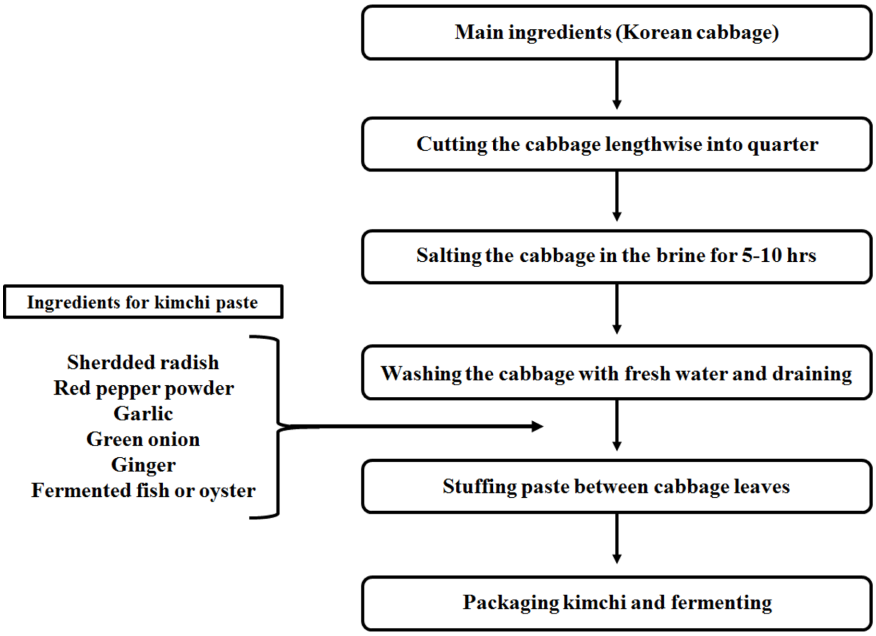

Fig. 1. Flow chart of kimchi preparation.

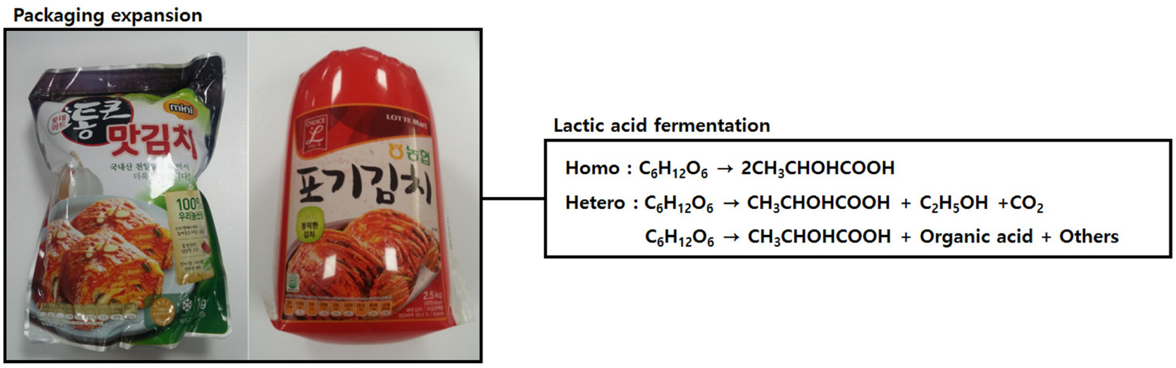

Fig. 2. Lactic acid fermentation of kimchi.

selective CO_2-permeable films, and CO_2 absorbents have been introduced to improve product quality and extend the shelf life of kimchi products. However, while these new methods have improved kimchi packaging technology, some are not feasible for commercialization. In this review, we investigate the recent trends in kimchi packaging and technology development in the commercial kimchi industry.

General Trends in Kimchi Packaging

As for most other food packaging, the principal roles of kimchi packaging are to contain and distribute kimchi easily, to protect kimchi products from the external environment and damage, to decelerate kimchi product deterioration, to retain the beneficial effects of fermentation, to extend shelf life, to maintain/increase the quality and safety of kimchi, and to provide consumers with ingredient and nutritional information. Prolonging the shelf life of kimchi requires retardation of enzymatic, microbial, and biochemical reactions using various strategies such as temperature control; moisture control; addition of chemicals such as salt, sugar, or natural acids; removal of oxygen; or a combination of these with effective packaging[5-7].

The most commonly used kimchi packaging materials are plastic, metal, glass, and paper. Functional kimchi packaging materials were recently introduced in the market. These often combine several packaging materials to exploit each material's functional merits, as shown in Table 1[8,9]. Each material has its own benefits and limitations in maintaining kimchi quality

Table 1. General package types for kimchi products in Korean markets[9])

Package type	Construction	Photo
Plastic pouch	PET+Al+CPP, PET+Al+PE, PET+Al+LLDPE, PET+PE, PET+LLDPE, Nylon+PE, PET+PE+LLDPE, PE	
Plastic container and tray	PET (body)+PE, PET (body)+PP, PP (body)+PE	
Glass bottle	Glass (body)+metal, Glass (body)+PP, Glass (body)+PE	
Can	Metal, PET (body)+Al (top)	

and freshness during distribution and storage; therefore, careful consideration is required in the choice of packaging materials with respect to distribution and storage conditions.

Plastic is the most commonly used material for kimchi packaging, in the form of plastic bags, trays, pouches, and rigid containers. Plastic was first introduced in the late 1800s and the first major commercial plastic spray bottle was developed in 1946 by Dr. Jules Montenier. Since then, it has been widely used in the food packaging industry. Owing to its superior cost effectiveness for mass production, moisture/grease barrier properties, and ease of deformation, plastic is currently one of the most popular packaging materials[7]). However, there are growing concerns for adopting plastic in packaging materials, mainly because of its lack of degradability, the closing of landfill sites, and growing water and land pollution issues.

Kimchi capacity is important for the consumer purchasing intention. Kimchi products are packaged in different sizes ranging from 40 g to 10 kg, and most are packaged in 500 g and 1 kg units[9]. Bulk kimchi products above 1 kg (family size) are available at grocery stores in plastic bags or rigid containers and are commonly packaged in plastic bags with cable ties. Kimchi products below 1 kg target single-person households and are most widely found at convenience stores and small local supermarkets in plastic pouches with aluminum foil, plastic trays with lids, or metal cans consisting of a tin plate (steel with a thin coating of tin) or aluminum and steel coated with a lacquer. Polyethylene terephthalate (PET) bodies with aluminum covers are increasingly used in the kimchi packaging market. Table 1 shows the various types of kimchi packaging described above.

With an increase in the kimchi market and sales, competitors attempt to differentiate themselves by changing their product packaging. One example of this is the development of a packaging method that mimics the traditional kimchi storage technique. Briefly, traditional kimchi storage involves putting freshly made kimchi in a special ceramic jar called an Onggi. A heavy stone is placed on top of the kimchi so that it is immersed in the fermentation liquid (Fig. 3). Several kimchi package technologies mimicking this traditional technique have been introduced in the market and are popular with customers because they improve the quality of taste and flavor during distribution and storage. The heavy object presses down on the kimchi packaging container, which maintains the quality of kimchi and prevents discoloration, bleaching, and contamination. Other materials used by manufacturers as packaging materials for market differentiation include paper and fabric. In a niche market, an Onggi designed by a master artisan is also used as a packaging material.

Beside the improvement of kimchi quality and extension of its shelf life, another great advancement in kimchi packaging is improved convenience in handling kimchi. A plastic container with a handle or a zippered bag that can be re-sealed makes the product more easy to use, thus giving a boost to the kimchi industry.

Fig. 3. Plastic packaging mimicking an Onggi (Stone pressing down on the kimchi).

Packaging Technology to Prevent Product Expansion

Several kinds of lactic acid bacteria (LAB) are known to be involved in kimchi fermentation, including *Lactobacillus* and *Leuconostoc* species[4]. Moreover, some LAB grow under aerobic conditions in the initial fermentation stage, producing a series of metabolic products including lactic acid, acetic acid, and CO_2 that are responsible for kimchi's distinctive flavor[4]. As noted above, the CO_2 gas produced in kimchi during storage can result in damage to the packaging and cause leakage[6]. To solve the leakage problem, CO_2 absorbents, selective CO_2-permeable films, and pinhole packaging systems were introduced to prevent bloating of kimchi pouches[6].

1. CO_2 absorber

Silica gel is widely used as a gas absorbent and some manufacturers use KOH, NaOH, $Ca(OH)_2$, $MgCl_2$, and $CaCl_2$ to absorb CO_2[10]. For this approach, a sachet of CO_2 absorbent is attached inside the kimchi packaging, as shown in Fig. 4, to remove the CO_2 that causes bloating[8]. Recently, Lee et al.[11] suggested using zeolite as a reversible CO_2 absorbent to relieve pressure buildup and/or bloating while maintaining an adequate level of equilibrated CO_2 partial pressure in the kimchi packaging. Additionally, Shin et al.[8] demonstrated that Na_2CO_3 shows good potential for absorbing CO_2 under adequate water supply and used variations in the water vapor content and CO_2 transmission rate of the sachet and plastic sheet containing Na_2CO_3 to control the CO_2 absorption rate. Yoon et al.[10] compared the utility of gas-absorbent materials such as KOH, NaOH, $Ca(OH)_2$, $MgCl_2$, and $CaCl_2$ to prevent package bloating and prolong the shelf life of kimchi. Their results showed that KOH and NaOH tend to retard the decrease in pH of kimchi. However, these materials fail to maintain suitable CO_2 levels in kimchi packaging and this can lead to depletion of CO_2 in the kimchi juice, thus causing loss of the product's characteristic fresh carbonic taste[8].

2. Gas-permeable packaging

Traditionally, fermented foods including kimchi, are stored in Korean earthenware called an Onggi[12,13], which is made of yellow, pulverized clay that leaves small, air-permeable pores[14]. This inherent breathability is one of the unique characteristics of Onggi pottery and positively contributes to the quality of fermented foods[12].

Using this principle, packaging materials have been designed with high-permeability films or micro-pores that eliminate the gas generated during storage and distribution. Laser perforation is the newest method to create micro-pores to increase gas permeability. Son et al.[15] introduced femtosecond laser

Gas-absorbent sachet | Gas absorber attachment inside kimchi packaging pouches

Fig. 4. Attachment of gas absorbers inside kimchi pouches.

micro-perforated films for modified atmosphere packaging. In an alternate approach, Lee et al.[12] suggested the use of permeability-controlled polyethylene containers. Kimchi fermented in these containers showed a stable fermentation pattern with respect to pH and acidity, which was not observed for kimchi fermented in the other containers tested.

3. Degassing valve

Gas generated from the storage and distribution process can be released through a degassing valve. Yu et al.[16] designed one-way degassing valves with ring-type rubber disks, called SP valves, to allow pressure release from an airtight package while preventing air from reentering the package. They showed that the SP valve can be applied to fermented food packaging and it is expected to contribute to kimchi packaging. Other degassing valves used for products such as coffee or fresh-cut have been difficult to apply to kimchi packaging because of the risk of leakage. Therefore, further studies in this area are needed.

4. pH indicator

The pH and acidity are major indicators of the degree of kimchi fermentation and can be used to detect the optimum point for ripeness of kimchi[3]. Such indicators would change color as the pH of the aqueous solutions drops, reflecting the equilibrium between dissolved CO_2 and carbonic acid[4]. Previous studies showed that the optimum conditions for kimchi were pH of 4.2 to 4.4 and acidity between 0.65 and 0.8%[3].

5. CO_2 indicator

In packaged kimchi, the partial pressure of CO_2 is an important factor indicating product quality since LAB continually produce CO_2 as a by-product of fermentation during storage and distribution[3]. The development of a visual indicator for the partial pressure of CO_2 would be the easiest way to provide untrained consumers with an easy method to monitor kimchi quality[4]. A color-indicating sachet consisting of a CO_2 absorbent and a chemical dye has been developed and evaluated for its application to kimchi packaging[17]. Under packaged conditions, the partial pressure profile of CO_2 changes with storage temperature and time, and an indicator reflecting changes in CO_2 levels in the package headspace can provide indirect information about kimchi quality[3]. Jung et al[3] and Meng et al[4] developed an irreversible chitosan-based

Table 2. Active packaging technologies for kimchi packaging to control gas production

Technology	Methods	Materials	Reference
CO_2 absorbent	A gas absorber was attached inside flexible pouches.	Commercial CO_2 absorbent ($Ca(OH)_2$)	Lee et al.[6]
	Na_2CO_3-based CO_2 absorbents were packed in sachets.	Calcium oxide, Magnesium Hydroxide, Calcium hydroxide	Shin et al.[8]
	A sachet of the CO_2 absorbent was attached inside kimchi packages (Performance comparison of gas-absorbing materials).	Potassium hydroxide, Calcium hydroxide, Sodium hydroxide, Magnesium chloride, Calcium chloride	Yoon et al.[10]
Gas permeable packaging	Micro-perforated film was prepared for modified atmosphere packaging.	Femtosecond laser	Son et al.[13]
	Perforated films was used as gas permeable packaging.	Laser perforated BOPP films	Golestan et al.[18]
Degassing valve	Ring-type rubber disk valve was used for degassing.	Ring-type rubber disk	Yu et al.[17]

Table 3. Intelligent packaging technology (CO_2 indicator) to detect fermentation of kimchi

Methods	Materials	Reference
Brilliant blue-incorporated chitosan-based CO_2 indicator solution was poured into and sealed in the LDPE sachet. The indicator sachet was then placed in the headspace of the package.	Chitosan, oxalic acid, Coomasie brilliant blue G-250, Hydrochloric acid, Acetic acid, Sodium hydroxide, Methanol	Meng et al.[4]
The chitosan-based indicator solution for CO_2 detection was sealed into square plastic sachets made of LDPE film. The indicator sachet bag was placed in the headspace of the kimchi package.	Chitosan powder, 2-methyl 1-propanol (AMP), Hydrrogen chloride, Sodium hydroxide	Jung et al.[3]
LDPE sachet attached	Calcium hydroxide and bromocresol purple or methyl red	Hong et al.[19]

Fig. 5. Indicator technology to detect fermentation degree of kimchi.

indicator to monitor kimchi quality corresponding to the partial pressure of CO_2 in the packaging headspace (Table 3). Thus, CO_2 indicators can indirectly identify the starting point of optimum ripening of kimchi since this parameter shows good correlation with the quality of packaged kimchi[3]. Overall, these studies suggest that color indicators can be employed as an effective technique to detect the ripeness of packaged kimchi products without destroying the package[3,4,17]. In order to detect product quality in the package, there must be direct contact between the food product/headspace and the quality detector. However, a major cause for concern is that most of intelligent packaging systems require that food be in direct contact with the sensor, and substances from the sensor may migrate into the food. Additionally, there have been no studies to date on holistic quality indicators and very little work has been done to develop gas indicators that monitor fermentation degree of kimchi[4].

Conclusions

This paper provides an overview of the current state of kimchi packaging technology, focusing on packaging materials, package design, and active/intelligent packaging technology for kimchi. It summarizes the current state of the field and underscores the need for further research and investment into the development of advanced technologies for industrial production, storage, and distribution of kimchi. Overall, we demonstrate the growth potential of the kimchi packaging industry. Additionally, we emphasize the need for more in-depth studies and greater investment in the development of advanced technologies for industrial applications, because most such approaches are not yet sufficiently effective for commercial application. Therefore, further studies are needed to resolve the limitations of each technology.

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