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Storage Stability and Shelf Life Characteristics of Korean Savory Sauce Products

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Abstract

This study evaluated the storage stability of a variety of sauce products in the Korean market, determined primary quality indices for three typical products, and proposed functional relationships that are useful for determining shelf life at different temperatures. Most of the products examined were found to combine hurdles of low pH, low water activity, and the use of heat processing as methods for producing the required storage stability while maintaining the sensory quality of the products. For a meat extract solution produced for cold noodles (pH = 4.3; a_w = 0.98), the primary quality change determining shelf life was lipid oxidation, determined here by the TBA value. The primary quality index of a soybean paste seasoning mix (pH = 4.0; a_w = 0.78), which had a microbial load of 2.8 log (CFU/g), was a decrease in its pH. The primary quality index for a sandwich spread (pH = 4.0; a_w = 0.88) was changes in its surface color. The temperature dependence of changes in the primary quality indices can be described by the Arrhenius equation, which can estimate the shelf life at any arbitrary limit as a function of temperature. The activation energies for changes in the primary quality indices of the meat extract solution, the soybean paste seasoning, and the sandwich spread were 20.3, 27.2, and 43.5 kJ/mol, respectively.

Key words: preservation hurdle, quality change kinetics, TBA value, pH, color

INTRODUCTION

There are a wide range of sauce products available that add flavor, moisture, and visual appeal to foods. Many new sauce products have been introduced into the Korean market because of drastic changes in lifestyle. Some of these sauces are based on traditional foods, while others are modified forms of western-style foods. These sauce products have a naturally high storage stability because of the preservative properties of ingredients such as organic acids and spices (1). Despite the variety of sauce products available and the variability in their ingredients, information about their storage stability is very limited. More extensive data on storage stability and quality deterioration of various sauce products would be useful for designing suitable storage conditions to optimize their shelf lives.

As sauces are normally a formulated liquid or semisolid food product, their storage stability can be measured by their emulsion properties, color changes, flavor deterioration, chemical degradation, and/or microbial activity (1,2). In practice, the shelf life of a sauce products is determined by a measurable primary quality deterioration index, as with any other food product (3,4). Appropriate selection of the primary quality index, therefore, constitutes the first step in studying storage stability and shelf life (5). Next, the dependence of changes in this primary quality index on internal and external factors needs to be elucidated. In particular, microbial contamination and growth are important for food safety and spoilage, and thus should be controlled properly. Microbial activity needs to be examined in relation to water activity, pH, storage temperature, and emulsion structure (2). However, there is no comprehensive understanding of the storage stability of Korean sauce products in relation to these factors.

The specific objectives of this study were, first, to describe the basic compositional characteristics and initial microbial contamination levels of Korean savory sauce products overall and, second, to determine primary quality indices for three typical Korean sauces. Finally, the study aimed to describe the relationship between changes in these indices and temperature in a form that will be useful for determining the products' shelf lives at various temperatures.

MATERIALS AND METHODS

Sauces

Products chosen to be representative of the entire

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range of sauces available in the Korean market were purchased from a manufacturer in Changnyeong, Korea (Table 1). The manufacturing process of most of the sauces consisted of mixing the ingredients, heating them in some cases, filling the packages, and then sealing or closing the packages. The manufacturer prepares liquid extracts on-site before mixing the ingredients, and usually obtains dry or paste ingredients from outside vendors.

Storage of selected sauces

Three sauce products (a meat extract solution for cold noodles, a soybean paste seasoning mix for cooked rice, and a sandwich spread), each representing a typical category of sauces, were selected for storage tests.

The meat extract solution for cold noodles was packaged in units weighing 340 g, and was packaged in a 102 μm thick nylon/polyethylene (PE)/linear low density polyethylene (LLDPE) film bag (13×20 cm). The meat extract solution is usually mixed with cold noodles at room temperature immediately before serving and eating. The term 'meat extract solution' will generally be used in this report. Soybean paste seasoning mix for cooked rice was packed in 480 g units in polyethylene terephthalate (PET) plastic bottles with snap caps (470 mL volume). This sauce is usually mixed with cooked rice and prepared vegetables, and will be referred to as 'soybean paste seasoning' in this report. The packs of semi-liquid sandwich spread weighed 285 g each and were packaged in PET plastic bottles with snap caps (275 mL). The spread is used to coat the inside surface of sandwich bread. The packages were subjected to storage tests at four different temperatures (5, 15, 25 and 35°C). At specified intervals during the storage period, three packages were removed and opened to measure their quality attributes.

Quality evaluation

Physical, chemical, and microbiological quality attributes relevant to each product were analyzed. The pH, water activity, soluble solid content, and salt content were measured, as these are basic indices for measuring changes in food composition and quality in evaluating food preservation stability. The pH of the sauces was measured using an Orion Model 520A pH meter (Orion Research Ins., Boston, USA). The soluble solid content of the sauces was determined using a refractometer (Atago Co., Tokyo, Japan). Water activity was measured using a Novasina Hygrometer (Model Humidat IC-3/2, Novasina AG, Switzerland). Salt content of the sauces was measured using a Salinometer (Model TM-30D, Takemura Electric works, Tokyo, Japan). Surface color of the sauces, a physical quality attribute, was measured in a Hunter color system ('L', 'a', and 'b' values) using a tristimulus Color Difference Meter (Model JC 801, Color Techno System Co., Tokyo, Japan).

To measure the microbial load and microbial growth rate in the sauces, 5 g of the sauce was removed and transferred aseptically into sterile stomacher bags, to which 45 mL of sterile 0.1% peptone (in water) was

Table 1. Physical, chemical, and microbiological quality attributes of sauce products

Product	Physical state	pH	Water activity (%)	Soluble solid (°Bx)	Salinity (%)	Microbial counts (log(CFU/g))	Hot filling
Breaded pork cutlet sauce	Fluid paste	4.31±0.01	89.7±0.1	24.5±0.5	2.65±0.01	ND*	Yes
Broiled hot rice cake sauce	Paste	4.57±0.04	87.0±0.2	54.8±0.3	1.68±0.02	4.61±0.01	Yes
Chicken kebab marinade	Fluid paste	5.01±0.01	86.9±0.4	48.4±0.4	3.42±0.02	1.20±0.02	Yes
Fish roe stew seasoning	Paste	4.75±0.06	84.7±0.3	42.9±0.3	5.91±0.06	2.42±0.03	Yes
Meat extract solution for cool noodle	Liquid	4.32±0.02	98.3±0.3	7.0±0.1	1.74±0.00	ND*	Yes
Mustard sauce	Fluid paste	3.77±0.03	89.2±0.1	32.5±0.2	1.56±0.02	1.28±0.03	Yes
Roast chicken sauce	Fluid paste	4.23±0.02	87.5±0.0	56.8±1.1	0.82±0.00	ND*	Yes
Sandwich spread	Fluid paste	4.01±0.03	88.1±0.1	55.2±0.3	0	ND*	Yes
Seafood stew seasoning	Paste	5.05±0.01	75.6±0.7	64.9±0.2	5.25±0.03	3.24±0.02	Yes
Seasoned soybean paste	Paste	5.15±0.01	89.2±0.3	41.0±0.2	4.42±0.11	3.24±0.02	Yes
Seasoning for grilled eels	Fluid paste	4.73±0.03	83.3±0.2	60.4±0.5	1.65±0.05	ND*	Yes
Soft tofu stew seasoning	Paste	5.04±0.01	84.3±0.0	41.5±0.5	11.97±0.26	ND*	Yes
Soybean paste seasoning mix for cooked rice	Fluid paste	4.02±0.00	77.7±0.2	51.4±0.2	1.65±0.04	2.80±0.021	Yes
Soy sauce/vinegar mix	Liquid	4.03±0.02	91.1±0.6	26.1±0.1	8.03±0.23	ND*	No
Soy sauce/wasabi mix	Liquid	4.17±0.01	89.1±0.2	29.1±0.1	4.93±0.09	1.73±0.02	No
Sweet-and-sour pork sauce	Fluid paste	4.21±0.05	85.7±0.0	28.9±0.1	1.37±0.04	ND*	Yes
Vinegar red-pepper paste	Fluid paste	3.84±0.01	85.7±0.5	54.1±0.1	1.91±0.03	2.24±0.01	No
Watery *kimchi* meaty solution	Liquid	4.20±0.01	98.1±0.1	9.9±0.1	1.85±0.07	ND*	Yes

*ND: not detected

then added. Samples were homogenized in the stomacher (Lab-Blender, TMC International, Seoul, Korea) for 2 minutes after which the aliquots were plated out directly or as 10-fold dilutions in 0.1% peptone (in water) onto Plate Count Agar (Difco Laboratories, Detroit, USA). Microbial colonies present on the plates after 3 days' incubation at 35°C were counted as aerobic bacterial counts and expressed as colony forming units (CFU) per gram.

To determine the degree of lipid oxidation in the stored sauces, the thiobarbituric acid (TBA) value was measured according to the method of Witte et al. (6). Twenty milliliters of the sample taken from the pack was combined with 50 mL of trichloroacetic acid (20% w/v in 1% phosphoric acid) and then made up to 100 mL with distilled water. Samples were mixed in a vortex for 2 minutes. The sample was then filtered through a Whatman No. 1 filter paper. Five milliliters of the filtrate and 5 mL of freshly prepared TBA solution (0.67% w/v in 0.025 M HCl) were combined in a test tube and mixed for 4～5 seconds. Tubes were stored in the dark for 15 hours to allow the color to develop. The absorbance was measured by a UV-VIS Spectrophotometer (UV-1610, Shimadzu, Tokyo, Japan) at a wavelength of 530 nm and this was multiplied by a factor of 12.58 to obtain the TBA value in mg malonaldehyde/kg sample.

RESULTS AND DISCUSSION

Basic storage stability characteristics of sauce products

Table 1 presents the general attributes and properties that are important for the preservation of a variety of sauce products used in Korean foods. All the sauce products examined were non-emulsified condiment sauces. Their physical state and appearance ranged from a thin liquid to a semi-liquid to a thick paste. A large proportion of the products were a mildly viscous suspension. Products to be consumed as a 'pour-over' sauce for mixing with cold noodles in a single serving (for example, meat extract solution and watery *kimchi* meat solution) were fluid sauces, which were packaged in a flexible plastic (nylon/PE/LLDPE 102 μm thick) pouch in units of about 340 g. Some products, such as sauce for broiled rice-cakes, seasoning for soft tofu stew, fish roe stew seasoning, seasoned soybean paste, and seafood stew seasoning were thick pastes. Sauces intended for multiple usages and to be served as small portions (most products except for meat extract solution and watery *kimchi* meat solution) were packaged in semi-rigid PET bottles of 285 or 480 g.

When pH and water activity indices were reviewed for their effect in preserving the sauces, most of the products had a pH of less than 4.6, except for chicken kebab marinade, soft tofu stew seasoning, fish roe stew seasoning, seasoning for grilled eels, seasoned soybean paste, and seafood stew seasoning, all of which had a water activity of less than 0.9. Microbial germination and growth would be suppressed in low pH products due to the antimicrobial effect of organic acids (1,2). Most of the high pH products, except seasoned soybean paste, seemed to depend on low water activity (less than 0.87), as their most important means of preservation. The seasoned soybean paste, which also had a high pH of 5.15 and a water activity of 0.89, was recorded to have been prepared from fermented soybean paste, which would have had a high load of heat-resistant *Bacillus* species (7-9). The presence of microorganisms in fermented sauces or their ingredients would be necessary and beneficial for maintaining the sensory quality of the sauces and for preserving them without posing any risk of food spoilage or poisoning. The same can be said for the chicken kebab marinade, the broiled rice-cake sauce, fish roe stew seasoning, soy sauce/wasabi mix, seafood stew seasoning, vinegar red-pepper paste, and soybean paste seasoning mix, which contain soybean paste and red-pepper paste among their ingredients (8). The hot fill packaging process does not inactivate bacteria of the *Bacillus* species, as mild pasteurization cannot inactivate these heat resistant bacteria, which are present in some sauce products. This may limit their shelf life, particularly under extreme temperature conditions (10,11). Some low pH products such as meat extract solution, watery *kimchi* meat solution, and soy sauce/vinegar mix seemed to rely solely on a low pH for their preservation. Other low pH products such as roast chicken sauce, sweet-and-sour pork sauce, vinegar red-pepper paste, soybean paste seasoning mix for cooked rice, and sandwich spread also maintained low water activity, which would further improve their storage stability.

Most of the sauce products, except the meat extract solution and the watery *kimchi* meat solution, contained high soluble solids, making the products viscous. A high content of soluble solids would also have contributed to lowering the water activity. Salt content of most of the sauces was in the range of 1% to 3%, which would have been chosen by the manufacturers to suit sensory tolerance under their normal conditions of use. Salt content above 5% was found in some sauces, such as soft tofu stew seasoning, soy sauce/vinegar mixture, fish roe stew seasoning, and seafood stew seasoning. High salt content may be acceptable in these sauces as they are mixed with other food items or dishes at low concentrations so that palatability of the food is not affected.

Most products used a hot-filling step, except for the soy sauce/vinegar mix, the soy sauce/wasabi mix, and the vinegar red-pepper paste containing acetic acid. Processing steps involving heating the ingredients and/or hot-fill packaging resulted in non-detectable initial numbers of aerobic bacteria in some products, which would have further improved their preservation. However, it cannot be said that the products that had some microbial load would be unstable or inferior in their preservation or storage. Surviving microorganisms in the products may be suppressed during subsequent storage by the preservative effects of low pH, water activity, and certain other ingredients (2). A combination of characteristics aiding preservation of the food would improve storage stability, while also satisfying sensory requirements (12).

A general overview of Table 1 thus suggests that each type of sauce product adopts its own combination of characteristics to satisfy quality requirements. However, more extensive storage tests of each product are required to fully characterize the products' storage stability and to define the primary quality criteria for these products. This study also investigated the storage stability and determined the shelf life of three typical sauce products, which were selected on the basis of their distinctive characteristics. The selected items were the meat extract solution for cold noodles, the soybean paste seasoning mix for cooked rice, and the sandwich spread; each of which had different quality and preservation characteristics. The meat extract solution had very high water activity and relatively low pH, with an absence of aerobic bacteria due to the use of hot-fill packaging. Its preservation factors were a low pH and the use of heat processing in hot filling. On the other hand, soybean paste seasoning had stringent preservation factors of a very low pH and water activity, but it had some microbial load, which probably came from the fermented soybean paste used in its manufacture. The sandwich spread had low water activity and relatively low pH, and no aerobic bacteria were detected initially. Differences in pH, water activity, and the level of microbial contamination were expected to result in different deterioration patterns, which would provide basic information for designing ideal storage conditions of the products and controlling their shelf life. Thus these three products may be representative of the typical categories of Korean sauce products grouped according to the use of types of formulations, processing, and packaging; and whose study may be applied to the similar sauce types.

Patterns of quality change and primary quality indices of three typical sauces

Because the meat extract solution had been heated for a long period and was then packaged using the hot-filling process, there was no growth of microorganisms during storage at the four temperatures tested (data not shown). When the meat extract was stored for 230 days, there was an increase in the salt and soluble solid content by approximately 10, 12, 13, and 16% at 5, 15, 25, and 35°C, respectively, which would have resulted from water loss through the packaging film. The pouch package made of permeable nylon/PE/LLDPE film with a high surface area to volume ratio would have resulted in water loss, causing concentration of the soluble solids. This increase in salinity and soluble solid content due to water loss occurred in conjunction with a decrease in water activity. Water activity decreased from 0.982 to approximately 0.95 at all temperatures after 230 days (specific data not shown). There was a greater moisture loss at higher temperatures because water loss depends on the packaging film's permeability to moisture and the water vapor pressure difference across the package layer (13,14), both of which increase with temperature. Use of high moisture barrier film, such as foil laminated films, would protect the product from the problem of high moisture loss. This work is based on the commercial package and future development may look for moisture barrier packaging.

Surface color, measured using the Hunter tristimulus system, did not show any significant change during 230 or 260 days of storage. The 'L' value was consistently around 25, the 'a' value was approximately -4, and the 'b' value was approximately 1 at the four temperatures tested (data not shown here).

The pH of the meat extract solution, initially 4.32, gradually decreased to reach 4.00～4.05 after 260 days at 5～25°C but it decreased more rapidly at 35°C to reach 3.94 after 230 days (Fig. 1(a)). The faster decrease in pH of spice and juice products during storage was also observed by Modi et al. (15) and Alklint et al. (16). The decrease in pH would have been due to chemical changes and not microbiological activity, as there was no microbial growth during storage. Considering that the meat extract contains some oil components from meat, free fatty acids would have been produced by the hydrolytic cleavage of triglycerides in the presence of moisture, thus decreasing pH (15,17).

The TBA value (mg malonaldehyde/kg sample), used as an indicator of lipid oxidation, increased significantly in the meat extract solution after storage, with greater changes occurring at higher temperatures (Fig. 1(b)). At

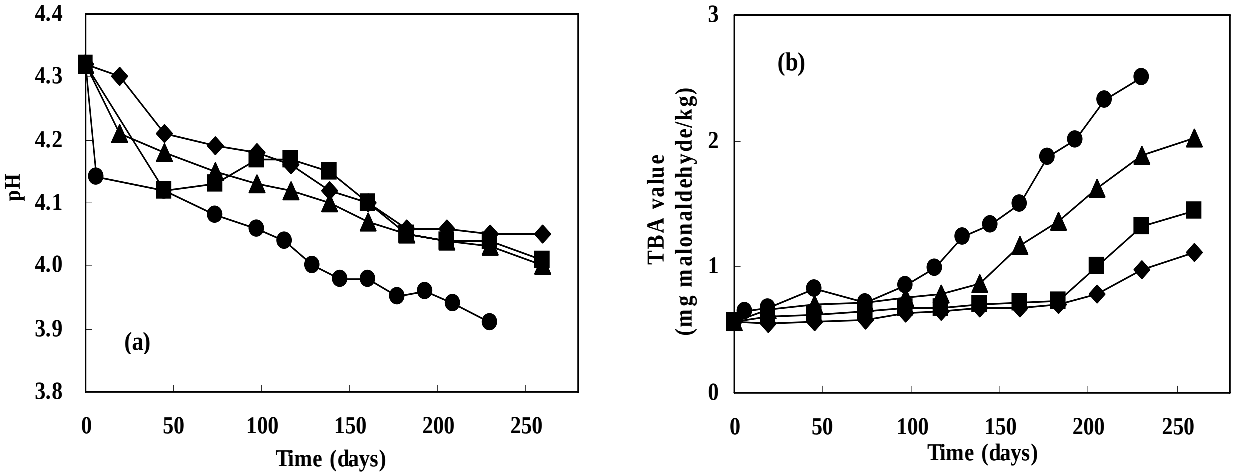

Fig. 1. Change in pH (a) and TBA value (b) of the meat extract solution stored at different temperatures. Average standard deviations for pH and TBA value were 0.02 and 0.09 mg/kg, respectively. ◆: 5°C, ■: 15°C, ▲: 25°C, ●: 35°C.

35°C, only a slight increase in TBA was observed during the first 74 days of storage, but there was a rapid increase in TBA values thereafter. At 5 and 15°C, the TBA value started to increase significantly after 183 days, before which there was no perceivable change. TBA value began to increase at 139 days when the meat extract solution was stored at 25°C. The observed increases in TBA value would have been due to increased lipid oxidation and the production of volatile metabolites in the presence of oxygen during storage. The increase in TBA value of thiobarbituric acid-malonaldehyde complex during the storage of fatty food products is well documented (15, 18,19). Both the lipid oxidation determined by TBA value and the observed decreases in pH may have been caused by hydrolytic and oxidative deterioration of the oil component within the food product, which would be expected to cause a rancid flavor (17).

Changes in pH and increases in the TBA value appeared to have potential for use as primary quality indices in determining shelf life of the meat extract solution. Even though both pH and TBA values could be used as primary quality indices, TBA value was more directly related to the product quality because of its direct relationship with the oxidation of lipids, which is important for the quality of the sauce products. Therefore, in the next step of this study, TBA value was used as a quality index, whose change to a certain degree was examined as a measure of the estimated shelf life.

The pH of the soybean paste seasoning was 4.02 initially, decreasing gradually to 3.89, 3.80, 3.71, and 3.58 after 250 days storage at 5, 15, 25, and 35°C, respectively (Fig. 2(a)). The gradual decrease in pH may have been caused by chemical reactions and microbiological growth, both of which would have been great-

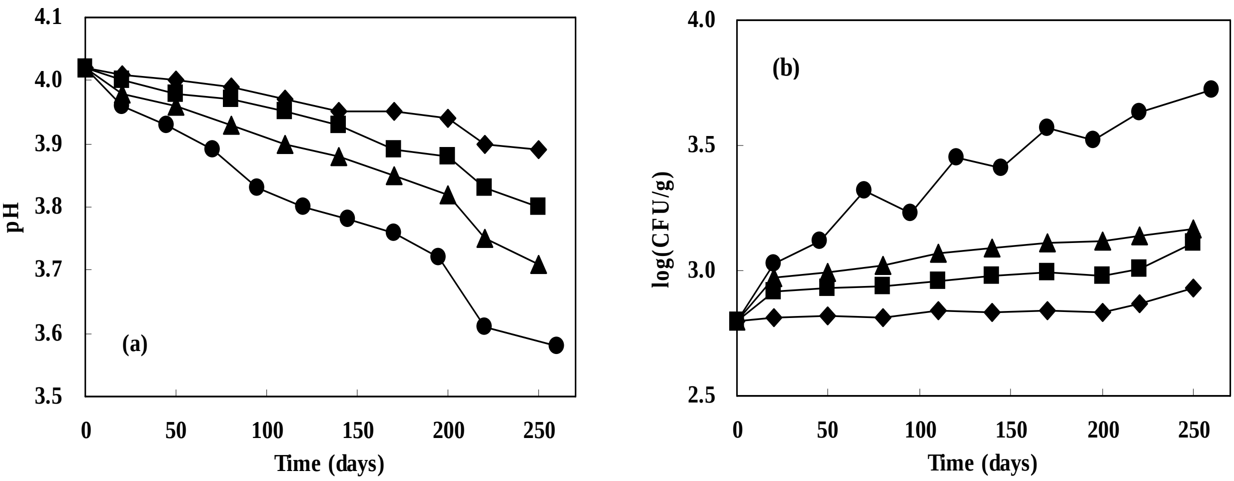

Fig. 2. Change in pH (a) and microbial counts (b) of the soybean paste seasoning stored at different temperatures. Average standard deviations for pH and microbial counts were 0.01 and 0.02 log(CFU/g), respectively. ◆: 5°C, ■: 15°C, ▲: 25°C, ●: 35°C.

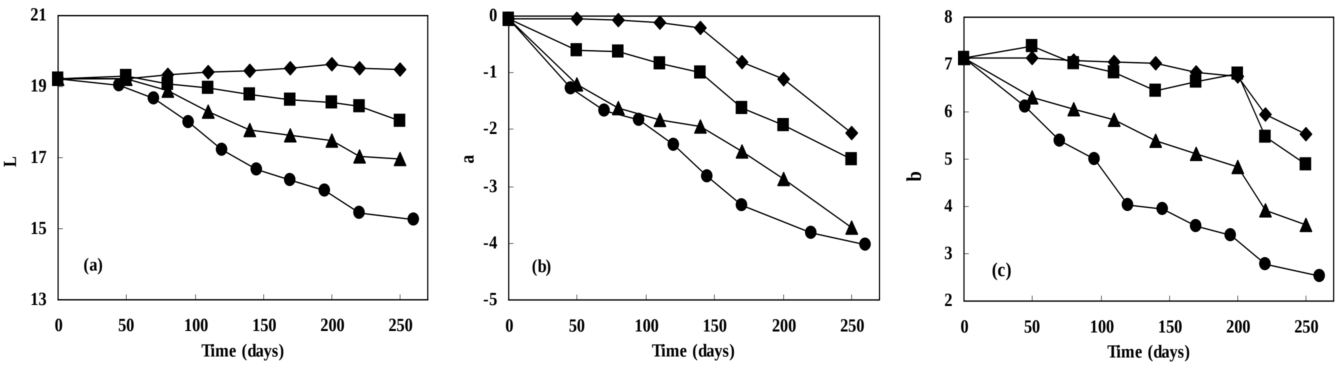

Fig. 3. Color changes in the soybean paste seasoning stored at different temperatures. Average standard deviations of color measurements were 0.29, 0.32, and 0.50 for 'L', 'a', and 'b' values, respectively. ◆: 5°C, ■: 15°C, ▲: 25°C, ●: 35°C.

er at higher temperatures (Fig. 2(b)). The bacteria residing and growing in the product can result in the production of organic acid and/or hydrolytic decomposition of lipid, which may produce fatty acids, thus causing a decrease in pH. Some microbial growth was observed even at low pH and low water activity of this product.

The soluble solid content and salinity of the soybean paste seasoning changed little during storage at any temperature (data not shown). The stable soluble solid and salt contents meant that little moisture was lost during storage. The packaging of the soybean paste in PET bottles with a snap cap seemed to have created a sufficient barrier to prevent moisture loss for more than 200 days. The benefits of the good barrier and gloss properties of PET bottles allow their wide use for packaging tea, edible oil, drinks, and sauce products (20).

The surface color of the soybean paste seasoning showed larger and more consistent changes in 'L' (lightness), 'a' (redness), and 'b' (yellowness) values at higher temperatures than at lower temperatures (Fig. 3). These color changes were visible, resulting in a darker and duller appearance of the products after they had been stored for a long time at high temperature. The 'L' values decreased steadily over 250 days during storage at 25 and 35°C, while there was a smaller decrease in 'L' at 5 and 15°C over the same period. The 'a' value remained almost constant during the first 140 days at 5 and 15°C, followed by a perceivable decrease during the remainder of the storage period. Similarly, the 'b' value did not change for the first 200 days at 5 and 15°C, but it then exhibited a perceivable decrease over the rest of the storage period. Both 'a' and 'b' consistently showed a greater decrease throughout the entire storage period at higher temperatures (Fig. 3).

Among the quality indices examined thus far for soybean paste seasoning, pH change was the most obvious and it showed the simplest pattern. Therefore, pH decrease seemed to be more directly related to the fundamental quality of the sauce and it would be easily used for the purpose of determining the shelf life of the soybean paste seasoning. Therefore, it has been proposed as a primary quality index for the soybean paste seasoning. Change in pH has often been used as an index for determining the shelf life of meat, fruit juices, and meals (16,21,22).

Soluble solid content and water activity of the sandwich spread changed little during storage except at 35°C, at which temperature water activity decreased from 0.88 to 0.84 after 210 days (specific data not shown here). The moisture barrier of the plastic (PET) bottle with a snap cap seemed relatively satisfactory for low temperature storage. As with the meat extract solution, absence of aerobic bacteria was maintained throughout storage for 210 days at all temperatures tested.

The sandwich spread initially showed a rapid drop in pH during storage and then leveled off later in the storage period (Fig. 4). The initial pH of 4.0 changed to approximately 3.6 after 150 days at temperatures above

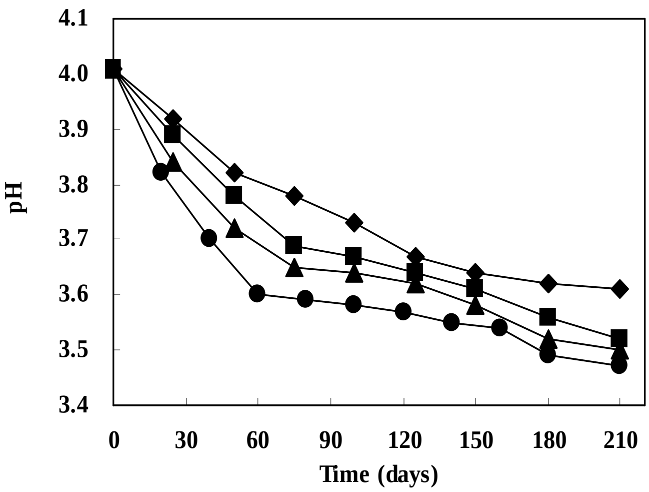

Fig. 4. Change in pH of the sandwich spread stored at different temperatures. Average standard deviation for pH was 0.02. ◆: 5°C, ■: 15°C, ▲: 25°C, ●: 35°C.

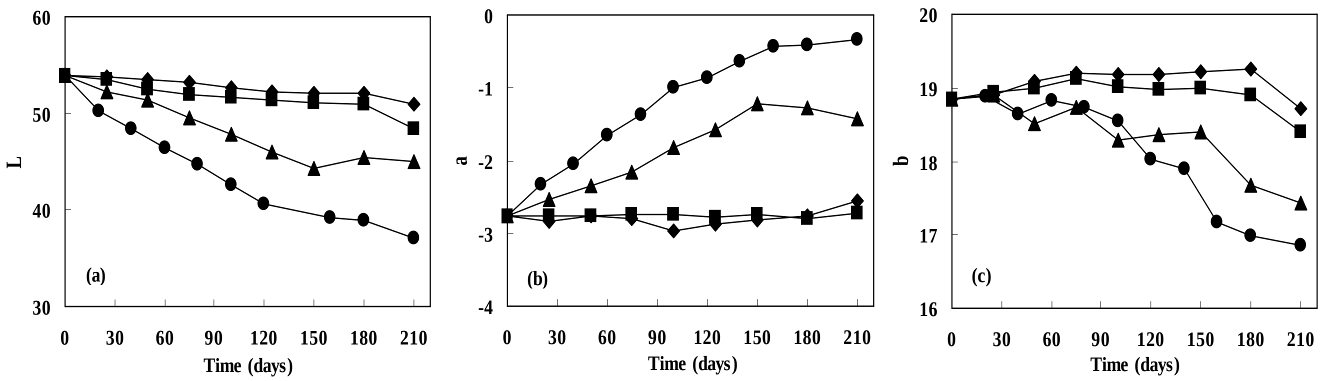

Fig. 5. Surface color change of sandwich spread stored at different temperatures. Average standard deviations of color measurements were 0.18, 0.14, and 0.19 for 'L', 'a', and 'b' values, respectively. ◆: 5°C, ■: 15°C, ▲: 25°C, ●: 35°C.

25°C. The rate and extent of pH change were greater at higher temperatures. Considering that there was no microbial growth in the sandwich spread, the observed decrease in pH was believed to be due to chemical reactions, including the hydrolysis of lipid components.

Obvious changes in surface color were observed. The 'L' and 'b' values decreased and the 'a' value increased towards a dark brown color during storage, with greater changes occurring at higher temperatures (Fig. 5).

Therefore, pH and surface color could be major primary quality indices for the sandwich spread. A high correlation has also been observed between the 'L' color value change and a decrease in pH (both of which affected the product's shelf life) in an extruded bar product of sorghum and peanut butter as a result of chemical changes (21). The kinetics of the 'L' value change for shelf life was evaluated in the sandwich spread, because of its simplicity, experimental load, discrimination in measurement, and clear temperature dependence.

Kinetics of primary quality index changes

The kinetic behavior of the primary quality indices shown in Figures 1～5 can be useful for determining the shelf lives of the three sauce products under various conditions. It should be noted that these finding are based on commercial products and some innovations in processing and packaging may change the quality change pattern and kinetics.

For the meat extract solution, a TBA value of 1.2 mg/kg was arbitrarily chosen as a minimum allowable limit to define the product's shelf life, based on the authors' subjective evaluation (for example, this would translate into a shelf life of 162 days at 25°C). The minimum threshold of TBA value in relation to the development of off-flavors was reported to be in the range of 0.5～2.0 mg/kg for cooked meat products (23,24). Thus, the TBA value of 1.2 mg/kg selected as a quality limit in this study is within the range comparable to those of other meat products. The relationship between the time taken to reach the defined quality limit and the temperature was shown to follow a type of Arrhenius equation (Fig. 6(a)) as below:

$$\ln(t_s) = 2441.5\frac{1}{T} - 3.0866 \quad (1)$$

where t_s is time period to 1.2 mg/kg in TBA value (day) and T is storage temperature in Kelvin.

The activation energy, i.e., the parameter for temperature dependence, in Equation 1 was calculated to be 20.3 kJ/mol. Equation 1 could be used to predict the

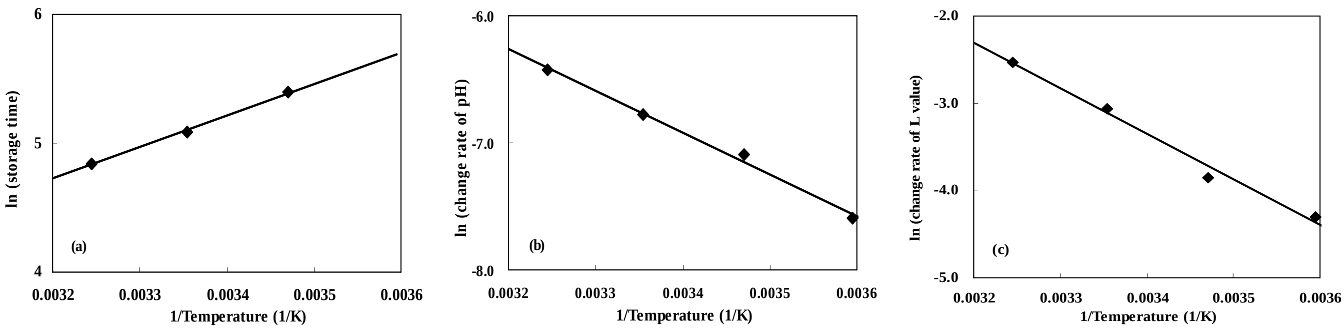

Fig. 6. Temperature dependence of the time for TBA value of the meat extract solution to reach 1.2 mg/kg (a), the pH change rate of soybean paste seasoning (b), and 'L' value change rate of sandwich spread (c).

storage time span to reach the quality limit at any temperature expected to be used for the storage and distribution of this product (for example 164 days at 25°C).

As mentioned above, pH decrease was chosen as the primary quality index for determining the shelf life of the soybean paste seasoning. It shows a simple pattern of change and has a clear temperature dependence, both of which are good properties for modeling shelf life. The pH decreased linearly over time, as shown in Fig. 2(a), thus making it possible to analyze its response using zero-order kinetics (14). When its rate of change was analyzed at different temperatures, its temperature dependence could be described by the Arrhenius equation (Fig. 6(b)), below.

$$\ln(-\frac{dpH}{dt}) = -3275.6\frac{1}{T} + 4.2173 \quad (2)$$

where (-dpH/dt) is rate of pH decrease (1/day) at storage temperature of T (K).

The activation energy from the Arrhenius plot was determined to be 27.2 kJ/mol. The shelf life required for the soybean paste seasoning to reach a certain pH can be predicted at any temperature from Equation 2 using the rate of temperature-dependent pH change. In this study, a pH decrease of 0.15 was arbitrarily chosen as the quality limit according to the authors' subjective judgment and used for determining the potential shelf life of soybean paste seasoning. This degree of pH change resulted in significant deterioration of flavor and aroma. Provisional shelf life, as the time required for the product to decrease in pH by 0.15 units, can be estimated easily from Equation 2 for any temperature (Fig. 7). Alklint et al. (16) determined the shelf life of carrot juice using a sigmoidal function to describe pH change. Baiano et al. (25) also reported that pH change of tomato sauce could be represented by a cosine function against time.

As described above, the decrease in 'L' of the sandwich spread over time was described as a simple linear pattern (zero order kinetics) and thus the slope of the fitted line was used to describe changes in product quality at different temperatures. Changes in the 'L' value have been widely used for determining the shelf life of a variety of food products (15).

The effect of storage temperature on changes in the 'L' value was described well by an Arrhenius equation (Fig. 6(c)), below, and the activation energy was calculated from the slope of the Arrhenius plot to be 43.5 kJ/mol.

$$\ln(-\frac{dL}{dt}) = -5231.6\frac{1}{T} + 14.436 \quad (3)$$

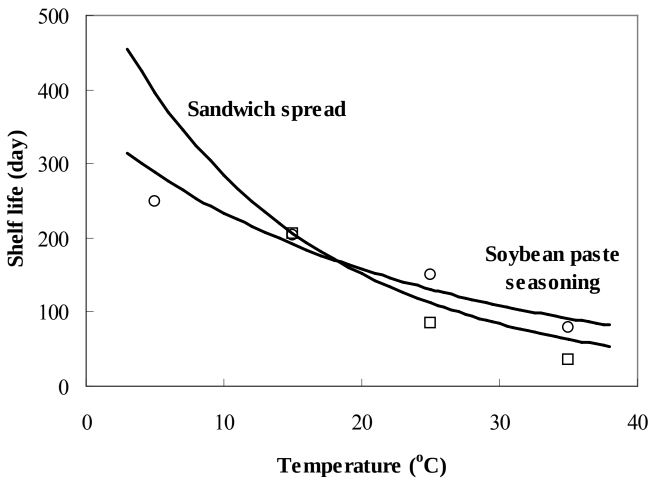

Fig. 7. Shelf life estimates of soybean paste seasoning and sandwich spread as a function of temperature, which were compared to experimental data (○, soybean paste seasoning; □, sandwich spread).

where (-dL/dt) is rate of 'L' value decrease (ΔL/day).

The activation energy of the sandwich spread (43.5 kJ/mol) was higher than those of the meat extract solution and the soybean paste seasoning (20.3 and 27.2 kJ/mol, respectively). This means that the sandwich spread has a greater sensitivity to storage temperature.

When a subjective quality limit based on appearance and flavor, a change in 'L' of 5 was chosen, the shelf life defined as time required for reaching the limits can be estimated at different temperatures from Equation 3 as shown in Fig. 7.

The kinetics of the observed changes in primary quality indices was presented and shown to be employed usefully for determining shelf life of the three tested sauce products. The authors' subjective sensory judgment was applied to determine a criterion for quality and to define a quality limit. A more extensive study examining the relationship between the primary quality index and the product's sensory quality would improve the soundness of the determination of shelf life. Generalization of quality criteria and limit to satisfy the consumer preference and safety is essentially required for robustness of the shelf life study, but not established yet as solid methodology. This is a topic for further study.

CONCLUSIONS

By examining the manufacturing processes and the intrinsic properties of Korean savory sauce products, it was found that various combinations of preservation methods are being used to maintain the stability of the products for extended periods. Storage tests of three typical sauce products were used to define the primary quality indices of lipid oxidation measured by the TBA value, pH decrease, and color change for a meat extract solution, a soybean paste seasoning, and a sandwich spread, respectively. The temperature dependence of the primary quality attributes could be described by the Arrhenius equation, thus allowing the shelf life at any arbitrary limit to be estimated as a function of temperature. The activation energies for quality changes in the meat extract solution, soybean paste seasoning, and sandwich spread were 20.3, 27.2, and 43.5 kJ/mol, respectively. This study presented an empirical approach for evaluating the storage stability of the commercial sauce products and determining kinetic models for their shelf life determination.

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REFERENCES

1. Jones AA, Man CMD. 1994. Ambient-stable sauce and pickles. In *Shelf Life Evaluation of Foods*. Man CMD, Jones AA, eds. Blackie Academic and Professional, London. p 275-295.
2. Pourkomailian B. 2000. Sauces and dressings. In *The Stability and Shelf-life of Food*. Kilcast D, Subramaniam P, eds. Woodhead Publishing, Cambridge, UK. p 311-331.
3. Steele P. 2000. Shelf-life testing. In *Understanding and Measuring the Shelf-life of Food*. Man CMD, ed. Woodhead Publishing, London. p 340-356.
4. Singh RP, Anderson BA. 2004. The major types of food spoilage. In *Understanding and Measuring the Shelf-life of Food*. Steele R, ed. Woodhead Publishing, Cambridge, UK. p 3-23.
5. Kim GT, Ko YD, Lee DS. 2003. Shelf life determination of Korean seasoned side dishes. *Food Sci Technol Int* 9: 257-263.
6. Witte VC, Krause GF, Bailey ME. 1970. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. *J Food Sci* 35: 582-585.
7. Cho DH, Lee WJ. 1970. Microbiological studies of Korean native soysauce fermentation: a study on the mocroflra of fermented Korean maeju loaves. *Korean Agric Chem Soc* 13: 35-42.
8. Kim GT, Koo KM, Paik HD, Lyu ES, Lee DS. 2002. Sous vide processing of seasoned spinach soup. *Food Service Tech* 2: 131-138.
9. Ryu SK, Kim IH, Kim JS, Choi SH, Oh MJ, Kim YK, Lee IK. 1998. Microflora and color of soybean paste sterilized by counterflow heat exchanger. *J Korean Biotech Bioeng* 13: 724-729.
10. Carlin F, Guinebretiere M-H, Choma C, Pasqualini R, Braconnier A, Nguyen-the C. 2000. Spore-forming bacteria in commercial cooked, pasteurised and chilled vegetable purees. *Food Microbiol* 17: 153-165.
11. Simpson MV, Smith JP, Simpson BK, Ramaswamy H, Dodds KL. 1994. Storage studies on a sous vide spaghetti and meat sauce product. *Food Microbiol* 11: 5-14.
12. Leistner L, Gould GW. 2002. *Hurdle technology combination treatments for food stability, safety and quality*. Kluwer Academic, New York. p 17-28.
13. Brown WE. 1992. *Plastics in Food Packaging*. Marcel Dekker, New York. p 292-357.
14. Singh RP. 1994. Scientific principles of shelf life evaluation. In *Shelf Life Evaluation of Foods*. Man CMD, Jones AA, eds. Blackie Academic & Professional. London. p 3-26.
15. Modi VK, Sidde Gowda GS, Sakhare PZ, Mahendrakar NS, Narasimha Rao D. 2006. Pre-processed spice mix formulation and changes in its quality during storage. *Lebensmittel-Wissenschaft und Technologie* 23: 423-429.
16. Alklint C, Wadsö L, Sjöholm I. 2005. Accelerated storage and isothermal microcalorimetry as methods of predicting carrot juice shelf-life. *J Sci Food Agric* 85: 281-285.
17. Kristott J. 2000. Fats and oils. In *The Stability and Shelf-life of Food*. Kilcast D, Subramaniam P, eds. Woodhead Publishing, Cambridge, UK. p 279-308.
18. Insausti K, Beriain MJ, Purroy A, Alberti P, Gorraiz C, Alzueta MJ. 2001. Shelf life of beef from local Spanish cattle breeds stored under modified atmosphere. *Meat Sci* 57: 273-281.
19. Patsias A, Chouliara I, Badeka A, Savvaidis IN, Kontominas MG. 2006. Shelf-life of a chilled precooked chicken product stored in air and under modified atmospheres: microbiological, chemical, sensory attributes. *Food Microbiol 23: 423-429.*
20. Sensidoni A, Leonardi M, Possamai A, Tamagnone P, Peressini D. 2004. Study of an innovative PET (polyethylene terephthalate) packaging for mayonnaise and evaluation of product shelf life. *Italian J Food Sci* 16: 139-150.
21. Anderson JC, Jones BD. 1999. Principal factor analysis of extruded sorghum and peanut bar changes during accelerated shelf-life studies. *J Food Sci* 64: 1059-1063.
22. Blixt Y, Borch E. 2002. Comparison of shelf life of vacuum-packed pork and beef. *Meat Sci* 60: 371-378.
23. Greene BA, Cumuze TH. 1982. Relationship between TBA numbers and inexperienced panelists. Assessments of oxidized flavour in cooked beef. *J Food Sci* 47: 52-58.
24. Tarladgis BG, Watts BM, Younthan MT, Dugan LR. 1960. A distillation method of the quantitative determination of malonaldehyde in rancid foods. *J Am Oil Chem Soc* 37: 403-406.
25. Baiano A, Tamagnone P, Marchutelli V, Del Nobile MA. 2005. Quality decay kinetics of semi-preserved sauce as affected by packaging. *J Food Sci* 70: E92-E97.

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