Evaluation of the quality change and estimation of the shelf life of instant Bibimbap (Korean Mixed Rice) during storage

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Abstract This study estimates the shelf life of four different instant bibimbaps. Each product was stored at 25, 35, or 45 °C for 180 days, and the changes in the physiochemical, microbiological, and sensory parameters were analyzed during storage. The total bacteria and coliforms for the bibimbaps were up to 4 and 1 log CFU/g, respectively. The highest population of yeast and mold was 1.98 log CFU/g, and Bacillus cereus was not detected in all bibimbaps. The moisture content and acid value were used to estimate the shelf life of bibimbaps. The shelf life of the four types of bibimbaps was over 4 years.

Keywords Bibimbap · Quality change · Shelf life · Storage time

Introduction

Because of the fast pace of modern life and irregular eating habits, instant foods have become more and more popular throughout the world. Bibimbap, a type of traditional Korean cooked rice that is mixed with various vegetables and ground meat and usually seasoned with gochujang (Korean traditional pepper paste), is used as an instant cooked food. Instant bibimbap is one of the most popular dried instant cooked foods in Korea, because it provides rich nutrition and flavor, is easy to cook, conveniently available, and can be stored at room temperature for a long time. Rehydration of the dried instant bibimbap is required before serving, and its quality after rehydration is very similar to that of the normal bibimbap. For these reasons, it is preferred by people who indulge in mountaineering and travel, and is mostly manufactured as a packed military food.

There are many factors that affect the quality of the moisture contents, such as material selection, refining, processing methods, packaging, and storage conditions. To guarantee the quality of the moisture contents, color, viscosity, and volatility are usually determined.

The shelf life of a product is the length of time over which the packaged product can be sold after it is manufactured. During the shelf life period, the intrinsic properties such as physical and/or chemical properties of products should remain acceptable under display, storage, and distribution. The shelf lives of the products are affected by many factors such as the types and proportions of ingredients, manufacturing process, packaging methods, and storage conditions (NZFSA 2005).

Two main methods are used for estimating the shelf life, i.e., the direct method and indirect method. In this work, we utilize an indirect method termed accelerated shelf life determination (ASLD) to estimate the shelf life of instant bibimbap. The ASLD method shortens the evaluation period by increasing the storage temperature and accelerating the rate of deterioration. The results are then used to estimate the shelf life at room temperature.
The present study was conducted to evaluate the changes in the quality and to estimate the shelf life of four types of instant bibimbaps during 180 days of storage.

Materials and methods

Sample preparation

Commercial sterilized-pouched kimchi (Korean traditional-fermented cabbage)-bibimbap, seafood-bibimbap, bulgogi (Korean traditional grilled marinated beef)-bibimbap, chicken-bibimbap which is common condiment of bibimbap were provided by Charm Foods (Ltd.), Korea. The samples were stored at 25, 35, and 45 °C for 180 days, and physicochemical, microbiological, and sensory evaluation was performed each month. All the experiments were repeated independently three times.

Determination of the moisture content during the storage time

A bibimbap sample (5 ± 0.05 g) was uniformly placed into a 105 °C infrared moisture content tester (Precisa Gravimetrics AG, Switzerland) and dried to a constant weight. The moisture content tester utilizes the heat/dry weight change measurement principle. This allows for an accurate (as low as 0.01 %) determination of the total moisture content.

Microbiological analyses

25 ± 0.05 g bibimbap samples were homogenized for 1 min in a sterile stomacher bag containing 225 mL of sterile 0.1 % peptone water (PW) using a stomacher (Bag Mixer® 400; Interscience Co., France) and then serially diluted in 0.1 % PW.

Determination of the total bacteria during the storage time

1 mL diluted sample was inoculated into tryptic soy agar (TSA; Difco Laboratories, USA) and incubated at 37 °C for 24 h. The colony forming units (CFU) per gram were counted at a dilution of 30–300 per plate.

Determination of the coliforms during the storage time

Aliquots of 1 mL of each serial dilution were plated onto 3 M™ Petrifilm™ E. coli/Coliform Count Plates (Petrifilm™ EC plates) and incubated at 35 °C for 48 h. The blue colonies with gas were then counted at a dilution of 30–300 CFU per plate.

Determination of the yeast and mold during the storage time

1 mL serial dilution was plated onto potato dextrose agar (PDA; Difco Laboratories) and incubated at 25 °C for 5 days. The colonies were then counted at a dilution of 30–300 CFU per plate.

Determination of the Bacillus cereus during the storage time

0.1 mL serial dilution was plated onto Mannitol Egg Yolk Polymyxin Agar (MYP; Difco) and incubated at 30 °C for 24 h. Colonies presenting a pink or purple coloration with an irregular edge surrounded by a white area were considered as positive for B. cereus and enumerated. The CFU per gram were counted at a dilution of 30–300 CFU per plate.

Overall sensory evaluation

The overall sensory characteristics of bibimbaps stored at 25, 35, and 45 °C for 180 days were evaluated by 10 trainees and 10 untrained panelists using the hedonic scale according to the methods described earlier with some modifications (Makun et al. 2007). The quality was assessed using the seven-point hedonic scale represented as follows: ‘1’ dislike extremely, not acceptable; ‘4’ neither like nor dislike, lower limit of acceptable range; ‘7’ like extremely, essentially free from any effect, original quality present. The parameters indicated overall acceptability, including the color, smell, and texture of the bibimbaps. The sensory evaluation was performed monthly, and points higher than four were considered to indicate acceptability of the food. Prior to sample evaluation, trained panelists participated in orientation sessions to familiarize the participants with the scale attributes of bibimbaps using the hedonic scale and quality assessment.

Shelf life determination

To estimate the shelf life of the bibimbap sample, physicochemical, microbiological, and sensory changes at different temperatures during the storage time were determined. The data were comparatively analyzed with the product failure point. In order to derive the formula for the relationship between product failure (Y) and storage time (X), the Visual Shelf life Simulator for Foods Program (2012) provided by the Korea Health Industry Development Institute (http://cheminet.homelinux.com:8880/vslsf/) was used to
determine the degree of association between quality changes with storage time. The final label for the shelf life of the products, which was estimated for room temperature ($25\,\text{°C}$), was considered based on the safety factor (0.7). Shelf life was calculated using the following equation:

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\text{Labeled shelf life of product} = \frac{\text{Estimated shelf life (month)}}{0.7}\times\text{Safety factor (0.7)}. \]

**Statistical analysis**

Changes in the acid value and peroxide value during the storage time were analyzed via the ANOVA procedure using SAS software (Version 9.2, SAS Institute Inc., USA) for a completely randomized design. When the effect was significant ($p < 0.05$), the mean separation was accomplished with Duncan’s multiple-range test.

**Results and discussion**

**Changes in moisture content during the storage time**

Microorganisms need free water for their growth in food products. Effective control of the moisture content of foods is one of the main food preservation strategies. Reducing the water activity ($A_w$) is not only an effective means of preserving foods and stabilizing the food supplies, but also a method which can be used to develop different types of shelf-stable foods (Ray 2004). Determining the effect of the relationship between moisture content and $A_w$ on microbial growth provides technical advantages for producing different types of intermediate-moisture ready to eat foods that can be stored over a wide range of temperatures for relatively long periods (Ray 2004). The moisture content also affects the physical and sensory characteristics of foods, such as the rehydration ratio, density, and increase in the volume of instant rice (Prasert and Suwannaporn 2009).

The changes in the moisture content of bibimbap during storage are shown in Fig. 1. According to the Korean Food Standards Code (2013), the failure point of instant foods in terms of moisture content was set to < 8 % (KFDA 2010). The initial moisture content of the kimchi-bibimbap, sea-food-bibimbap, bulgogi-bibimbap, and chicken-bibimbap were 1.05, 1.14, 1.07, and 1.53 %, respectively. After 180 days of storage, the moisture content of the four types of bibimbap decreased. Storage at higher temperature accelerated the decrease of the moisture content.

**Changes in total bacteria during the storage time**

The presence of microorganisms in food may result from contamination of food in the food chain, including cultivation, irrigation, harvesting, processing, transportation, display, and storage. The total bacterial count can be used
as an indicator of the overall microbial quality and sanitary condition of foods. According to the Korean Food Standards Code (2013), the total bacterial counts should be lower than 5 log CFU/g for instant cooked foods (processed foods) that need very simple heating processing or equal processing before intake (KFDA 2010).

The overall microbiological quality changes of four types of bibimbaps are shown in Table 1. During the storage time, the highest total bacterial counts in kimchi-bibimbap, seafood-bibimbap, bulgogi-bibimbap, and chicken-bibimbap were 3.39, 3.18, 3.24, and 3.73 log CFU/g, respectively. Thus, during storage, the total bacterial count of four types of bibimbap at 25, 35, and 45 °C were all lower than 4 log CFU/g.

**Changes in coliforms during the storage time**

The presence of coliforms is an indication of external contamination; thus, the total coliform bacterial count is normally used as an indicator of microbes. In most cases, coliforms themselves are not the cause of disease, but their presence can be used to indicate that other pathogenic bacteria of fecal origin may also be present (Yin and Ding 2008). During 180 days of storage, coliform bacteria were occasionally detected, and the coliform bacterial counts were all lower than 1 log CFU/g.

**Changes in yeast and mold during the storage time**

Fungal biodiversity is one of the most important contributors to mycotoxin contamination on crop plants. Dried products can be infected with fungi and other contaminants either pre-existing on the raw materials, or acquired during drying processes that take place under unhygienic conditions. Further spoilage can take place during processing, transportation, and display. It was reported that Aspergillus, Penicillium, and Fusarium are frequently found in rice (Osman et al. 1999; Park et al. 2005). Similarly, Makun et al. found that Aspergillus, Penicillium, Fusarium, Alternaria, Mucor, and Rhizopus were found in rice. According to Aydin et al. (2011), the mold count of retailed rice ranged from 1 to 4 log CFU/g. Mycotoxins possibly present in moldy rice include aflatoxins, ochratoxin, and fumonisins (Weidenboerner 2000). Mycotoxins are harmful to human health and can decrease food quality leading to economic losses, including loss of commercial value. There is much evidence to indicate that mycotoxins are carcinogens and cause immunosuppression (Kovács 2004). The highest populations of yeast and mold in kimchi-bibimbap, seafood-bibimbap, bulgogi-bibimbap, and chicken-bibimbap during the storage time were 1.13, 1.98, 1.77, and 1.77 log CFU/g respectively, and there was no clear trend between the storage time and storage temperature.

**Changes in Bacillus cereus during the storage time**

Cereulide is a toxin that is produced by Bacillus cereus is hazardous to health because it exerts high liver toxicity, mitochondrial toxicity, lipophilicity, and immunotoxicity (Hoornstra et al. 2003). Uncooked rice grains are usually contaminated with B. cereus spores that are stable to heat and can survive at boiling temperature (Sarrias et al. 2003). The heat-resistant spores can re-germinate, proliferate, and may produce emetic toxin if the contaminated cooked rice is subsequently stored at room temperature for long enough (Gilbert et al. 1974; Johnson et al. 1984). In this study, there was no B. cereus detected in any of the samples during 180 days of storage.

**Determination of overall sensory change**

Evaluation of the changes during the storage time was conducted throughout the 180 days of storage, and the data are summarized in Fig. 2. The overall degree of the sensory scores, which include color, flavor, texture, and appearance, decreased during the storage time. During 180 days of storage, the sensory scores of samples that were stored at 25 and 35 °C were all above the defect limit (four point), whereas the sensory scores of the samples that were stored at 45 °C were lower than the defect limit. In particular, there was an evident development of brown color for the four types of bibimbaps at 45 °C (data not shown). The color change may be affected by the browning reaction between the constituents of the bibimbaps such as amino acid, peptides, and proteins with reducing sugars.

**Shelf life determination**

Herein, the moisture content and acid value were used to estimate the shelf life of bibimbap. The final labeled shelf life was estimated for room temperature and considered based on the safety factor (0.7). The labeled shelf life of the kimchi-bibimbap, seafood-bibimbap, bulgogi-bibimbap, and chicken-bibimbap were 57, 53, 48, 55, and 49 months and all longer than 4 years. A variety of combat rations have shelf life requirements between 12 and 36 months (Barrett and Cardello 2012). The family of Unitized Group Rations (UGR)TM, which includes the UGR Heat & ServeTM, has a shelf life requirement of 36 months at 80 °F (about 26.7 °C), and the Fielded Individual Combat Rations, including the Meal Ready to EatTM, have a shelf life requirement of 36 months at 80 °F (about 26.7 °C) and 6 months at 100 °F (about 37.8 °C) (Barrett Cardello 2012). Based on the present analysis, dried instant bibimbap may be a good choice as a meal replacement food for long-term storage and may be utilized as a leisure food or emergency food for military purposes.
| Sample | Kınıchi-Bibimbap | Seafood-Bibimbap | Bulgogi-Bibimbap | Chicken-Bibimbap |
|--------|------------------|------------------|------------------|------------------|
|        | Total Bacteria (log CFU/g) | Coliforms (log CFU/g) | Fungi (log CFU/g) | Total Bacteria (log CFU/g) | Coliforms (log CFU/g) | Fungi (log CFU/g) | Total Bacteria (log CFU/g) | Coliforms (log CFU/g) | Fungi (log CFU/g) |
| Storage Temp. (°C) | Storage Period (day) | | | | | | | |
| 25 | 0 | 2.80 ± 0.15 | 0.53 ± 0.92 | 0.33 ± 0.58 | 2.55 ± 0.29 | 0.76 ± 0.85 | 0.43 ± 0.58 | 2.21 ± 0.56 | ND | ND | 2.83 ± 0.14 | 1.10 ± 0.17 | 1.08 ± 0.14 |
| 30 | 0 | 2.61 ± 0.23 | ND | 1.91 ± 0.04 | 2.39 ± 0.18 | ND | 1.94 ± 0.06 | 2.72 ± 0.08 | ND | ND | 2.66 ± 0.29 | ND | 1.77 ± 0.13 |
| 30 | 0 | 3.17 ± 0.29 | ND | 1.59 ± 0.35 | 2.83 ± 0.04 | 0.33 ± 0.58 | 1.76 ± 0.29 | 2.86 ± 0.54 | ND | ND | 2.87 ± 0.09 | 0.33 ± 0.58 | 1.48 ± 0.16 |
| 90 | 0 | 3.24 ± 0.27 | ND | 0.55 ± 0.58 | 2.65 ± 0.89 | 0.43 ± 0.75 | 1.13 ± 0.55 | 3.24 ± 0.10 | 0.53 ± 0.92 | 0.67 ± 0.29 | 3.20 ± 0.11 | 0.33 ± 0.58 | 0.33 ± 0.58 |
| 120 | 0 | 3.31 ± 0.37 | 0.54 ± 0.09 | 0.96 ± 0.24 | 2.92 ± 0.03 | 0.17 ± 0.29 | 1.87 ± 0.20 | 2.98 ± 0.33 | 0.15 ± 0.21 | 1.38 ± 0.59 | 3.73 ± 0.07 | ND | 0.85 ± 0.21 |
| 150 | 0 | 3.02 ± 0.54 | ND | 0.75 ± 0.35 | 3.02 ± 0.13 | ND | 1.01 ± 0.29 | 2.44 ± 0.18 | ND | ND | 3.26 ± 0.21 | ND | 0.08 ± 0.14 |
| 180 | 0 | 3.36 ± 0.07 | ND | 0.08 ± 0.14 | 2.83 ± 0.40 | ND | 0.72 ± 0.26 | 3.24 ± 0.22 | ND | ND | 3.53 ± 0.05 | ND | ND |
| 35 | 0 | 2.80 ± 0.15 | 0.53 ± 0.92 | 0.33 ± 0.58 | 2.55 ± 0.29 | 0.76 ± 0.85 | 0.43 ± 0.58 | 2.21 ± 0.56 | ND | ND | 2.83 ± 0.14 | 0.70 ± 0.17 | 1.08 ± 0.14 |
| 30 | 0 | 2.39 ± 0.07 | ND | 1.06 ± 0.36 | 2.46 ± 0.06 | ND | 1.58 ± 0.23 | 2.47 ± 0.34 | ND | ND | 2.75 ± 0.24 | 0.48 ± 1.03 | 1.39 ± 0.44 |
| 90 | 0 | 2.98 ± 0.31 | ND | 1.13 ± 0.38 | 2.48 ± 0.43 | ND | 1.02 ± 0.14 | 2.75 ± 0.37 | ND | ND | 3.16 ± 0.11 | ND | 1.23 ± 0.21 |
| 120 | 0 | 3.01 ± 0.09 | ND | 0.33 ± 0.58 | 3.00 ± 0.20 | ND | 1.79 ± 0.19 | 2.97 ± 0.14 | ND | ND | 3.62 ± 0.07 | ND | 1.08 ± 0.62 |
| 150 | 0 | 3.24 ± 0.20 | ND | 0.38 ± 0.66 | 3.18 ± 0.80 | ND | 0.12 ± 0.20 | 3.21 ± 0.09 | ND | ND | 3.14 ± 0.23 | ND | 0.17 ± 0.29 |
| 180 | 0 | 3.39 ± 0.05 | ND | 0.08 ± 0.14 | 2.48 ± 0.40 | ND | 0.93 ± 0.26 | 3.05 ± 0.28 | ND | ND | 3.26 ± 0.21 | ND | 0.08 ± 0.15 |
| 45 | 0 | 2.80 ± 0.15 | 0.53 ± 0.92 | 0.33 ± 0.58 | 2.55 ± 0.29 | 0.76 ± 0.85 | 0.43 ± 0.58 | 2.21 ± 0.56 | ND | ND | 2.83 ± 0.14 | 0.80 ± 0.17 | 1.08 ± 0.14 |
| 30 | 0 | 2.43 ± 0.35 | ND | 1.25 ± 0.33 | 2.63 ± 0.21 | ND | 1.39 ± 0.22 | 2.36 ± 0.12 | 0.20 ± 0.17 | 1.33 ± 0.05 | 2.47 ± 0.10 | 0.91 ± 0.19 | 1.12 ± 0.43 |
| 90 | 0 | 2.44 ± 0.16 | ND | 0.22 ± 0.38 | 2.68 ± 0.87 | ND | 1.98 ± 0.14 | 2.80 ± 0.19 | ND | ND | 3.39 ± 0.41 | ND | 1.39 ± 0.53 |
| 120 | 0 | 3.51 ± 0.16 | ND | 0.38 ± 0.66 | 2.81 ± 0.38 | ND | 0.80 ± 0.98 | 3.21 ± 0.12 | ND | ND | 3.52 ± 0.04 | ND | 0.33 ± 0.29 |
| 150 | 0 | 3.39 ± 0.05 | ND | 1.99 ± 0.83 | 2.58 ± 0.47 | ND | 1.00 ± 0.29 | 2.89 ± 0.21 | ND | ND | 3.23 ± 0.22 | ND | ND |
| 180 | 0 | 3.02 ± 0.05 | ND | 0.30 ± 0.05 | 2.86 ± 0.27 | 0.66 ± 0.72 | ND | 3.35 ± 0.08 | ND | ND | 3.37 ± 0.22 | ND | ND |

ND (not detected) <1.0 log CFU/g
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Fig. 2 Changes of overall sensory characteristics for four types of Bibimbap during storage. (A) Kimchi-Bibimbap, (B) Seafood-Bibimbap, (C) Bulgogi-Bibimbap, and (D) Chicken-Bibimbap stored at 25, 35, and 45 °C with different storage time.