pISSN 1229-1153 / eISSN 2465-9223 *J. Food Hyg. Saf.*
Vol. 36, No. 5, pp. 382~391 (2021)
https://doi.org/10.13103/JFHS.2021.36.5.382

**Journal of Food Hygiene and Safety**
Available online at http://www.foodhygiene.or.kr

# Microbial Contamination Levels of Red Pepper Powder Purchased in Gyeonggi Province and Changes in Characteristics According to the Storage Method

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(Received July 7, 2021/Revised September 8, 2021/Accepted September 15, 2021)

**ABSTRACT -** The purpose of this study was to investigate the microbial contamination of red pepper powder distributed within Gyeonggi province in 2020 according to the place of purchase, the country of origin, and whether the HACCP certification and sterilization were conducted, and to evaluate the change of quality according to the storage method. Upon collecting and analyzing 100 samples, *Bacillus cereus* was detected in 3 cases (2 cases in large supermarkets and 1 case in traditional markets) and *Clostridium perfringens* in 27 cases (9 cases in large supermarkets and 18 cases in traditional markets). The levels of the total aerobic bacteria were not significantly different between the red pepper powder purchased from large supermarkets and traditional markets. However, the frequency of red pepper powder exceeding 7 log CFU/g of total aerobic bacteria was higher in traditional markets than in large supermarkets. Microbial quality was not significantly different regardless of the storage temperature (30°C, 4°C, -20°C) and the packaging method (zipper bag and clean bag) after 7 months of purchase. However, the moisture contents and ASTA color value of red pepper powder stored at 30°C decreased remarkably after 3 months of storage. It is desirable to store red pepper powder in a refrigerator or freezer in order to maintain its quality during long-term storage.

**Key words :** Red pepper powder, Long-term storage, Microbial growth, Quality change, Storage method

Red pepper (*Capsicum annuum L.*), native to the Amazon River in South America, is a perennial herb belonging to the family Solanaceae such as pepper plants. It was introduced into East Asia in the late 16th century by Portuguese traders[1]. The average yield of pepper is 248 kg/10 ha and domestic products are preferred to the extent that domestic products account for 59.3% of dried red pepper[2]. Red pepper powder has become an important seasoning indispensable to Korean diet, widely used in gochujang, kimchi, and salted seafood due to its unique spicy taste and red color[3]. The red pepper powder is particularly not only eaten directly without heating in the foods such as muchim but also shown high consumption in processed foods such as sauces and ramen. It has been also known to consume 2 kg of red pepper powder per person per year[4].

Red peppers are generally harvested between August and October. Some of them are used for raw food, and most of them are consumed as dried products, except for Dadaegi, which is made by crushing red pepper and adding spices such as garlic and sugar[5]. Since storage properties are low due to their high moisture contents, they are usually stored in the form of crushed red pepper powder or stored as dried red peppers which are grounded into powder whenever needed. Red pepper powder is highly susceptible to microbial contamination during drying, milling, and distribution after harvest of raw red pepper, and there are differences in storage methods for each household after purchase. Proper management is required for long-term storage because red pepper powder might have different physicochemical and microbiological qualities depending on storage methods such as temperature and humidity[6]. It has been known that the red color of red pepper powder was greatly affected by storage temperature, light and packaging conditions, and water activity particularly affected non-enzymatic browning reaction, fat rancidity, and microbial growth. Bacterial growth is active at high water activity (over 0.87) and microorganisms including yeast and mold could grow over 0.80 water activity. However, even for a dried product with a low water activity (below 0.80), the amount of

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moisture absorbed might increase due to the difference in the water vapor pressure between the surrounding and the food depending on storage conditions such as storage temperature and humidity. This might change to the environment where microorganisms could easily grow[7].

Hazard Analysis and Critical Control Point (HACCP) system refers to a system that scientifically identifies the risk factors that might cause physical, chemical and biological hazards in the entire process, including warehousing, storage of raw/subsidiary materials, pre-treatment, manufacturing, processing and storage from the food production to final consumption, and intensively manages each process in order to prevent the occurrence of hazardous factors in advance. Since the food safety management regulations for food types such as fish cakes, frozen foods (pizza, dumplings and noodles), frozen desserts and retort foods were established in 2003, Korea has been expanding the subject of mandatory HACCP application yearly[8]. Among the hazards that could occur in red pepper powder, biological hazards include mold and foodborne pathogens such as pathogenic *Escherichia coli* (*E. coli*) and *Staphylococcus aureus*. Chemical hazards include heavy metals and pesticide residues, and physical hazards include iron powder, vinyl and string[9]. Most companies are small and do not have systematic hygienic management, except for the large red pepper powder manufacturers that established some HACCP systems.

The purpose of this study was to investigate microbial contamination of red pepper powder according to the place of purchase, the country of origin, application of HACCP system and sterilization process in Gyeonggi province in 2020 and suggest the correct storage method through quality evaluation to the storage method and period of red pepper powder.

## Materials and Methods

### Samples

A total of 100 samples of red pepper powder in Gyeonggi Province was collected from February to November in 2020 and microbial contamination was investigated. Depending on the place of purchase and the country of origin, it was divided in to large supermarket (37 domestic and 13 imported) and traditional market (25 domestic and 25 imported), and all sampling and pre-treatment procedure were performed under aseptic conditions in a clean room.

### Analysis of hygienic indicators

At first, 25 g of the sample and 225 mL of sterile saline solution were put into a sterile stomacher bag and homogenized with the stomacher (Seward, Worthing, UK) to be used as a test solution. If necessary, dilution solution for each step such as 10 times, 100 times and 1,000 times was prepared and the prepared stepwise test solution was immediately used for the experiment.

Total aerobic bacteria and *E. coli* were analyzed according to '8. General tests 4. Microbiological Test Methods' in the Korean Food Standard Codex[10]. One mL of the test solution and 1 mL of each stepwise dilution solution were inoculated into two or more dry rehydratable film media (3M Petrifilm AC; 3M, St Paul, MN, USA), followed by incubation at 35±1°C for 48±2 hours to calculate the total aerobic bacteria. The film that produced 15 to 300 red colonies per one dry film mediums was selected and calculated. The number of the total aerobic bacteria was calculated by multiplying the average number of colonies by the dilution factor.

One mL of the test solution and 1 mL of each stepwise dilution solution were inoculated into two or more dry rehydratable film media (3M Petrifilm EC; 3M, St Paul, MN, USA), followed by incubation at 35±1°C for 48±2 hours to calculate *E. coli*. Among the blue colonies formed as a result, the number of colonies with bubbles around them was calculated by multiplying the average number of colonies by the dilution factor.

### Analysis of foodborne pathogens

Analysis of foodborne pathogens for 100 samples was conducted according to the 'Food Poisoning Screening Method' specified in the 'Methods for Studies on Bacterial Factors of Food Poisoning'[11]. Twenty five g of the sample and 225 mL of TSB solution (Tryptic soy broth; Oxoid, Hampshire, UK) were put into a sterile stomacher bag and homogenized with the stomacher, followed by enrichment culture at 36°C for 24 hours. At the same time, 10 g of the sample and 90 mL of sterile saline solution were put into a sterile stomacher bag and homogenized with the stomacher for sample solution. One mL of the sample solution was inoculated into a cooked meat medium (Oxoid, Hampshire, UK), followed by anaerobic culture at 37°C for 24 hours. After 1 mL of each culture was centrifuged for 3 minutes at 13,000 rpm, the supernatant was discarded, and 200 μL of sterile distilled water was added. After boiling for 10 minutes at 100°C, the suspension was centrifuged for 3 minutes at 13,000 rpm. The obtained supernatant was used as a template DNA for Polymerase Chain Reaction (PCR).

PowerChek™ Gram Positive Multiplex Detection Kit (Kogen biotech, Seoul, Korea), PowerChek™ Gram Negative Multiplex Detection Kit (Kogen biotech), PowerChek™ Diarrheal *E. coli* 8-plex Detection Kit (Kogen biotech) and PowerChek™ *Vibrio vulnificus* Detection Kit (Kogen biotech) were used to identify specific genes of 12 types of foodborne pathogens. After the PCR reaction was performed using the kit by the method suggested by the manufacturer, the final product was confirmed using QIAxcel DNA High

Resolution kit (QIAGEN, Hilden, Germany) and QIAxcel (QIAGEN). The strain and specific gene conditions of each kit were shown in Table 1. As a result of PCR analysis, the foodborne pathogens with specific genes were isolated and confirmed according to the test method listed in the Korean Food Standard Codex[10]. Identification of the bacteria was used VITEK2[12] (Biomerieux, Paris, France). A sufficient number of colonies purely isolated were suspended into 3 mL of sterile saline in the clear test tube. The turbidity was adjusted as follows: GN compact (0.50-0.63), GP compact (0.50-0.63), BCL compact (1.80-2.20) and ANC compact (2.70-3.30). The suspension was loaded into a cassette with each compact. The cassette was inserted into the filler. When filling was completed, the cassette was put into the Loader. The growth and metabolism of bacteria were taken inside the microwell of the compact, and the change in these chemical reactions was measured every 15 minutes by VITEK 2 COMPACT program.

### *Clostridium perfringens* count

For *Clostridium perfringens* (*C. perfringens*) count, 1 mL of the test solution and 1 mL of each stepwise dilution solution were aseptically dispensed into two or more sterile petri dishes. Ten to fifteen mL of TSC agar medium (Tryptose-Sulfite-Cycloserine Agar; Oxoid, Hampshire, UK) maintained at 43-45°C without egg yolk was added and mixed well by turning left and right, and then solidified. After adding 10 mL of the same medium on the coagulated medium and overlapping it, anaerobic culture was performed at 35-37°C for 24±2 hours. Plates in which no more than 150 typical black colonies were identified were taken and counted. Five or more typical colonies from the counted plate were selected and inoculated on nutrient agar (Difco, New York, NY, USA) at 35-37°C for 18-24 hours in anaerobic culture. The bacteria identified as gram-positive bacilli was tested by biochemical test using VITEK 2 with ANC VITEK 2 compact (Biomerieux). It was calculated by multiplying the average number of colonies of the number of confirmed bacteria by the dilution factors.

### *Bacillus cereus* count

For *Bacillus cereus* (*B. cereus*) count, 3 sheets of MYP agar (Mannitol Egg Yolk Polymyxin Agar; Biomerieux, Paris, France) were spread so that the total inoculation solution of the test solution and stepwise dilution became 1 mL, and incubated at 30°C for 24±2 hours. Pink colonies with cloudy rings that produced lecithinase were selected and counted. Five or more typical colonies from the counted plate were selected and inoculated on nutrient agar at 30°C for 18-24 hours. The bacteria identified as gram-positive bacilli was tested by biochemical test using VITEK 2 with BCL VITEK 2 compact (Biomerieux). It was calculated by

**Table 1.** Specific genes of foodborne pathogens for multiplex PCR kit

| Multiplex PCR kit | Pathogenes | Target gene |
|---|---|---|
| PowerChek™ Gram Positive Multiplex Detection Kit | *Listeria monocytogenes* | *prfA* |
| | *Clostridium perfringens* | *cpa, cpe* |
| | *Bacillus cereus* | *groEL* |
| | *Staphylococcus aureus* | *femA* |
| PowerChek™ Gram Negative Multiplex Detection Kit | *Salmonella* spp. | *invA* |
| | *Yersinia enterocolitica* | *inv* |
| | *Vibrio parahaemolyticus* | *toxR* |
| | *Vibrio cholerae* | *ctx* |
| | *Campylobacter jejuni* | *hipO* |
| | *Campylobacter coli* | *lysC* |
| | *Shigella* spp. | *ipaH* |
| PowerChek™ Diarrheal *Escherichia coli* Multiplex Detection Kit | Enterohaemorrhagic *Escherichia coli* (EHEC) | *stx1, stx2* |
| | Enterotoxigenic *Escherichia coli* (ETEC) | *ST (STh/STp), LT* |
| | Enteroinvasive *Escherichia coli* (EIEC) | *ipaH* |
| | Enteroaggregative *Escherichia coli* (EAEC) | *aggR* |
| | Enteropathogenic *Escherichia coli* (EPEC) | *eaeA, bfpA* |
| PowerChek™ *Vibrio vulnificus* Detection Kit | *Vibrio vulnificus* | *vvh* |

multiplying the average number of colonies of the number of confirmed bacteria by the dilution factors.

### Yeast and mold count

One mL of the test solution and 1 mL of each stepwise dilution solution were inoculated into two or more PDA agar (Potato Dextrose Agar; Difco) by incubation at 35±1ºC for 5 to 7 days. Yeast and mold count was calculated by multiplying the average number of colonies by the dilution factor.

### Analysis of changes in the quality characteristics according to the storage method

In order to analyze the quality characteristics according to the storage temperature and the packaging method, 800 g of red pepper powder purchased from the large super market was placed in a large Ziploc bag (Ziploc, Bangkok, Thailand) and a clean bag (Cleanwrap, Gimhe, Korea). Freezer storage of each samples was stored in a -20ºC freezer (F-A243GM, LG Electronics, Seoul, Korea), refrigerated storage was stored in a 4ºC refrigerator (CA-G17DZ, LG Electronics), and high temperature storage was stored in a 30°C incubator (MIR-154, Sanyo, Osaka, Japan). Hygienic indicators (total aerobic bacteria and *E. coli.*), *C. perfringens* count, yeast and mold count, moisture content, and ASTA color value were measured from the moment of purchase until 7 months after storage.

### Measurement of moisture content

The moisture content of red pepper powder was measured using an automatic moisture analyzer (Moisture Analyzer, MA-100, Sartorius, Goettingen, Germany).

### Measurement of American Spice Trade Association (ASTA) color value

For the measurement of ASTA color value, 0.1 g of the sample was added to 100 mL of acetone. After standing in the darkroom for 16 hours, the absorbance was measured at 460 nm using a UV/Vis spectrophotometer (Lambda 465; PelkinElmer, Wellesley, MA, USA), and calculated using the following equation.

$$\text{ASTA color value} = \frac{\text{absorbance} \times 16.4}{\text{sample weight (g)}}$$

### Statistical analysis

All the data were obtained by the tests conducted in triplicate. In this study, microbial count was represented as log CFU/g. Means and standard deviations were calculated through statistical processing. Results were subject to t-test and one-way analysis of variance (ANOVA) with Duncan's new multiple rage test at significance level of $P<0.05$ using SPSS software 19 (SPSS Inc, Chicago, IL, USA). In addition, a chi-square test ($\chi^2$-test) was performed to compare the frequencies between each item.

## Results and Discussion

### Microbial contamination in commercial red pepper powder

#### Analysis of hygienic indicators of commercial red pepper powder

Total aerobic bacterial count for 100 samples of red pepper powder in Gyeonggi Province was showed in Table 2. The levels of the total aerobic bacteria in the collected red pepper powder were detected in the range of 4.75-8.74 log CFU/g. The average detection levels of the total aerobic bacteria in red pepper powder purchased from large super markets (6.49 log CFU/g) were lower than that purchased from traditional markets (6.60 log CFU/g), but there was not significantly different. However, the frequency of red pepper powder exceeding 7 log CFU/g in the total aerobic bacteria, indicating the entry into the decay stage[13], was higher in the traditional markets (13 out of 50) than in large super markets (8 out of 50). The red pepper powder in traditional market was commonly sold in bulk with unpacked condition. Even though it was covered with a transparent lid, the red pepper powder was frequently exposed to the external environment because they were scooped out whenever purchased. The possibility of cross-contamination by the seller was also high, so it was considered that the seller should pay more attention to hygienic quality control.

According to the country of origin, the average detection levels of the total aerobic bacteria in domestic red pepper powder (6.62 log CFU/g) were higher than those in imported red pepper powder (6.43 log CFU/g), but there was not significantly different. Lee et al.[14] also reported that there was not significantly different in the levels of the total aerobic bacteria as a result of evaluating the microbial quality of red pepper powder according to the country of origin. According to application of HACCP system, the average detection levels of the total aerobic bacteria in red pepper powder with HACCP system (6.45 log CFU/g) were lower than those without HACCP system (6.63 log CFU/g), but there was not significantly different. According to application of sterilization process, the average detection levels of the total aerobic bacteria in red pepper powder with sterilization process (6.41 log CFU/g) was lower than those without sterilization process (6.63 log CFU/g), but there was not significantly different. UV irradiation for a short period of time was typically used as the sterilization method in the production of the red pepper powder with HACCP system[15,16]. UV irradiation was expected to reduce microorganisms through damage to the DNA

**Table 2.** Contamination rate of total aerobic bacteria in red pepper powder

| Variables | Total aerobic bacteria contents (log CFU/g) | | | | | |
|---|---|---|---|---|---|---|
| | <6 | 6-7 | >7 | Min | Max | Mean±SD |
| The place of purchase | | | | | | |
| Large supermarket (n=50) | 9[1)] | 33 | 8 | 4.75 | 7.9 | 6.49±0.70[2)] |
| Traditional market (n=50) | 7 | 30 | 13 | 5.18 | 8.74 | 6.60±0.70 |
| The country of origin | | | | | | |
| Domestic (n=62) | 9 | 39 | 14 | 4.75 | 8.74 | 6.62±0.71 |
| Imported (n=38) | 7 | 24 | 7 | 5.04 | 7.52 | 6.43±0.68 |
| Application of HACCP | | | | | | |
| Yes (n=46) | 9 | 30 | 7 | 4.75 | 7.9 | 6.45±0.70 |
| No (n=54) | 7 | 33 | 14 | 5.18 | 8.74 | 6.63±0.70 |
| Sterilization | | | | | | |
| Yes (n=38) | 9 | 23 | 6 | 4.75 | 7.9 | 6.41±0.74 |
| No (n=62) | 7 | 40 | 15 | 5.18 | 8.74 | 6.63±0.66 |

[1)]Number of samples.
[2)]Total aerobic bacteria in the same variables was not significantly different ($P$>0.05; t-test).

structure. Since it could only act on surface sterilization due to properties of the energy source, the sterilization effect was limited. Choi et al.[17)] also reported that UV irradiation showed a microbial reduction effect around 1 log CFU/g, and the effect was not remarkable. *E. coli* was not detected in all collected red pepper powder.

### Analysis of foodborne pathogens of commercial red pepper powder

Foodborne pathogens for 100 samples of the red pepper powder in Gyeonggi Province were showed in Table 3. *B. cereus* was detected in 3 cases, *C. perfringens* was detected in 27 cases, and other foodborne pathogens were not detected. *B. cereus* was detected in 2 samples (domestic-1, imported-1) purchased from large supermarkets, and 1 sample (domestic-1) purchased from traditional market. Van Doren et al.[18)] reported that a mass outbreak of food poisoning caused by dried peppers contaminated with *B. cereus* had appeared in Canada, Germany and France. However, Oh et al.[19)] reported that the detection rate of *B. cereus* was high in the raw material and washing stage, but the detection rate was greatly reduced in the samples obtained at the later stage of processing such as milling and metal detection. This study also showed that the detection rate of *B. cereus* in the final product was only 3%. *B. cereus* count was less than 190 CFU/g, which was suitable for all standard and specification of *B. cereus* of the Korean Food Standards Codex: *B. cereus* ≤ 1,000 CFU/g. The possibility of food poisoning by *B. cereus* in red pepper powder was very low because *B. cereus* might cause food poisoning when there were more than $10^3$-$10^4$ CFU/g in food[20)].

**Table 3.** Foodborne pathogens in red pepper powder

| Foodborne pathogens | Detection No. | Range |
|---|---|---|
| *Bacillus cereus* | 3 | 0-190[1)] |
| *Clostridium perfringens* | 27 | 0-60 |
| Pathogenic *Escherichia coli* | N.D.[2)] | - |
| *Listeria monocytogenes* | N.D. | - |
| *Staphylococcus aureus* | N.D. | - |
| *Salmonella* spp. | N.D. | - |
| *Yersinia enterocolitica* | N.D. | - |
| *Campylobacter jejuni/coli* | N.D. | - |
| *Vibrio parahaemolyticus* | N.D. | - |
| *Vibrio cholerae* | N.D. | - |
| *Vibrio vulnificus* | N.D. | - |
| *Shigella* spp | N.D. | - |
| Total | 30 | - |

[1)]Units : CFU/g.
[2)]N.D. : not detected.

Table 4 showed the detection rate of *C. perfringens* according to the characteristics of collected red pepper powder. According to the place of purchase, the detection rate of *C. perfringens* in red pepper powder purchased from traditional markets (36%) was significantly higher than that from large supermarkets (18%) ($P$<0.05). According to the country of origin, the detection rate of *C. perfringens* in imported red pepper powder (42.1%) was significantly

**Table 4.** Prevalence of *Clostridium perfringens* in red pepper powder

| Variables | *Clostridium perfringens* | | |
|---|---|---|---|
| | Presence (n=27) | Absence (n=73) | $\chi^2$ |
| The place of purchase | | | |
| Large supermarket (n=50) | 9(18.0)[1)] | 41(82.0) | 4.11* |
| Traditional market (n=50) | 18(36.0) | 32(64.0) | |
| The country of origin | | | |
| Domestic (n=62) | 11(17.7) | 51(82.3) | 7.1* |
| Imported (n=38) | 16(42.1) | 22(57.9) | |
| Application of HACCP | | | |
| Yes (n=46) | 9(19.6) | 37(80.4) | 2.39 |
| No (n=54) | 18(33.3) | 36(66.7) | |
| Sterilization | | | |
| Yes (n=38) | 5(13.2) | 33(86.8) | 5.96* |
| No (n=62) | 22(35.5) | 40(64.5) | |

[1)]Number of samples (%).
*$P$<0.05 by chi-square test.

higher than that in domestic red pepper powder (17.7%) ($P$<0.05).

According to the application of HACCP system, the detection rate of *C. perfringens* in red pepper powder produced without HACCP system (33.3%) was higher than that produced with HACCP system (19.6%), but there was not significantly different. It was noteworthy that 46 out of 50 red pepper powder purchased from the large super markets were HACCP certified products.

According to the sterilization process, the detection rate of *C. perfringens* in red pepper powder produced without sterilization process (35.5%) was significantly higher than that with sterilization process (13.2%) ($P$<0.05). Most red pepper powers sold in large supermarkets were HACCP certified, and it was distributed in the form of final products through an automated production system. On the other hand, red pepper powders sold in traditional markets were produced in a small-scale form, and were not packaged or

**Table 5.** Contamination rate of yeast and molds in red pepper powder

| Variables | Yeast and molds (log CFU/g) | | | | | |
|---|---|---|---|---|---|---|
| | <6 | 6-7 | >7 | Min. | Max. | Mean±SD |
| The place of purchase | | | | | | |
| Large supermarket (n=50) | 16[1)] | 32 | 2 | 4.80 | 7.32 | 6.25±0.60[2)] |
| Traditional market (n=50) | 18 | 24 | 8 | 4.40 | 8.45 | 6.26±0.75 |
| The country of origin | | | | | | |
| Domestic (n=62) | 21 | 37 | 4 | 4.72 | 8.45 | 6.25±0.67 |
| Imported (n=38) | 13 | 19 | 6 | 4.40 | 7.2 | 6.27±0.68 |
| Application of HACCP | | | | | | |
| Yes (n=46) | 15 | 30 | 1 | 4.80 | 7.32 | 6.22±0.59 |
| No (n=54) | 19 | 26 | 9 | 4.40 | 8.45 | 6.29±0.74 |
| Sterilization | | | | | | |
| Yes (n=38) | 13 | 24 | 1 | 4.80 | 7.32 | 6.21±0.61 |
| No (n=62) | 21 | 32 | 9 | 4.40 | 8.45 | 6.29±0.71 |

[1)]Number of samples.
[2)]Yeast and molds in the same variables was not significantly different ($P$>0.05; t-test).

scooped out whenever purchased. *C. perfringens* count was less than 60 CFU/g, which was suitable for all standard and specification of *C. perfringens* of the Korean Food Standards Codex: n=5, c=2, m=100, M=1,000.

### Yeast and mold count in red pepper powder

Yeast and mold count for 100 samples of red pepper powder in Gyeonggi Province was showed in Table 5. The levels of yeast and mold in the collected red pepper powder were detected in the range of 4.40-8.45 log CFU/g. The average detection levels of yeast and mold in red pepper powder were not significantly different regardless of the place of purchase, the country of origin, application of HACCP system and sterilization process. Jung et al.[21] also reported that the levels of yeast and mold were detected $4.95\times10^2$-$3.19\times10^6$ CFU/g (2.70-6.50 log CFU/g) in commercial red pepper powder.

### Changes in the quality characteristics of red pepper powder according to the storage method

#### Changes in microbial quality of red pepper powder

Microbial quality was not significantly different regardless of the storage temperature (30°C, 4°C, -20°C) and the packaging method (zipper bag and clean bag) (data not shown). The initial value of the total aerobic bacteria at the moment of purchase was 7.01 log CFU/g, and there was little change in the number of the total aerobic bacteria according to the storage temperature and the packaging method from the moment of purchase until 7 months after storage. In addition, *E. coli* was not detected from the moment of purchase until 7 months after storage. The changes in *C. perfringens* count according to the storage temperature and the packaging method did not show a significant difference as the storage period increased. The initial value of yeast and mold count at the moment of purchase was 6.64 log CFU/g, and there was little change in yeast and mold count according to the storage temperature and the packaging method from the moment of purchase until 7 months after storage. In spite of dried foods, bacteria or molds that survived during the drying process could remain alive for months or years[22]. Kim et al.[23] reported that as a result of storage under distribution and accelerated storage conditions of powdered soup, the number of the total aerobic bacteria did not significantly increase even if the storage period was extended due to low water activity. The water activity of red pepper powder was known to be 0.526-0.676, and it was known to be stored for a long time at room temperature even after opening due to its low water activity. However, the management of temperature and humidity was required for dry powder food when stored after opening because exposure to high relative humidity could significantly affect the water activity and microbiological quality of the food[5,22].

#### Changes in physicochemical quality in red pepper powder

The change in moisture content according to the storage temperature and the packaging method of red pepper powder was shown in Fig. 1. The initial moisture content of red pepper powder was 7.05%. As the storage period became longer, moisture content of red pepper powder changed little in the case of refrigerated and frozen storage. However, the moisture content of red pepper powder stored at 30°C showed a tendency to decrease as the storage period increased. After 3 months of storage, the moisture content of red pepper powder remarkably decreased. After 7 months of storage, the moisture content of red pepper powder stored in a zipper bag decreased to 5.16%, and the moisture content of red pepper powder stored in a clean bag decreased to 3.71%. Lee et al.[24] also showed that the moisture content decreased as the storage period increased, when red pepper powder was stored for 1 year. The change of the ASTA color value according to the storage temperature and packaging method of red pepper powder was shown in Fig. 2. The change of the ASTA color value according to the storage temperature and storage container of red pepper powder is shown in Fig. 2. The initial ASTA color value of red pepper powder was 117.94. As the storage period became longer, the change in the ASTA color value was little in the case of refrigerated and frozen storage. On the other hand, the ASTA color value of red pepper powder stored at 30°C significantly decreased as the storage period increased. On the other hand, the ASTA color value of red pepper powder stored at 30°C showed a tendency to decrease significantly as the storage period increased. After 7 months of storage, the ASTA color value of red pepper powder stored in a zipper bag decreased to 61.89, and the ASTA color value stored in a clean bag decreased to 47.27. The red pigment of red pepper powder was capsanthin, which accounted for the most at 35%, and in addition, β-carotene 10%, violaxanthin 10%, cryptoxanthin 6%, etc. were included[25]. The auto-oxidation of red pepper pigment was accelerated as the temperature increased. Kim and Lee[26] reported that auto-oxidation of carotenoid compounds was promoted as the temperature increased and it was thought to be due to the fact that it caused pigment destruction. As the storage period of red pepper powder stored at 30°C was prolonged, the red pigment of red pepper powder was decreased due to auto-oxidation, which was thought to lower the ASTA color value. The reduction rate in ASTA color value of red pepper powder stored in a clean bag was statistically significantly

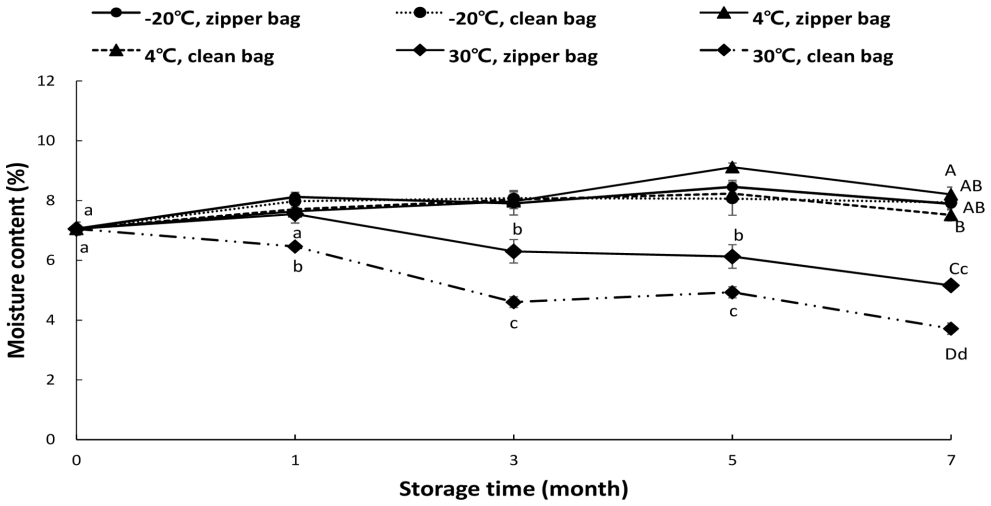


**Fig. 1.** Change in moisture content of red pepper powder stored with different packaging method at -20, 4 and 30°C for 7 months.
A-D: Different letters within the storage period are significantly different at $P<0.05$ by Duncan's multiple range test.
a-d: Different letters within the storage temperature are significantly different at $P<0.05$ by Duncan's multiple range test.

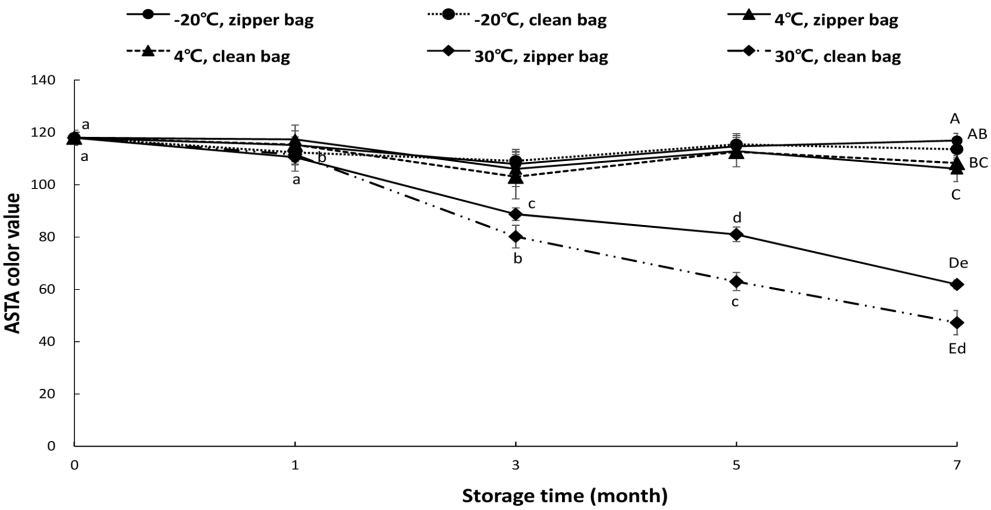


**Fig. 2.** Change in ASTA color value of red pepper powder stored with different packaging method at -20, 4 and 30°C for 7 months.
A-E: Different letters within the storage period are significantly different at $P<0.05$ by Duncan's multiple range test.
a-d: Different letters within the storage temperature are significantly different at $P<0.05$ by Duncan's multiple range test.

higher than that in a zipper bag ($P<0.05$). The moisture could protect carotenoids from oxidation by influencing the free radicals generated during the oxidation process of the pigment[27]. As a results, it was thought that the reduction rate of the ASTA color value of red pepper powder stored in a zipper bag with a high moisture content was lower than that in a clean bag. Proper management such as sealing and freezing/refrigeration was required in order to maintain the physicochemical quality of red pepper powder.

## 국문요약

2020년 경기도내 유통 중인 고춧가루의 미생물 오염도를 구매 장소, 원산지, HACCP 및 살균 여부에 따라 조사하고, 보관방법에 따른 품질 변화를 연구하였다. 유통 중인 고춧가루 100건을 수거하여 검사한 결과 3건(대형마트 2건, 재래시장 1건)에서 *Bacillus cereus*가 검출되었으며, 27건(대형마트 9건, 재래시장 18건)에서 *Clostridium perfringens*가 검출되었다. 대형마트와 재래시장에서 수거한 고춧가루의 일반세균수 검출량은 통계적으로 유의적인 차이는 없었으나 7 log CFU/g을 초과하는 고춧가루의 수는 대형마트보다 재래시장이 더 많았다. 보관온도(30°C, 4°C, -20°C)와 보관용기(지퍼백, 비닐봉투)에 따라 7개월까지 저장 실험한 결과, 저장 기간에 따라 미생물학적 품질에는 큰 차이가 나타나지 않았다. 그러나 30°C에 저장한

고춧가루의 수분함량 및 ASTA color value는 저장 3개월 이후 크게 감소하였다. 따라서 고춧가루의 장기 보관 시 품질을 유지하기 위해서는 냉장고 또는 냉동고에 보관하는 것이 바람직하다고 생각된다.

## Conflict of interests

The authors declare no potential conflict of interest.

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## References

1. Govindarajan, V.S., Salzer, U.J., Capsicum-production, technology, chemistry, and quality part 1: History, botany, cultivation, and primary processing. *Critical Reviews in Food Science & Nutrition*, **22**, 109-176 (1985).
2. Kang, S.R., Cho, W.H., Na, M.H., Choi, D.W., Consideration of Environmental Factors and Growth Factors and Watering Facilities for Prediction of Pepper Production. *JKDAS,* **22**, 177-188 (2020)
3. Ku, K.H., Kim, N.Y., Park, J.B., Park, W.S., Characteristics of color and pungency in the red pepper for Kimchi. *Korean J. Food Sci. Technol.*, **33**, 231-237 (2001).
4. Shin, H.H., Lee, S.R., Attempts to estimate the use level of red pepper in kimchi and kochujang (hot soy paste). *Korean J. Food Sci. Technol.*, **23**, 301-305 (1991).
5. Hwang, S.Y., An, Y.H., Shin, G.M., A study on the quality of commercial red pepper powder, *Korean J. Food & Nutr.*, **14**, 424-428 (2001).
6. Byun, M.W., Yook, H.S., Kwon, J.H., Kim, J.O., Improvement of hygienic quality and long-term storage of dried red pepper by gamma irradiation, *Korean J. Food Sci. Technol.*, **28**, 482-489 (1996).
7. Ko, J.W., Lee, W.Y., Lee, J.H., Ha, Y.S., Choi, Y.H., Absorption characteristics of dried shiitake mushroom powder using different drying methods, *Korean J. Food Sci. Technol.,* **31**, 128-137 (1999).
8. MFDS, (2021, January 4). Development of General Model for Hazards Analysis at a Manufacturing Process. Retrieved from https://scienceon.kisti.re.kr/srch/selectPORSrchReport.do?cn=TRKO201000014812
9. MFDS, (2021, January 4). Red pepper powder HACCP management for small producer. Retrieved from https://mfds.go.kr/brd/m_584/view.do?seq=11932&srchFr=&srchTo=&srchWord=&srchTp=&itm_seq_1=0&itm_seq_2=0&multi_itm_seq=0&company_cd=&company_nm=&page=5
10. MFDS, (2021, January 4), Korean Food Standard Code. Retrieved from: https://www.foodsafetykorea.go.kr/foodcode/01_02.jsp?idx=263
11. MFDS, (2021, January 4), Food Poisoning Screening Method. Retrieved from http://www.nifds.go.kr/brd/m_18/view.do?seq=12490
12. Pincus, D.H., Microbial identification using the bioMérieux Vitek® 2 system. Encyclopedia of Rapid Microbiological Methods. *Bethesda*, *MD: Parenteral Drug Association*, 1-32 (2006)
13. Gang, S.T., Yoon, J.Y., 2004, Food microbiology, Hyungseul, Seoul, pp. 414-430
14. Lee, H.J., Kim, G.R., Park, K.H., Kim, J.S., Kwon, J.H., Effect of electron beam irradiation on microbiological and physicochemical properties of dried red pepper powders of different origin. *Korean J. Food Sci. Technol.*, **47**, 13-19 (2015).
15. Park, S.B., Kwon, S.C., Microbiological hazard analysis for HACCP system application to red pepper powder. *Journal of the Korea Academia-Industrial Cooperation Society*, **16**, 2602-2608 (2015).
16. Song, Y.J., Park, S.W., Chun, S.C., Choi, M.J., Chung, K.C., Lee, S.K., Efficient treatment methods for reducing *Escherichia coli* populations in commercially-available red pepper powder in Korea. *J. Korean Soc. Food Sci. Nutr.*, **41**, 875-880 (2012).
17. Choi, J.B., Cheon, H.S., Chung, M.S., Cho, W.I., Microbial reduction effect of steam heating, UV irradiation, and gamma irradiation on red pepper powder. *Korean J. Food Sci. Technol.*, **52**, 177-182 (2020).
18. Van Doren, J.M., Neil, K.P., Parish, M., Gieraltowski, L., Gould, L.H., and Gombas, K.L., Foodborne illness outbreaks from microbial contaminants in spices, 1973–2010. *Food microbiology*, **36**, 456-464 (2013).
19. Oh, S.W., Koo, M.S., Kim, H.J., Contamination patterns and molecular typing of *Bacillus cereus* in red pepper powder processing. *Appl. Biological Chemistry*, **55**, 127-131 (2012).
20. Andersson, A., Ronner, U., Granum, P.E., What problems does the food industry have with the spore-forming pathogens *Bacillus cereus* and *Clostridium perfringens*?. *Int. J. Food Microbiol.*, **28**, 145-155 (1995).
21. Jeong, M.S., Ahn, J.J., Akram, K., Kim, G.R., Im, J.G., Kwon, J.H., Microbiological and physicochemical quality characterization of commercial red pepper powders. *J. Food Hyg. Saf.*, **28**, 1-6 (2013).
22. Kim, J.Y., Bae, Y.M., Hyun, J.E., Kim, E.M., Kim, J.C., Lee, S.Y., Microbiological quality of dried and powdered foods stored at various relative humidities. *J. East Asian Soc. Diet. Life*, **27**, 576-582 (2017).
23. Kim, K.H., Lee, H.J., Lee, S., Kim, H.J., Lee, E.Y., Kim,

N.Y., Yook, H.S., Microbiological.sensorial characteristics of gamma irradiated-commercial powdery soup during accelerated storage. *J. Korean Soc. Food Sci. Nutr.*, **35**, 1064-1069 (2006).
24. Lee, S.M., Park, J.B., Kim, S.A., Hwang, I.K., The changes of capsaicinoids and ASTA color value of red pepper powder packed with different packaging materials. *Korean J. Food Cook. Sci.*, **19**, 439-446 (2003).
25. Shin, H.H., Lee, S.R., Quality attributes of Korean red pepper according to cultivars and growing areas. *Korean J. Food Sci. Technol.*, **23**, 296-300 (1991).
26. Kim, J.O, Lee, K.H., Effect of temperature on color and color-preference of industry-produced Kochujang during storage. *J. Korean Soc. Food Nutr*., **23,** 641-646 (1994).
27. Labuza, T.P., Tannenbaum, S.R., Karel, M., Water content and stability of low moisture and intermediate moisture foods. *Food Technol.*, **24**, 543-550 (1970).