Inhibitory Effect of Cinnamon Powder on Pathogen Growth in Laboratory Media and Oriental-Style Rice Cakes (Sulgidduk)

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ABSTRACT

There has been an increasing interest in the use of natural plant materials as alternative food preservatives. We examined the antimicrobial effects of natural plant materials used as additives against foodborne pathogens in laboratory media and Sulgidduk, oriental-style rice cakes. Cinnamon, mugwort, and garlic powder solutions (3%) were tested for their antimicrobial activities against pathogens in laboratory media. Sulgidduk prepared with different amounts of cinnamon powder (1, 3, and 6%) was inoculated with a Staphylococcus aureus or Bacillus cereus cocktail. The samples were air or vacuum packaged and stored at 22 ± 1°C for 72 h, and microbial growth was determined. Cinnamon powder showed more inhibitory properties against pathogens such as Salmonella enterica serovar Typhimurium, Escherichia coli O157:H7, Listeria monocytogenes, S. aureus, and B. cereus than did mugwort or garlic powder. The populations of S. aureus and B. cereus in Sulgidduk containing cinnamon powder were significantly lower than in the control during storage time. Different packaging methods did not result in a significant difference in pathogen growth. In a sensory evaluation, Sulgidduk containing 1 and 3% cinnamon powder did not significantly differ from the control sample in any of the attributes tested other than flavor. These results indicate that natural plant materials such as cinnamon powder could be used as food additives to improve the microbiological stability of rice cakes.

As concern over the safety of chemical additives has risen in recent years, consumer interest in the use of natural products as alternative food preservatives has increased (9). Consequently, natural antimicrobials are receiving a good deal of attention for a number of microorganism control issues. Due to the increasing demand for natural food additives, herbs and spices have emerged as popular ingredients to replace synthetic antimicrobial and antioxidant agents (18, 20).

Garlic (Allium sativum), a common perennial herb found in the United States, is known to have antibacterial, antifungal, and antiviral properties. A wide range of microorganisms are sensitive to crushed garlic (11). Mugwort (Artemisia vulgaris) is another common perennial herb found throughout the Western United States (28). Many studies have been conducted to understand its medical properties, but its antimicrobial properties have not been studied. Cinnamon is one of the oldest herbal medicines, mentioned in Chinese texts as far back as 4,000 years ago, and it is also one of the most frequently consumed spices (21, 22, 25). Essential oils, which have been used for decades to increase the shelf life of foods, are becoming more popular due to their antioxidant and antimicrobial properties (8). Matan et al. (17) reported that substances in cinnamon and clove essential oils inhibited the growth of molds, yeasts, and bacteria. Gutierrez et al. (10) reported that spices and herbs containing 0.05 to 0.1% essential oils have demonstrated activity against certain pathogens, including Salmonella Typhimurium, Escherichia coli O157:H7, Listeria monocytogenes, Bacillus cereus, and Staphylococcus aureus in food systems. Herbs and spices are typically commercially used in the form of dried leaves or powder, but most research conducted has reported on the antimicrobial effects of herbs and species used in the extracted form (7, 8, 10, 30).

Rice cakes (Sulgidduk) are popular food items in Asia, and they can be manufactured using a variety of bases, such as regular rice, sweet rice, white rice, and tapioca, and may include a variety of other ingredients, such as red beans, green beans, mung beans, and sesame seeds (13). Rice cakes are cooked by steaming, frying, or boiling in water. Steaming is the most convenient and popular method for manufacturing a variety of rice cakes (14). Freshly steamed rice cakes are soft, pliable, and elastic, but with time, they undergo retrogradation. Retrogradation causes hardening in starch-based foods, and the rate of retrogradation is maximized at around 5°C (27, 32). Thus, it is not recommended to store rice cakes under refrigerated conditions; rice cakes made to be sold are held at room temperature for 1 day and then discarded (14, 15, 19). The storage of rice cakes at room temperature allows the rapid growth of microorganisms, including pathogens. Generally, steam cooking rice cakes will destroy the vegetative cells of various pathogens (14). However, spore-forming bacteria, such as B. cereus, will survive during cooking and grow...
after the germination of spores during storage. In addition, the sources and conditions that allow contamination after cooking are numerous. Therefore, we evaluated the antibacterial effects of natural plant materials including mugwort, garlic, and cinnamon powder against various foodborne pathogens in laboratory media. We also examined the effects of cinnamon powder on the growth of *B. cereus* (spore-forming bacteria) and *S. aureus* (indicator of postcooking contamination) on rice cakes.

**MATERIALS AND METHODS**

**Bacterial strains and culture conditions.** Three strains each of *E. coli* O157:H7 (ATCC 35150, ATCC 43889, and ATCC 43890) and *S. aureus* (ATCC 12600, ATCC 12692, and ATCC 49444), one strain of *L. monocytogenes* (ATCC 19115), three strains of *B. cereus* (ATCC 10876, ATCC 13061, and W-1), and one strain of *Salmonella enterica* serovar Typhimurium (ATCC 49371) were obtained from the Department of Food and Nutrition at Chung-Ang University. Individual strains were cultured in tryptic soy broth (TSB; Difco). The final pellets were resuspended in buffered peptone water to adjust the initial concentration (10^5 to 10^7 CFU/ml) before inoculation into TSB or onto rice cakes.

Inhibitory effects of mugwort, cinnamon, and garlic powder in laboratory media. Mugwort powder, cinnamon powder, and garlic powder (all products of Korea) were purchased from a local grocery store in Seoul, Korea. To investigate the inhibitory effect of each powder against pathogens, 3% (wt/vol) powder was added to 10 ml of TSB, and the tubes were autoclaved for 15 min at 121°C. The autoclaved TSB tubes, either with or without 3% powder, were inoculated with 0.1 ml of each pathogen-containing mixture (*S. aureus* ATCC 12600, *B. cereus* ATCC 13061, *Salmonella Typhimurium* ATCC 49371, *E. coli* O157:H7 ATCC 35150, and *L. monocytogenes* ATCC 19115) at a concentration of 10^2 to 10^3 CFU/ml. Inoculated tubes were incubated at 25°C, and the population numbers were enumerated after 0, 12, 24, and 48 h of growth on tryptic soy agar (TSA; Difco) following 10-fold serial dilution using 9 ml of sterile peptone water.

**Inhibitory effects of cinnamon on oriental-style rice cakes during storage.** To investigate the inhibitory effects of cinnamon against pathogens such as *S. aureus* and *B. cereus*, oriental-style rice cakes (Sulgidduk) were prepared with or without the addition of cinnamon powder, as shown in Figure 1. Table 1 shows the formulas of rice cakes containing various concentrations of cinnamon powder. As a control, 200 g of sieved (mesh size, 20) rice flour (product of Korea), 25 g of water, 20 g of sugar, and 2 g of salt were mixed thoroughly with gloved hands. Test rice cakes were prepared by adding 1, 3, or 6% (wt/wt) cinnamon powder based on the amount of rice flour in the mixture (2, 6, or 12 g of cinnamon powder was added, and the same amount of rice flour was eliminated; the test rice cakes are referred to as CM1, CM3, and CM6, respectively). Rice cakes with or without cinnamon powder were steam cooked at 100°C for 20 min after sieving the mixed ingredients (sieve mesh size, 40). After steaming, the rice cakes were cooled to room temperature, and *S. aureus* (ATCC 12600, ATCC 12692, and ATCC 49444) or *B. cereus* (ATCC 10876, ATCC 13061, and W-1) was inoculated on the surface of cooled rice cakes by deposition of 0.1 ml of diluted culture cocktails in buffered peptone water using a micropipette corresponding to approximately 10^3 to 10^5 CFU/g. After inoculation, the rice cakes (20 g) were placed in UV-sterilized plastic bags (AVR 008; thickness, 70 μm including nylon [15 μm] and polyethylene [55 μm]; oxygen permeability, 55 cc μm/KPa dm^-2_ at 23°C and 60% relative humidity; CSE Co., Ansan, South Korea) and packed in either air or a vacuum. Air packaging consisted of sealing without eliminating the air in the bag, and vacuum packaging was conducted by evacuating the air with a vacuum-packaging machine (AVS 200, CSE Any Vac, CSE Co.). Packaged samples were stored at 25°C for 3 days.

**Bacterial enumeration.** Inoculated and stored rice cakes (20 g) were placed in a stomacher bag containing 40 ml of peptone water.

![FIGURE 1. Flow chart depicting the preparation of rice cakes (Sulgidduk) containing various concentrations of cinnamon powder.](image-url)
RESULTS AND DISCUSSION

Table 2 shows the changes in bacterial populations of foodborne pathogens in laboratory medium (TSB) with or without 3% mugwort, garlic, or cinnamon powder during storage at room temperature (25 ± 2°C) for 48 h. Initial levels of pathogens ranged from 2.02 to 2.96 log CFU/ml.

In the TSB without botanical powder (control), pathogen levels increased significantly during storage at room temperature (P < 0.05), resulting in levels of 5.47 to 7.57 log CFU/ml after 12 h of storage and 6.92 to 9.25 log CFU/ml after 48 h of storage. The addition of mugwort, garlic, or cinnamon powder to the TSB effectively inhibited or delayed the growth of all tested pathogens except *E. coli* O157:H7, and the effectiveness of each botanical powder differed for each type of pathogen. Mugwort and garlic powders did not effectively inhibit the growth of *Salmonella* Typhimurium, *E. coli* O157:H7, or *S. aureus*. After 48 h of storage, the levels of these three pathogens were 8.95, 8.69, and 6.37 log CFU/ml, respectively, in TSB with 3% mugwort and 8.86, 8.91, and 7.90 log CFU/ml, respectively, in TSB with 3% garlic powder. The amounts of these three pathogens in the control were 8.93, 9.07, and 8.39 log CFU/ml after 48 h of storage. The amount of *L. monocytogenes* in TSB with 3% mugwort powder was 4.45 log CFU/ml after 12 h of storage, which increased to 9.03 log CFU/ml after 48 h of storage. Mugwort powder effectively inhibited the growth of *L. monocytogenes*.

### Statistical analysis

All experiments were repeated three times with duplicate plates, and the averages of the duplicate plate counts from the three replications were converted to units of log CFU per milliliter or gram. The data were analyzed with analysis of variance for a completely randomized design in SAS (Version 8.1, SAS Institute Inc., Cary, NC). When the effect was significant (P < 0.05), mean separation was accomplished with Duncan’s multiple range test.
monocytogenes until 24 h of storage compared with control, but it did not significantly inhibit its growth after 48 h of storage. The addition of 3% garlic or cinnamon powder significantly suppressed the growth of L. monocytogenes during storage. The levels of L. monocytogenes, S. aureus, and B. cereus decreased during storage with the addition of cinnamon powder.

Of the types of bacteria tested, B. cereus was most effectively inhibited by all three of the botanical powders. Levels of B. cereus decreased during 12 h of storage when cinnamon powder was added. After 48 h of storage, the levels of B. cereus in TSB with 3% garlic and cinnamon powder were 3.88 and 0.95 log CFU/ml, respectively, compared with 6.92 log CFU/ml in the control. In a laboratory medium, the addition of garlic powder was more effective for inhibiting the growth of gram-positive bacteria than the addition of mugwort powder. The addition of cinnamon powder was effective against all five types of bacteria, although its effectiveness was stronger for gram-positive than gram-negative bacteria. Other studies have reported similar results (2, 12, 26). Campo et al. (2) investigated the antimicrobial effects of rosemary extracts in a food model, rice cakes. We focused on B. cereus and S. aureus. B. cereus causes food poisoning associated with the consumption of rice-based foods (3, 4, 29) and survives during the cooking process because it produces spores. S. aureus is commonly associated with human infections and has been previously studied as an indicator for postprocessing contamination (16).

The populations of S. aureus and B. cereus in rice cakes containing different concentrations of cinnamon powder and stored in air or vacuum packaging are presented in Figure 2a and 2b, respectively. The initial population of S. aureus inoculated onto rice cakes was <2 log CFU/g. After 24 h of storage, the levels of S. aureus in the control with air or vacuum packaging increased to 5.56 and 5.47 log CFU/g, respectively, and S. aureus numbers in the samples stored with air packaging with 1, 3, and 6% cinnamon powder were 3.65, 2.15, and 2.37 log CFU/g, respectively (Fig. 2a). After 72 h of storage, the control and the sample with 1% cinnamon powder had the highest populations of the microorganisms assayed, whereas the samples with 3 and 6% cinnamon powder had the lowest (P ≤ 0.05). These results indicate that the addition of cinnamon powder into the rice cakes inhibited the growth of total aerobic bacteria. There were also significant differences between air and vacuum packaging (P ≤ 0.05). The initial level of B. cereus inoculated onto rice cakes was about 2.5 log CFU/g. After 12 h of storage, the populations of B. cereus in the control with air or vacuum packaging increased to 4.67 and 4.19 log CFU/g, respectively (P ≤ 0.05) (Fig. 2b). After 12 h of storage, the populations of B. cereus in samples stored with air packaging with 1, 3, and 6% cinnamon powder were 1.14, 1.36, and 1.65 log CFU/g, respectively, and for those samples stored in vacuum packaging, the populations were 0.97, 1.05, and 1.31 log CFU/g, respectively. After 72 h of storage, the levels of B. cereus in rice cakes containing 1, 3, and 6% cinnamon powder were significantly lower than in the controls, which had levels of 4.25 log CFU/g in air packaging and 4.04 log CFU/g in vacuum packaging.
Therefore, the addition of cinnamon powder effectively suppressed the growth of B. cereus in rice cakes during 72 h of storage.

Although steam cooking during the production of rice cakes should completely destroy the vegetative cells of pathogenic microorganisms, it may not be effective for destroying spore-forming bacteria, such as B. cereus (14). Surviving bacterial spores can germinate, grow, and produce toxins during the storage of rice cakes at room temperature, resulting in foodborne illness in consumers. Therefore, it is important to develop a way to inhibit the growth of such bacteria in rice cakes. Lee et al. (14) reported that steam cooking reduced the number of B. cereus spores by 1 to 2 log CFU/g and reduced the numbers of other foodborne pathogenic bacteria by >6 log CFU/g.

Table 3 shows the results of tests to score the sensory attributes of rice cake containing various concentrations of cinnamon powder. Of the attributes tested, rice cakes with 6% cinnamon powder (CM6) got significantly lower scores than the other samples and the control. Therefore, the addition of 6% cinnamon powder is not acceptable for rice cake production. Rice cakes with 1 and 3% cinnamon powder (CM1 and CM3) did not significantly differ from the control in any of the attributes tested other than flavor. The scores for the flavor of rice cakes with 1 and 3% cinnamon powder were significantly higher (P ≤ 0.05) than the control and CM6. Therefore, the addition of 3% cinnamon powder to rice cakes is most beneficial when considering both the inhibition of microorganism growth and the sensory results. However, since the number of panelists used in this study was not great enough to represent a consumer panel, additional studies are needed prior to commercial application.

Several studies have examined the antimicrobial effects of cinnamon powder, cinnamon oil, or other plant extracts against various foodborne pathogens. Matan et al. (17) reported that cinnamon and clove oil volatiles showed inhibitory effects on the growth of S. aureus and Pediococcus halophilus, and their effects increased with increased CO₂ concentration. Other studies have reported that cinnamon oil inhibits the growth of mycotoxigenic molds (1) and yeasts (5). Goni et al. (8) reported that the vapor phase of cinnamon oil showed better suppression effects than the direct contact of cinnamon oil on the growth of certain microorganisms, including E. coli, Yersinia enterocolitica, Salmonella Choleraesuis, L. monocytogenes, S. aureus, Enterococcus faecalis, and B. cereus. The activity of cinnamon is due to the presence of cinnamaldehyde, an aromatic aldehyde that inhibits amino acid decarboxylase activity (31). Cinnamon bark is rich in cinnamaldehyde (50.5%), which is highly electronegative, and such electronegative compounds interfere in biological processes involving electron transfer and react with nitrogen-containing components such as proteins and nucleic acids, therefore inhibiting the growth of the microorganisms. In addition, cinnamon oil contains benzoic acid, benzaldehyde, and cinnamic acid, of which the lipophilic moiety has been recognized as being responsible for its antimicrobial property (24), as in other antimicrobial compounds such as eugenol (25).

In conclusion, a 3% addition of cinnamon to 97% rice powder effectively inhibited the growth of B. cereus and S. aureus and was also found to be acceptable in a sensory evaluation. The addition of cinnamon powder to rice cakes could improve their antimicrobial properties by inhibiting the growth of spore-forming bacteria and their toxin production as well as improve their sensory qualities, including color, texture, nutrient content, and flavor. Additional studies examining the inhibitory activities of cinnamon in other types of rice cakes or other food products and its effect on sensory properties are required prior to commercial application.

**REFERENCES**


