

# Pre-Treatment Effects of Hot-Water and Sodium Hypochlorite on Storage Quality of Cured Winter squash var. ‘Bochang’

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**ABSTRACT---** Winter squash var. *Bochang* were subjected to hot water treatment (HWT) at 55 °C and dipped in NaOCl solution at 200 ppm separately prior to curing. Cured squash were immediately stored at 5 °C, 12 °C and at room temperature (RT) of 25±3 °C. Stored winter squash were monitored for changes in quality including weight loss, mold infection and incidence of chilling injury.

Rind color of ‘Bochang’ as expressed by color value ‘b’ was delayed by pre-treatment of NaOCl 90 days after storage at 12 °C and 60 days by HWT at RT. NaOCl and HWT have no influence on the rate of rind color change in ‘Bochang’ stored at 5 °C. Firmness regardless of treatment was generally higher in squash stored at 5 °C until four months. Level of soluble solids content (SSC) on the first month of storage increased as triggered by HWT and curing when stored at 5 °C. Levels of SSC in the succeeding stage of storage further increased in a stable manner until three months. Pre-treatment with NaOCl and HWT is effective in reducing mold infection until four months but not enough to reduce weight loss until three months of storage. ‘Bochang’ stored at 5 °C exhibited the lowest weight loss. The presence of fungi belonging to *Fusarium* genera contributed much to loss in weight. Unlike other varieties of winter squash, chilling injury was not manifested in ‘Bochang’ stored at 5 °C.

**Keywords---** firmness, fungi, rind color, weight loss, chilling injury

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## 1. INTRODUCTION

Winter squash, *Cucurbita maxima* Duch (Cucurbitaceae) var. ‘Bochang’ has been grown in Korea from Japan for more than 20 years. ‘Bochang’ is one of the sweetest varieties among winter squashes containing soluble sugars as high as 22.4% in fresh weight. The average weight of the fruit is 500 grams at harvest. Aside from being a common vegetable, this variety is processed as source of starch for squash noodles and other products like candies and pastries (Lee et al., 2002). Winter squash is grown extensively in South Korea. However, most of the harvest is of low quality in terms of storability. Growing practices has been a problem especially when winter squash are grown under naked soil conditions without covering materials such as straw mulches that would serve as barriers from sources of contamination. In addition, most varieties are inherently susceptible to fungal attack even before storage. Chilling injury in most variety of squash is likewise a problem at low temperature storage (Gibe and Lee, 2008). These are characteristics unfavorable for longer storage and a threat to the export market’s stability. Problems on how to reduce fungal infection by any possible intervention and establishing optimum conditions have to be addressed in some ways to improve the current situation.

Hot water treatment is a known intervention to reduce fungal incidence in some commodities. The treatment is done by submerging a commodity in hot water at a specified temperature within pre-determined period based on commodity being treated and the pests that may be present (APHIS, 1993). Hot water treatment is common especially in tropical fruits such as mango. Hot-water immersion is currently used to successfully treat mangoes infested with the mediteranean fruit fly and several different *Anastrepha* species of fruit fly before importation into the United States from Mexico, the Caribbean, and Central and South America (APHIS, 1993). This technology is the only acceptable method for treatment of postharvest diseases as requirement for export. Hot-water immersion also has the additional benefit of controlling postharvest microbial diseases such as anthracnose and stem end rot (Couey, 1989; McGuire, 1991). Successful hot-water immersion quarantine treatments against fruit flies were also developed for papayas (Couey and Hayes, 1986), guavas (Gould and Sharp, 1992), and bananas (Armstrong, 1982). At present, this technology has been extended to other fruits such as Satsuma mandarin (Hong et al., 2006) and oranges (Palou et al., 2001). Heat treatment

technologies were likewise used for post-harvest insect control for fresh vegetables (e.g., peppers, eggplant, tomatoes, cucumber, and zucchini squash), bulbs, and cut flowers (Tsang et al., 1995; APHIS 1993; Hansen et al., 1992).

In the same way, chlorination is one of the few chemical options available to help manage postharvest diseases in harvested fruits and vegetables. When used in connection with other proper postharvest handling practices, chlorination is effective and relatively inexpensive. Chlorination was found effective in reducing mold infection in cured 'Bochang' for long periods (Lee et al., 2008). Curing alone, on the other hand, has been regarded as a form of intervention to manage fruit rots in storage. Harvesting at the right maturity with proper curing and storage at 7.5 to 13°C lessened incidence of fruit rots (Wood, 1981). Curing at 30°C for two to three days before storage at 10°C reduced storage rot (Nagao et al., 1991). Wounds, cuts and bruises can be treated to minimize rots by storing at 27 to 30°C and relative humidity of 80% for 10 days before transferring to long term storage (Rubatzky and Yamaguchi, 1997).

This study investigated the effectiveness of hot water (HWT) and NaOCl treatment in maintaining quality of winter squash 'Bochang' during storage for at least 4 months at different temperatures.

## 2. MATERIALS AND METHODS

**2.1 Plant Materials.** Winter squash var. 'Bochang' was procured from Hampyeong province. Squash was grown in an open field on ground lined with black plastic sheets to make sure that fruits do not come in contact with the soil. On the day of harvest, squashes were inspected and sorted. The best quality ones were chosen and were transported to NHHRI the following day. The squashes weighed 0.55 kg on the average.

**2.2 Hot water treatment.** About 10 fruits per batch in net bags were packed and dipped in hot water at 55°C for 1 minute in a temperature controlled water bath (Model DS-23S). After treatment, excess water on fruit surface was wiped out using paper towels and further surfaced-dried in ambient air before curing. Treatments were labeled as HWT at 55°C and then stored separately at 5°C, 12°C, and at room temperature (RT) (25±3°C).

**2.3 Sodium Hypochlorite (NaOCl) treatment.** To compare effectiveness of HWT with NaOCl treatment, winter squash of similar sizes were pre-treated with 200 ppm NaOCl solution (pH of 6.5) using a water bath (Model DS-23S). 'Bochang' in a net bag containing about 10 heads per batch was dipped into NaOCl solution for 30 seconds at 27°C. After dipping, squash was wiped with paper towels and air dried for an hour before curing. The treatments were labeled as NaOCl at 200 ppm and then stored separately at 5°C, 12°C, and RT.

**2.4 Curing and storage.** After HWT and NaOCl pre-treatments, squashes were exposed to curing conditions of 28 ± 1°C with 70 ± 5% relative humidity for 15 days (Nagao *et al.*, 1991; Rubatzky and Yamaguchi, 1997). Six groups of samples were subjected to curing conditions. Each group of samples contained three squashes in three replicates. These samples were analyzed monthly for quality changes. Another batch of samples containing five squashes in six replicates was subjected to the same curing conditions. These samples were intended for monthly investigation of mold infection, weight loss and chilling injury. All cured squash in plastic crates were kept separately at 5°C, 12°C, and RT storage rooms for at least four months.

**2.5 Quality Analysis.** Each month, fruits representing each treatment were sliced twice horizontally making a 5 cm-thick circular cut in the middle of the fruit. The cut resulted in three piece slices; the top slice, the middle and the bottom slice. The middle slice was analyzed for firmness and sugar content while the top and bottom parts were analyzed for soluble solids content (SSC).

**Soluble Solids Content.** (SSC) of squash was measured monthly by using a refractometer (Model Atago). Peeled samples from the top and bottom cut of squash were grated and squeezed through 4-layer cheesecloth. Extracted cell sap was used for SSC analysis.

**Firmness (N).** Samples from the middle section of the fruit were analyzed for firmness by using a texture analyzer. Three spots were pricked on flat surface of sliced samples with a cylindrical probe (3 mm in diameter) mounted on a drill stand at a speed of 3 mm per second and deformation distance of 8 mm. Firmness (N) was measured and calculated by a software (Texture expert Stable Micro System Ltd. version 1.22 ) installed in the computer that operates and controls the texture analyzer.

**2.6 Mold Infection, Chilling injury and Weight loss.** Loss in weight, incidence of mold infection and occurrence of chilling injury were monitored throughout the storage period. Weight loss was calculated from a difference in weight measured every month. Squash in storage were also observed for development of chilling injuries.

### 3. RESULTS AND DISCUSSION

#### 3.1 Treatment Effects on Quality

**3.1.1 Rind color.** The effects of pre-treatment with hot water at 55°C were compared with NaOCl in terms of preserving green color and increasing storability for longer periods. Increase in color patterns from dark green to yellow as expressed by Hunter 'b' value is presented in Fig. 1. 'Bochang' have a 'b' value of 5 when harvested 45 days after flowering. Generally, rind color gradually turned yellow regardless of pre-storage treatments and storage conditions as expressed by an increase in 'b' value. When fruits were stored at 12°C, yellowing was delayed in NaOCl treated 'Bochang'. This observation supports earlier results of Lee et al. in 2008 that NaOCl is capable of delaying de-greening or yellowing in 10-day cured or air-dried 'Bochang' stored at 12°C with a consistent low 'b' value after a month until the end of the storage period of five months. On the other hand, the delay of color change in hot water treated 'Bochang' was apparent after two months at room temperature (RT). Hot water treatment of 'Bochang' likely favors room temperature storage. There was no difference between treatments up to two months of storage, especially at storage temperature 5°C. In most cases, the final 'b' value seemed to be more influenced by storage temperature especially at lower temperatures and not by pre-treatments. Thus, rind color was less likely to develop or to turn yellow at 5°C storage.

**3.1.2 Firmness (N).** Firmness, a texture parameter is an important factor determining quality in squash. The changes in firmness of 'Bochang' subjected to NaOCl and HWT are presented in Fig. 2. In most cases, firmness in 'Bochang' decreased until the second month of storage but increased again on the third month. This phenomenon was evident in 12°C and 5°C stored 'Bochang'. On the other hand, HWT treated 'Bochang' stored at 12°C exhibited an increase in firmness a month earlier in storage. HWT may have triggered this early increase in firmness. As previously observed, re-increased firmness was recorded on the third month where SSC was at its peak. The conversion of starch into sugar in the initial months of storage may have influenced the decrease in firmness. The accumulation of sucrose, on the other hand, may have influenced re-increasing firmness of 'Bochang' on the third month. The same behavior of change in firmness was also observed in 10-day cured 'Bochang' stored at 12°C (Lee et al., 2008) and in cured Ebis stored for 4 months at 5 and 12°C (Gibe et al., 2008). The concrete reason for such behavior has yet to be known. At RT storage, no re-increasing firmness in 'Bochang' pre-treated with NaOCl and hot water was observed at 3 months.

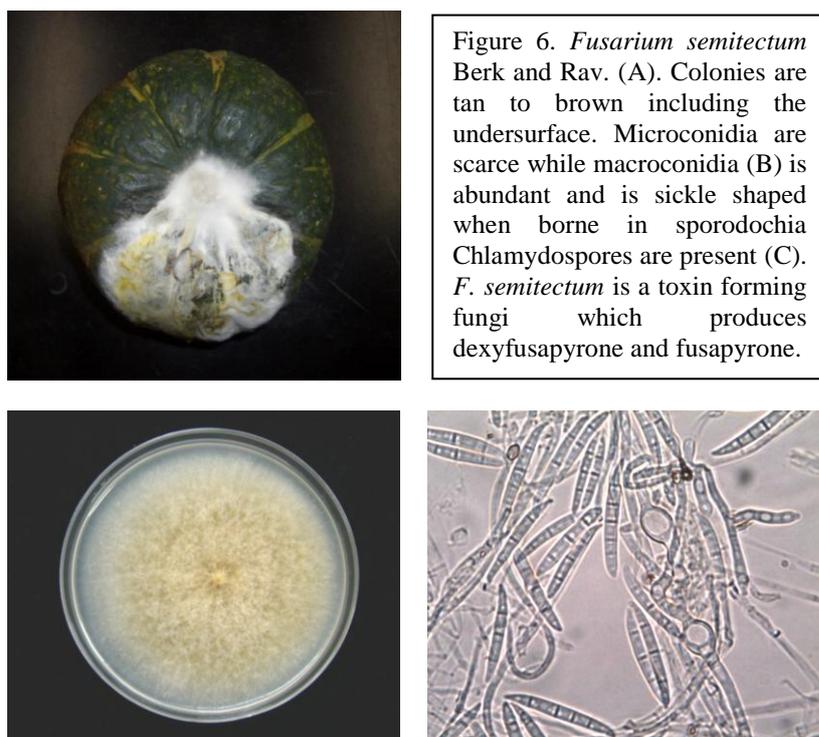
**3.1.3 SSC.** The level of SSC in cured 'Bochang' previously exposed to HWT and NaOCl is presented in Fig. 3. Curing at 28±1°C for 15 days increased the level of SSC in 'Bochang'. SSC was at the same level before the actual storage study (0 month). However, after a month, increase in SSC among treatments has become noticeable. HWT in particular triggered an early increase in SSC after a month especially at 5°C storage. The increase in SSC coincided with the increase in firmness on the same treatment and condition. The increase in SSC in cured 'Bochang' was more apparent at three months storage. An increase in soluble solids content indicated changes in carbohydrate content that include conversion of starch into sugar (Roura et al. 2004). Decrease in starch content was generally observed in most squash varieties in storage and the amount of decrease varied with cultivar (Corrigan et al. 2001). Sweetness and sucrose levels in buttercup increased while dry matter (DM) content and starch decreased. The increase in sucrose level in storage suggested that starch maybe converted to sucrose after a certain stage of maturity and as ripening progresses (Harvey et al., 1997) and the conversion is initiated by a breakdown of starch through hydrolysis with alpha-amylase being the primary enzyme responsible for this (Irving et al., 1999).

No data on SSC are presented after 3 months in untreated but cured and HW treated 'Bochang' because all samples have been infected by molds and were readily discarded.

#### 3.2 Storage Rots and Weight loss

The build up of fungal infection in stored 'Bochang' is presented in Fig. 4. Squash fruits are still free of any fungal infection after a month of storage. During the second month, fungal infection was noticeable in most treatments except in HWT and NaOCl treated 'Bochang' stored at 5°C. 'Bochang' pre-treated with NaOCl and HWT had a reduced infection when compared with the untreated 'Bochang' until four months. It is very clear that NaOCl and HWT contributed to reducing infection by surface sterilization. NaOCl treated 'Bochang' at 5°C was kept free from any fungal infection until four months of storage while HWT reduced mold infection to 5%. However, at five months storage, HWT manage to surpass effectiveness of NaOCl by reducing infection by 10%. Lower temperature of 5°C may have been compatible with NaOCl and HWT in suppressing growth of fungi in storage. HWT is comparable with NaOCl in terms of effectiveness in reducing mold infection for long-term storage at 5°C. Squash stored at RT had been discarded before five months of storage. All samples have deteriorated due to mold infection. Rotting due to molds is a serious problem in growing and storing squash in Korea. Sixty percent of squash in Korea are grown in an open field (NHHRI). In the present study, squash as experimental stocks were grown in the field and therefore rotting caused by soil-borne *Fusarium* was high in storage.

Total weight loss that includes moisture and loss due to mold infection is presented in Fig. 5. 'Bochang' stored at 5°C exhibited a consistently low weight loss until the end of storage period of three months regardless of treatments. On the other hand, weight loss in 'Bochang' at RT pre-treated with NaOCl was consistently lower than HW treated fruits. HWT, in addition to curing, triggers increase in SSC while increased SSC encourages mold infection and therefore results to higher weight loss at higher temperature storage (RT). At lower temperature of 12°C, HWT is comparable with NaOCl in reducing weight loss but at 5°C, NaOCl is way more effective than HWT. The presence of fungi belonging to *Fusarium* genera contributed much to loss in weight in storage. Eight species of *Fusarium* associated with stored 'Bochang' include *Fusarium moniliforme* S., *F. scirpi* L., *F. oxysporum* S. *F. solani* M., *F. avenaceum* S. *F. chlamydosporum* W. R., *F. equiseti* S. and *Fusarium semitectum* Berk and Rav. as the most predominant Fig. 6.



Effectiveness of HWT and NaOCl in reducing mold infection and weight loss is dependent on temperature. With curing alone, the activity of molds become low as temperature is decreased. With pretreatments of NaOCl and HWT before curing, mold activity was even reduced and therefore resulted in lower weight loss.

### 3.3 Chilling Injury

Chilling injury symptoms was not observed in 'Bochang' stored at 5°C. This phenomenon was in contrast with what was observed in 'Ebis' and 'Kurijimang' at 5°C storage where chilling injury could be manifested as early as 2 months (Gibe and Lee, 2008). Varietal difference was the main reason for its inherent tolerance to chilling injury. Bochang variety is smaller in size as compared with the more popular 'Ebis', 'Ajjimang' and 'Kurijimang'. Bochang is less than half the size of 'Ebis'. Other reasons such as curing, moisture content before storage, firmness, starch content and the manner this variety was grown may have contributed to its inherent tolerance. For this reason, temperature requirement in storage of Bochang could be addressed differently. This phenomenon of chilling indurance could be a good area for further research in Bochang.

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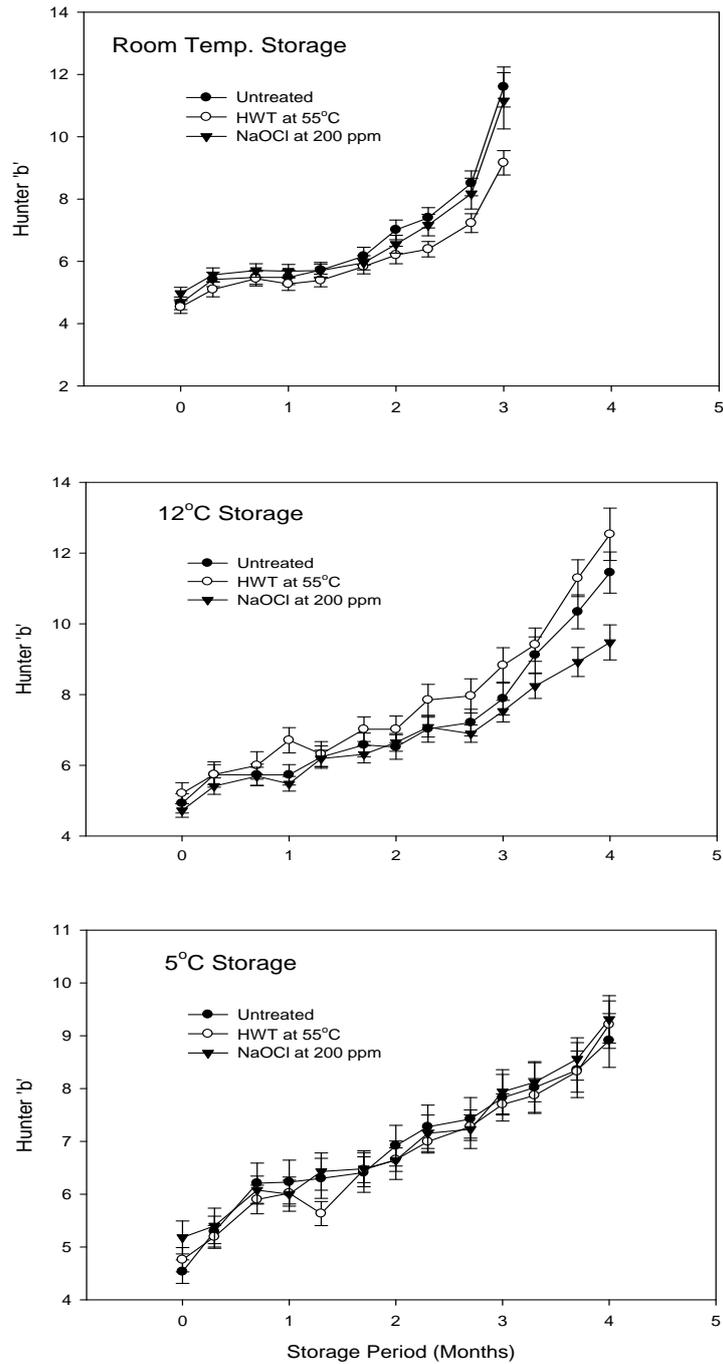
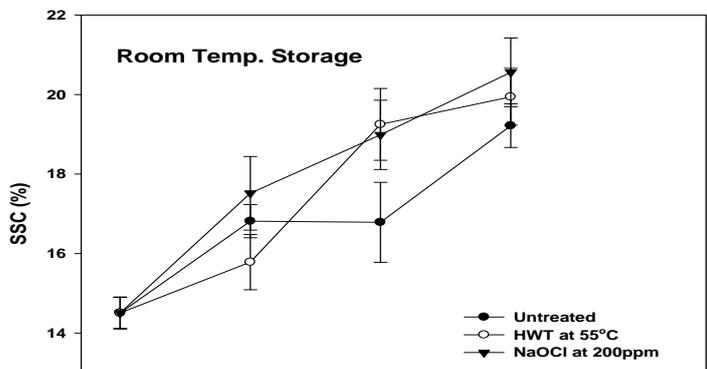
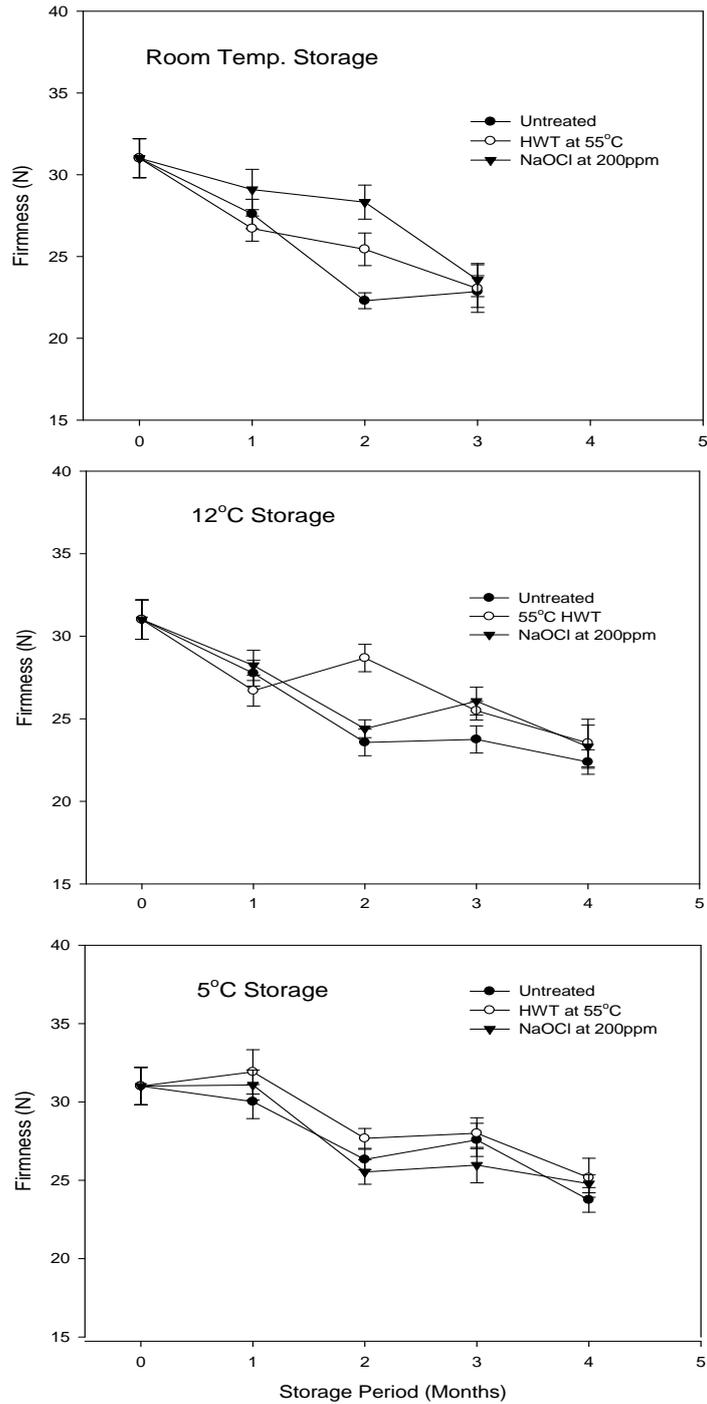


Fig. 1. Changes in rind color of 'Bochang' as affected by hot-water treatment (HWT) and NaOCl prior to storage at RT, 12°C and 5°C for at least 4 months.



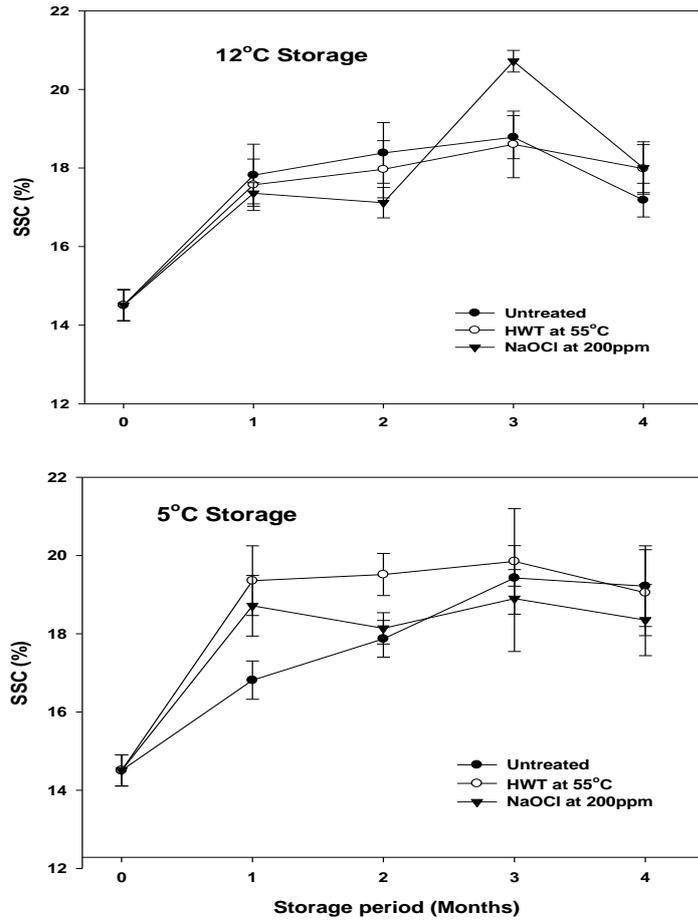


Fig. 3. Soluble solids content in 'Bochang' either untreated or treated separately with NaOCl and hot water (HWT) prior to storage at RT, 12°C and 5°C for at least 4 months

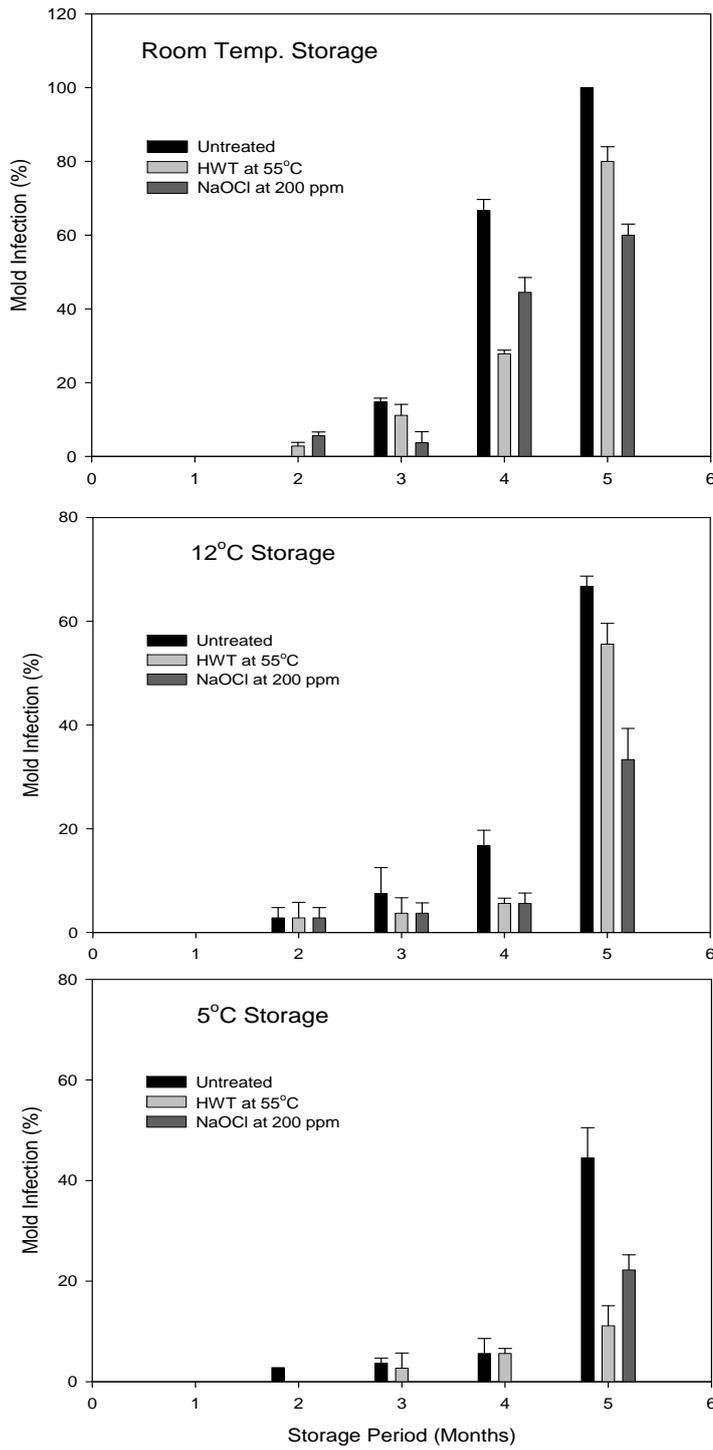


Fig. 4. Incidence of fungal infection in 'Bochang' either untreated or treated separately with NaOCl and hot water (HWT) prior to storage at RT, 12°C and 5 °C

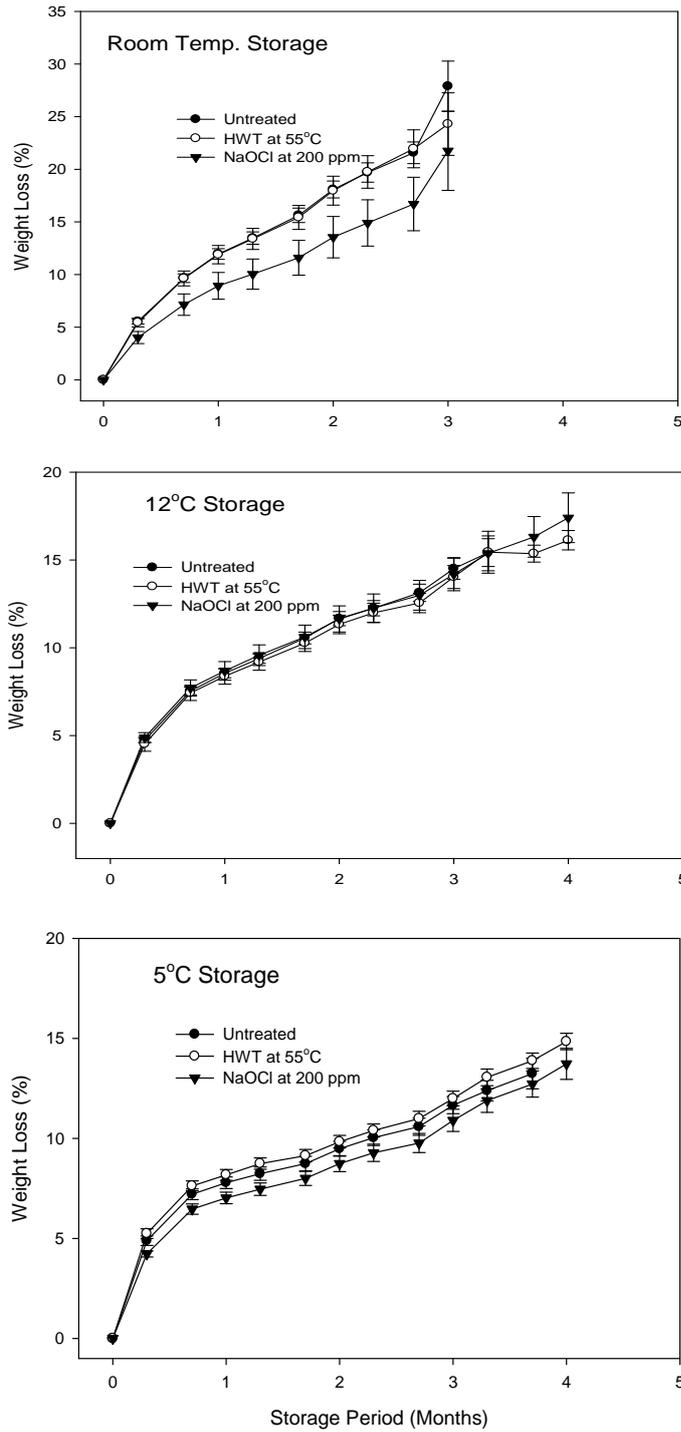


Fig. 5. Weight loss in 'Bochang' either untreated or treated separately with NaOCl and hot water (HWT) prior to storage at RT, 12°C and 5°C