# Effects of Hot Water Dipping and Storage Materials on Storage Quality of Fresh Galangal Rhizome *Alpinia Galanga* (Linn.)

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**Abstract.** *Fresh galangal rhizome has a very short marketable life of 7 days at room temperature. To gain more opportunity for marketing purposes consequently to extend fresh galangal rhizome shelf life, therefore, this research was aimed to evaluate storage qualities after hot water treatment (HWT). The eight-month-old galangal rhizomes (Alpinia galanga L.) were harvested from a local orchard farm. Later, they were prepared and dipped in hot water at 40°C for 10 min followed by a tap water dip for 10 min, then dried. The HWT treated samples were then packed in nylon-linear low-density polyethylene (LLDPE) and polypropylene (PP) bags and subjected to heat sealing. All samples were stored at 13±0.4°C with 85%RH for 36 days, following the storage quality evaluations on 3 days intervals. The experimental results revealed that HWT treated samples presented no significant changes in L*-a*-b*-H° (Pale yellow) values regardless of film pouch types. The hardness of HWT treated samples packed in all pouch types was not significantly different from the control. The microstructural assessment of control tissue and HWT galangal rhizome tissues at day 0 which were packed in both pouch types has presented similar appearances. In conclusion, HWT might help to minimize changes in some postharvest qualities of galangal rhizome during storage at low temperatures for 36 days regardless of packaging types.*

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## 1. Introduction

Galangal (Alpinia galangar) (lesser or greater galangal) belongs to the Zingiberaceae family which provides food, spices, medicines, dyes, and perfumes, as well as antimicrobial agents [1]. The essential oil of rhizome and leaves have been reported to have about 31 and 28 constituents, respectively, with the major compound being 1,8-cineole [2]. Furthermore, galangal contains a wide variety of bioactive compounds with alternative pharmacological and medical properties [3]. Galangal rhizome is an edible rootstock that is commonly consumed around South East Asian countries. The main suppliers of galangal rhizome in the international markets are Thailand, Indonesia and India [3], [4].

Heat treatment or hot water treatment (HWT) is widely used for postharvest treatment due to its many benefits such as, disease control, insect disinfestation, altering tissue responsiveness to cold storage, inhibiting ripening, chemical-free and maintaining fresh quality [5]-[14]. HWT varies according to production practices, season, growing location and fresh maturity. The applications of HWT are done at temperatures between 43 and 53°C for several min up to 2 h [15]. HWT at 42.5°C for 30 min. before LDPE and MAP could reduce weight loss, decay and mold growth, maintain firmness and inhibit the ripening process of tomato when stored at 10°C for 14 days [16]. A similar study has been reported that after NaCl washing, dipping guava at 40°C for 10 min. could reduce weight loss and decay during storage at 13°C for 30 days [17]. Mild heat treatment at 50°C for 60 seconds was also reported for suppresses phenylalanine ammonialyase (PAL), polyphenol oxidase (PPO), and peroxidase (POD) activities [18].

Shelf-life extension for fresh commodities via modified atmosphere packaging has been applied successfully. Alterations of $O_2$ and $CO_2$ concentrations are practiced to extend the shelf life of either whole or pre-cut fresh produce. Several studies are presenting this preservation technique which effectively minimizes the physiological and microbial deteriorations [19]-[24]. Additionally, low-temperature storage, mild heat treatment, irradiation, chemical applications as well as $CO_2$ and ethylene ($C_2H_4$) absorbers have been introduced to prolong fresh commodity shelf life because of the synergistic effects between these techniques and modified atmosphere packaging. Several studies have reported that postharvest management such as postharvest treatments, types of plastic bags, coating materials as well as storage temperature could extend the shelf life of fresh produce[25]-[29].

Thailand is the primary supplier of fresh galangal to the international markets, especially to other Asian countries. The distribution of fresh galangal rhizome products is mostly done under ambient temperature resulting in the short shelf life of only 5-7 days. Consequently, ambient temperature storage results in postharvest losses due to high temperatures accelerating physiological and microbial deterioration. Furthermore, inadequate preparation and packaging processes result in food loss and food waste [30]. Therefore, this research was aimed to apply HWT prior fresh galangal rhizomes be stored in two types of pouches and kept at low temperature in order to minimize the storage quality deteriorations and could extend fresh galangal rhizome.

## 2. Materials and Methods

### 2.1 Plant Material Preparations

The commercial mature (approx. eight-month-old) galangal (A. galanga) rhizomes were harvested from a local orchard, Thailand. The rhizomes were then washed with tap water to remove dirt and the stem and small roots trimmed, then 300 g ± 10 g galangal rhizomes were prepared as the samples. The samples were later treated with hot water at 40°C for 10 min according to the optimal condition obtained from a preliminary study (data not shown). After that, the samples were dipped in tap water for 10 min at room temperature to reduce the residual heat and dried with cheesecloth. The control sample was dipped in sterilized water for 10 min followed by a tap water dip for 10 min, then dried and packed in a plastic container without heat sealing.

### 2.2 Packaging and Storage Conditions

The storage bags used in this study were LLDPE and PP. LLDPE of 80 µm and PP of 180 µm thicknesses were chosen due to being generally used and giving high gas barrier. The HWT treated rhizomes were individually packed in LLDPE and PP bags and heat-sealed. The storage conditions for treated and control samples were at temperatures of 13 ± 0.4°C with 85% RH for 36 days.

### 2.3 Storage Quality Measurements

The storage quality changes in all samples were evaluated at 3-day intervals. Each treatments were assessed with five replicates for skin color (L*-a*-b*-H°), firmness and percentage of weight loss change analysis. The microstructural assessment was performed using a scanning electron microscope (SEM) for comparing the control tissue at day 0 and the treated samples at the end of storage.

#### *2.3.1 Skin Color*

Skin color was measured using a portable spectrophotometer (Miniscan EZ-MSEZ, Hunterlab, USA) set up at 10° observation with illuminant D65 with measuring the head diameter of 8 mm. Changes in skin color during storage were pursued by evaluating the rhizome skin color at same positions which were three different points marked around the rhizomes (previous study) to obtain the average values of L*, a*, b* and H°. The reported values represented the average of 15 samples for each treatment. L* indicates lightness on a scale of 0 (black) to 100 (white), a* indicates green (-) to red (+), b* indicates blue (-) to yellow (+) and H° indicates surface coloration.

#### *2.3.2 Hardness and Percentages of Weight Loss*

The hardness was measured using a texture analyzer (TA-XTPlus, Stable Micro Systems, UK). Sample was placed on the sample platform of the texture analyzer which had previously installed an 8-mm diameter flat-ended stainless steel cylindrical probe. During firmness test, the probe penetrated the rhizome flesh at 10 mm (depth) distance compression ($F_{compress}$) to obtain the maximum force (Newton, N). The test parameter for the compression test was 2 mm.s-1 for pre-test and test speed. The force-distance curves were received and extracted to achieve the maximum force. Changes in weight loss during storage were measured and expressed in percentages. Samples for weight loss evaluation were designed to be different due to minimizing the storage interruption.

#### *2.3.3 Morphological Observations*

Tissue samples of control at day 0, control at day 18th, HWT treated and packed by LLDPE and PP pouches which stored for 36 days were cut along the axis with a razor blade. Observations of galangal rhizomes cross-sections were performed under an environmental SEM and energy dispersive x-ray spectrometer (SEM-EDS) (Quanta 250, FEI Company, Hillsboro, Oregon, US) without prior specimen preparation. Morphological observations of each samples were performed at 1000x magnifications.

#### *2.3.4 Statistical Analysis of Data*

The experiments were conducted using a completely randomized design in a factorial arrangement with five replicates. The analysis of variance (ANOVA) of the data was conducted using PASW statistics 18 (SPSS Inc., USA). The differences between the means were compared by Duncan multiple comparison method at $P < 0.05$.

## 3. Results

### 3.1 Effects of HWT on the Skin Color of Galangal Rhizome

Table 1 shows the changes in L* and a* values with different treatments. The increasing trends but not significant of L* values of control and HWT treated and packed in LLDPE and PP pouches were observed. These increasing trends seemed to fluctuate. It was observed some significant drop in L* values of the control sample and HWT treated and packed in PP pouch on day 6 followed swinging up. the L* values of control and treated samples showed no significant changes compared to the L* values on day 0. The changing trend of a* values of HWT treated and packed in LLDPE and PP pouches was observed to be reduced most of them compared to the initial values but not significant. On the contrary, during storage, the a* values of control samples seem to be increased but not significant. After 36 days of storage, the a* values of HWT treated and packed in LLDPE and PP pouches presented some constant reduction but not significant while the a* values of the control sample displayed varying increases but not significant.

Table 2 illustrates changes in b* and H° values of control and treated samples. The overall changing trends of b* values of HWT treated and packed in LLDPE and PP bags were reduced with some fluctuations. It was observed that b* values of HWT treated and packed in LLDPE and PP pouches were reduced with and without significance during storage. It was noticed that on day 6 the b* values of all samples were reduced drastically and significantly different from the initial values. However, at the end of storage, the b* values of HWT treated and packed in LLDPE bags and control samples were not significantly different from the initial values. While the samples treated by HWT and PP storage presented a significant reduction on day 36.

Changes in H° values were observed and presented in Table 2. This study notes that there was some reduction and rise of H° values of HWT treated and packed in LLDPE and PP pouches but not significant during storage for 36 days. Changes of H° values on the color wheel indicated pale-yellow. The drops of H° value observed in the control sample were higher than that observed in HWT treated and packed with LLDPE and PP bags after storage for 36 days.

## 3.2 Changes of Hardness and Weight Loss of Galangal Rhizomes

Changes in hardness and percentages of weight loss of control and HWT treated and packed in LLDPE and PP bags were evaluated and the results are presented in Table 3. This study observed that all samples showed reduction and increase in hardness during storage for 36 days but no significant differences. After 36 days of storage, the hardness of LLDPE and PP storage samples increased with no significant differences. Percentages of weight loss presented as growing up trends in all samples. For the percentages of weight loss, this study noted that the percentages of weight loss of samples treated by HWT and packed in LLDPE and PP bags were grown up consistently after being stored for 36 days. Besides, there were significant differences in weight loss percentages of the control sample after 36 days of storage.

| **Colour parameters** | | **L*** | | | **a*** | |
|---|---|---|---|---|---|---|
| **Storage days** | **Control*** | **LLDPE** | **PP** | **Control** | **LLDPE** | **PP** |
| 0 | 40.1±1.7$^{abc}$ | 43.8±1.3$^{cdef}$ | 42.8±0.9$^{bcdef}$ | 5.2±0.4$^{ab}$ | 6.3±0.4$^{ab}$ | 5.4±0.6$^{ab}$ |
| 3 | 43.4±1.5$^{bcdef}$ | 45.4±0.9$^{cdef}$ | 47.7±0.7$^{f}$ | 6.0±0.7$^{ab}$ | 6.0±0.6$^{ab}$ | 5.0±0.6$^{ab}$ |
| 6 | 35.8±0.8$^{a}$ | 40.5±1.7$^{abcd}$ | 37.9±1.3$^{ab}$ | 5.1±0.3$^{ab}$ | 5.0±0.6$^{ab}$ | 3.9±0.5$^{a}$ |
| 9 | 47.7±1.2$^{ef}$ | 46.2±0.8$^{ef}$ | 47.2±0.2$^{ef}$ | 6.6±0.4$^{ab}$ | 6.1±0.4$^{ab}$ | 5.3±0.7$^{ab}$ |
| 12 | 42.0±0.6$^{bcdef}$ | 42.0±1.3$^{bcde}$ | 42.2±1.2$^{bcdef}$ | 6.1±0.4$^{ab}$ | 5.2±0.4$^{ab}$ | 4.5±0.6$^{ab}$ |
| 15 | 45.3±1.0$^{cdef}$ | 42.2±0.7$^{bcdef}$ | 43.8±1.1$^{cdef}$ | 6.9±0.3$^{ab}$ | 5.2±0.4$^{ab}$ | 4.6±0.3$^{ab}$ |
| 18 | 44.6±1.5$^{cdef}$ | 43.7±0.8$^{cdef}$ | 46.1±0.6$^{def}$ | 7.7±0.4$^{b}$ | 5.7±0.5$^{ab}$ | 5.3±0.7$^{ab}$ |
| 21 | - | 43.8±1.3$^{cdef}$ | 46.5±0.5$^{ef}$ | - | 5.2±0.5$^{ab}$ | 5.6±0.8$^{ab}$ |
| 24 | - | 44.3±1.3$^{cdef}$ | 45.0±0.7$^{cdef}$ | - | 5.3±0.5$^{ab}$ | 5.4±1.0$^{ab}$ |
| 27 | - | 44.3±0.6$^{cdef}$ | 44.2±0.9$^{cdef}$ | - | 5.1±0.3$^{ab}$ | 5.3±0.8$^{ab}$ |
| 30 | - | 46.3±0.9$^{ef}$ | 45.8±0.8$^{def}$ | - | 5.5±0.5$^{ab}$ | 4.8±0.9$^{ab}$ |
| 33 | - | 43.2±0.9$^{bcdef}$ | 45.1±0.4$^{cdef}$ | - | 5.1±0.4$^{ab}$ | 5.1±1.1$^{ab}$ |
| 36 | - | 44.2±0.8$^{cdef}$ | 44.2±0.4$^{cdef}$ | - | 5.2±0.4$^{ab}$ | 5.0±1.0$^{ab}$ |

**Table 1** Effects of HWT on L* and a* values of galangal rhizome when stored at 13±0.4°C with 85 %RH for 36 days. Numbers represent mean values (n=5) with standard error. Letters within columns indicate significant differences ($P < 0.05$). *The end of the control sample was on day 18 due to it being unable to be consumed.

| Parameters | b* | | | H° | | |
|---|---|---|---|---|---|---|
| Storage days | Control* | LLDPE | PP | Control | LLDPE | PP |
| 0 | 25.8±1.4$^{defg}$ | 31.7±0.8$^{hi}$ | 31.9±1.8$^{i}$ | 76.8±3.0$^{bc}$ | 78.7±0.6$^{bc}$ | 80.6±0.7$^{c}$ |
| 3 | 23.3±0.7$^{cdef}$ | 25.4±1.0$^{defg}$ | 26.8±0.7$^{fghi}$ | 75.6±1.8$^{bc}$ | 76.8±0.8$^{bc}$ | 79.5±1.1$^{c}$ |
| 6 | 14.4±1.0$^{a}$ | 19.8±1.6$^{bc}$ | 15.9±1.5$^{ab}$ | 67.0±2.4$^{a}$ | 75.6±0.8$^{bc}$ | 77.0±0.9$^{bc}$ |
| 9 | 24.4±0.4$^{cdef}$ | 25.6±0.3$^{defg}$ | 27.0±0.4$^{fghi}$ | 74.4±1.1$^{abc}$ | 76.6±0.8$^{bc}$ | 78.8±1.4$^{c}$ |
| 12 | 22.0±1.0$^{cdef}$ | 21.2±1.1$^{cde}$ | 21.0±0.9$^{cd}$ | 74.0±1.5$^{abc}$ | 76.5±0.5$^{bc}$ | 78.3±1.6$^{bc}$ |
| 15 | 24.4±0.6$^{cdef}$ | 21.6±0.8$^{cde}$ | 22.0±0.7$^{cdef}$ | 73.9±0.6$^{abc}$ | 76.5±0.7$^{bc}$ | 77.4±1.5$^{bc}$ |
| 18 | 25.2±1.0$^{def}$ | 24.8±0.5$^{cdef}$ | 25.1±0.3$^{def}$ | 70.8±2.4$^{ab}$ | 77.0±1.0$^{bc}$ | 78.3±1.5$^{bc}$ |
| 21 | - | 23.2±1.5$^{cdef}$ | 26.7±0.5$^{fgh}$ | - | 77.5±0.5$^{bc}$ | 78.3±1.7$^{bc}$ |
| 24 | - | 26.0±0.9$^{defg}$ | 25.3±0.7$^{defg}$ | - | 78.7±0.8$^{bc}$ | 78.0±2.0$^{bc}$ |
| 27 | - | 24.5±0.5$^{cdef}$ | 24.7±0.9$^{cdef}$ | - | 78.0±0.6$^{bc}$ | 77.7±1.6$^{bc}$ |
| 30 | - | 25.4±0.6$^{defg}$ | 25.2±0.5$^{defg}$ | - | 78.4±0.7$^{bc}$ | 79.4±2.0$^{c}$ |
| 33 | - | 26.0±0.6$^{defg}$ | 25.0±0.6$^{def}$ | - | 79.0±0.8$^{c}$ | 79.2±2.0$^{c}$ |
| 36 | - | 30.2±0.8$^{ghi}$ | 26.3±0.6$^{efg}$ | - | 78.8±0.9$^{c}$ | 79.4±2.0$^{c}$ |

**Table 2** Effects of HWT on b* and H° values of galangal rhizome when stored at 13±0.4°C with 85 %RH for 36 days. Numbers represent mean values (n=5) with standard error. Letters within columns indicate significant differences ($P < 0.05$). *The end of the control sample was on day 18 due to it being unable to be consumed.

## 3.3 Effects of HWT on Morphological Galangal Tissues

Fig. 1 exhibits the changes in morphological properties of control at day 0 (Fig. 1A), control at day 18th (Fig. 1B) and HWT treated and packed in LLDPE and PP pouches at day 36th (Fig. 1C, 1D) galangal rhizome samples. The tissues of control at day 0 galangal rhizome were distributed uniformly. Comparing the control at day 0 tissue (Fig. 1A) with the control at day 18th tissue, it was observed clearly that the control at day 18th tissue showed a nonhomogeneous deformation and considerable shrinkage in the cellular structure. While the cellular arrangements of HWT were treated and packed in LLDPE and PP pouches at day 36th (Fig. 1C, 1D) samples were similar to that of control at day 0 tissue (Fig. 1A). However, this study noted that there were slight differences between samples in LLDPE and PP containers. The galangal tissues of HWT treated and stored in LLDPE pouch showed a more uniform distribution than the samples kept in PP pouch at the end of storage.

## 4. Discussions

There is a wide range of HWT that could maintain quality attributes of fresh-cut fruits and vegetables such as inhibiting microbial effect [31], [32], wound healing [33], delaying color development [16], [34]-[36], volatile emission [37] and reducing chilling injury [38], [39]. Similarly, this study found that during storage, the L*, b*, a* and Hue° (Pale yellow) of HWT treated samples stored by LLDPE and PP pouches shown no significant difference from the initial values. Reduction of b*value of samples stored by LLDPE and PP materials were consistent with previous studies on HWT and MAP [16], [34], [35], [36] and on HWT, activated carbon (AC) and MAP [40]. The possible explanation could be due to abiotic stress as a subsequent effect following HWT [41]. Our results showed no significant increase in L* and no significant decrease in a* and H° values hence it could be noted that HWT might have some effects on the color quality of fresh galangal rhizome during storage at low temperatures for 36 days regardless of storage materials.

Effects of mild heat treatment on firmness maintenance have been reported for muskmelon [42], fresh-cut melon [43] and strawberry fruit [44]. Hot water dip contributed to the inhibition of endogenous enzymes related to cell wall degradation resulting in maintaining tissue firmness [42]. The present study revealed that the hardness of HWT treated samples was increased but not significant both in LLDPE and PP storages. It could be suggested that HWT might strengthen the galangal rhizome tissues as a result of increasing hardness. This is supported by the SEM analysis which showed that LLDPE (Fig.1C) and PP (Fig.1D) storage tissues distribute uniformly and similar to the control tissue at day 0 (Fig.1A) without damage at the end of storage.

| **Parameters** | **Hardness (N)** | | | **Weight loss (%)** | | |
|---|---|---|---|---|---|---|
| **Storage days** | **Control*[ns]** | **LLDPE[ns]** | **PP[ns]** | **Control** | **LLDPE** | **PP[ns]** |
| 0 | 263.0±22.0 | 312.5±36.4 | 323.3±40.4 | 0.0±0.0[a] | 0.0±0.0[a] | 0.0±0.0 |
| 3 | 355.9±76.8 | 391.9±52.5 | 469.8±47.5 | 7.6±0.6[b] | 0.5±0.0[a] | 0.2±0.0 |
| 6 | 446.9±25.0 | 302.2±21.7 | 416.4±70.9 | 12.9±0.8[c] | 0.7±0.0[a] | 0.5±0.0 |
| 9 | 297.0±24.6 | 245.7±24.2 | 266.0±18.4 | 18.4±1.3[d] | 0.8±0.0[a] | 0.6±0.0 |
| 12 | 288.2±15.6 | 361.1±49.5 | 297.8±34.2 | 22.9±3.1[de] | 1.0±0.0[a] | 1.0±0.1 |
| 15 | 296.4±52.4 | 431.7±48.2 | 321.4±42.4 | 24.3±2.7[e] | 1.2±0.0[a] | 1.0±0.1 |
| 18 | 380.3±72.3 | 380.8±62.4 | 422.4±65.1 | 20.5±1.8[de] | 1.2±0.0[a] | 1.1±0.1 |
| 21 | - | 343.6±57.8 | 461.3±53.6 | - | 1.4±0.0[a] | 1.1±0.1 |
| 24 | - | 348.9±34.6 | 410.0±54.3 | - | 1.4±0.0[a] | 1.2±0.1 |
| 27 | - | 399.8±48.7 | 395.0±23.1 | - | 2.0±0.0[a] | 2.2±0.2 |
| 30 | - | 428.3±57.2 | 401.6±41.0 | - | 2.3±0.1[a] | 2.0±1.3 |
| 33 | - | 315.8±28.7 | 322.2±47.6 | - | 2.6±0.1[ab] | 2.3±1.3 |
| 36 | - | 455.6±36.2 | 463.6±61.8 | - | 2.7±0.1[ab] | 2.4±1.4 |

**Table** 3 Effect of HWT on hardness and weight loss of galangal rhizome when stored at 13±0.4°C with 85 %RH for 36 days. Numbers represent mean values (n=5) with standard error. Letters within columns indicate significant differences ($P < 0.05$). *The end of the control sample was on day 18 due to it being unable to be consumed.

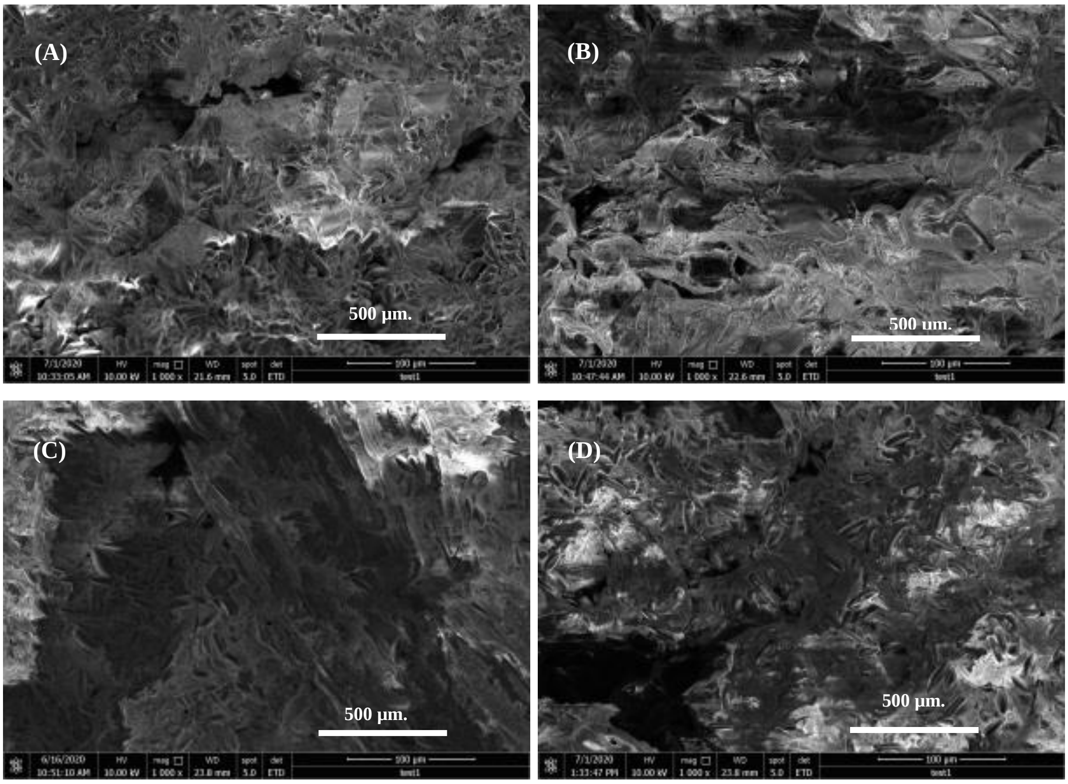


**Fig. 1** Effects of HWT on the microstructures of galangal tissues. The figure indicates the comparison of SEM of galangal tissues between control and treated tissues after storage at 13±0.4°C with 85 %RH; control at day 0 (A), control at day 18th (B), LLDPE at day 36th (C) and PP at day 36th (D)

## 5. Conclusion

Reportedly, application of HWT prior fresh produces being stored could minimize changes, subsequently could prolong shelf life. This research concludes that HWT could minimize changes in postharvest quality of fresh galangal rhizomes stored by LLDPE and PP pouches during storage at low temperatures for 36 days. The results reveal that HWT is possible to delay the color changes in fresh galangal rhizome stored by LLDPE and PP bags. Also, it could be noted that HWT prior storage is possible to maintain the hardness of fresh galangal rhizome stored in LLDPE and PP pouches during cold storage as indicated by the microstructural observation.

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## References

[1] A. Hamad, A. Alifah, A. Permadi and D. Hartanti, “Chemical constituents and antibacterial activities of crude extract and essential oils of Alpinia galanga and Zingiber officinale”, *Inter. Food. Res. J*. vol. 23, pp.837-841, 2016.

[2] A. Tewari, A. K. Pant, C. S. Mathela, N. Mengi, E. Kohl and H. J. Bestmann, “Volatile constituents of Alpinia calcarata Rosc”, *J. Ess. Oil Res*. vol. 11, pp. 739-741, 1999.

[3] G. Dash, J. K. Patra, S. Gonçalves, A. Romano, E. P. Gutiérrez-Grijalva, J. B. Heredia, A. D. Tulakdar, S. Shome and H. S. Shin, “Galangal, the multipotent super spices: A comprehensive review”, *Tre. Food Sci. & Tech*. vol. 101, pp. 50-62, July 2020.

[4] P. N. Ravindran, and I. Balachandran, “Galangal. Handbook of herbs and spices”, Woodhead publishing series in *F. Sci. Tech. Nutri*. vol. 3, pp. 357-364, 2006.

[5] S. Lurie, “Postharvest heat treatments”, *Posth. Bio. Tech. J*. vol. 14, pp. 257–269, 1998.

[6] R. E. Paull, and N.J. Chen, “Heat treatment and fruit ripening” *Posth. Bio. Tech. J*. vol. 21, pp. 21-37, 2000.

[7] J. Tang, E. Mitcham, S. Wang and S. Lurie, “Heat Treatments for Postharvest Pest Control: Theory and Practice” Oxon: *CABI International*. 2007.

[8] A. Prathapan, M. Lukhman, C. Arumughan, A. Sundaresan and K. G. Raghu, “Effect of heat treatment on curcuminoid, colour value and total polyphenols of fresh turmeric rhizome” *Inter. Food. Sci. Tech*. vol. 44, pp. 1438-1444, Jun. 2009.

[9] M. Bassal, and M. El-Hamahmy, “Hot water dip and preconditioning treatments to reduce chilling injury and maintain postharvest quality of Novel and Valencia oranges during cold quarantine”, *Posth. Bio. Tech. J*. vol. 60, pp. 186-191. 2011.

[10] C. A. Bustamante, C. O. Budde, J. Borsani, V. A. Lombardo, M. A. Lauxmann, C. S. Andreo, M. V. Lara and M. F. Drincovich, “Heat treatment of peach fruit: modifications in the extracellular compartment and identification of novel extracellular proteins” *Plant physic. biochem*. vol. 60, pp. 35-45, Nov. 2012.

[11] J. Liu, Y. Sui, M. Wisniewski, S. Droby, S. Tian, J. Norelli and V. Hershkovitz, “Effect of heat treatment on inhibition of Manilinia fructicola and induction of disease resistance in peach fruit”, *Posth. Bio. Tech. J*. vol. 65, pp. 61-68, Mar. 2012.

[12] S. Lurie, and R. Pedreschi, “Fundamental aspects of postharvest heat treatments”, *Hort. Res*. Doi:10.1038/hortres.2014.30. 2014.

[13] P. V. Mahajan, O. J. Caleb, Z. Singh, C. B. Watkins and M. Geyer, “Postharvest treatment of fresh produces”, *Phil. Trans. Royal Soc. A*. 372:20130309 DOI:10.1098/rsta.2013.0309. 2014.

[14] A. Spadoni, M. Guidarelli, S. M. Sanzani, A. Ippolito and M. Mari, “Influence of hot water treatment on brown rot of peach and rapid fruit response to heat stress”, *Posth. Bio. Tech. J*. vol. 94, pp. 66-73, Aug. 2014.

[15] E. Fallik, “Prestorage hot water treatments (immersion, rinsing and brushing)”, *Posth. Bio. Tech. J*. vol. 32, pp. 125–134, May 2004.

[16] S. Itoh, and K. Itoh, “Combined effects of hot water treatment (HWT) and modified atmosphere packaging (MAP) on quality of tomatoes”, *Pack. Tech. Sci*. vol. 16, pp. 171–178, Sep. 2003.

[17] P. Sarunya, “Effects of washing with NaCl solution and hot-water dip on postharvest quality of guava (Psidium guajava L.) fruit cv. Pean seetong during storage”, *Agri. Sci. J*. vol. 44, pp.182-185, 2013

[18] C. V. Abeele, K. Raes and I. Sampers, “Effect of mild heat treatment on browning-related parameters in fresh-cut iceberg lettuce”, *J. Food Biochem*. vol. 43. DOI:10.1111/jfbc.12906. 2019.

[19] N. Liamnimitra, M. Thammawong, C. Techavuthiporn, K. Fahmy, T. Suzuki and K. Nakano, “Optimization of bulk modified atmosphere packaging for long-term storage of ‘Fuyu’ persimmon fruit”, *Posth. Bio. Tech. J*. vol. 135, pp. 1-7, Jan. 2018.

[20] R. B. Waghmare, and U. S. Annapure, “Integrated effect of radiation processing and modified atmosphere packaging (MAP) on shelf life of fresh fig”, *J. Food Sci Tech*. vol. 55, pp.1993-2002, Jun. 2018.

[21] S. Ali, A. S. Khan, A. U. Malik, M. A. Anjum, A. Nawaz and H. M. S. Shah, “Modified atmosphere packaging delays enzymatic browning and maintains quality of harvested litchi fruit during low temperature storage”, *Scientia Hort*. vol. 254, pp. 14-20, Aug. 2019.

[22] A. Sheikhi, S. H. Mirdehghan and L. Ferguson, “Extending storage potential of de-hulled fresh pistachios in passive-modified atmosphere”, *Sci. F. Agri*. vol. 99, pp. 3426-3433. Jan. 2019.

[23] H. Li, X. Li, R. Wang, Y. Xing, Q. Xu, Y. Shui, X. Guo, W. Li, H. Yang, X. Bi and Z. Che, “Quality of fresh-cut purple cabbage stored at modified atmosphere packaging and cold-chain transportation”, *Inter. J. F. Pro*. vol. 23, pp. 138-153, Jan. 2020.

[24] Q. Zhao, M. Jin, L. Guo, H. Pei, Y. Nan and J. Rao, “Modified atmosphere packaging and 1-methylcyclopropene alleviate chilling injury of ‘Youhou’ sweet persimmon during cold storage”, *F. Pack. Shelf life*. vol. 24, 100479. Doi:10.1016/j.fpsl.2020.100479. 2020.

[25] A. A. Kader, “Post-harvest quality maintenance of fruits and vegetables in developing countries”, In: Lieberman, M., *Post-Harvest physiology and crop preservation*. Plenum Publishing Corporation. 455-469. 1983.

[26] T. Adhikary, P. P. S., Gill and S. K. Jawandha, “Enhancement in Shelf Life of Fruits using Aloe Vera gel coating - A Review”, In: Compendium of Abstracts of the 3rd *International Conference on Bio-resource and Stress Management*. Jaipur, India, (Abstr). 2002.

[27] P. Baraily, R. A., Kaushlk and M.Gurjar, “Extension of postharvest shelf life of custard apple using modified atmospheric packaging and storage temperature”, In: Compendium of Abstracts of the 3rd *International Conference on Bio-resource and Stress Management*. Jaipur, India, (Abstr). 2017.

[28] N. Kumar, and K. S. Thakur, “Extending postharvest storage life of non-astringent persimmon cv. Fuyu by 1-MCP treatments”, In: Compendium of abstracts of the 3rd *international conference on bio-resource and stress management*. Jaipur, India, (Abstr). 2017.

[29] R. Maiti, A. K. Thakur, A. Gupta and D. Mandal, “Postharvest management of agricultural produce”, In book: *Research Trends in Bioresource Management and Technology*. Publisher: American Academic Press, USA., pp.137-166, 2019.

[30] FAO., 2018. "Food loss and waste and the right to adequate food: making the connection", Rome. Italy. *Food and Agriculture Organization*, Available: http://www.fao.org/resources/infographics/

infographics-details/en/c/414196/. 29th January 2020 [Accessed: Oct. 25, 2021].

[31] P. Maxin, R. W. S. Weber, H. L. Pedersen and M. Williams, "Control of wide range of storage rots in naturally infected apples by hot-water dipping and rinsing", *Posth. Bio. Tech. J*. vol. 70, pp. 25-31, Apr. 2012.

[32] T. Kabelitz, B. Schmidt, W. B. Herppich and K. Hassenberg, "Effects of hot water dipping on apple heat transfer and post-harvest fruit quality", *LWT-Food Sci. Tech*. vol. 108, pp. 416-420, July 2019.

[33] R. Yang, Y. Han, Z. Han, S. Ackah, Z. Li, Y. Bi and Q. Yang, "Hot water dipping stimulated wound healing of potato tubers", *Posth. Bio. Tech. J.* vol. 167, pp.111245, Sep.2020.

[34] M. S. Tian, A. B. Woolf, J. H. Bowen and I. B. Ferguson, "Changes in color and chlorophyll fluorescence of broccoli florets following hot water treatment", *J. Amer. Soc. Hort. Sci*. vol. 12, pp. 310-313, Mar. 1996.

[35] M.S. Ali, K. Nakano and S. Maezawa, "Combined effect of heat treatment and modified atmosphere packaging on the color development of cherry tomato", *Posth. Bio. Tech. J*. vol. 34, pp. 113-116, Oct. 2004.

[36] S. Kaewsuksaeng, M. Nomura, M. Shigyo, and N. Yamauchi, "Suppression of chlorophyll breakdown and quality changes by hot water treatment of 'Pichit 1' Lime (Citrus aurantifolia Swingle) fruit", *The Horticulture J*. vol. 88, pp. 541-547, 2019.

[37] O. J. Caleb, K. Ilte, W. B. Herppich, M. Geyer and P. V. Mahajan, "Impacts of minimal processing and hot water dipping of 'Sonata' strawberries on volatiles emitted during storage", *Sci. Hort*. vol. 243, pp. 385-391, 2019.

[38] M. Zhang, W. Liu, C. Li, T. Shao, X. Jiang, H. Zhao and W. Ai, "Postharvest hot water dipping and hot water forced convection treatments alleviate chilling injury for zucchini fruit during cold storage", *Aci. Hort*. vol. 249, pp. 219-327. Apr. 2019.

[39] Y. Pan, M. Xu, Y. Guo, J. Zhang and Z. Li, "Effect of hot water treatment on chilling injury and lignification of cold-stored fresh areca nut (Areca catechu L.)", *J. Food. Sci. Tech*. vol. 57, pp. 4337-4344, Apr. 2020.

[40] G. Bailén, F. Guillén, S. Castillo, M. Serrano, D. Valero and D. Martínaz-Romero, "Use of activated carbon inside modified atmosphere packages to maintain tomato fruit quality during cold storage", *J. Agri. F. Chem.* vol. 54, pp. 2229-2235, Mar. 2006.

[41] D. M. Hodge, and P. M. A. Toivonen, "Quality of fresh-cut fruits and vegetables as affected by exposure to abiotic stress", *Posth. Bio. Tech. J*. vol. 48, pp. 155-162, 2008.

[42] L. Yuan, Y. Bi, Y. Ge, Y. Wang, Y. Liu and G. Li, "Postharvest hot water dipping reduces decay by inducing disease resistance and maintaining firmness in muskmelon (Cucumis melo L.) fruit", *Scientia Hort*. vol.161, pp. 101-110, Sep. 2013.

[43] A. C. Silveira, E. Aguayo, M. Chisari and F. Artás, "Calcium salts and heat treatment for quality retention of fresh-cut 'Galia' melon", *Posth. Bio. Tech. J*. vol. 62, pp.77-84, Oct. 2011.

[44] G. A. Martínez, and P. M. Civello, "Effect of heat treatment on gene expression and enzyme activities associated to cell wall degradation in strawberry fruit", *Posth. Bio. Tech. J*. vol. 49, pp. 38-45, July 2008.


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