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Impact of storage condition on postharvest preservation of fresh *Bambusa* sp. shoot

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Abstract

This research was aimed to study postharvest senescence of fresh *Bambusa* sp. shoot. The harvested bamboo shoots were packed in linear low-density polyethylene (LLDPE, 0.07 mm thick) bag and stored in 2 conditions: ambient (29±3°C) and refrigerated temperatures (5±3°C). The physical and chemical properties during the 7 days storage were investigated for postharvest quality management. The storage of the bamboo shoots at ambient greatly affected the physical and chemical properties (weight loss, discoloration, reducing sugar content and total acidity content) compared to the refrigerated storage. Under the ambient storage, critical weight loss of shoots (approximately 5) was recorded at day 4 storage along with the darkening of the basal section. Moreover, the reducing sugar rapidly decreased to 50% of the initial at day 2 storage. Sensory evaluation was conducted, and consumers were able to accept bamboo shoots stored at ambient up to one day of storage. On the other hand, bamboo shoots stored in refrigerated up to 7 days were acceptable. This is due to the quick change of color and odor of the bamboo shoots which can be the quality indicators of the harvested shoots.

1. Introduction

Bamboo, a plant of the family Poaceae and sub-family Bambuseae, is the longest grass in the world (Shukla *et al.*, 2012; Sindhal *et al.*, 2013). Among over 1,439 described species in 116 genera bamboo in the world (Clark, 2012), Thailand has contributed more than 13 species belonging to 80-90 genera (Mahayotpanya and Phoungchandang, 2015). Bamboo is recognized as an important natural resource for the paper industry, traditional handicraft, medicine and food business. *Bambusa* sp. species are selected species from *Bambusa burmanica Gamble* by seeding. The maximum height of this species is 7-12 m. In one kilogram of fresh weight, there are 4-5 harvested shoots from the mature bamboo shoot. Phuanchik *et al.* (2015) recommended that *Bambusa* sp. shoot should use in food business rather than wood industry because of its typical flavor and texture. Sindhal *et al.* (2013) revealed that the shoot was the ideal food because of low fat, high dietary fiber and rich in mineral content. This was in an agreement with Sood *et al.* (2017) who studied the quality-related attributes of four species of bamboo shoots (*Phyllostachys pubescens*, *Dendrocalamus asper*, *Dendrocalamus hemilltoni* and *Bambusa bambos*). Kusalaruk and Limsangouan (2015) also reported that *Bambusa burmanica Gamble* shoot contained about 91-92% moisture content, 0.06% fat, 2.23-2.60% dietary fiber and 3.44% protein including 18 amino acids.

Although the previous research showed the benefit of the bamboo shoots for consumption, cyanide, a dangerous compound, is still being a problem for consuming fresh bamboo. It was found that the average cyanide contents in general bamboo shoots were 167 mg/kg (Teerapapthamkul *et al.*, 2011). The low content of cyanide was found in *Bambusa* sp., only 0.22 mg/kg tested by The Industrial Metrology and Testing Service Centre, Thailand Institute of Scientific and Technological Research, Thailand. The market price of *Bambusa* sp. shoot in Thailand is 60-90 Baht/kg (2-3 US dollars). The distinctive point of the *Bambusa* sp. shoot that makes this shoot more popular than the other shoot was its typical flavor, sweet taste, not nasty and can be consumed in fresh condition. However, the shelf life of bamboo shoots is limited due to deterioration of quality-related attributes from the postharvest procedure. There was various research that studied about the deterioration of various bamboo shoots (Kleinhenz *et al.,* 2000; Lu and Xu, 2004; Shen *et al.*, 2006; Zhou *et al.*, 2012). The

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studies were revealed that the shelf life of bamboo shoot at ambient temperature in open storage and non-MAP (modified atmosphere packaging) condition was only 1 day caused by color changed and sweetness decreased. The suggestive solution that could extend its shelf life was stored in low-temperature condition or suitable MAP condition. However, so far there were no studies conducted on quality-related attributes of *Bambusa* sp. shoot after postharvest. Therefore, the purpose of this research was to study the physical and chemical changes of the fresh-cut *Bambusa* sp. shoot during storage for postharvest quality management.

2. Materials and methods

2.1 Materials

Fresh bamboo shoots of *Bambusa* sp. were obtained from a commercial bamboo farm in Phitsanulok province, Thailand. Shoots were harvested in the morning and transported at an ambient temperature (29±3°C) to the laboratory within an hour. Before conducting analysis, 2 cm of basal shoots were cut for adjusting the basal surface. All shoot sample were washed by water and dried. Then, the shoot samples were selected on criterions as follow: 0.30-0.80 kg of weight, 15-20 cm of length and 3-4 cm basal of diameter.

2.2 Packaging and storage temperature

The bamboo shoot samples were divided into two treatment: (1) stored in LLDPE bags at 29±3°C, 60% relative humidity; (2) stored in LLDPE bags at 5±3°C, 80% relative humidity. Experimental periods were 7 days. The size of the bag was 25 cm x 38 cm, 0.07 mm in thick and has 12 holes (5 mm diameter size).

2.3 Physical properties

2.3.1 Color measurement

The color change of the basal and middle of the shoot was measured using Chroma Meters (Model CR-400, Konica Minolta, INC.) in terms of CIE L* (lightness), a* (redness and greenness) and b* (yellowness and blueness). The color of the same samples was measured every day. The color value was obtained by the meters and expressed as L* (lightness), h (hue angle) and C* (chroma) values. Hue angle and chroma were calculated using the following formula.

$$\text{Hue angle } (h) = \tan^{-1}(b^*/a^*) \quad (1)$$

$$\text{Chroma } (C^*) = (a^{*2} + b^{*2})^{1/2} \quad (2)$$

2.3.2 Weight loss

For determining weight loss during storage, five shoots in each treatment were numbered. Weight of each shoot was measured with precision balance (model ME3002E, Mettler Toledo) having least count of 0.001 g. The loss in weight was expressed as percentage of the original fresh weight.

2.3.3 Texture analysis

The firmness of shoot samples was measured using a texture analyzer (Model CT3-100, Brookfield Engineering Laboratories, MA) equipped with a 2 mm stainless steel cylinder probe. The firmness was conducted on the basal and middle section of each peeled shoot. The penetration speed of 2 mm/s was set to determine 50 percentage deformation. The averages of firmness were expressed in force (N).

2.4 Chemical properties

2.4.1 Total acidity

Total acidity was measured using titration method. In each treatment, the peel shoot was chopped, crushed and filtered. A total of 2 mL of filtrate was placed in a volumetric flask, and 2-3 drops of phenolphthalein solution (Merck, Germany) was added. The solution was titrated with 0.01 N sodium hydroxide (NaOH, RCI Labscan, Thailand) to a pink end point. The total acid was expressed as percentage of the initial sample solution. Measurement of total acidity was repeated for three experimental replicates of each treatment.

2.4.2 Sugar content

Sugar content in shoot samples was determined using a colorimetric method by UV/Vis Spectrophotometer (AOAC, 2000). The solution from crushed and filtered the shoot was diluted with deionized water. The 2 mL of diluted sample was placed in a tube, and 2 mL of 6 M hydrochloric (HCl, GAMMACO, Thailand) was added. Placed the sample in boiling water for 10 mins after that, 8 mL of 2.5 M NaOH and 2 mL of 0.05 M 3,5-Dinitrosalicylic acid solution (DNSA, Merck, Germany) were added. The sample tube was covered by Parafilm (Bemis, USA) and placed in boiling water for 5 mins followed by ice water for 10 mins. The mins of the sample was measured with a UV-Spectrophotometer (Model Evolution 201, Thermo Scientific, US) at 580 nm, using blank as control. The sugar content of the sample was interpolated from the standard curve and expressed as g/L.

2.4.3 Proximate analysis

Proximate composition was measured by AOAC method (AOAC, 2000). The proximate composition was determined after 4, and 7 days of storage period. Moisture content was expressed as percentage of wet basis. The protein, fat, fiber, carbohydrate and ash were expressed as percentage of dry basis.

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2.5 Sensory evaluation

The consumer acceptance test from the sensory evaluation was performed every day by consumers (n=50) who were non-smokers and consume bamboo shoot at least once a week. The shoot samples were presented individually in plastic container. The shoot samples were codded with 3-digit random numbers. Overall liking, appearance, color and odor based on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely) were evaluated (Peryam and Pilgrim, 1957).

2.6 Data analysis

All data (with three replicates) were statistically analyzed by analysis of variance (ANOVA) using SPSS version 16.0 (SPSS Inc., Chicago, IL) to examine significant differences of the evaluated properties. Duncan's multiple range test (DMRT) was applied for multiple comparisons. The significant level of ANOVA and DMRT was justified at p-value lower than 0.05.

3. Results and discussion

3.1 Color measurement

Color of bamboo shoots changed during storage temperature and storage time. The shoot appearance in different storage temperature is presented in Table 1. For the ambient condition, brownish-black spots were detected on shoots after 3 days of storage and developed into the dark in 4 days storage. This result was in an agreement with Nugrahedi *et al.* (2004) who reported that shoots started to discolor within 1 day and after 3 days was brown-black. Whereas shoot sample that kept at 5±3°C had only a few yellow stains on the basal section after 7 days of storage. The values of L*, h and C* during storage condition are presented in Table 2. and Table 3. However, we found similar pattern of discoloration of the basal section; the L* and h value of 3 days storage was significantly different ($p<0.05$) from the control sample. For 7 days storage in refrigerated condition, L* value was significantly different ($p<0.05$) from the first day (83.27±1.75), then it slightly decreased to 77.49±2.19 on the last day of storage. For the shade (h) of bamboo shoots, it was not significantly different ($p> 0.05$). This result was in agreement with Kleinhenz *et al.* (2000) who found that shoots stored at 8°C had discoloration after 6 days of storage where the basal surface was turned into yellow. The discoloration in bamboo shoots occurred due to enzymatic browning. Phenylalanine ammonia lyase and peroxidase were activated from tissue injury due to postharvest (Chen *et al.*,1989; Nugrahedi *et al.*, 2004). Moreover, it was found that the middle section shoot color did not change during the storage period because those enzymes were not activated. To inhibit the formation of the activity of peroxidase and phenylalanin ammonialyas, Shen *et al.* (2006) reported to apply modified atmosphere packaging (MAP) treatment that the gas components were 2% O_2, 5% CO_2 and 93% N_2, so, the shoot browned slightly and remained edible.

3.2 Weight loss

The percentage of relative fresh weight of bamboo shoot samples are presented in Figure 1. Weight loss at ambient condition sample was higher than refrigerated condition. The weight loss percentage of sample kept in ambient condition increased from 1.70±0.42 to 8.19±1.47 while another sample increased from 1.03±0.33 to 2.79±0.45. Kleinhenz *et al.* (2000) reported that shoots which had lost more than 5% were visually rated unacceptable. From this study, the weight loss percentage of the ambient condition at 4 days storage, was approximately 5%, so it can be concluded that this sample was visually unacceptable after 4 days of storage. The relative humidity also affected to weight loss due to the differences in relative humidity and vapor pressure gradients between shoots and air which were affected to water loss from shoots. For reduction percentage of weight loss suggest using the suitable packaging material that minimized condensation within the package (Kleinhenz *et al.*, 2000).

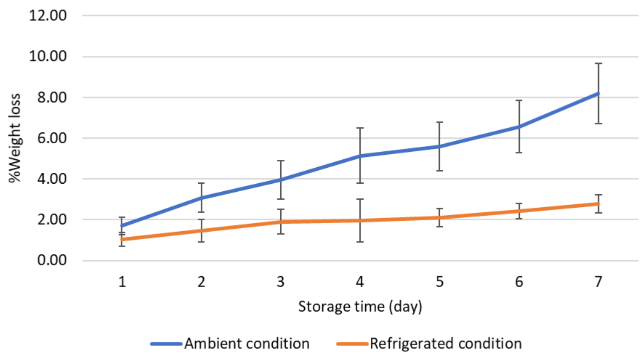

Figure 1. Weight loss of bamboo shoot was stored in LLDPE bag that affected by storage temperature

3.3 Firmness

The firmness of basal and middle fresh bamboo shoots kept in different storage conditions are presented in Table 4. The basal section had more firmness than the middle section in all condition due to the accumulation of cellulose and lignin in the basal section. It was found that the firmness of ambient samples was significantly increased after day 2 and 3 ($p<0.05$). Xu *et al.* (2004) reported that lignin content increased 15.8% in the basal section during storage while it decreased in the middle section of shoot. These results suggested that the lignifying process take place in the basal section. Meanwhile, the firmness of the basal section of the

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Table 1. Appearance of shoot during storage in each treatment

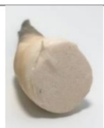
Storage Time (Day)	Ambient Condition	Refrigerated Condition	Storage Time (Day)	Ambient Condition	Refrigerated Condition
1			5		
2			6		
3			7		
4					

Table 2. color value of the basal section during storage in each treatment

Treatment	L*	h	C*
Control	83.27±1.75^{a}	86.63±3.37^{a}	13.83±1.46^{d}
AC day 2	77.90±2.28^{ab}	83.14±0.51^{ab}	23.00±1.57^{b}
AC day 3	71.61±6.67^{c}	80.02±3.84^{bc}	29.39±1.47^{a}
AC day 4	65.35±4.24^{d}	76.56±2.20^{c}	31.61±2.82^{a}
RC day 2	81.70±0.77^{ab}	86.72±0.59^{a}	14.45±0.53^{cd}
RC day 3	80.24±3.31^{ab}	86.02±1.01^{a}	15.21±2.43^{cd}
RC day 4	79.32±1.60^{ab}	85.01±0.41^{a}	16.42±1.15^{cd}
RC day 5	78.22±1.30^{ab}	85.01±1.30^{a}	15.78±2.66^{cd}
RC day 6	79.77±2.09^{ab}	83.15±2.64^{ab}	16.83±1.70^{cd}
RC day 7	77.49±2.19^{b}	82.19±2.68^{ab}	17.94±1.24^{c}

Table 3. color value of the middle section during storage in each treatment

Treatment	L*	h	C*
Control	81.85±3.33^{bc}	93.85±1.33^{a}	18.28±2.06^{ab}
AC day 2	78.09±0.87^{c}	87.14±2.57^{cde}	18.12±2.49^{ab}
AC day 3	83.23±1.40^{ab}	90.67±1.67^{b}	15.98±1.95^{bc}
AC day 4	77.48±1.28^{c}	85.80±1.47^{e}	20.93±2.72^{a}
RC day 2	80.38±0.98^{ab}	89.38±2.34^{bcd}	12.69±0.34^{c}
RC day 3	84.14±0.47^{a}	90.15±0.50^{bc}	13.06±2.04^{c}
RC day 4	84.27±0.73^{a}	89.27±1.33^{bcd}	12.13±0.94^{c}
RC day 5	82.36±1.62^{ab}	89.48±2.47^{bcd}	14.91±3.80^{bc}
RC day 6	80.25±1.46^{bc}	86.39±0.72^{de}	18.68±0.82^{ab}
RC day 7	82.60±3.32^{ab}	87.94±1.46^{bcde}	14.03±5.20^{bc}

AC = Ambient condition; RC = Refrigerated condition. All values are means ± standard deviation (n = 3). Different superscripts in the same column indicates significant difference ($p<0.05$).

Table 4. Firmness of the basal and middle section of shoot during storage in each treatment

Treatment	Firmness (N)	
	Basal section	Middle section
Control	12.39±0.97^{cd}	8.28±1.10^{ab}
AC day 2	15.22±0.10^{a}	7.50±0.16^{bc}
AC day 3	14.79±2.98^{ab}	8.73±0.85^{ab}
AC day 4	13.01±0.39^{bc}	8.90±0.87^{a}
RC day 2	11.03±0.35^{cd}	6.12±0.28^{d}
RC day 3	10.23±0.35^{d}	6.79±0.87^{cd}
RC day 4	12.12±0.17^{cd}	8.41±0.44^{ab}
RC day 5	10.83±0.58^{cd}	6.86±0.73^{cd}
RC day 6	11.54±1.06^{cd}	7.72±0.13^{abc}
RC day 7	12.63±0.38^{c}	7.67±0.26^{abc}

Table 5. Total acid (%) and reducing sugar content of shoot during storage in each treatment

Treatment	Total acid (%)	Reducing sugar content (g/L)
Control	0.069±0.004^{e}	52.42±3.32^{a}
AC day 2	0.129±0.312^{a}	20.25±0.50^{e}
AC day 3	0.123±0.379^{a}	19.21±0.29^{e}
AC day 4	0.129±0.050^{a}	17.21±1.38^{e}
RC day 2	0.089±0.001^{cd}	43.08±0.76^{b}
RC day 3	0.107±0.005^{b}	42.08±2.75^{b}
RC day 4	0.107±0.005^{b}	40.92±2.08^{bc}
RC day 5	0.098±0.001^{cd}	33.71±0.29^{d}
RC day 6	0.065±0.005^{cd}	35.29±1.42^{d}
RC day 7	0.084±0.002^{d}	38.38±1.56^{c}

AC = Ambient condition; RC = Refrigerated condition. All values are means ± standard deviation (n = 3). Different superscripts in the same column indicates significant difference ($p<0.05$).

Table 6. Proximate composition of the bamboo shoot during storage in each treatment (percentage)

Treatment	Moisture	Protein	Fat	Fiber	Carbohydrate	Ash
Control	91.85±0.20	1.99±0.31	0.92±0.02	0.92±0.08	3.63±0.22	0.68±0.06
AC day 4	92.77±0.19	2.74±0.52	0.77±0.04	1.01±0.01	1.87±0.30	0.84±0.03
RC day 4	92.56±0.19	1.85±0.73	0.61±0.03	0.71±0.04	3.62±0.30	0.65±0.03
RC day 7	92.70±0.21	1.80±0.05	0.03±0.01	0.72±0.06	3.79±0.13	0.95±0.11

AC = Ambient condition; RC = Refrigerated condition. Moisture content is expressed as % wet basis. All values are means ± standard deviation (n=3) refrigerated sample was not significantly different from the control ($p>0.05$). The firmness of the middle section of the refrigerated sample slightly decreased after storage for 3 days and was not significantly different ($p>0.05$) through the period of storage. Luo *et al.* (2008) reported that shoot firmness, lignin and cellulose increased and accelerated by higher storage temperature and there was a positive correlation between them and low temperature is an effective method for delaying lignification of bamboo shoot.

3.4 Total acidity, sugar content and proximate analysis

Total acidity and reducing sugar content are shown in Table 5. Total acidity of all sample was significantly increased after 2 days of storage ($p<0.05$). The increasing rate of total acidity of the ambient sample was higher compared to the results of total acidity of refrigerated storage. The reducing sugar content of ambient samples decreased more than 50% from the control while the refrigerated sample decreased only 17.81%. The low sugar content and high acidity could effect to shoot flavor and lead to low customer acceptance (Xia, 2006). Thammawong *et al.* (2009) revealed that not only storage time effected to the total sugar content of bamboo shoot but also different maturity. Underground bamboo shoots which newly sprouted has higher sugar content comparison with emerged shoots. Lu and Xu (2004) found that the reducing sugar of the basal rapidly decreased during the first 10 days of storage while apical sections declined slightly at the beginning of the storage.

The proximate analysis of the bamboo shoots is shown in Table 6. Moisture content is an important factor in fresh shoots, all treatments were moisture content over 90% (wet basis) and not different due to temperature and duration storage. In the 4 days of storage, the content of protein, fiber and ash composition of ambient samples increased while fat and carbohydrate content decreased. By the way, the amount of moisture and fiber content were not different from the control. Protein, fat and fiber contents of refrigerated samples deceased from 4 days to 7 days storage but carbohydrate and ash content increased during this period. It could be said that temperature and storage period effect to nutrient degradation and these were the beginning of a shoot deterioration. This result was in agreement with Zhang *et al.* (2017), reported that storage temperature and time were important factors which effected on nutrients and the storage in low temperature could maintain a high level of nutritive constituents compared with storage in room temperature. Moreover, Ding *et al.* (1997), Ding *et al.* (2006) and Song *et al.* (2013) reported that temperature plays as a major role in causing senescence of agriculture product.

3.5 Sensory evaluation

The 9 -Point hedonic scale test was acquired for the evaluation of consumer acceptance toward stored bamboo shoot conditions. Overall liking, appearance, color and odor of the samples were evaluated. The results are shown in Table 7. It can be seen that, on the first day of harvested shoots, the consumer evaluated the sample from like moderately to like very much (7-8 points). After one day of storage, the hedonic scores of all attributes of ambient condition sample decreased to neither like nor dislike to slightly like (5-6 points) and were significantly different from the control ($p<0.05$). The scores of ambient condition sample continuously reduced to slightly dislike to neither like nor dislike (4-5 points) after 3 days. While the hedonic scores of most attributes of refrigerated condition sample were still slightly like to like moderately (6-7 points) during storage and only odor factor was significantly different from the control ($p<0.05$). After 2 days of storage, color and odor scores of ambient condition sample were lower than 5 which can be considered as a level to decide that this food in unacceptable for the consumer (Grosso and

Table 7. Sensory evaluation of the bamboo shoot during storage in each treatment

Treatment	Color	Appearance	Odor	Overall liking
Control	7.86 ± 0.96^{a}	7.60 ± 1.25^{a}	7.93 ± 0.85^{a}	7.66 ± 1.07^{a}
AC day 2	5.40 ± 1.54^{c}	5.40 ± 1.36^{b}	5.66 ± 1.25^{cd}	5.93 ± 1.53^{b}
AC day 3	5.00 ± 1.37^{c}	5.40 ± 1.40^{b}	4.86 ± 1.15^{de}	5.33 ± 1.49^{b}
AC day 4	4.93 ± 1.54^{c}	5.13 ± 1.59^{b}	4.53 ± 1.02^{f}	5.06 ± 1.70^{b}
RC day 2	7.21 ± 0.77^{ab}	7.26 ± 1.18^{a}	7.33 ± 0.94^{bc}	7.33 ± 0.87^{a}
RC day 3	7.13 ± 0.72^{ab}	7.20 ± 0.65^{a}	6.46 ± 0.81^{b}	7.06 ± 0.57^{a}
RC day 4	7.20 ± 0.91^{ab}	6.93 ± 0.93^{a}	6.86 ± 0.96^{b}	7.00 ± 0.89^{a}
RC day 5	7.06 ± 1.29^{ab}	6.93 ± 1.12^{a}	6.86 ± 1.45^{b}	6.93 ± 1.18^{a}
RC day 6	7.00 ± 1.21^{ab}	6.86 ± 1.20^{a}	6.80 ± 1.28^{b}	6.93 ± 1.39^{a}
RC day 7	6.93 ± 1.00^{b}	6.86 ± 0.88^{a}	6.80 ± 1.11^{b}	6.93 ± 1.06^{a}

AC = Ambient condition; RC = Refrigerated condition. All values are means ± standard deviation (n = 3). Different superscripts in the same column indicates significant difference ($p<0.05$).

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Resurreccion, 2002). It can be told that consumers accepted the shoot which kept ambient temperature storage for 1 or 2 days while the refrigerated shoot could be kept for 7 days. The appearance of the basal section was the first impression and important quality parameter judged by consumer. The darker color of basal shoot effected on quality and shelf life of bamboo shoot, but the color of the middle shoot was still white-yellow color throughout the shelf life.

4. Conclusion

In this study, the important deterioration factors of the bamboo shoot were color, odor and decreasing sugar content which related to consumer acceptance. The shelf life of bamboo shoot at ambient temperature was 1 day due to the brown color of the basal section and the sugar content gradually decreased to approximately 50%. The shoots kept in refrigerated condition could be stored at least for 7 days. The low sugar content and high acidity could affect to fresh shoot flavor together with discoloration of basal shoot led to low customer acceptance. So, the possible quality indicators of the bamboo shoot after harvesting could be color and odor for the commercial launched product because of easily recognized by sight.

Conflict of Interest

The authors declared no conflict of interest.

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