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Properties of Chestnut Starches and Steamed Chestnuts with Different Pretreatment and Storage Conditions

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Abstract This study investigated the effects of pretreatment and storage conditions on the properties of stored chestnuts. Effects on chestnuts of refrigerated storage (RNT) and frozen storage (FNT) with no pretreatment, frozen storage after oxalic acid treatment without blanching (FON) and with blanching (FOB) were examined. Water binding capacity, swelling power, solubility, and viscosity of the starch produced from RNT, FNT, and FON were similar to those of the starch produced from control (CON). FOB showed significant differences in these properties from CON. Textural properties of starch gels prepared from stored chestnuts except FOB also were very similar to those of CON starch gels. The sensory characteristics of steamed FON and FNT were similar to those of steamed CON except in brown color and hardness. Steamed FNT tended to have higher brown color and lower hardness than steamed FON. Steamed RNT showed significant differences in all the sensory properties except in hardness and cooked chestnut flavor. Steamed FOB was significantly higher than steamed CON in water release and off-flavor. Among the storage conditions examined, frozen storage with oxalic acid treatment is recommended for the long-term storage of chestnuts.

Keywords: chestnuts, starch, storage, oxalic acid treatment, blanching, physicochemical and sensory characteristics

Introduction

Recently the production volume of chestnuts reached an excessive supply condition and storage of chestnut became a great concern to preserve its quality. However, when chestnuts are stored in room temperatures, the quality is deteriorated due to sprouting, insect attacking, and rotting (1). In order to protect the changes in quality and to extend the shelf-life of chestnuts, low-temperature, cellar storage, controlled atmosphere (CA) storage, irradiation, and fumigation have been used (2-4). However, the expenses of these storage methods are high, and the sprouting and decomposition problems remain (2,3).

Among domestic produce of chestnuts, more than 70% of the chestnuts are exported to Japan and more than 90% of the chestnuts are exported after peeling the nutshell and the skin (5). The peeled chestnuts have various problems such as decomposition, releasing of soluble components, and browning reaction during storage (6). The main reason for the browning reaction of the peeled chestnut is polyphenol oxidase and thus blanching, acids, and alum can be used to reduce the browning reaction by inactivating the enzyme activity or changing the optimum condition for the enzymes (6-8). However, importers of the chestnuts prefer chestnut products without pretreatments or alum addition, and thus the proper storage method for chestnuts are necessary to extend the shelf life. However, the processing conditions to control the changes of chestnut quality for long-term storage have not yet been elucidated. Also, there is no research to examine changes in properties of chestnut starch during storage with different storage conditions and pretreatments. Therefore, the aim of this study was to observe the changes in the physicochemical properties of chestnut starch and the sensory characteristics of steamed chestnuts and to determine the adequate long-term storage condition of chestnuts.

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Materials and Methods

Materials Chestnuts were purchased all at once from Jungahn Agricultural Cooperatives joint market in Gongju, Chungnam, Korea.

Pretreatment of chestnut for the storage The control chestnut (CON) was prepared immediately after purchase in order to minimize the change in quality as follows: aliquots (1 kg) of chestnut were put into polyethylene bags (27×28 cm) and stored in a deep freezer (−70°C, ULT2586-5-D-30; DuPont Suva Refrigerants, Asheville, NC, USA).

In order to examine the effect of refrigeration (RNT), batches of 1 kg chestnut with the outer shell remained were put into polyethylene bags which had nine 1 cm cross breathing holes for the ventilation of chestnuts. The bags were stored at 4°C.

Frozen chestnuts were prepared with different pretreatments before storing the chestnuts. Frozen chestnut without pretreatment (FNT) was prepared without peeling the outer shell. They were stored in a deep freezer (−70°C) for 48 hr and then kept in a freezer (−18°C) until used. In order to examine the effect of oxalic acid treatment (FON), 30 peeled chestnuts were put into 2 L of 0.05% oxalic acid (Duk-San Chemicals, Seoul, Korea) for 30 min in order to prevent the surface browning due to the air exposure (9). The chestnuts were washed with water 3 times and placed in the sieve for 1 min, and the remaining water was removed with paper towel. Batches of 300 g chestnut were placed in polyethylene bags (18×20 cm), put into a deep freezer for 48 hr, and then kept in a freezer.

Chestnuts were also blanched after oxalic acid treatment (FOB). For blanching, 300 g chestnuts treated with oxalic acid were put into 10 L of hot water (90°C) for 1 min. After blanching, they were cooled in cold water for 5 min and then washed 3 times. After standing in a sieve for 1 min to remove remaining water, the chestnuts were put into a deep freezer for 48 hr, and then kept in a freezer.

The samples of RNT, FNT, FON, and FOB were stored in a deep freezer until used for physicohemical and sensory analyses after the designated storage periods (3 and 6 months) to minimize the changes.

Preparation of chestnut starches Chestnut starches were prepared using the method of Park *et al.* (10) with some modification. Chestnuts were peeled and cut into small pieces. Chestnuts were ground for 3 min with distilled water in blender (31B91; Waring Dynamics, New Hartford, CT, USA) at the maximum speed. The ground chestnuts were filtered through 80 mesh sieve in order to obtain the filtrate. The filtrate was kept for one night at 4°C for the starch to be precipitated. The precipitate was washed with distilled water 6 times repeatedly and were dried in a dryer (0445; Dong-Yang Science Co., Seoul, Korea) at 35°C for 48 hr and passed through a 100 mesh sieve. The prepared starch was put into an airtight container and was stored in a desiccator at room temperature until required.

Proximate composition of chestnut and chestnut starch Moisture, lipid contents, protein, and ash of chestnut and its starch were determined by AOAC method (11)

Water binding capacity (%) of chestnut starches Water binding capacity (WBC) of chestnut starches was determined using the method of Medcalf and Gilles (12) with partial modification. A suspension of 1 g starch (dry weight basis, d.b.) in 20 mL distilled water was agitated for 1 hr at room temperature, and centrifuged (Sorvall Rte600B Refrigerated Centrifuge; DuPont Co., Wilmington, DE, USA) at 2,000×g for 15 min. The centrifuge tube was put upside down for 1 min in order to remove the free water. WBC was calculated using the following equation:

WBC (%) = [(wet wt. of starch − dry wt. of starch)/ dry wt. of starch] ×100

Swelling power and solubility of chestnut starches Starch (0.5 g, d.b.) was dispersed in 40 mL of distilled water and then heated in a shaking water bath (120 rpm, C-WB; Chang-Shin Chemicals, Seoul, Korea) for 30 min at 60, 70, 80, and 90°C. Centrifugation was followed at 2,000 ×g for 30 min. Swelling power was measured by the partial modification of Schoch's method (13). The weight of soluble materials was obtained by weighing the supernatant (ⓐ) dried at 105°C. The hydrated solid (ⓑ) from residual precipitate were used for swelling power determination. The swelling power was calculated as follows;

Swelling power (%) = [wt. of ⓑ/{dry wt. of sample × (100−solubility in water (%))}] ×100

And, total carbohydrate concentration in the supernatant ⓐ was determined by the method of the phenol-sulfuric acid (13). Then, the solubility power in water was calculated by the following equation.

Solubility power in water (%) = (total carbohydrate concen. in supernatant ⓐ/dry wt. of sample) ×100

Viscoamylograph characteristics of chestnut starch suspensions The pasting characteristics of chestnut starch suspensions were measured using the method of Medcalf and Gilles (12) with a viscometer (Viscograph-E, No. 8-025-25; Brabender, Duisburg, Germany). The suspension containing 8% starch (w/w, d.b.) was heated at a rate of 1.5°C/min from 30 to 95°C, held at 95°C for 30 min, and then cooled to 50°C.

Textural properties of chestnut starch gels The textural characteristics of chestnut starch gels were evaluated using a texture analyzer (TX-XT2i; Stable Microsystems Ltd., Godalming, England). To prepare the gels, starch suspension (8%, w/w, d.b.) was heated in boiling water for 15 min while being stirred constantly. The hot paste was then poured into a disposable petri dish (50×12 mm), ensuring no air bubbles formed, and then covered. The paste was cooled for 1 hr at room temperature, and the gel was stored for 24 hr in an incubator at 20°C. The operating conditions of the texture analyzer for the gels were as followed: probe type, SMS-p/5 (stainless cylinder type, 5 mm diameter); distance, 40% strain; load cell force, 25 kg; pre-test speed, 2.0 mm/sec; test speed, 0.5 mm/sec; post-test speed, 2.0 mm/sec. The chestnut starch gels were compressed 2 times for the measurement (14,15).

Sensory analysis of steamed chestnuts The outer shells of CON, RNT, and FNT samples were removed in the frozen stage and put in water (22±2°C) before steaming. FON and FOB samples were placed in room temperature. Two L of water was heated in a aluminum pot (22×18 cm, Cook Star, Seoul, Korea) on a hot plate (S1500; Rommelsbcher Eleckrohausgerate GmbH, Berlin, Germany) at the maximum heat (No. 12) and when the water started boiling, 300 g of prepared chestnuts were put on the steaming plate in the steamer and heated for the additional 30 min. The steamed samples were cooled in a room temperature for 1 hr and were used for the sensory evaluation.

For the evaluation of flavor and texture attributes, 2 chestnuts per sample were put on a white bowl (8.5×5 cm), covered with a lid and presented to the each panelist. The samples were coded with 3-digit random numbers and the filtered water (Ceramic Filter System, Supercape, Dalton, Fairey Industrial Ceramics Ltd., London, UK) was provided for cleansing and rinsing palates before and between samples. For the evaluation of appearance, 5 chestnuts per sample were presented in a white bowl to be evaluated by all the panelists.

The sensory evaluation was performed using 8 female panelists in the Dept. of Food Science and Technology at Ewha Womans Univ., Seoul, Korea). These panelists had previous experiences in performing sensory evaluation of various food products. Training continued until panelists were familiarized with the attributes and the evaluation

Table 1. Proximate composition[1)] of chestnut and chestnut starch

Sample	Moisture (%)	Crude protein[2)] (%)	Crude lipid (%)	Ash (%)
Chestnut	63.73±0.23	3.17±0.09	0.43±0.01	0.98±0.00
Chestnut starch	11.62±0.18	0.17±0.00	0.17±0.07	0.05±0.00

[1)]Means±SE of triplicate.
[2)]Crude protein = nitrogen × 6.25.

procedure, and the panelists showed reproducibility. Panelists evaluated intensities of 6 attributes; brown color (BC), cooked chestnut flavor (CF), sweet taste (ST), off-flavor (OF), hardness (HA), and amount of water release (WR). The intensity was evaluated on a 15-point category scale (1=weak, 15=strong) and the larger number represented the stronger intensity. Except the appearance attribute, the evaluations were conducted in the individual booths under the dim red light to avoid the bias due to the differences in color among the samples. Brown color of the steamed chestnuts was evaluated on the separate samples under the fluorescent light after the evaluation of flavor and texture attributes. All the samples were evaluated in 4 replications. The sensory evaluations were conducted with the randomized complete block design (RCBD). The sessions were held twice a day at 11 a.m. and 4 p.m. for 2 consecutive days.

Statistical analysis Statistical software (SAS Institute, Cary, NC, USA) was used for the analysis of variance (ANOVA) and Duncan's multiple range test (p<0.05) to determine significant effects and differences among the different pretreatment and storage conditions.

Results and Discussion

Approximate composition of chestnut and chestnut starch Moisture, ash, protein, and lipid contents of chestnut and its starch are shown in Table 1.

WBC of chestnut starches WBC of starches from the stored chestnuts with the different pretreatments and storing conditions are shown in Table 2. The starch samples, except FOB starch, were not significantly different from CON starch in WBC. RNT starch was the most similar in WBC to CON starch, and FOB starch exerted the highest WBC among the starch samples. This result indicates that the internal structure of starch was disrupted by blanching, and thus non-crystalline area of starch increased. This result is supported by Lim *et al.* (7). All the chestnut starches, except FNT starch, tended to have higher WBC with extended storage period from 3 to 6 months; however, the differences in WBC were not significantly different. In the case of FNT starch, as the storage period was extended, WBC was decreased slightly.

Swelling power and solubility of chestnut starches Swelling power of chestnut starches is shown in Table 3. At 60 and 70°C, all the stored chestnut starches had higher swelling power than CON starch. FOB starch had the highest swelling power at 60 and 70°C but swelling power became lower at high temperatures (80 and 90°C). At 90°C it was much lower than that of CON starch. This result is supported by the research of Lim *et al.* (7) in that the swelling power of chestnut flour showed lower swelling power when blanched at high temperature. The lower swelling power of FOB starch at the high temperature could be explained by the disruption of starch granule structure during the blanching process.

Solubility of chestnut starches is shown in Table 4. FOB starch had the highest solubility among the starch samples. Blanching could have cause disruption of crystalline structure in starch granules thus increasing release of amylose molecules. RNT starch had slightly higher solubility than CON starch, and FNT and FON starches did not show

Table 2. Water binding capacity (WBC)[1)] of chestnut starches with the different pretreatment and storage conditions

Chestnut[2)]	Storage month	WBC (%)
CON	0	139.24^{b}
RNT	3	138.18^{b}
	6	147.74^{b}
FNT	3	155.11^{b}
	6	150.88^{b}
FON	3	144.08^{b}
	6	152.92^{b}
FOB	3	230.00^{a}
	6	243.43^{a}

[1)]Means of triplicate; means not sharing a superscript letter are significantly different (p<0.05, Duncan's multiple range test).
[2)]CON, control; RNT, refrigerated chestnut; FNT, frozen chestnut; FON, frozen chestnut with oxalic acid treatment; FOB, frozen chestnut with oxalic acid treatment and blanching.

Table 3. Solubility[1)] of chestnut starches with the different pretreatment and storage conditions

Chestnut[2)]	Storage month	Solubility at °C (%)			
		60	70	80	90
CON	0	1.31^{b}	4.91^{cd}	7.20^{cd}	11.05^{d}
RNT	3	1.96^{b}	6.93^{b}	10.58^{b}	13.21^{c}
	6	2.00^{b}	6.60^{bc}	9.65^{b}	12.94^{c}
FNT	3	0.82^{b}	4.58^{d}	6.83^{cd}	10.26^{de}
	6	1.17^{b}	4.28^{d}	7.22^{cd}	9.43^{e}
FON	3	1.23^{b}	5.18^{bcd}	7.81^{c}	10.06^{de}
	6	0.75^{b}	4.12^{d}	5.98^{d}	9.88^{de}
FOB	3	14.16^{a}	13.08^{a}	13.92^{a}	17.10^{b}
	6	13.82^{a}	13.76^{a}	14.83^{a}	20.15^{a}

[1)]Means of triplicate; means within a column not sharing a superscript letter are significantly different (p<0.05, Duncan's multiple range test).
[2)]CON, control; RNT, refrigerated chestnut; FNT, frozen chestnut; FON, frozen chestnut with oxalic acid treatment; FOB, frozen chestnut with oxalic acid treatment and blanching.

Table 4. Swelling power[1)] of chestnut starches with the different pretreatment and storage conditions

Chestnut[2)]	Storage month	Swelling power at °C (%)			
		60	70	80	90
CON	0	3.40^{f}	10.38^{f}	21.27^{d}	26.82^{bc}
RNT	3	4.72^{c}	15.31^{ab}	23.86^{ab}	27.91^{b}
	6	5.28^{bcd}	15.26^{ab}	25.33^{a}	31.25^{a}
FNT	3	4.81^{c}	15.53^{ab}	22.29^{bcd}	26.99^{bc}
	6	5.38^{bc}	14.89^{b}	23.33^{bc}	27.06^{bc}
FON	3	4.99^{cde}	15.89^{a}	22.52^{bcd}	26.05^{c}
	6	4.96^{de}	13.85^{c}	21.87^{cd}	26.55^{bc}
FOB	3	6.27^{a}	12.78^{d}	16.03^{e}	18.38^{e}
	6	5.47^{b}	11.57^{e}	16.14^{e}	20.02^{d}

[1)]Means of triplicate; means within a column not sharing a superscript letter are significantly different ($p<0.05$, Duncan's multiple range test).
[2)]CON, control; RNT, refrigerated chestnut; FNT, frozen chestnut; FON, frozen chestnut with oxalic acid treatment; FOB, frozen chestnut with oxalic acid treatment and blanching.

significant differences from CON starch. RNT starch showed slightly higher solubility than CON starch, and this could be caused by the actions of hydrolytic enzymes, breaking starch molecules into smaller molecules including sugars during prolonged refrigerated storage (16).

Pasting and viscosity characteristics of chestnut starch pastes The viscosity characteristics of chestnut starch pastes with different pretreatment and storage conditions are shown in Table 5. The initial pasting temperatures for chestnut starch were between 62.5-65.3°C and the FNT starch at 3 months of storage showed the lowest value and was significantly different from that of CON starch. The peak temperatures were between 80.3-88.9°C. FNT and FON starches had higher, and FOB starch had lower peak temperatures than CON starch at both storage periods. Viscosity characteristics (peak viscosity, viscosity after holding for 30 min, and cooling to 50°C) of FNT, FON, and RNT starches were higher than those of CON starch. FOB starch showed the lowest peak viscosity, characteristics. Park *et al.* (17) also reported that the chestnut starch with previous heat-moisture treatments showed lower viscosity than the untreated starch. This is probably due to the less rigid starch granules. Viscosity characteristics are dependent on the rigidity of starch granules which affect the swelling power of starch granules and amount of amylose leaching out in the starch suspensions. The lower viscosity characteristics of FOB starch could be related to the decreased swelling power at the high temperatures.

The breakdown viscosity of starch granules indicates the degree of disintegration of swollen starch granules due to heat or shear force. All the stored chestnut starches had lower breakdown viscosity than the control. Especially, the breakdown viscosity of FOB starches was markedly lower than the other chestnut starches. The lower breakdown viscosity of FOB starch is probably related to the lower peak viscosity which was caused by blanching (17).

The setback of RNT starch at 3 months of storage was not significantly different from CON starch, but at 6 months it was higher. FNT and FON starches had lower setback than CON starch indicating lower viscosity increase during cooling. The setback of FOB starch which went through blanching was the lowest among the stored chestnut starches.

Textural properties of the chestnut starch gels The textural properties of starch gels from the stored chestnuts are shown in Table 6. Hardness of all the starch gels prepared from chestnut stored for 3 months was not significantly different from that of CON starch gel. With the 6 month storage, the hardness of RNT gel was significantly higher than the other gels and these gels were not significantly different from each other.

The springiness, cohesiveness, gumminess, and chewiness of all the starch gels prepared with chestnut stored for 3 months, except FOB gel, were not significantly different from those of CON gel. However, after 6 months storage of chestnuts, RNT gels had lower springiness and cohesiveness than those of CON gel, and FNT and FON gels also had lower values in the most textural properties than CON gel. With 6 months storage, RNT gel was very

Table 5. Brabender viscoamylograph characteristics[1)] of chestnut starch suspensions with the different pretreatment and storage conditions

Chestnut[2)]	Storage month	Temperature (°C)		Viscosity (B.U.)				
		Initial pasting	Peak pasting	Peak (P)	Holding 30 min at 90°C (H)	Cooling to 50°C (C)	Break down (P-H)	Setback (C-H)
CON	0	64.6^{ab}	84.8^{c}	801^{c}	511^{c}	734^{c}	290^{a}	223^{b}
RNT	3	63.4^{bc}	85.1^{c}	836^{bc}	587^{b}	817^{b}	249^{bc}	230^{b}
	6	63.7^{bc}	86.7^{b}	845^{bc}	624^{ab}	904^{a}	221^{c}	280^{a}
FNT	3	62.5^{c}	88.7^{a}	901^{a}	648^{a}	814^{b}	253^{b}	165^{d}
	6	63.7^{bc}	88.9^{a}	868^{ab}	608^{ab}	805^{b}	260^{ab}	197^{c}
FON	3	63.7^{bc}	88.4^{a}	910^{a}	633^{ab}	805^{b}	277^{ab}	172^{d}
	6	64.3^{ab}	88.2^{a}	878^{ab}	613^{ab}	812^{b}	265^{ab}	199^{c}
FOB	3	63.9^{abc}	80.3^{d}	270^{d}	221^{d}	297^{d}	49^{d}	76^{e}
	6	65.3^{a}	81.7^{d}	221^{e}	171^{e}	249^{d}	50^{d}	78^{e}

[1)]Means of triplicate; means within a column not sharing a superscript letter are significantly different ($p<0.05$, Duncan's multiple range test).
[2)]CON, control; RNT, refrigerated chestnut; FNT, frozen chestnut; FON, frozen chestnut with oxalic acid treatment; FOB, frozen chestnut with oxalic acid treatment and blanching.

Table 6. Textural properties[1)] of chestnut starch gels with the different pretreatment and storage conditions

Chestnut[2)]	Storage month	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
CON	0	16.50^{bc}	0.96^{ab}	0.45^{a}	7.36^{ab}	7.22^{a}
RNT	3	17.04^{bc}	0.91^{bc}	0.44^{a}	7.48^{ab}	6.86^{a}
	6	19.89^{a}	0.83^{cd}	0.39^{bc}	7.75^{a}	6.48^{a}
FNT	3	16.79^{bc}	1.02^{a}	0.42^{ab}	7.11^{ab}	7.30^{a}
	6	17.81^{b}	0.77^{de}	0.36^{c}	6.33^{bc}	4.92^{b}
FON	3	16.85^{bc}	1.00^{ab}	0.44^{a}	7.44^{ab}	7.46^{a}
	6	17.59^{b}	0.73^{ef}	0.32^{d}	5.55^{cd}	4.08^{bc}
FOB	3	15.29^{c}	0.65^{fg}	0.30^{d}	4.64^{d}	3.05^{cd}
	6	15.23^{c}	0.61^{g}	0.30^{d}	4.75^{d}	2.77^{d}

[1)]Means of triplicate; means within a column not sharing a superscript letter are significantly different ($p<0.05$, Duncan's multiple range test).
[2)]CON, control; RNT, refrigerated chestnut; FNT, frozen chestnut; FON, frozen chestnut with oxalic acid treatment; FOB, frozen chestnut with oxalic acid treatment and blanching.

Table 7. Sensory characteristics[1)] of steamed chestnuts with the different pretreatment and storage conditions

Chestnut[2)]	Storage month	Brown color	Hardness	Water release	Cooked chestnut flavor	Sweet taste	Off-flavor
CON	0	5.91^{bc}	9.16^{a}	5.84^{d}	8.91^{a}	7.53^{bcd}	3.63^{c}
RNT	3	9.53^{a}	7.84^{ab}	8.59^{a}	8.31^{a}	10.22^{a}	3.63^{c}
	6	10.19^{a}	8.66^{ab}	8.56^{a}	7.88^{a}	8.50^{b}	5.84^{a}
FNT	3	6.69^{bc}	8.28^{ab}	6.41^{cd}	7.66^{a}	7.19^{bcd}	4.25^{bc}
	6	7.06^{b}	7.31^{b}	7.22^{abcd}	8.78^{a}	8.13^{bc}	3.63^{c}
FON	3	6.53^{bc}	8.66^{ab}	7.06^{abcd}	8.22^{a}	8.03^{bcd}	4.25^{bc}
	6	5.31^{c}	9.09^{a}	6.69^{bcd}	7.75^{a}	7.66^{bcd}	4.22^{bc}
FOB	3	5.06^{c}	8.47^{ab}	7.53^{abc}	7.81^{a}	6.75^{cd}	5.72^{a}
	6	4.97^{c}	8.84^{ab}	8.03^{ab}	7.84^{a}	6.56^{d}	5.19^{ab}

[1)]Means of 4 replicates (with 8 panelists); means within a column not sharing a superscript letter are significantly different ($p<0.05$, Duncan's multiple range test).
[2)]CON, control; RNT, refrigerated chestnut; FNT, frozen chestnut; FON, frozen chestnut with oxalic acid treatment; FOB, frozen chestnut with oxalic acid treatment and blanching.

similar to CON gel in most of the texture properties. However, the refrigeration for storage would not be desirable when the spoilage rate was considered; it appeared to be 20% in 3 months and 50% in 6 months. FOB gels had the lowest textural properties among the starch gels. Effects of blanching on the properties of starch (7,17) were also confirmed in the starch gel of stored chestnuts which had been blanched before storage.

Sensory characteristics of steamed chestnuts The sensory characteristics of steamed chestnuts with the different pretreatment and storage conditions were evaluated (Table 7). For brown color (BC), RNT was higher than CON while FNT, FON, and FOB which were stored at frozen state were not significantly different from CON. The reason for the higher brown color of RNT could be because the normal metabolism of chestnuts was inhibited and the free sugars were accumulated due to the refrigerated storage causing Maillard reaction during steaming process. This result can be supported by the increased browning of French potato product when the refrigerated potatoes were used (18). Sacchetti *et al.* (19) also reported that chestnut flour with high reducing sugar contents and high amino acids such as lysine and methionine could enhance the Maillard reaction rate during the high temperature treatments. Also, activity of enzymes such as peroxidase during refrigerated storage could be the reason for the stronger brown color of RNT. The enzyme activity could be decreased with oxalic acid treatment and blanching. Oxalic acid treated chestnut had nonsignificant changes in FON at 6 months of storage indicating the effectiveness in the prevention of appearing brown color. The effect was more obvious in FOB which had not only oxalic acid treatment but also blanching which also deactivates the enzyme activity.

Steamed stored chestnuts were not significantly different from CON in; hardness with 3 and 6 months of storage except FNT stored for 6 months. For water release (WR), RNT and FOB were significantly higher than CON. The high WR of RNT could be explained partly by the hydrolysis of starch during storage which could result in lower water holding capacity of steamed chestnut. However, the high WR of FOB could be due to heat treatment prior to storage which might have caused higher water content.

Cooked chestnut flavor (CF) of stored chestnuts was lower than that of CON but was not significant. In sweet taste (ST), FNT, FON, and FOB were not significantly different from CON while RNT was higher than CON especially at 3 months of storage. The reason for the high ST of RNT at 3 months of storage could be the accumulation of disaccharides such as sucrose and maltose from hydrolysis of starch by enzymes. However, some of the sugars seemed to be consumed by microorganisms during further storage thus lowered sweet taste as shown at 6 months of storage. Nha and Yang (1) also reported that the contents of sucrose and maltose of chestnut were increased until 5 to 7 weeks during the refrigerated (1°C) storage period of chestnut and then decreased with the extended storage period.

In off-flavor, RNT was not significantly different from CON at 3 months of storage, but was significantly increased at 6 months. During the refrigerated storage, aldehydes, ketones, and alcohols, produced from bacterial deterioration could cause off-flavor at 6 months of storage (20). FOB also had significantly higher off-flavor than CON at both storage periods. This could be related to the reduction in desirable flavors including sweet taste. FNT and FON were not significantly different from CON even at 6 months in off-flavor intensity.

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