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Research Article

The Effects of Cultivar Type on the Quality Characteristics of Chinese Chestnuts (*Castanea mollissima*) Canned in Sugar Syrup

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Abstract: This study compared the single grain weight, the carbohydrate composition (starch, amylose, total sugar, reducing sugar, pectin, fibre) and moisture, protein, fat and ash contents of four Chinese chestnut cultivars (Banhong, Yankui, Yanlong and Zaofeng) from the Yan mountain range of China. Results showed that the tannin content of the pellicle of the chestnuts and the rate of its loss during the canning heat treatment had a significant effect on pellicle removal ($p<0.05$). Analysis of the canned chestnuts after storage at room temperature (25±2°C) suggested that Banhong was most preferred with a sensory score of 6.15 after 7 days and 5.79 after 180 days of storage. No significant quality differences were observed between the Zaofeng and Banhong cultivars, while the quality of the Yanlong and Yankui cultivars was significantly lower ($p<0.05$). We have obtained some dependence between the chestnuts' physicochemical components and the overall acceptability of the canned chestnuts.

Keywords: Chestnuts canned in sugar syrup, correlation, cultivars, physicochemical composition, sensory quality

INTRODUCTION

The Chinese chestnut (*Castanea mollissima*) is a high-value plant species with an important role in the food consumption, economy and ecology of China (Guo *et al*., 2012). Within this species, the chestnuts from the Yan mountain range belong to a cultivar group from North China with a long history of cultivation and a unique, intensely sweet flavor and glutinous mouth-feel. Therefore, Yan chestnuts have a special position in Chinese chestnut production and are renowned at home and abroad.

Chestnuts have a short shelf life due to their high moisture and sugar content (Nha and Yang, 1996; Attanasio *et al*., 2004). In China, one third of the annual chestnut harvest is exported to Japan (Vossen, 2000); the remainder being mainly roasted and consumed locally, during which a large proportion is damaged, causing a great economic loss (Deamaison and Adria, 1986; McCarthy and Meredith, 1988). Previous investigations (Wu *et al*., 2003) revealed that freezing chestnuts would reduce gumminess and increase hardness during storage. Therefore, processing chestnuts using canning in sugar syrup could be an effective and promising way to improve the product shelf life for commercial production purposes.

However, many problems exist such as broken chestnut fruit, unacceptable browning and turbid sugar syrup in canned chestnuts. Su *et al*. (2012) studied the effect of cultivar on the processing characteristics of canned chestnuts using sensory quality screening. Overall, there are few data available on the quality of Chinese chestnuts canned with sugar syrup and very few reports on the effects of cultivar. To overcome these problems, we aim to optimize the quality of chestnuts canned with sugar syrup and to determine the effects of using different cultivars from the Yan mountain range.

MATERIALS AND METHODS

Sample preparation: Chinese chestnuts (*Castanea mollissima*) were obtained from the Yan mountain range and selected for uniformity and size; any bruised or diseased fruits being discarded. The cultivars chosen were Banhong, Yankui, Yanlong and Zaofeng, which were harvested from the orchards in September/October.

Processing technique for canning chestnuts:

Shell and pellicle removal: One kilogram batches of chestnuts of the four varieties were immersed in hot water (70°C) for 8 min. The shells were then cut and removed along with the pellicle (the soft skin) without damaging the nuts (Tanaka *et al*., 1981).

Colour protection: After removing the shell and pellicle, the nuts were immediately immersed in a colour-protection solution containing 2% citric acid, 0.08% EDTA-2Na and 0.5% ascorbic-acid (Long and

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Alben, 1969; Himelrick and Ingle, 1981; Vamos-Vigyazo and Haard, 1981).

Precooking using the temperature-gradient method: Chestnut kernels (1 kg) were precooked with color protection liquid (3 kg) and 0.2% calcium chloride hardening agent (3 kg) using the temperature-gradient method. This method consists of a first stage; raising the temperature to 50-60°C over 10 min, a second stage: 75-85°C over the next 15 min, a third stage; 95-97°C over the next 15 min and the final fourth stage; 100°C for 5 min. After this treatment, the chestnuts were rinsed with 50-60°C water for a few minutes and then rinsed again with ambient temperature water (25±1°C) to cool them. After cooling, the chestnuts were immersed in 1% chitosan glacial acetic acid (w/v) for 1-2 min and then baked at 68±2°C for 9±1 min.

Sugar syrup preparation: The sugar syrup (30% w/w) was prepared using distilled water and white granulated sugar, adding 0.02% EDTA as a color fixative. After boiling, the syrup was filtered through three layers of gauze.

Filling: The glass jars, used as containers (220 mL), had walls of uniform thickness free of incorporated bubbles. The jars were sterilized at 121±1°C for 30 min before use in a vertical autoclave (BXM-30R, Boxun, Shanghai, China). After filling with precooked chestnuts (130 g) and pouring in sugar syrup, a headspace of 1 cm was retained.

Venting and sealing: The filled glass jars were placed in a hot water bath until the temperature reached 80°C, then allowed to vent for a further 15±2 min and sealed immediately.

Sterilization and cooling: The canned chestnuts were then sterilized at 90±0.5°C for 30 min in an electrically-heated thermostatically-controlled water bath (HHS-11-6, Boxun, Shanghai, China) and then cooled at room temperature.

Determining the chemical composition of Chinese chestnuts: The moisture, crude protein, fat, total ash, crude fibre contents in the raw ingredients were determined using the AOAC methods Nos. 925.09, 920.87, 920.85, 923.03 and 991.43, respectively (AOAC, 1990, 2005). The starch, total sugars, reducing sugars and pectin contents were determined by an enzymatic procedure according to AOAC (1997). The tannin content of the pellicle of the Chinese chestnut was determined by a rapid complex titration (Manab, 1980; Kurogi and Bessho, 1980). Amylose was determined by iodine colorimetry (Williams *et al*., 1970; Juliano *et al*., 1981).

Browning index: The appearance of the canned chestnuts was determined by measuring the extent of the total browned area on each fruit surface on a scale from 0 = no browning, 1 = browning spots, 2 = slight browning (<1/10), 3 = moderate browning (1/10-1/3), 4 = moderate-serious browning (1/3-1/2) up to 5 = serious browning (>1/2). The browning index was calculated using the follow formula:

Index = ∑ (browning scale * percentage of corresponding fruits within each class)

Fruits evaluated with an index higher than 2.0 were considered to be unacceptable (Peng and Jiang, 2004).

Colour: The colour of the chestnut samples canned in sugar syrup was measured using a WSC-S colour reader (Exact Science Inc., Shanghai, China) using the CIELAB colour scales. Ten readings were taken from different fruits from one canned jar and the mean value was recorded. The total colour change (ΔE) was calculated from Eq. (1):

$$\Delta E = [(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2]^{1/2} \quad (1)$$

The values for raw chestnut fruits, represented as L_0, a_0 and b_0, were taken as reference points and were 68.59, 1.99 and 30.56, respectively (Demirkesen *et al*., 2011; Tian *et al*., 2012).

Overall acceptability: Product acceptability was evaluated by 40 consumer assessors (20 males, 20 females between the ages of 18 and 45) selected from the staff and graduating class students of the Food Engineering and Chestnut Engineering Departments of Hebei Normal University of Science and Technology. Assessors evaluated the chestnuts canned in sugar syrup for color, flavor, taste, appearance (clarity of syrup and the complete fruit), texture using 7-point hedonic scales scored from 1 = extremely dislike to 7 = extremely like of each item. After an orientation session for the assessors, the samples, coded with three digits, were given in a random order to the assessors (Altan *et al*., 2008; Gajula *et al*., 2008; Henock *et al*., 2011).

Texture: The texture characteristics of the Chinese chestnuts canned in sugar syrup (hardness, springiness, gumminess and chewiness) were measured using a TA-XT2i Texture Analyzer (Texture Technologies Corp, Scarsdale, NY, USA) fitted with a 2 mm diameter cylindrical probe. The hardness, springiness, gumminess and chewiness values were considered as the mean peak compression force and expressed in N. The probe used a pre-test speed of 2.0 mm/sec, a test speed of 0.5 mm/sec and a distance of 50% strain (penetration depth). The force-time curves were recorded and analysed by the Texture 32 software program (version 3.0, Texture Technologies Corp.). Ten measurements were performed on each sample and averaged.

Total dissolved solids: For this test, 10 g chestnuts were ground and added to 30 mL distilled water, then the mixture was centrifuged (10000 g for 10 min). The supernatant was measured for total dissolved solids using a saccharimeter (PAL-α, Atago Inc., Tokyo, Japan).

Data analysis: All analyses were performed in triplicate. For the physicochemical measurements and scores from the sensory assessors, the results were subjected to Analysis of Variance (ANOVA). The *F*-values were significant ($p<0.05$). The analysis was performed using SPSS software (IBM SPSS Statistics, IBM Corp., Version 17.0).

RESULTS AND DISCUSSION

Chemical composition of the raw materials: Table 1 shows that the carbohydrate content differs significantly between the four Chinese chestnut cultivars ($p<0.01$), which agrees with the results of Yang *et al*. (2008). The Zaofeng cultivar had the highest starch content, but a significantly ($p<0.01$) lower amylose content (5.82±0.10%). The soluble amylose dissolves from the starch grains and disperses in the syrup under the action of heat (Demiate *et al*., 2001; Attanasio *et al*., 2004). Thus the factor directly affecting the turbidity of sugar syrup in canned chestnuts is amylose content. The Zaofeng and Banhong cultivars had significantly higher total sugar contents than the other two ($p<0.01$). Our investigations revealed that there was no significant difference ($p>0.05$) in enzymatic browning, but the Maillard reactions were strong at the high temperature during sterilization. The Yankui cultivar had the lowest reducing sugars content (0.59±0.03%, $p<0.01$), thus aiding color protection. The pectin content showed the greatest difference between the four cultivars; Yankui had the highest level and Banhong the lowest. The Zaofeng cultivar had the highest crude fibre content; Yankui and Banhong the lowest.

Table 2 shows that the Zaofeng cultivar had the smallest single grain weight (6.29±1.35 g), which was significantly lower than the others ($p<0.01$). The moisture in chestnuts was about 50~54% and was significantly higher in Banhong and Yankui cultivars than in Yanlong and Zaofeng ($p<0.05$). The chestnuts had up to 4~6% protein; Yanlong with the highest level (5.29±0.09%) and, in contrast, Zaofeng with the lowest level (4.12±0.06%). The fat content in these four cultivars was 0.4~0.7% with significant differences between them ($p<0.05$). The four chestnut cultivars showed no significant differences in ash content.

Tannin in the pellicle: The tannin contents in the pellicles of the four chestnut cultivars are listed in Table 3. Pellicle removal is a key process during canned chestnut processing. Table 3 shows that tannin contents were significantly different between cultivars, with the Zaofeng cultivar having the highest value (13.65±0.11, g/100 g). The tannin loss was about 33.35~51.23% during precooking with Banhong losing the most, 51.23±1.52%, significantly more than the Yanlong and Yankui cultivars ($p<0.01$). Meanwhile, pellicle removal from the Banhong cultivar was easier than the other cultivars in the process of manual operation.

Quality evaluation of canned chestnuts: Table 4 shows the processing characteristics of the four chestnut cultivars. No significant differences were observed in the hardness of the four cultivars, while after storage for 180 days, hardness values had decreased significantly ($p<0.01$) probably because of the osmosis of sugar syrup into the chestnuts (Gounga *et al*., 2007). Yanlong had the highest springiness values but values for all four cultivars changed little after 180 days of storage. The gumminess values varied significantly between cultivars ($p<0.05$) after 7 days of storage; the Zaofeng cultivar had the highest value (6.79 N) and Yankui the lowest (0.53 N). After 180 days of storage, the gumminess of all canned chestnuts except Banhong reduced significantly ($p<0.05$). The Zaofeng cultivar had the highest chewiness (46.85 mJ) and Yankui the lowest (0.35 mJ). However, the chewiness of the Banhong and Yankui cultivars

Table 1: Carbohydrate composition and content of fresh Chinese chestnut fruits

Cultivar	Starch (%, wb)	Amylose (%, wb)	Total sugars (%, wb)	Reducing sugars (%, wb)	Pectin (%, wb)	Fibre (%, wb)
Banhong	18.52±0.52[b]	7.49±0.19[b]	13.58±0.14[a]	0.93±0.07[a]	0.84±0.02[c]	0.69±0.03[c]
Yankui	17.32±0.77[c]	8.35±0.15[a]	10.45±0.08[b]	0.59±0.03[b]	4.57±0.08[a]	0.35±0.01[c]
Yanlong	17.64±0.30[c]	7.45±0.04[b]	9.35±0.09[c]	1.12±0.04[a]	0.98±0.02[c]	1.95±0.05[b]
Zaofeng	19.17±0.34[a]	5.82±0.10[c]	13.20±0.23[a]	1.15±0.03[a]	2.25±0.04[b]	2.56±0.07[a]

The different letter on the shoulder of the values indicate significant difference ($p<0.05$); wb: Wet basis

Table 2: Chemical composition of fresh Chinese chestnut fruits

	Mass per nut (g, wb)	Water (%, wb)	Protein (%, wb)	Fat (%, wb)	Ash (%, wb)
Banhong	7.74±1.19[a]	53.02±0.37[a]	4.53±0.03[b]	0.41±0.04[c]	1.21±0.10[a]
Yankui	7.67±1.42[a]	53.55±0.22[a]	4.75±0.06[b]	0.53±0.06[b]	0.98±0.05[a]
Yanlong	7.98±1.34[a]	50.74±0.36[b]	5.29±0.09[a]	0.63±0.03[a]	0.87±0.07[a]
Zaofeng	6.29±1.35[b]	50.47±0.14[b]	4.12±0.06[c]	0.53±0.09[b]	0.96±0.03[a]

The different letter on the shoulder of the values indicate significant difference ($p<0.05$); wb: Wet basis

Table 3: Tannin content in Chinese chestnut pellicles

	Raw fruits (g/100 g pellicle)	Cooked fruits (g/100 g pellicle)	Loss rate (%)
Banhong	9.17±0.12^{c}	4.47±0.06^{d}	51.23±1.52^{a}
Yankui	7.35±0.08^{d}	4.86±0.13^{c}	33.88±1.08^{c}
Yanlong	9.70±0.13^{b}	6.46±0.08^{b}	33.35±2.08^{c}
Zaofeng	13.65±0.11^{a}	8.65±0.07^{a}	36.61±1.61^{b}

The different letter on the shoulder of the values indicate significant difference ($p<0.05$); wb: Wet basis

increased significantly, while Yanlong and Zaofeng decreased significantly after 180 days of storage ($p<0.05$). The Yankui cultivar had the highest Browning Index (1.8±0.04) and Banhong the lowest (0.2±0.03) after precooking, while there was no significant difference between these four cultivars after 180 days of storage. The Yankui cultivar had significantly lower total dissolved solids than the other three ($p<0.05$) after 7 days of storage. However, during storage, the total dissolved solids value reduced significantly as solids continued dissolving into the sugar syrup with the four cultivars showing no significant differences between each other after 180 days of storage ($p>0.05$).

Table 5 shows a comparison of the four chestnut cultivars regarding color, sensory attributes and overall acceptability after 7 and 180 days of storage. The color values (difference between sample and fresh) differed significantly between cultivars ($p<0.05$). The color of the chestnuts became deeper during storage, but no significant difference was seen between the four cultivars. The flavor of the canned chestnuts was not significantly different ($p>0.05$) between cultivars after 7 days of storage but after 180 days, the flavor of the Yanlong and Yankui cultivars decreased significantly ($p<0.05$), but Zaofeng and Banhong showed no significant changes. For the appearance (clarity of syrup and the complete fruit) of canned chestnuts, Banhong received the highest score of 6.43, in spite of there being a little sediment in the glass jars after 180 days. The Yankui cultivar received the lowest score after 180 days of storage because of more sediment, the score being significantly lower than that at 7 days ($p<0.01$).

Table 4: Effect of storage time at 25±2°C and cultivar on processing characteristics of canned chestnuts

	Storage time	Banhong	Yankui	Yanlong	Zaofeng
Hardness (N)	Day 7	14.97±1.29^{aA}	13.24±1.57^{aA}	13.16±2.35^{aA}	15.15±1.81^{aA}
	Day 180	8.30±1.52^{B}	7.86±0.91^{B}	9.45±0.67^{B}	10.25±2.41^{B}
Springiness (mm)	Day 7	6.97±1.26^{bA}	6.64±0.04^{bA}	9.15±0.45^{aA}	7.21±0.88^{bA}
	Day 180	6.98±0.24^{A}	7.45±1.26^{A}	7.89±0.73^{A}	6.40±1.21^{A}
Gumminess (N)	Day 7	3.29±0.98^{cA}	0.53±0.04^{dA}	5.06±1.18^{bA}	6.79±0.40^{aA}
	Day 180	4.75±0.64^{A}	0.34±0.09^{B}	1.52±0.31^{B}	3.33±0.98^{B}
Chewiness (mJ)	Day 7	23.75±1.41^{cB}	0.35±0.07^{dB}	35.95±3.59^{bA}	46.85±1.79^{aA}
	Day 180	32.63±1.78^{A}	0.84±0.07^{A}	11.64±1.28^{B}	25.42±2.13^{B}
Browning index	Day 7	0.40±0.02^{c}	1.50±0.03^{b}	1.80±0.04^{a}	0.20±0.03^{d}
	Day 180	0.40±0.02	1.50±0.03	1.80±0.04	0.20±0.03
Total dissolved solids (%)	Day 7	21.20±0.12^{aA}	19.20±0.21^{bA}	24.90±0.15^{aA}	24.30±0.18^{aA}
	Day 180	18.10±0.16^{B}	11.70±0.13^{B}	17.40±0.13^{B}	17.10±0.08^{B}

Means followed by the different capital letters in a column (day 7 and 180) are significantly different at $p<0.05$; Means followed by the different lowercase letters in the same row are significantly different ($p<0.05$)

Table 5: Effect of storage time and cultivar on sensory quality of canned chestnuts

	Storage time	Banhong	Yankui	Yanlong	Zaofeng
Color (ΔE)	Day 7	1.94^{bA}	3.81^{aA}	3.72^{aA}	2.05^{bA}
	Day 180	2.19^{A}	3.99^{A}	3.87^{A}	2.19^{A}
Flavor	Day 7	6.15^{aA}	6.18^{aA}	6.02^{aA}	6.31^{aA}
	Day 180	6.13^{A}	5.04^{B}	5.19^{B}	6.28^{A}
Appearance	Day 7	6.43^{aA}	6.09^{bA}	6.01^{bA}	6.01^{bA}
	Day 180	5.58^{B}	3.87^{B}	4.53^{B}	5.73^{A}
Taste	Day 7	6.26^{aA}	5.84^{bA}	5.37^{cA}	6.17^{aA}
	Day 180	6.68^{A}	5.87^{A}	5.87^{A}	6.59^{A}
Overall acceptability	Day 7	6.15^{aA}	5.42^{bA}	5.20^{bA}	5.90^{aA}
	Day 180	5.79^{aA}	4.27^{bB}	4.50^{bB}	5.63^{aA}

Means followed by the different capital letters in a column (day 7 and 180) are significantly different at $p<0.05$; Means followed by the different lowercase letters in the same row are significantly different ($p<0.05$)

Table 6: Correlation coefficients between some of the physicochemical properties and the overall acceptability of canned chestnuts

	AC	RSC	PC_1	PC_2	MPN	TC	OA
AC	1	-0.799**	0.359	0.624*	0.857**	-0.997**	-0.649*
RSC		1	-0.758**	-0.078	-0.374	0.801**	0.483
PC_1			1	-0.159	-0.148	-0.338	-0.526
PC_2				1	0.838**	-0.581*	-0.717**
MPN					1	-0.852**	-0.522
TC						1	0.605*
OA							1

AC: Amylose content; RSC: Reducing sugars content; PC_1: Pectin content; PC_2: Protein content; MPN: Mass per nut; TC: Tannin content of pellicle; OA: Overall acceptability; **: Significant at $p<0.01$; *: Significant at $p<0.05$

The clarity of the sugar syrup and appearance of the complete fruit of Zaofeng showed no significant differences (p>0.05) between before and after storage. The taste of the Zaofeng, Yanlong and Banhong cultivars improved after 180 days of storage but not significantly (p>0.05). The results for overall acceptability showed that Banhong was the most liked cultivar with scores of 6.15 at 7 days and 5.79 at 180 days of storage. No significant differences for overall acceptability and taste were observed between Zaofeng and Banhong cultivars, whereas the Yanlong and Yankui cultivars both scored significantly lower (p<0.05). The sensory results were similar to other studies (Su *et al*., 2012), however, they had not analyzed the relationship of quality and the chemical components.

Dependence of the physicochemical properties on the overall acceptability: Since little research has been found about the dependence between physicochemical characteristics of chestnuts and their quality after canning, this study compared four cultivars using similar methods to Altan *et al*. (2008) and the results are shown in Table 6. This suggests that the overall acceptability of canned chestnuts was correlated with several physicochemical characteristics of the chestnuts. The amylose content of chestnuts was significantly negatively correlated with the overall acceptability of the canned chestnuts (r = -0.649, p<0.05). The reason for this may be that the soluble amylose dissolved the starch grains which dispersed into the sugar syrup, leading to the appearance of sediment (De Vasconcelos *et al*., 2009, 2010). The reducing sugars content in the chestnuts was positively correlated with the overall acceptability of the canned chestnuts but not significantly (p>0.05). The pectin content in the chestnuts was negatively correlated with the overall acceptability of the canned chestnuts and not significantly (p>0.05). But the protein content was very significantly negatively correlated with overall acceptability (r = -0.717, p<0.01). The reason for this may be that the chestnuts, undergoing the high temperatures during canning, became darker and therefore less acceptable because of Maillard reactions, an effect linked to protein content. The mass per nut was negatively correlated with the overall acceptability of the canned chestnuts but not significantly (p>0.05). The tannin content of the pellicle on the chestnuts was significantly positively correlated with the overall acceptability of the canned chestnuts (r = 0.605, p<0.05). The reason may be that the lower the tannin content the greater is the loss rate during the canning process leading to increased acceptability. It was also observed that with higher tannin levels, shell removal was easier with less chestnut kernel injury and lower rates of broken kernels. From these results, we can suggest that the chemical constituents of chestnut cultivars, such as the amylose, protein and tannin content, have a direct relationship with the overall acceptability of the canned chestnuts. The chemical constituents have a great influence on overall acceptability of chestnuts canned in sugar syrup, for example, color, flavor, taste and appearance.

CONCLUSION

Through studying the effect of the physical and chemical composition of four chestnut cultivars from the Yan mountain ranges on the overall acceptability of the canned chestnuts, we can conclude that the content of some of the chemical components were significantly different (p<0.05) leading to differences in the quality of the canned chestnuts. Banhong was most preferred with a sensory score. Zaofeng cultivars are suitable for canned in sugar syrup too.

The major influences on the quality of chestnuts canned in sugar syrup are the appearance (clarity of syrup and the complete fruit) and the color. The effect of high protein and reducing sugar content in the Chinese chestnuts was reflected in the high intensity of the Maillard reactions during canning which led to browning of the chestnut kernels. Also, the amylose and tannin contents of the pellicle in chestnuts have a great effect on the clarity of the syrup and the complete fruit. On the basis of this study it can be recommended that chestnut cultivars with higher tannin content in the pellicle and lower amylase and protein contents in the fruit would be most suitable for producing good quality canned chestnuts. There is no dependence between fiber, fat and ash in fresh Chinese chestnut fruits and their quality after canning. Our results may also provide another avenue for the commercial use of a wider range of Chinese cultivars. Further research will be required to discover those special characteristics which might make consumers prefer them over other types of canned chestnuts.

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