African Journal of Food Science Vol. 4(11), pp. 693 - 702, November 2010
Available online http://www.academicjournals.org/ajfs
ISSN 1996-0794 ©2010 Academic Journals

Full Length Research Paper

Physico-chemical characteristics and sensory quality of Singhara (*Trapa natans* L.): An Indian water chestnut under commercial and industrial storage conditions

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Accepted 24 August, 2010

The physicochemical properties of water chestnut (*Trapa natans* L. var. *bispinosa* Roxburgh.) were investigated. Contents of moisture, crude lipid, crude fibre, crude ash, and crude protein were 81.12, 0.36, 0.72, 1.33, 1.87%, respectively. Total soluble solids and titrable acidity determined was 7.2 and 0.142%, respectively. The shelf life of whole water chestnut at ambient, refrigerated, frozen and aqueous conditions was studied. The effect on weight loss, total soluble solids, titrable acidity, total sugars, color and internal visual analysis, eating quality and textural properties of white kernel were evaluated over the storage time period. Samples kept at frozen conditions exhibited better storage life in comparison to others. The frozen samples illustrated slow but gradual decline in TSS over the storage period. The total acidity, too, followed the same trend of decline in value from initial value 0.144 %. The decrease in acidity was sharp in case of control, refrigerated and aqueous samples in comparison to those at frozen conditions.

Key words: Water chestnut, physicochemical properties, TSS, shelf life, texture, eating quality.

INTRODUCTION

In wake of growing demand of the consumers for natural foods having good therapeutic values, water chestnut offers excellent opportunity. The high consumption values of the fresh fruit are probably linked to the high nutritional and organoleptic value, and also to the increasing interest of the consumers towards organic products. Water chestnut (*T. bispinosa* Roxb.) popularly known as *Singhara* in India, is an aquatic angiosperm. It belongs to the family *Trapaceae*, one of the free-floating plants, grown in shallow water fields, ponds or swampy lands in tropical and sub-tropical countries (Takano and Kadono 2005). The water chestnut kernel is covered with a thick jet-black outer pericarp shaped like a horn protruding from the head of a buffalo. Its main root system adheres in the muddy soils at the bottom of the pond and it is connected with floating leaves by herbaceous stems in water body. It is grown in India mainly for human consumption either in the form of vegetable, dried to make flour to prepare flattened bread called chapatti or in the shape of sweet dishes of many kinds according to individual’s taste. The kernel is delicious and contains carbohydrates, proteins and essential minerals. It also contains a plentiful B vitamins (including B1, B2, B5 and B6), E, A, and vitamin C. Due to the sweet, tender and delicious taste, cooked water chestnut is one of the popular starchy desserts in Asian countries.

Majumdar and Jana (1977) and Lee and Hwang (1998) studied physicochemical analyses of water chestnut fruit to provide fundamental data for water chestnut processing and product development. Water chestnut prefers warm and humid environment. The fresh product

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is minimally processed and therefore maintains a fresh like state. However, minimally processed fresh products have relatively short life because of large amount of tissue disruption and increased metabolism (King and Bolin 1989; Watada et al., 1990; Varogquaux et al., 1996; Paull and Chen 1997), which results in a very rapid onset of enzymatic browning (Brecht 1995; Buta and Abbott 2000).

Rodrigues et al. (1964) studied the processing of water chestnuts and found that canning in 0.1 % citric acid (pH 4.2) and sterilization for 15 min were the best. Treatment with 0.1 M citric acid markedly extended the shelf life, inhibited surface coloration and disease development, and reduced the loss in eating quality associated with the contents of ascorbic acid and total soluble solid, titratable acidity and ascorbic acid (Peng et al., 2004). Cordenunsi et al. (2003) opined that cold storage is an efficient way to preserve strawberries, since no deleterious changes were observed either sensorially or nutritionally except small changes in some of the quality parameters.

Peng and Jiang (2006) investigated the potential usage of salicylic acid as a powerful anti-browning agent in fresh-cut Chinese water chestnut and found that it delayed discoloration, maintained eating quality and reduced or delayed activities of polyphenol oxidase (PPO), peroxidase (POD) and phenylalanine ammonia lyase (PAL), in fresh cut Chinese water chestnut.

Though Indian water chestnut popularly known as *Singhara* in local language is a highly nutritive fruit, it has failed to get all importance attention of food processors. Our earlier findings encompassed work on water chestnut drying characteristics (Singh et al., 2008), native water chestnut starch (Singh et al., 2009), and modified water chestnut starch (Singh et al., 2009) which will help this important commodity get the required attention from food processors. As water chestnut is available for only 2-3 months in a year and this fruit has to be made available for longer time for food processors, its storage life had to be studied in detailed. As conventional cold stores are easily available in India which store potatoes and onions for year round availability, these stores can easily be used for storing of water chestnut too.

The objectives of the present study were:

i) to investigate physicochemical analyses of the fruit to provide base for its processing and product development and
ii) to study the effect of different storage temperatures on shelf life and eating quality of whole water chestnut.

MATERIALS AND METHODS

Materials

Fully matured fresh water chestnuts (red variety) were procured from local grower from three different locations and any bruised or diseased fruits were discarded. The corms were then washed under running potable water to remove surface dirt and air dried.

Methods

Weight and true density

Twenty corms were picked up randomly and weighed. The same fruits were peeled off to remove shell and the white kernels obtained thereof, were weighed. The weights were taken in triplicates. Average weights were reported. The true density was recorded by the displacement of distilled water in a 1000 ml measuring cylinder. The results were reported as g/ml.

Length-breadth ratio (L/B)

The length and breadth of the ten corms selected randomly were recorded using a graph paper and results were reported as L/B ratio. The same procedure was followed for water chestnut kernels obtained after decorticating whole water chestnut.

Moisture, crude fat, ash, fibre and protein content

The outer shell of water chestnut corm was removed by hand using a knife and the moisture, crude fat, ash, fibre and protein content were determined following methods described in AOAC 2006.

Total soluble solids, titrable acidity

Tissues (20g) from 10 slices of water chestnut kernel was homogenized in a laboratory grinder (M/s. Sujata, New Delhi, India) and then centrifuged for 10 min at 10000xg. The supernatant was collected to analyze total soluble solids as (degree Brix) °Bx (a measurement of the fraction of sugar per hundred parts aqueous solution, by mass) using Abbe's refractometer (Erma Incorporation, Tokyo, Japan). Titratable acidity (TA) was measured according to AOAC (2006) and expressed as citric acid.

Total and reducing sugars

The reducing and total sugars were determined by following the method as described in Ranganna (1986).

Effect of different storage temperatures on shelf life of whole water chestnut

Storage condition variables

Near uniform size corms were selected and divided into four batches. Each batch comprising 60 corms was stored at different temperatures. One lot was stored in plastic trays under refrigerated conditions at 4°C, the second at frozen conditions at -18°C; third lot was kept in glass jar containing water at ambient temperature and the final lot was kept at ambient temperature as control.

Weight

Two whole fruits in each lot were marked for identification. These marked corms were removed periodically from storage and weighed to record weight loss.

Total soluble solids and titrable acidity

Total soluble solids and titrable acidity of water chestnut slices were analyzed at regular intervals during shelf life studies. The procedure adopted was same as discussed earlier. The fruits stored at freezing temperature were brought to ambient temperature before further analyses.

Reducing and total sugars

The samples were periodically removed, decorticated and analyzed for change in reducing, total and non-reducing sugars following procedures as stated earlier.

Color

A Hunter color measuring system (Hunter Color Diff. Meter, Miniscan XE plus, Hunter Associates Laboratory Inc., Reston, VA) was used to measure the color. Individual corms were cut transversely and each sample was measured thrice for color values. The information given by L*, a*, and b* is generally expressed as the total color, with L* representing the brightness or dullness, a* for redness to greenness, and b* for yellowness to blueness. The ΔE value was calculated using the following equation:

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

Internal quality (visual)

The whole water chestnut corms were removed from storage periodically for visual analysis. The method adopted by Kays and Sanchez (1985) was followed with a little variation. Individual corms were cut transversely and rated visually on a scale of 1 (excellent) to 5 (poor). The general criteria for each class were: 1- white, no discoloration; 2 – slight discoloration; 3 – 50 % discoloration, 4 – abundant discoloration upto 75 %; 5 – completely discolored or decayed.

Eating quality

The fruits were taken out, decorticated and analyzed for eating quality of the white kernel using six-member panel. At each withdrawal, samples were randomly selected and scored on a scale of 9 (excellent) to 1 (poor) in terms of appearance and flavor (Peng and Jiang, 2004).

Texture profile

A Texture Analyzer (TAXT2i, Stable Micro Systems, Godalming, Surrey, U.K.) was used to measure the texture of the kernel. The whole water chestnut corm was decorticated and was cut into a cube of 20 mm × 20 mm × 10 mm and placed breadth wise on the platform. The texture profile analysis was done to a distance of 10 mm at a pre-test speed of 3.0 mm/s, test speed of 2.0 mm/s and a post- test speed of 10.0 mm/s using a Warner-Bratzel shear cell. The force required to cut the fruit cube was expressed in N (Newton).

Statistical analysis

The data reported in all the tables were subjected to one-way analysis of variance (ANOVA) using Minitab Statistical Software version 13 (Minitab, Inc., State College, USA).

RESULTS AND DISCUSSION

Physical analysis

Average weights of whole water chestnut and white kernel obtained after decorticating were 22.56 and 12.05 g, respectively. The average weight of the edible part that is the kernel was 53.41% of the whole corm. Majumdar and Jana (1977) reported the average weight of whole fruit as 10.28 g and that of husked fruit or kernel as 5.29 g. The ratio of weight of kernel to husk was calculated as 1.15 in comparison to 1.06 as reported by Majumdar and Jana (1977). The true density of the white kernel was higher at 1.09 than that of whole water chestnut at 0.96 g/ml. The ratio of true density of kernel to corm calculated was 1.14.

The whole water chestnut bears two big spines on the broader side of the fruit (Figure 1a) which needs to be taken care of during hand peeling. The white kernel resembles the shape of heart have a thin light brownish color rind on one side of the fruit. L/B ratio calculated was 1.14 and 1.13 for whole water chestnut corm and water chestnut kernel, respectively (Figures 1a and b).

Chemical composition of water chestnut kernel

Chemical analysis of the fruit showed that the moisture content of water chestnut kernel was 81.12% (wet basis). Fresh nuts having considerable water content are taken at breakfasts (Puste 2004) and are believed to suppress stomach and heart burning. The total soluble solids content of the fruit was 7.2°Brix confirming presence of good amount of sugars.

Total acid in terms of citric acid present was 0.142% which is higher than reported by Majumdar and Jana (1977). The difference may be attributed to difference in variety and gap of period. Negligible amount of fat content was noticed in the fruit as 0.36% which substantiates its importance as dietary food. Lee and Hwang (1998) also reported low crude lipid content in Chinese water chestnut as 0.06%. Total ash content obtained in fruit was 1.33% confirming good amount of minerals contained in the fruit. The potassium content of 0.41% has been reported as the major mineral present with iron and manganese contents which were 0.21 and 0.08%, respectively, being the minor minerals present (Lee and Hwang 1998).

Crude fibre content of the water chestnut kernel was found to be 0.72% slightly higher than reported in Chinese water chestnut by Lee and Hwang (1998) as 0.60%. Total protein content calculated in the fruit was 1.87%. Low protein content has been earlier reported in water chestnuts (Puste, 2004). Lee and Hwang (1998) reported the contents of moisture, crude protein, crude lipid, crude ash, crude fibre and carbohydrate in the Chinese water chestnuts to be 79.40, 1.74, 0.06, 1.10,

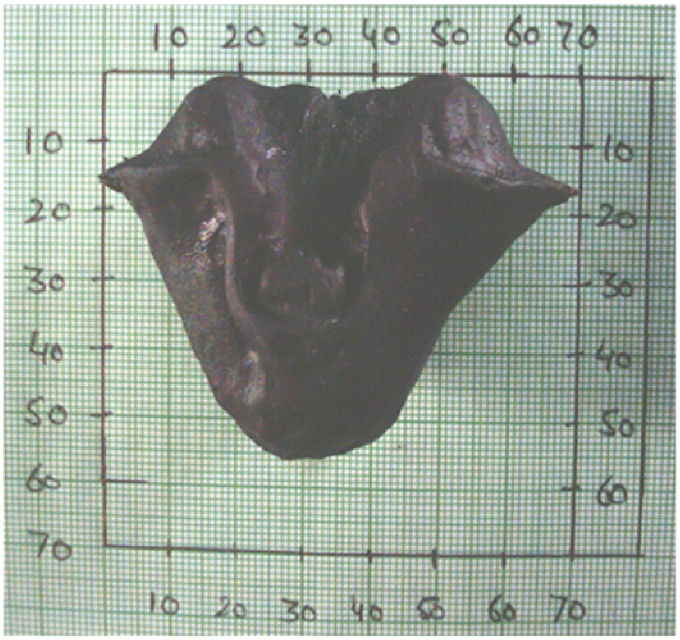

Figure 1a. Whole water chestnut.

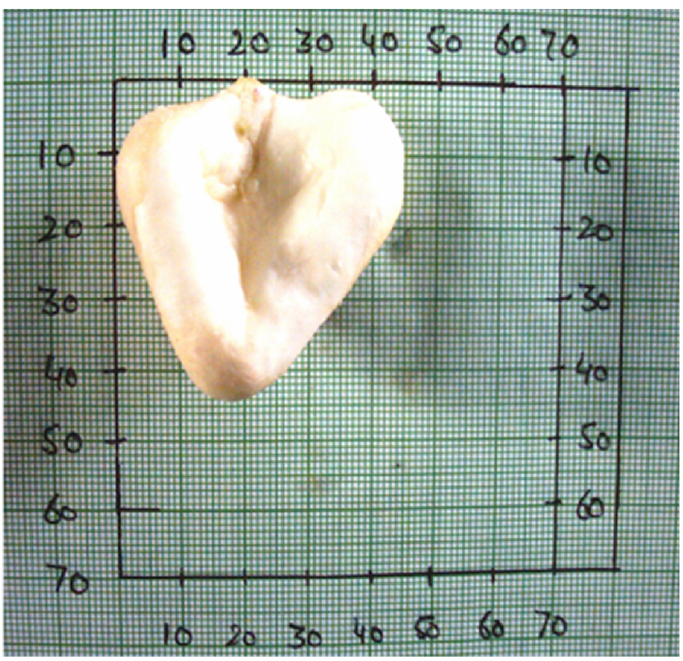

Figure 1b. Water chestnut kernel.

0.60 and 17.71%, respectively. The results in the present study on Indian water chestnut are quiet comparable with those reported by Lee et al. (1998).

The total sugars, reducing sugars and non-reducing sugars found in juice of fresh water chestnut kernel were 5.63, 1.27 and 4.36%, respectively. The free sugars reported in Chinese water chestnut juice were sucrose (8.58%), glucose (1.64%) and fructose (1.58%) being

Table 1. Chemical composition of fresh water chestnut kernel[a].

Constituent	Percent (wet basis)
Moisture	81.12 ± 0.5
Total soluble solids (° Brix)	7.2 ± 0.2
Total acidity	0.142 ± 0.03
Crude lipids	0.36 ± 0.02
Total ash	1.33 ± 0.04
Crude fibre	0.72 ± 0.02
Total proteins	1.87 ± 0.03
Total sugars	5.63 ± 0.04
Reducing sugars	1.27 ± 0.02
Non-reducing sugars	4.36 ± 0.03

n = 3; [a] Means (standard deviation) of triplicate analysis.

major components and maltose as trace component. The proportions of major free sugars in total soluble content of juice were 78.19% in comparison to 66.0% as reported by Lee and Hwang (1998).

Effect of storage temperatures on physicochemical and shelf life of water chestnuts

Weight

Weight of the whole fruit decreased significantly in control samzxple stored at room and refrigerated temperatures in first ten days (Table 1). In the first thirty days, loss in weight recorded was 74.26, 68.01, 13.59 and 0.54%, respectively for control, refrigerated, frozen and water containing samples. Moisture levels of fruits have been reported to remain more or less constant under low temperature storage, but prolonged storage often leads to a decrease in moisture content (Afoakwa and Sefa-Dedeh 2001; Zare et al., 2002). The decrease in weight was slow and gradual in samples stored in frozen conditions. In case of water chestnuts stored in aqueous solution, the weight increased initially possibly because of absorption of water by the peel of the fruit and decreased afterwards due to decaying of the shell and fruit. In addition, odoriferous metabolites are produced by storage rots or through their action rendered water chestnut uneatable. Similar observations have been earlier forwarded by Kays and Sanchez (1985) who conducted a series of storage environments for a 6-month period for 2 seasons.

Samples kept at room temperature got completely dried up after 90 days and did not show any further decrease in weight thereafter. The samples stored at refrigerated conditions reached similar conditions but after 120 days. The samples stored in water started decaying after the first 10 days and decayed 100% in 40 days, hence discarded. Frozen samples maintained good conditions up to 350 days of storage.

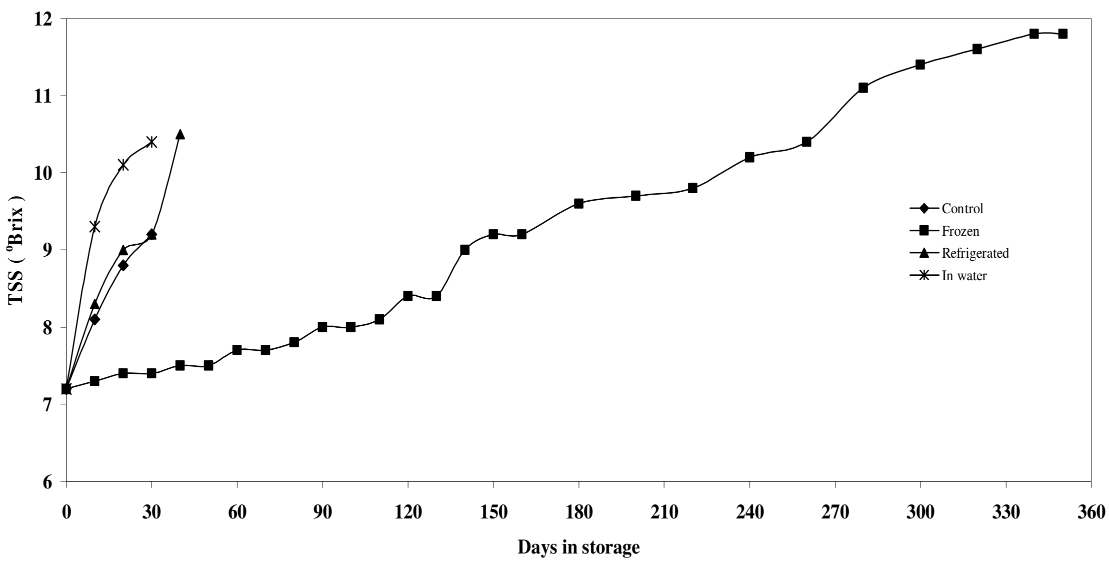

Figure 2. Effect of storage conditions on total soluble solids of water chestnut kernels.

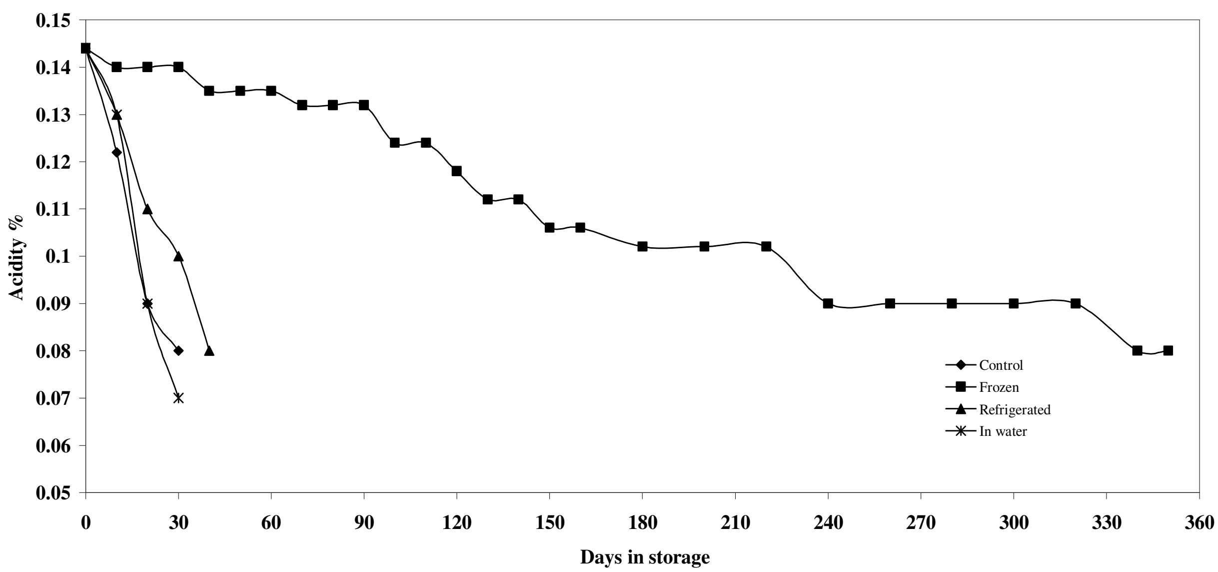

Figure 3. Effect of storage conditions on acidity of water chestnut kernels.

Total soluble solids and titrable acidity

The effect of storage conditions on total soluble solids and titrable acidity are given in Figures 2 and 3, respectively. The total soluble solid (TSS) content of fresh water chestnut kernel was 7.2°Brix. The control samples showed a significant increase in TSS to 8.1°B in first 10 days then a gradual decrease thereafter to 5.1°B before it became dry. Refrigerated samples exhibited a gradual decrease in TSS content with the storage time. The control samples (ambient) got dried up after 40 days and that of refrigerated after 50 days so the extraction of juice for TSS was not possible, hence stopped. The frozen samples illustrated slow but gradual decline in TSS over the storage period. TSS in this case increased initially from 7.2 to 8.2°B in first 10 days followed by gradual decline thereafter to final value of 3.9°B. The decrease in total soluble solid may be attributed to the inactivation of hydrolyzing enzymes which are responsible for the breakdown of polysaccharide into simple sugars. However, a sharp and rapid decline in TSS content was noticed in samples stored in water

Table 2. Effect of storage conditions on the weight of whole water chestnut[ab].

Days	Weight (g)			
	Control	Refrigerated (4°C)	Frozen (-18°C)	In water
0	27.74	29.38	33.12	31.23
10	13.55 (51.15[c])	12.25 (58.30[d])	31.78 (4.04[b])	31.89 (-2.11[a])
20	10.51 (62.11[c])	10.58 (63.99[c])	29.49 (10.96[b])	32.65 (-4.55[a])
30	7.14 (74.26[d])	9.40 (68.01[c])	28.62 (13.59[b])	31.06 (0.54[a])
40	6.91 (75.09[d])	8.59 (70.76[c])	27.52 (16.91[b])	29.65 (5.06[a])
50	6.88 (75.20[c])	7.96 (72.91[b])	26.28 (20.65[a])	Spoiled
60	6.85 (75.31[b])	7.54 (74.34[b])	25.72 (22.34[a])	-
70	6.84 (75.34[b])	7.24 (75.36[b])	24.60 (25.72[a])	-
80	6.83 (75.38[b])	7.09 (75.87[b])	24.12 (27.17[a])	-
90	6.83 (75.38[b])	6.97 (76.28[b])	23.53 (28.95[a])	-
100	6.82 (75.41[b])	6.89 (76.55[b])	23.07 (30.34[a])	-
110	6.81 (75.45[b])	6.88 (76.58[b])	22.72 (31.40[a])	-
120	6.81 (75.45[b])	6.88 (76.58[b])	22.39 (32.40[a])	-
130	6.81 (75.45[b])	6.87 (76.62[b])	22.02 (33.51[a])	-
140	Dried	6.87 (76.62[b])	21.95 (33.72[a])	-
160	-	Dried	21.67 (34.57)	-
180	-	-	21.49 (35.11)	-
200	-	-	21.35 (35.54)	-
220	-	-	21.22 (35.93)	-
240	-	-	21.09 (36.32)	-
260	-	-	20.97 (36.68)	-
280	-	-	20.90 (36.90)	-
300	-	-	20.85 (37.04)	-
320	-	-	20.81 (37.17)	-
340	-	-	20.77 (37.29)	-
350	-	-	20.72 (37.44)	-

[a]Values in brackets shows the % difference in weight. [b]Mean values in the same row with different letters are significantly different (*$P < 0.05$).

(Figure 1) before being rotten. Earlier Peng and Jiang (2004) reported decline in TSS of fresh cut Chinese water chestnut slices and in apple slices (Son et al., 2001) during storage.

The total acidity, too, followed the same trend of decline (Figure 2) from initial value of 0.144%. The decrease in acidity was sharp in case of control, refrigerated and aqueous samples in comparison to those at frozen conditions. These results confirm the findings of Crouch (2003) who reported that there was a decline in titrable acidity in apple fruit after harvesting. Tahir and Ericsson (2003) too reported a marked difference in acidity of apples after storage.

Total sugars

The change in total, reducing and non-reducing sugar content of the fruits during storage is summarized in Table 2. Total sugars in case of control and refrigerated samples depicted an increase in first 10 days, followed by decline which continued till the end of storage period. This, however, was not the case with frozen samples where a gradual decrease in total sugars was observed.

The decrease in total sugars may be attributed to conversion of glucose into starch during storage. Non-reducing sugars too displayed decline in all the samples. However, in case of frozen samples the reducing sugars increased initially till the end of 260 days, followed by decline to a level of 0.82%. The observed differences could be attributed to hydrolysis of sucrose and/or respiration, or combination of both effects (Wills et al., 1998). At low temperature, the linear amylose molecules aggregate together to crystallize, and the water held between their structures is released which leads to decrease in total soluble sugar.

Color

Color profile of the slices of water chestnut kernel is shown in Table 3. ΔE value for fresh kernel was

Table 3. Effect of storage conditions on sugars of water chestnut kernel[a].

Days	Control			Refrigerated			Frozen			In water		
	TS	NRS	RS	TS	NRS	RS	TS	NRS	RS	TS	NRS	RS
0	5.63 ±0.3	4.36 ±0.5	1.27 ±0.5	5.63 ±0.4	4.36±0.2	1.27±0.4	5.63 ±0.5	4.36±0.5	1.27 ±0.4	5.63 ±0.3	4.36 ±0.3	1.27 ±0.6
10	6.24 ±0.2	4.59 ±0.9	1.65 ±0.2	5.94 ±0.3	4.41±0.5	1.53±0.4	5.41±0.8	4.31±0.3	1.10 ±0.6	5.51 ±0.5	4.35 ±0.5	1.16 ±0.7
20	4.17 ±0.4	2.28 ±0.4	1.89 ±0.1	4.57 ±0.4	2.86±0.4	1.71±0.6	5.45±0.5	3.81±0.5	1.64 ±0.7	3.71 ±0.9	2.39 ±0.7	1.32 ±0.5
30	2.69 ±0.1	1.26 ±0.8	1.43 ±0.1	3.13 ±0.1	1.66±0.3	1.47±0.7	5.14±0.5	2.91±0.3	2.23 ±0.7	2.72 ±0.6	1.61 ±0.4	1.11 ±0.2
40		Dried		1.97 ±0.5	0.83±0.3	1.14±0.7	4.78±0.3	2.60±0.1	2.18 ±0.4		Spoiled	
50					Dried		4.71±0.6	2.60±0.7	2.11 ±0.4			
80							4.12±0.5	1.79±0.7	2.33 ±0.9			
110							3.78±0.4	1.71±0.6	2.07 ±0.5			
140							3.29±0.6	1.33±0.6	1.96 ±0.4			
170							3.19±0.3	1.09±0.8	2.10 ±0.6			
200							2.78±0.4	1.01±0.5	1.77 ±0.8			
230							2.49±0.5	0.95±0.3	1.54 ±0.1			
260							2.05±0.3	0.74±0.2	1.31 ±0.5			
290							1.59±0.3	0.49±0.9	1.10 ±0.5			
320							1.24±0.7	0.45±0.3	0.79 ±0.3			
350							1.15±0.2	0.33±0.5	0.82 ±0.1			

TS: Total sugars; NRS: Non-reducing sugars; RS: Reducing sugars. [a] Mean (standard deviation) of triplicate analysis. n = 3.

93.765 which deteriorated sharply to 71.495 in case of samples stored in water, at the end of 30 days. The loss was mainly due to the transfer of purple color of the shell to the kernel which resulted in red-purple color spots. Although, in case of refrigerated and control samples the loss in color value was due to decreased L* values (whiteness), but decreased values of a* and b*, which was as a result of increased redness and yellowness respectively due to desiccation, were equally responsible. The color estimation was stopped when samples dried up in both the cases. The color values of frozen samples showed slow but consistent decrease in color values. The minimum color value of kernel slices obtained at the end of storage period was 87.49. Ismail et al. (2008) opined that low temperature preserved the color, however, prolonged storage, even at low temperature, eventually caused color changes.

Internal quality (visual)

Softening of the fruit and browning of the kernels were major factors for evaluation of internal quality. The samples stored in aqueous conditions showed lowest internal visual quality with 100% fruits decayed after 40 days. Product odor was the serious problem encountered which started by the end of first 10 days and increased progressively day by day. Similar observations were recorded by Kays and Sanchez (1985). Water chestnuts stored at room temperature and refrigerated conditions retained better internal quality till the time they got dried up, as shown in Figure 4. 3. 8% of the total fruit stored at refrigerated temperature and 20% of the samples stored at ambient conditions got decayed which were removed as and when noticed. Fruit samples stored at frozen conditions displayed highest internal visual quality retention among all the treatments.

Eating quality

Appearance loss is the main factor that limits the shelf life of water chestnuts, similar to other minimally processed fruits and vegetables (Laurila

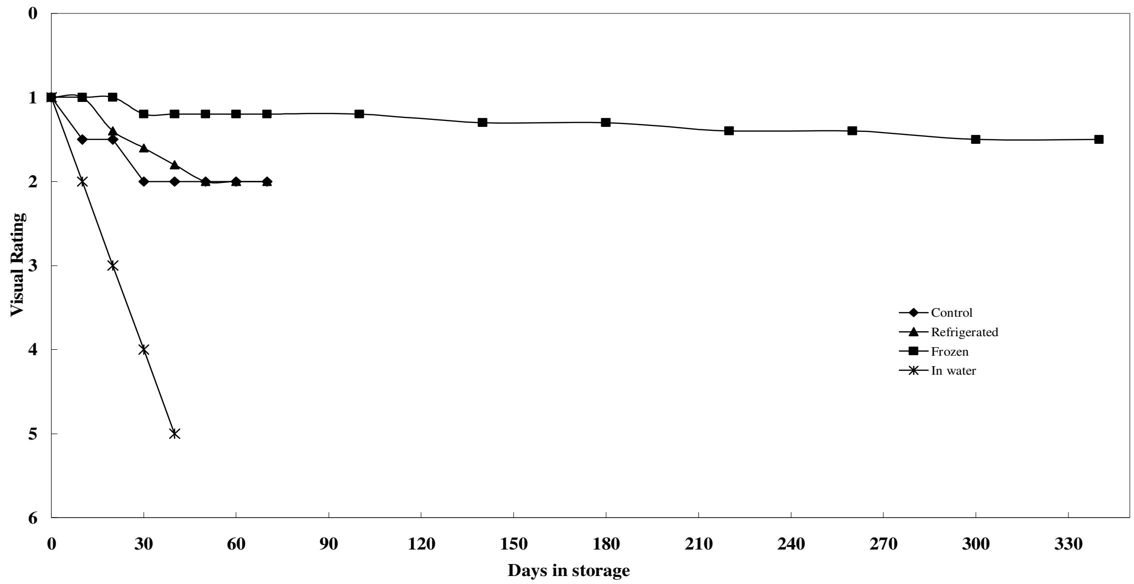

Figure 4. Internal (visual) rating of the water chestnut kernel slices during storage at different temperatures.

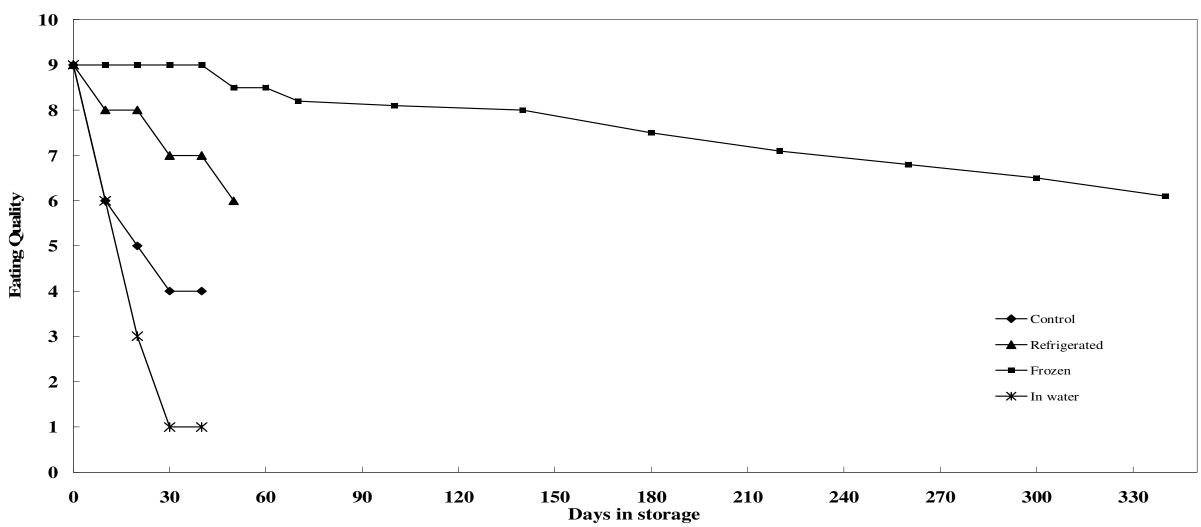

Figure 5. Eating quality of the water chestnut kernel slices during storage at different temperatures.

et al., 1998; Son et al., 2001). As shown in Figure 5, the eating quality declined sharply in case of fruits stored in aqueous conditions due to odoriferous metabolites produced by rot organisms or through their action rendering even sound corms un-marketable. In case of refrigerated and control samples the decline in eating quality was due to loss of moisture and thus crispness in slices rather than off flavors. Frozen samples exhibited and maintained excellent eating quality till first 5 months of storage but thereafter they did show a decline owing to loss of moisture due to desiccation but were still acceptable.

Textural analysis

Table 4 shows the textural analysis of the water chestnut kernels drawn from different storage conditions at regular intervals. Water chestnut is well known for its crispness. They retain most of its crispness even after thermal processing (Loh et al., 1982; Klockeman et al., 1991). Parker et al. (2003) suggested that thermal stability of texture in Chinese water chestnut may be dependent on 8.8’ – diferulic acid (Aryltetralyn form). Maintenance of textural properties of plant material depends upon their chemical composition and cellular structure (Sterling and

Table 4. Effect of storage conditions on color value of water chestnut kernels[ab].

Day	ΔE			
	Control	Frozen	Refrigerated	In water
0	93.765[a]	93.765[a]	93.765[a]	93.765[a]
10	91.562[b]	93.745[c]	92.837[bc]	87.449[a]
20	89.387[b]	93.407[d]	91.291[c]	81.369[a]
30	89.066[b]	93.125[d]	91.037[c]	71.495[a]
40	Dried	93.034[b]	90.822[a]	Spoiled
50	-	92.899	Dried	-
80	-	92.901	-	-
110	-	91.279	-	-
140	-	90.592	-	-
170	-	90.298	-	-
200	-	89.465	-	-
230	-	89.189	-	-
260	-	88.951	-	-
290	-	88.508	-	-
320	-	88.015	-	-
350	-	87.493	-	-

[a] Means average of two values. [b]Mean values in the same row with different letters are significantly different (*$P < 0.05$).

Table 5. Effect of storage conditions on texture of water chestnut kernels[ab].

Days	Force (N)			
	Control	Refrigerated (4°C)	Frozen (-18°C)	In water
0	2.735±0.2[a]	2.735±0.2[a]	2.735±0.2[a]	2.735±0.2[a]
10	8.439±0.4[c]	4.059±0.3[b]	2.865±0.4[a]	2.256±0.2[a]
20	15.019±0.4[d]	9.056±0.3[c]	2.902±0.2[b]	2.064±0.2[a]
30	17.029±0.5[c]	16.564±0.2[c]	3.265±0.3[b]	1.943±0.2[a]
40	Dried	19.341±0.3[b]	3.291±0.3[a]	Spoiled
50	-	Dried	3.334±0.4	-
60	-	-	3.346±0.3	-
70	-	-	3.520±0.4	-
80	-	-	3.598±0.3	-
90	-	-	3.699±0.3	-
100	-	-	3.710±0.4	-
110	-	-	3.745±0.4	-
120	-	-	3.799±0.3	-
130	-	-	3.813±0.4	-
140	-	-	3.869±0.3	-
160	-	-	4.001±0.4	-
180	-	-	4.256±0.3	-
200	-	-	4.377±0.4	-
220	-	-	4.411±0.3	-
240	-	-	4.445±0.4	-
260	-	-	4.524±0.3	-
280	-	-	4.537±0.4	-
300	-	-	4.675±0.3	-
320	-	-	4.678±0.4	-
340	-	-	4.698±0.3	-
350	-	-	4.721±0.3	-

[a] Means (standard deviation) of triplicate analysis. [b]Means values in the same row with different letters are significantly different (*$P < 0.05$).

Bettelhein 1955).Initial value of force required to cut was recorded as 2.735 N, which showed significant increase in values owing to loss of moisture and thus crispness in fruit over storage time. Control samples reached value of 17.029 N and those at refrigerated at 19.341 N before being dried up. However, frozen samples maintained good textural properties although it got declined at the end of storage time. According to Van Buren (1968), firmness in vegetables depends upon the intercellular adhesion localized at middle lamella region between cells. Even at the end of storage time the fruits stored at frozen conditions were quiet juicy although it got a little meaty because of desiccation and loss of moisture. On the contrary, samples in aqueous conditions got soft and pulpy progressively before getting completely rotten (Table 4). The smelling of water caused serious problems and thus had to be discarded.

Conclusion

White kernel obtained after decorticating whole fruit was found to be 53.41% of the whole corm. Contents of moisture, crude lipid, crude fibre, crude ash, and crude protein in water chestnut kernel were 81.12, 0.36, 0.72, 1.33, 1.87% respectively. Whole water chestnut corms kept at frozen conditions exhibited excellent shelf life in terms of eating and visual quality. The texture of the water chestnut kernels obtained after decorticating whole corms kept in frozen conditions, were found to be best in comparison to others. TSS in case of frozen samples increased initially from 7.2 to 8.2°B in first 10 days followed by gradual decline thereafter to final value of 3.9°B. Decrease in total acidity and total soluble solids were observed in all fruits kept in different storage temperatures. Total sugars showed gradual decline in concentration in all storage conditions. The samples stored in aqueous conditions exhibited lowest storage life as 100% fruit got spoiled within 40 days.

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