Tender coconuts for export market : evaluation of cultivars and improved protocol for extended shelf-life

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It is important to harvest tender nuts at the proper stage at peak quality as the quality cannot be improved after harvest, it can only be maintained. Percentage of sucrose, glucose, fructose and total sugars in nut water is higher in eight-month-old nuts than seven-month-old nuts. Percentage of sugars in nut water is different among the cultivars, except sucrose at seven-month-stage.

Abstract

Nut water of young coconut *(Cocos nucifera)* has a good export market potential as a natural beverage. However, the post harvest quality has to be preserved for four to six weeks to meet export market requirement of far-away destinations. This study evaluated the cultivars suitable for tender nut purpose and tested the effectiveness of vacuum packing and cold storage in extending shelf-life of tender coconuts up to 4-6 weeks, on the basis of its chemical constituents in nut water. The nut water of seven different cultivars namely *King coconut* (KC), *Bodiri* (BD), *Cameroon Red Dwarf* (CRD), *Dwarf Brown* (DB), *Dwarf Yellow* (DY), *Dwarf Red* (DR) and *Dwarf Green* (DG) of two maturity stages (seven- and eight-month-old) was analysed for glucose, fructose, sucrose, total soluble sugars and mineral content. In the storage trials, the sugars of nut water and appearance of nuts during storage were compared with fresh young coconuts. BD, KC and DG appeared most suitable cultivars as a beverage with respect to high content of sugars and K^+. For the consumers who prefer high sugars but low K^+, DR appeared a suitable cultivar and for consumers who prefer tender nut water with minimum sugar taste, DB and CRD appeared most suitable cultivars. The post-harvest quality of 7-8 month-old coconuts was preserved after 36-38 days when the nut surface was disinfected with Captan (0.6 g/L), vacuum packed in polythene (gauge size 300), enclosed in net packing and 7-ply carton and stored in a cabinet at 13-15°C and 70% RH.

Introduction

Coconut *(Cocos nucifera* L.) is a versatile and an important commercial palm in the tropics of the world. The nut water or liquid endosperm of young coconuts is a nutritious, natural beverage as it is rich in sugars (mainly reducing sugars), minerals (mainly K^+), vitamins (mainly B & C) and amino acids. The calorific value of tender coconut water is 17.4 kcal /100g (Jayasekara and Fernando, 1989; Dhamodaran *et al.*, 1993; Ediriweera, 1996). Therefore, it is not only a thirst quenching drink but a mineral drink, which is also beneficial for human health. The composition and volume of nut water differ with cultivars (Poduval *et al.*, 1998).

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There is a growing demand locally as well as globally for consumption of natural food commodities. According to entrepreneurs, the nut water of young coconut has a high market potential overseas and there is a higher demand for the whole coconut compared to processed or canned coconut water. The price of a tender coconut in the local market varies from US$ 0.10-0.15 and is very much higher in the overseas market (US$ 2-4). The young nut can be successfully air-freighted in good condition to foreign markets within a day or two. For large export volumes, sea freight would be more economical, but requires 2-4 weeks shipping time. The major problem with the export of tender coconuts is the physico-chemical changes that take place after harvest, and during the period of sea freight and transport up to the point of sale. Tender coconuts cannot be stored more than one week at ambient temperature due to shrinkage and discolouration of the outer skin (epicarp), the fall of perianth, microbial attack on the perianth region and decomposition of the nut water. The content of invert sugars (glucose and fructose) of nut water decreased from 5% to 1.8% and sucrose decreased from 0.16% to 0.03% within 9-10 days at ambient temperature (Ranasinghe *et. al,* 1999). Therefore, if technology could be developed to maintain the quality of young coconuts up to four to six weeks (without causing notable loss of quality), an enormous export potential exists to generate more income to coconut growers at their farm gate.

Once the technology for extending shelf-life of tender coconuts is available, there should be a continuous supply of tender nuts for export. There are several coconut cultivars with a great potential to be used as a beverage in Sri Lanka as well as in the export market. King coconut (variety *aurantiaca)* is locally used as a popular beverage and it can be easily and economically grown in almost all the coconut growing lands in Sri Lanka. *Bodiri* (variety *typica)* nuts are produced in large numbers in a bunch and have less commercial value as mature nuts, copra or desiccated coconut. The low weight and the small size *of Bodiri* nut should make it attractive for export market as tender nuts. Dwarf Green (DG), Dwarf Yellow (DY), Dwarf Red (DR), Dwarf Brown (DB) and Cameroon Red Dwarf (CRD) (variety *nana)* have a potential to be used as a beverage due to the taste of nut water and the cosmetic appearance. In addition, all these cultivars have the advantage of palm height which is short in stature and it is very much beneficial in harvesting nuts with minimum damage. The most suitable harvesting stage (seven to eight months stage after pollination), disinfection method (0.6 g per L Benlate), temperature range for storage (13-15^{0}C) and wrapping material (Polypropylene cling film) for preserving king coconut for a period of 28-30 days were identified (Ranasinghe *et al.,* 1999; Wimalasekara *et al.,* 1998) and the same protocol was found suitable for other varieties such as *Bodiri* (Ranasinghe *et al.,* 2000a). The commercial viability of the technology was confirmed *via* a trial shipment and a simulated shipment (Ranasinghe *et al.,* 2000 b; 200), a simple tool for opening the tender nut was developed (Ranasinghe, 2000c) and the whole package was disseminated to entrepreneurs (Ranasinghe and Wimalasekara, 2002). However, for sending the tender nuts to far-away destinations such as Japan, Korea, United Kingdom, Netherlands, USA etc *via* sea freight the existing protocol has to be improved for extending shelf-life up to about six weeks. Vacuum packing is suggested as a suitable method for extending safe shelf-life of most fruits and vegetables as this method can reduce oxidation, dehydration and microbial spoilage which help to slow down deterioration of the produce. This packing method is commonly used for long term storage (few months) of dry food and also for shorter-term storage (few weeks) of fresh foods such as fruits, vegetable, meat etc. (Bachmann and Earles, 2000).

The pleasant taste of nut water is mainly attributed to the sugars and mineral components present (Chikkasubbanna *et al.,* 1990) and changes in these parameters may occur with the cultivar, stage of maturity, duration after harvest and storage condition. Therefore, main objectives of the study were to identify the cultivars suitable for tender nut purposes and to test the effectiveness of vacuum packing and cold storage in extending the shelf-life of tender coconut up to 5-6 weeks.

Materials and Methods

Two sets of experiments were conducted. The first set for evaluation of cultivars and the second set for extending the shelf-life of tender nuts.

Experiment 1

Selection of palms

The experiment was carried out to evaluate suitable cultivars for the tender nut purpose on the basis of its chemical constituents. Twelve cultivars of variety *typica, nana* and *aurantiaca* were subjected to a preliminary organoleptic screening for the quality of tender nut water. Of these, seven cultivars were selected for detail chemical analysis. Tender nuts (seven and eight months after pollination) of seven selected cultivars *viz. King coconut (KC)(variety aurantiaca), Bodiri (BD)(variety typica) Dwarf Green (DG), Dwarf Yellow (DY), Dwarf Red (DR), Dwarf Brown (DB) (variety nana) and Cameroon Red Dwarf (CRD) (variety nana, -exotic)* were collected at six-monthly intervals for a period of two years from Bandirippuwa and Pottukulama Research Stations of the Coconut Research Institute. The palms were of the same age and were subjected to uniform agronomic and cultural practices. The design was a completely randomized single tree plot with eight replicates per cultivar.

Chemical analysis

Water of seven-month and eight-month old coconut, collected into plastic vials immediately after opening the nut, was stored at -20°C until analysis. Concentration of sugars and minerals of nut water was analysed.

Estimation of sugar content in the nut water

Coconut water was diluted (1:100 v/v), purified using a Sep-pak cartridge and analysed for sucrose, glucose, fructose and total sugar using a high performance liquid chromatography (HPLC) system (Waters, USA) with a sugar-pak column.

Estimation of mineral content in the nut water

Potassium, sodium, calcium and magnesium contents of the nut water were determined using an Atomic Absorption Spectrophotometer (GBC, Australia).

Experiment 2

Effectiveness of vacuum packing under cold storage (13-15°C) for extending shelf life of tender king coconut with respect to the changes in cosmetic appearance, microbial growth on the perianth region and concentration of sugars of nut water was tested in a series of assays. The observations were recorded in nuts or nut water before (fresh) and after storage. The design was completely randomized with at least sixteen replicates (nuts) per treatment. The experiment was repeated six times within a two year period (2006-2007).

Harvesting, transporting, packing and storing of nuts

Tender nuts (seven to eight months after pollination) of *King Coconut* collected from Bandirippuwa Research Station, Coconut Research Institute were used for the study. The palms were of the same age and were subjected to uniform agronomic and cultural practices. King coconuts were harvested in the morning and transported on the same day to the laboratory with extreme care to avoid any fresh mechanical damage. The King coconuts were separated from the bunch using a sharp knife. The cut was made as close as possible to the nut without damaging the perianth. Nuts were cleaned for surface debris and sorted for uniform size, appearance and absence of any defects. The post harvest treatments, packing and storing were completed on the same day.

Surface sterilization and packing material

The nuts were randomly divided into two groups; treated nuts (disinfected with a fungicide) and untreated nuts (not disinfected). In a preliminary experiment, three packing materials (Nylon-Low Density Polyethylene, Normal Oriented Polypropylene and Polyethylene) were tested for vacuum packing and clear polythene with gauge 300 found most suitable (Ranasinghe *et al.*, 2006) and hence used in present experiments. The cut surface of the stalk, perianth and outer skin of the 'treated' nuts were wiped with cotton wool or paper tissues moistened with Captan (0.6g/L of water) solution and allowed to dry in air for 2-3 minutes, vacuum packed in clear polythene and completely covered with a net pack (McFoam Net, McBolon Polymer Pvt Ltd; Sri Lanka) to reduce mechanical damage during handling, transportation and storage. The 'untreated' nuts were vacuum packed and covered with net pack without fungicide application.

Storage trials

The King coconuts were packed immediately in 7-ply thick corrugated cardboard cartons. Four circular vents, each one cm diameter (two on each long side) and two hand holes were made in each carton. Eight King coconuts were packed in

each carton. Immediately after packing, the cartons were stored in a cold cabinet (Sanyo, Japan) maintained at 13-15°C and 70 % RH. The temperature and %RH of the cold cabinet were monitored continuously.

Evaluation of quality of King Coconuts during storage

Sampling of the nuts was conducted after 21-23, 28-30, 33-35 and 36-38 days of storage and the changes in external appearance of tender coconuts and deterioration of nut water during storage were evaluated. At each sampling, nuts were removed randomly from the storage boxes. Colour and external appearance of coconuts, taste and chemical constituents of the nut water were analysed along with the observations on colour, odor and turbidity of nut water, and compared with fresh nuts.

Determination of colour changes of nut surface

Colour of the outer skin of the nut was determined visually using the International colour chart (Fujihira Industry Co; Ltd; Tokyo, Japan) for vegetables and fruits.

Determination of the quality of nut water

Changes in colour, odor and turbidity of nut water were compared (by visual observations) with that of fresh nuts and the absence of changes in colour, odor and turbidity was considered as the necessary pre-requisite for the sensory and chemical evaluation.

Sensory evaluation

Triangle tests were conducted according to the method described in Ranasinghe *et al.*, (2003) to assess whether the taste of nut water had changed during storage. In each triangle two glasses of fresh King coconut water and one glass of stored King coconut water were used. The fresh coconut water used in the taste panel was obtained from freshly harvested King coconuts of the same maturity, from the same plantations on the date of evaluation. As a precautionary measure, the fresh coconut water was stored at 15°C for about half an hour before the sensory evaluation to make the temperatures of the stored and fresh coconut water as uniform as possible.

Chemical analysis

Sugars (sucrose, glucose, fructose and total) and minerals (potassium, sodium, calcium and magnesium) of coconut water were analysed as explained in Experiment 1.

Statistical analysis of data

The data were analysed with one-way ANOVA using the SAS statistical package. Means were separated by Duncans Multiple Range Test.

Results

Evaluation of cultivars (Experiment 1)

The volume of nut water and the yield per bunch showed differences among the cultivars. DB and DY have the maximum volume of nut water (400-500 ml) at the drinking stage (7-8 months old) and BD has the minimum volume (200-250 ml per nut). BD yields the highest number of nuts per bunch (Table 1).

Table 1. Volume of nut water (mean ± sd) and yield per bunch of the selected cultivars

Cultivar	Volume of nut water (ml)	No. of nuts/bunch
King coconut (KC)	528.3±21.05	10-30
Bodiri (BD)	235.6±10.39	10-40
Cameroon Red Dwarf (CRD)	334.0±13.29	12-30
Dwarf Brown (DB)	458.8±30.89	10-30
Dwarf Yellow (DY)	462.2±26.24	10-25
Dwarf Red (DR)	373.5±16.59	15-30
Dwarf Green (DG)	277.6±17.45	10-25

Analysis of sugars in nut water

Percentage of sugars increased with nut maturity and significant differences in cultivars with respect to sugar contents, except sucrose at seven-month stage, were observed. In seven-month old nuts, there was no significant difference ($p < 0.05$) in sucrose content among the cultivars (Fig. 1a). The maximum sucrose content of eight-mo nth-old nuts (0.5 %) was found in BD and DR and the minimum was found in DB and DY (0.27% and 0.19%) and the difference was statistically significant (Fig. 1b). The highest percentage of glucose at seven-month-stage was found in BD nuts and it was significantly higher than DB, CRD, DY and DR. The glucose content of KC and DG at this maturity stage was similar to that of BD. The lowest percentage of glucose was found in DB and it was significantly lower than KC, BD and DG (Fig. 1c). Similarly, the highest percentage of fructose at seven-month-stage was found in BD nuts and it was significantly higher than all other cultivars except DG. The

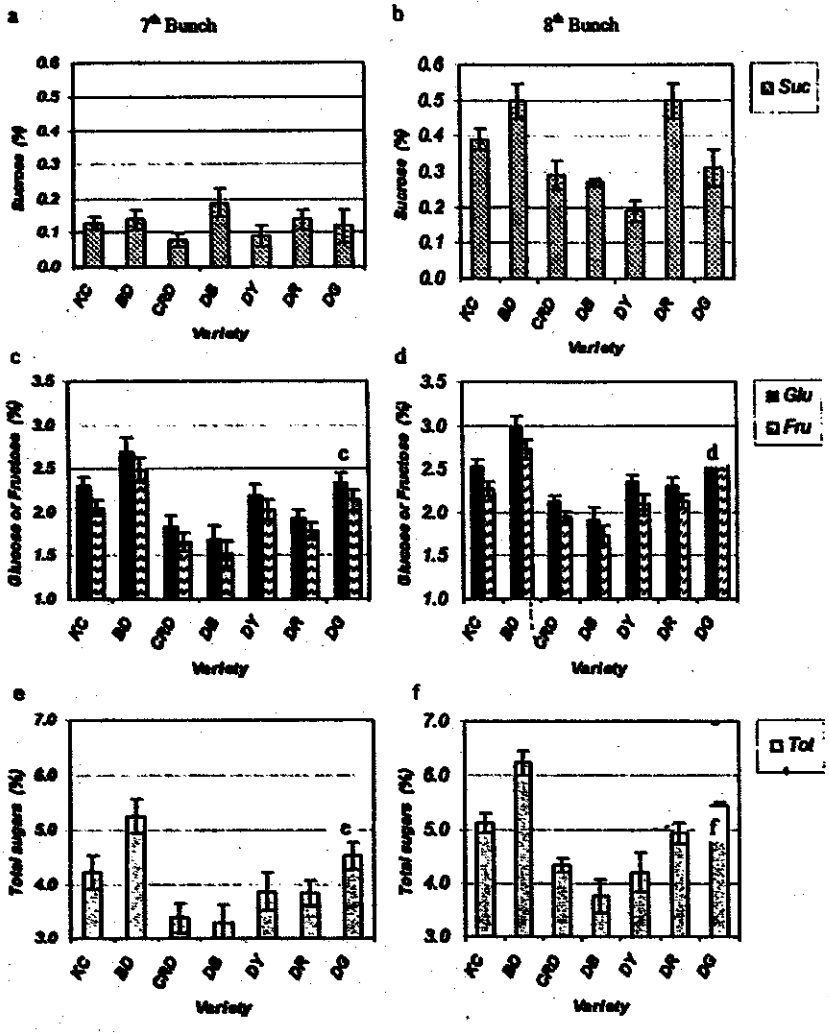

Fig. 1. (a & b) Sucrose (g/100ml) (c & d) glucose and fructose (g/100ml) and (e & f) total soluble sugars (g/100ml) in nut water of seven (a, c & e) and eight month-old (b, d & f) nuts in seven coconut cultivars, king coconut (KC), bodiri (BD), Cameroon red dwarf (CRD), dwarf brown (DB), dwarf yellow (DY), dwarf red (DR) and dwarf green (DG)

lowest amount of fructose at seven-month-stage was found in DB and it was significantly lower than KC, BD, DY and DG (Fig. 1c). At eight-month-stage BD showed the highest percentage of glucose and fructose and it was significantly higher than all other cultivars except DG. DB showed the lowest glucose and fructose content and it was significantly lower than all other cultivars except CRD (Fig. 1d). As a result, percentage of total soluble sugar (TSS) was also highest in BD nuts of both stages (seven and eight months) and it was significantly higher than DB, CRD, DY and DR. DB and CRD recorded the lowest content of sugars in seven-month-old nuts (Fig. 1e). Maximum TSS in eight-month stage was observed in BD nuts and it was significantly higher than all other cultivars. The minimum TSS was observed in DB and it was significantly lower than KC, BD, DR and DG (Fig. 1f).

Analysis of major minerals in nut water

Significant differences were also observed among cultivars in respect of potassium, sodium, magnesium and calcium contents. In both seven- and eight-month-old nuts, BD contained the highest potassium content in nut water followed by DG, DB and KC whilst CRD, DY and DR contained the lowest (Fig. 2a & b). Sodium and magnesium levels were significantly higher and calcium level was significantly lower in DR and DG compared to other cultivars in both maturity stages (Fig. 2c & d).

Experiment 2 :

Colour and external appearance of stored King coconuts

After 36-38 days of storage, the colour and brightness of the epicarp (outer skin) of King Coconut were not changed. There were no symptoms of shrinkage of the outer skin in both 'treated' (with fungicide 0.6g/1) and 'untreated' (without fungicide) nuts (Table 2). However, the perianth fall was observed in 30% of nuts in both treatments. In fungicide treated nuts, the browning of perianth was observed only in 20% of nuts whilst it was 100% in untreated nuts. Microbial infection on the perianth was observed in 10% of treated nuts and the percentage was much higher (30% of nuts) in untreated nuts. The sensory evaluation study showed that nut water and kernel are suitable for consumption in 90% of the treated nuts whilst it was only 65% in untreated' nuts. It appeared that vacuum packing and cold storage (13-15^{0}C) only could arrest the microbial growth on the soft perianth

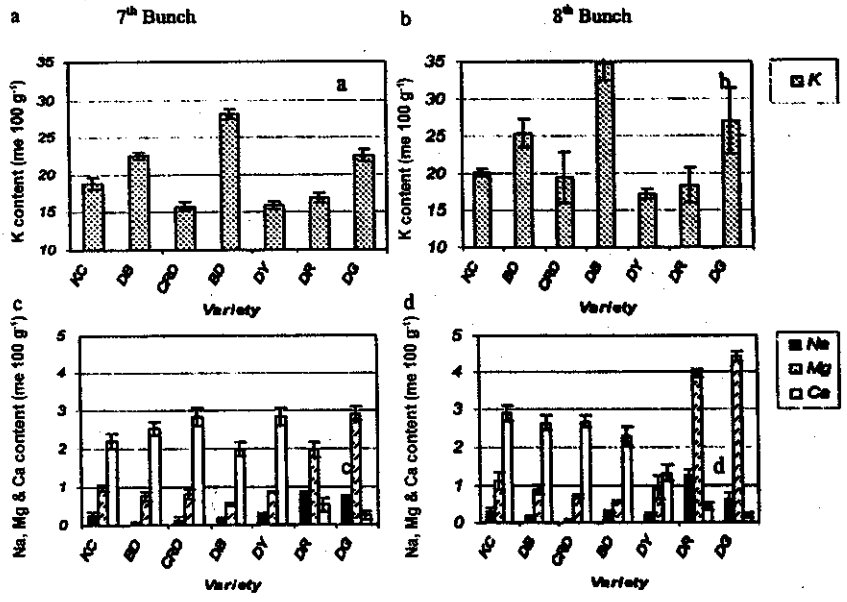

Fig. 2. Potassium (me 100g-1) (a & b) and Na, Mg and Ca contents (me 100g^{-1}) (c & d) in nut water of seven coconut cultivars, king coconut (KC), bodiri (BD), Cameroon red dwarf (CRD), dwarf brown (DB), dwarf yellow (DY), dwarf red (DR) and dwarf green (DG)

region up to about three weeks (data not shown) and for long-term storage (36-38 days) the application of a fungicide is essential in addition to vacuum packing and cold storage (Table 2).

fungicide) nuts are presented here and the data of untreated nuts are not presented. There were no significant differences in glucose, fructose or total soluble sugar contents of the nut water among 'fresh' and stored

Table 2. The effect of application of a fungicide (treated) on cosmetic appearance and sensory characters of tender king coconuts after 36-38 days of storage at 13-15°C under vacuum packing compared to 'fresh'-nuts. Untreated : no fungicide application

Cultivar	Fresh	after 36-38 days of storage Treated	Untreated
Skin colour (no change)	100%	100%	100%
Outer skin (no shrink)	100%	100%	100%
Perianth fallen	0%	30%	30%
Perianth turned brown	0%	20%	100%
Infected perianth	0%	10%	30%
Nut water suitable for consumption	100%	90%	65%
Kernel suitable for consumption	100%	90%	65%

Chemical constituents of nut water

The concentration of main sugars of nut water after 36-38 days of storage was compared with sugar concentrations of 'fresh nuts' (before storage). The data of 'treated' (with King coconuts. Sucrose was not detected in fresh nuts and it was slightly increased during storage compared fresh nuts (Table 3).

Table 3. Sugar content of young coconut water at the time of picking (fresh) and after 36-38 days of storage at 13-15°C with fungicide application and vacuum packing

Component	Content (mg 100 ml^{-1})	
	fresh	After 36-38 days
Sucrose	np	0.222±0.055
Glucose	2.410±0.102	2.640±0.035
Fructose	2.100±0.091	2.220±0.061
Total	5.000±0.070	5.160±0.076

Discussion :

It is important to harvest tender nuts at the proper stage at peak quality as the quality cannot be improved after harvest, it can only be maintained. Percentage of sucrose, glucose, fructose and total sugars in nut water is higher in eight-month-old nuts than seven-month-old nuts. Percentage of sugars in nut water is different among the cultivars, except sucrose at seven-month-stage. Generally BD, KC, DG and DR recorded higher sugar contents irrespective of the maturity stage and DB, DY and CRD recorded lower sugar contents. Potassium is the major mineral present in tender coconut water and it's concentration along with sugar concentrations play an important role in the characteristic taste (Nathanael, 1952). Similar to sugars, BD had the highest potassium content in nut water followed by DB, DG and KC. Accordingly, on the basis of nutritional aspects, BD, KC and DG appeared most suitable cultivars as a beverage with high content of sugars and potassium. For the consumers who prefer a good taste but low potassium, DR appeared a

suitable cultivar and for consumers who prefer tender nut water with minimum sugar taste, DB and CRD appeared most suitable cultivars. DY is a cultivar with moderate sugar content and low mineral content. These factors coupled with an appreciable volume of nut water favour the choice of these cultivars for the tender nut purpose. Dhamodaran *et al.,* (1993) evaluated 12 coconut cultivars (indigenous to India and exotic) on the basis of a biochemical analysis and revealed that Chowghat Orange Dwarf (COD) had the maximum amount of total and reducing sugars and highest consumer acceptability followed by Malayan Orange Dwarf (MOD) and Philippine Ordinary (PO). Out of ten coconut cultivars, Poduval *et al,* (1998) found PO, Malayan Yellow Dwarf (MYD) x West Coast Tall (WCT) and Tall x Dwarf hybrid to have appreciable amount of nut water and sugar contents and suggested that these cultivars to serve as tender nuts under West Bengal conditions.

The pleasant taste of nut water is mainly attributed to the sugars and mineral matter. At the same time the volume of water is also important from the consumers' point of view as it is a thirst quenching drink and volume of nut water is at its maximum during the 7-8 months stage (Nathanael, 1952). Therefore, cultivars that will fulfill the need of tender nut having the above mentioned qualities should be recommended for cultivation. The month of harvest has also to be standardized while choosing a cultivar for drinking. Most of the studies conducted in other countries and in the authors' laboratory show that seven to eight months after fruit set should be considered as the month of harvest for the use as tender nut (Ranasinghe *et al,* 1999; Poduval *et al,* 1998; Wimalasekara *et al,* 1998; Dhamodaran et. al., 1993).

The study also developed an improved technology package for extending the shelf-life of tender nuts. The young coconuts harvested at 7-8 month maturity, disinfected with 0.6g/L Captan, vacuum packed in polythene (300 gauge size) and stored at low temperature (13-15°C) could be preserved for 36-38 days without deterioration in quality (without causing notable loss of quality). Under these conditions, decomposition of nut water and changes in the cosmetic appearance of the nut were delayed, prolonging the keeping quality. Vacuum packing prevented the discolouration and shrinking of the outer skin (epicarp) of nuts by arresting oxidation, respiration and dehydration and maintained freshness of the produce. Furthermore, it avoids surface contamination during handling and transportation. The sensory evaluation showed that water and kernel of 90% of nuts after 36-38 days of storage was not different to that of fresh nuts. However, only vacuum packing and cold storage, i.e.; without surface sterilization with a fungicide, was not suitable for extending shelf-life more than three weeks as vacuum packing does not sterilize the foods. Packaging plays a very important role in ensuring safety of the product during storage, transportation and distribution, and in protecting desired sensory characteristics and microbial soundness till the end of the expected shelf-life of the produce. Vacuum packing increased the shelf-life of dehydrated pineapple slices, with respect to chemical, microbiological and quality attributes (David and Thirumaran, 2003). Raw onions packed under vacuum, after washing in either water or hypochlorite increased the shelf-life up to 30 days at 4°C (Martinez *et al,* 2005). Maciel *et al.,* (1992) showed that polythene-wrapped young green coconuts (dwarfs) stored at 12°C for four weeks were better preserved compared to unwrapped nuts or the nuts stored at 4°C or 22°C. Low temperature storage retards aging due to ripening, softening, textural and colour changes, undesirable metabolic changes and respiratory heat production, moisture loss and the wilting and microbial spoilage. One of the most important functions of low temperature storage is to control the crop's respiration rate. The loss of stored food reserves through respiration means decreased food value, loss of flavour, loss of weight and more rapid deterioration (Wilson *et al,* 1995).

Some coconut cultivars suffer from the disadvantage that it is seasonal in bearing, and improved planting material of this variety is lacking. Therefore, the Coconut Research Institute has already

placed a major emphasis in the development of an improved king coconut strain for stable yield and non-seasonal bearing in order to increase the income of the grower and favour national production. Good quality king coconut seedlings (non seasonal in bearing and desirable palatability) provided to growers for on-farm conservation will be used as main sources of king coconuts for export market. It is proposed to place the same emphasis on other suitable cultivars to obtain a stable yield and high quality tender nuts. In addition, few more cultivars that were collected from Southern part of Sri Lanka are under evaluation for tender nut purposes.

In conclusion, BD, KC and DG appeared most suitable cultivars as a beverage with respect to high content of sugars and potassium. The post-harvest quality of 7-8 month old tender coconuts could be preserved for 36-38 days when the nut surface was disinfected with Captan (0.6 g/L), vacuum packed in polythene (gauge size 300), enclosed in net packing and stored at 13-15°C and 70% RH in a 7-ply carton in a cold cabinet. J

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