

PROCESSING AND PRESERVATION
OF TENDER COCONUTS
(Cocos nucifera. L)

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DIVISION OF AGRICULTURAL ENGINEERING
UNIVERSITY OF AGRICULTURAL SCIENCES,
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PROCESSING AND PRESERVATION
OF TENDER COCONUTS (*Cocos nucifera.L*)

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DEDICATED TO
MY
BELOVED PARENTS, GRAND MOTHER
& BROTHER

**DIVISION OF AGRICULTURAL ENGINEERING
UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE**

CERTIFICATE

This is to certify that the thesis entitled "PROCESSING AND PRESERVATION OF TENDER COCONUTS (*Cocos nucifera. L*) submitted by Mr. NIKHIL. D. H. in partial fulfilment of the requirement of the Degree of MASTER OF SCIENCES (Agricultural Engineering) in POST-HARVEST PROCESS AND FOOD ENGINEERING to the University of Agricultural Sciences, Bangalore, is a record of bonafide research work done by him during the period of his study in his university under my guidance and supervision and no part of the thesis has been submitted for the award of any degree, diploma, associate-ship, fellowship or any other similar titles.

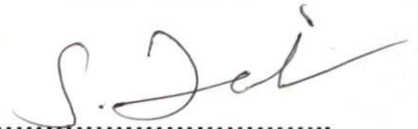
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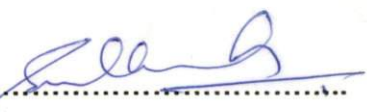



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INTRODUCTION

1 - INTRODUCTION

The coconut palm (*Cocos nucifera.L*) is being extolled as "**KALPAVRUKSHA**" or the tree of heaven most important and widely distributed commercial palm throughout India. It is being cultivated since time immemorial as references are available in various literary works including Ramayana. Its cultivation is largely confined to the coastal region of the country. It is believed to be originated from the South East Asia (Indonesia) and distributed throughout the tropics between 20N and 20S latitudes upto an elevation of 900 metres.

The major coconut growing countries of the world are Philippines, Indonesia, India and Srilanka. With an annual production of 13088.00 million nuts from an area of 1897.40 million hectares during 1997-98, India ranks third among the coconut growing countries. Coconut growing States are Karnataka, Kerala, Tamilnadu, Andhra Pradesh, Maharashtra, Gujarat, Orissa, West Bengal and some North Eastern States. Kerala ranks first with an annual production of 5911 million nuts from an area of 1020.40 million hectares during 1997-98 (Chrtsty Fernandez, 1999). India produced 13.088 million nuts over an area of 1.897 thousand hectares during the year 1998 (Punchihewa, 2000).

Several products are directly or indirectly prepared from the coconuts includes the desiccated coconut, copra, coconut oil and copra meal cake are the most important for international trade. The fruit is ovoid in shape and the husk is about the size of football. It consists of four parts, the husk, shell, kernel and water.

In all the coconut growing countries, a part of the yield is harvested at the tender stage for tender coconut water as a beverage. In India alone, it is estimated that nearly 500 million nuts are harvested and consumed at a tender nut stage for quenching the thirst during summer months in growing areas. The coconut water, technically is the liquid endosperm that fills the central cavity enclosed by a solid endosperm and protected by the hard shell and husk. Its soft tender meat or solid endosperm is a delicious dessert. Tender coconut water is not only a thirst quenching drink but a mineral drink that cures most of man's diseases and helps him regain his lost health.

Its numerous medicinal properties have been described elaborately in our ayurvedic literatures and no other natural drink tends itself to such diversity of applications and uses in our traditional systems (Nanda Kumar, 1995).

The proper storage of tender coconuts has been a concern for tender coconut vendors and too little is known about the storage condition for green coconuts to preserve the coconut water. The

traditional method of its extraction is difficult, time consuming and risky. It is an art to use a machete to remove the husk from one end of a tender coconut to expose a part of its shell and to cut open a small hole in the exposed portion of the shell to extract its water or liquid endosperm.

Therefore, present study was conducted in order to determine the storage condition and consumer acceptability of preserved coconut water and to fabricate simpler machine for extraction of water from tender coconuts with the following objectives.

- 1) Standardization of storage condition for extension of shelf life of tender coconuts.
- 2) Physico-chemical analysis of tender coconut stored at ambient and cool chamber condition.
- 3) Organoleptic evaluation of tender coconut water stored in different storage conditions.
- 4) Development of energy efficient punching equipment for opening tender coconuts.

**REVIEW OF
LITERATURE**

2 - REVIEW OF LITERATURE

Coconut is regarded as one of the most important palms of the World. The composition and quality of the nuts varies with climatic conditions under which it is grown. The effect of variety, maturity, composition and quality differs from various ecological conditions under which it is cultivated. The composition of the nuts largely depends on production practices, climatic conditions, storage atmosphere and temperature maintained during storage. Coconuts possess hard shell at its age of 6-8 months. Hence trimming or cutting to extract liquid endosperm is generally very difficult. The available literature on various aspects such as maturity, composition, storage and equipments used for trimming of nuts to extract tender nut water is critically reviewed here under.

2.1 Maturity:

Walker (1906) reported that the green mature nut contained 33.7 per cent copra based on fresh weight, while ripe nut contained 50.1 per cent copra. Further, after storing the nuts for two months the quantity of copra increased to 53.9 per cent. The increase in copra content was attributed to decrease in coconut water.

Gonzales (1914) studied some of the changes in ripening coconut and found that during the first three months of nut development there was no kernel formation and from fourth

month (0.08 cm) to seventh month (1.2cm) the kernel thickness increased progressively.

Child and Nathanael (1950) observed the presence of reducing sugars in the immature to seven month old nuts, subsequently non reducing sugars showed increasing trend. Thereafter, the total sugar decreased to two per cent in fully ripe nuts (12 months old).

Cutter et.al., (1952) reported that in the beginning of nut development, large nuclei like substances suspended in the nut water subsequently gets incorporated into developing endosperm appearing as non cellular jelly in the early stage of nut development.

Krishnamarar (1957) studied the pattern of nut development and reported that in the earlier stages of development upto four months, the female flowers or buttons grow faster in length than in breadth, accompanied by a marked increase in weight and volume. Later, growth was more in width than in length but the weight and volume of the nut progressively increased upto the 10th month. Subsequently, maturity followed with drying and shrinking of nut resulted in the reduction of weight and volume.

The cavity inside the nut differentiates itself in the first two months and increases considerably reaching its maximum size in the sixth month and having full of nut water throughout this

period. The meat formation starts as a thin and soft layer from sixth month onwards and increases in hardness till the end though the rate of increase declines as the nut ripens. With increase in thickness of the kernel there was progressive decrease in the quantity of nut water with maturity.

Pandalai (1958) reported that in the early stages of the nut development when the endosperm formation occurs, invert sugars and amino acids accumulate in the water and reaches a maximum concentration during fifth or sixth month. Sucrose appears thereafter and the concentration of total sugars reduce. Total soluble solids increase gradually as the nut matures reaching maximum at the seventh month just before the kernel begins to form and declines further.

Pillai et. al., (1960) revealed the development of nut based on the dry weight and found that the husk reached its maximum growth during the eighth month, shell at tenth month, kernel in the eleventh month and maximum oil accumulation starts further.

Delendo (1967) observed the variations in the relative weight of coconut shell, meat and water besides changes in the textural composition of coconut kernel at different stages of maturity. The moisture content of copra decreased with maturity of nuts.

Nambiar et. al., (1969) concluded that the nut development was maximum during fourth month and continued till seventh month, further there was a decrease in its growth and development. They also found three distinctive phases of nut development, the first phase consists of a slow progressive growth for three months after fertilization of flowers, followed by rapid development till seventh month and finally faster decline in growth during last two months of nut development. The rate and growth of the nut during the second phase of active development were highly correlated with the final volume, weight of the nut and copra content. Adverse seasonal variations coinciding with this active period of nut development affect the rate of growth, size and copra content.

Investigation carried out by Nambiar et. al., (1969) indicated the growth pattern of coconut and reported that season plays vital role on the composition and quality of nut during its maturity and ripening. They take nearly 11 to 12 months to mature depending upon seasonal variations.

The relative concentration of free amino acids in the liquid endosperm differs with stage of maturity, seasons and soil conditions as revealed by Gunawardena (1973).

Subramanian and Vasudevan (1977) reported that the season and age of the nuts influenced the water content. They observed that the amount of water ranges from 400-590 millilitre per nut as a varietal character.

According to Kamaldevi and Velayutham (1978) the maximum quantity of water per nut was found in Chowghat Dwarf orange x west coast tall hybrid and a significant positive correlation was also found between the volume of the water and copra content during the tenth month of sampling.

Thampan (1984) worked on the maturity and development of the nut and found that after the fertilization of the flowers it takes about 11 to 12 months for the flowers to develop into a matured nut. In about 160 days the nut attains full size and the meat begins to form as a thin layer of jelly around the shell. Even before the formation of the meat the shell encloses a clear, sweet refreshing liquid endosperm reaching maximum quantity around 160 days of maturity.

Satyabalan and Mathews (1984) conducted correlation studies on nut and copra characteristics of west coast tall, harvested during different months of the year. They reported a significant correlation between weight of the nut unhusked and weight of husked nut to the fresh weight of the kernel, weight of husked nut and fresh weight of the shell, weight of husked nut and weight of copra, fresh weight of kernel and weight of copra, weight of shell and weight of copra. The differences noticed in the characters were attributed to the seasonal variations during nut development.

In the process of nut ripening, nut water was partially replaced by meat. The endocarp or shell began to harden when the nut was about 220 days old. The shell became fully hardened and the meat fully formed when the nut was 11 to 12 months old. Though the fresh weight of the meat was maximum during the tenth month, the weight of dried kernel or copra was highest during the twelfth month.

Changes in chemical composition of coconut water during maturation are indicative of change in quality (Jaylekshmy et. al., 1986).

Chikkasubbanna et. al., (1990) reported that for obtaining the adequate amounts of nutrients and sugars in the coconut liquid endosperm the nuts should be harvested between the seventh and eight months of maturity.

2.2 Physico-chemical composition of the nut:

Walker (1906) observed that water of immature nut for tender coconut at endosperm stage was saturated with carbon dioxide. This may be due to the enzymatic reactions during the changes in carbohydrates to other compounds.

Child and Nathanael (1950) observed that the volume of water increased from 2 ml in one month to 600 ml in the six month old nuts and thereafter decreased to 242 ml in ten months

old nuts. Total solids increased from first month (2.89 g/100 ml) to seventh month (6.01 g/100ml) and thereafter decreased in 10 month old nuts (4.20 g / 100 ml). So also the total sugars from 1.54 g/100ml in the first month to 5.02 g/100 ml in six month old nuts, later decreased as the nuts matured.

Chemical composition of tender coconut water will have (95.5%), Nitrogen (0.5%) Potassium (6.6%), total soluble solids (4.71g/100ml), reducing sugar (0.8g/100ml), non reducing sugars 91.28g/100ml, total sugars (2.08 g/100 ml) and ascorbic acid 92.2-3.7 mg/100 ml) and that the calorific value of tender coconut water was 17.40 per 100 g with nutritive ratio of 1:42.25 (Pandalai 1958).

Subramanian and Swaminathan (1959) confirmed that the kernel of fresh coconut contained minerals like, potassium (436 mg), calcium (13 mg), magnesium (52mg), iron (2.08mg), copper (0.32 mg), Phosphorus (94mg), sulphur (33mg) and chlorine (114 mg) per 100 grams of meat.

Nathanael (1959) found that the gelatinous kernel at about 6 months development amounted to 22 g per nut, water (94.6%) and Oil (0.9%). The ripe nut of 13 months old contained kernel (272 kg) with moisture (42.5%) and oil (68.1%) on dry weight basis.

The composition of mature coconut water of 4.7g total soluble solids reducing sugars (0.8g), sucrose (1.28 g), total

sugars (2.08g), sodium (105mg), potassium (312 mg) and chloride (183 mg) per 100 ml of coconut water (Subramanian and Swaminathan 1959).

Davis (1962) estimated the nutritive value of coconut endosperm as follows: Sugar (5%) and vitamin C (2.2 to 3.2 mg / 100 ml). In addition to it had minerals, amino acids and other vitamins. The water had a calorific value of 17.4 / 100 g and contained traces of nitrogen, potassium, calcium, magnesium and iron. The chemical composition of coconut varies with its maturity and season. The composition was, coconut husk weight (286g), moisture (15%), pH (96.3) and potassium (286.0%), coconut shell: moisture (6.07%), lignin (32.3%), ash (0.23%), coconut water (unripe) : total solid (4.71 g), reducing sugars (0.80%), sucrose (1.28%) and total sugars (0.63%) per 100 ml.

The pH of fresh buko was reported 5.6 and that of kernel was 6.6. The fresh buko had a composition of moisture (81%), protein (1.8%), fat (3.7%), ash (0.7%), fibre (0.9%) and carbohydrates (11.8%) (Manoto and Aspiras 1970).

The proximate analysis of different components in the west coast tall variety of coconut was investigated by Satyabalan et. al., (1970) and reported that husked nut weight was 518.38 g, the % weight of nut water 19, % weight of kernel 53 and shell 23%.

Vijayan et. al., (1977) found that coconut water contained carbohydrates, proteins, fats and vitamins. Among the various minerals present potassium was the major constituent.

Subramanian and Vasudevan (1977) worked on the physical and chemical composition of coconut water and found that the pH of water was 5.9, titrable acidity was 78 to 234 mg of KOH/litre and the chloride content varied from 32 to 46 milli equivalents per litre.

Vijayan et.al., (1977) reported that the potassium content of the water varied from 0.232 to 0.360 g/100 ml of water. The variety Fiji registered the highest potassium content of 0.360g followed by San Blas with 0.348g. It was least in Goa variety from 0.200 to 0.280 g/100 ml of water. The maximum amount was recorded in Fiji and the minimum was in Gangabondam.

According to Sandoval (1978) the meat of laguna variety of coconut during maturity consisted crude protein of $3.49 \pm 0.58\%$ and free nitrogen (7.25%).

Reddy et. al., (1979) confirmed that the San Raman variety produced the heaviest nuts (267g) and Dwarf green the lightest (258g). Percentage of Kernel was highest (4%) in Gangabondam whereas west coast tall gave the highest per cent of oil in the dried kernel (77%).

Rosario et. al., (1979), studied the chemical changes in developing coconut fruit. The proximate composition, sugars, phospho lipids and enzyme activities were determined with the increase in maturity and the following changes were observed. a) decrease in moisture, carbohydrate and ash with subsequent increase in fat content, b) highest invertase activity and reducing sugar concentration at around the sixth month, these sugars being glucose in the meat and glucose and xylose in water, c) the predominance of albumin in the younger stages and of globulin in the more mature nuts with both fractions comprising 80-91 per cent of the total proteins at all stages of nut development. Positive activity of esterases, phosphatases, catalase, invertase and peroxidase was noted.

Lapitan and Mabesa (1983) while comparing Golden and Laguna two coconut varieties found that the moisture content was same in both varieties with similar maturity.

Lapitan and Mabesa (1983) estimated the chemical composition of Golden and Laguna coconut varieties and found that pH (5.60 ± 0.10), reducing sugars ($0.60 \pm 0.03\%$), total sugars ($3.24 \pm 0.04\%$), sucrose (2.44 ± 0.02) for laguna and pH (5.55 ± 0.13), reducing sugars ($0.83 \pm 0.04\%$), total sugars ($3.24 \pm 0.02\%$), and sucrose ($2.29 \pm 0.09\%$) for golden coconuts respectively.

Thampan (1984) reported that tender nut water has calorific value of 17.4 per cent per 100 ml of water. He found that the composition of tender nut water as water (15.5%), protein (0.1%), fat (0.1%), mineral matter (0.41%), carbohydrate (4%), calcium (0.02%), phosphorus (0.01%) and iron (0.5mg) per 100 grams.

According to Thampan (1984), the mineral composition of water was as follows, sodium 105 mg/100 ml, potassium 312 mg/100 ml, calcium (29.0), magnesium (30.0), iron (0.10), copper (0.04), phosphorus (37.0), sulphur (24.0) and chlorine (183.0). He also found that tender coconut had potash as the major constituent.

Thampan (1984) estimated that the pH of water varied from 4.8 to 5.3 and it contained both ascorbic acid and B-complex vitamins. The concentration of ascorbic acid ranged from 2.2 to 3.7mg/100 ml which gradually diminished as the kernel began to harden.

According to Banzon and Escarda (1986) the coconut was used as food at all stages of maturation; the endosperm varied in composition not only according to maturity but also according to location in the nut. A gradient existed from testa side to cavity side. These variations in composition were important considerations in the processing and utilization of coconut. Although coconut oil was largely made up of saturated fats, it was low in C₁₈ fatty acids. The fatty acids from younger nuts

had a high content of linoleic acid. Unrefined coconut oil had a high content to tocopherols but this greatly reduced by the refining process. Oil from mature nut could provide the necessary amount of polyunsaturates in Philippines filled milks. The composition of coconut milk/cream, flour, water etc., influenced their utilization and necessarily their nutritional value.

Jaylekshmy et. al., (1986) worked on the changes in the chemical composition of coconut water collected from the nuts at eight progressive stages of maturity. They analysed titrable acidity, pH, total solids, total and reducing sugars, total and non-protein nitrogen, fat and fatty acid, composition and mineral constituents. Marked reduction in the volume of water accompanied by significant changes in the chemical composition were observed during maturation on per cent water basis, drastic reduction in the total solids, sugars, ash and mineral constituents was noticed where as fat and protein contents were found to increase with maturation.

Chikkasubbanna et. al., (1990) studied on the effect of maturity on the physical as well as chemical characteristics of tender coconut (*Cocos nucifera. L. Var. Arsikere Tall*) water to assess the optimum stage of harvest of tender nuts. Nut weight, volume of water, weight of kernel, shell and fibre, TSS, pH, acidity, reducing and non reducing sugars, nitrogen, protein, potassium and sodium were recorded at monthly intervals in the nut water.

Maciel et. al., (1992) studied on the chemical parameters of the tender nut water and confirmed that total solids (5) per cent, total sugars (2.1) per cent, reducing sugars 1.9 per cent, ash 0.6 per cent, calcium 59.6 mg /100 ml, phosphorus 10.2 mg/100 ml, Chlorine 0.3 mg/100 ml, sodium 38 mg/litre and potassium 21.4 mg / litre are present in nut water.

Poduval et. al., (1998) studied to identify cultivars suitable for tender nut purpose in the state of West Bengal. Ten coconut cultivars were selected for the study. Volume of nut water, TSS, acidity, reducing sugars, nitrogen, phosphorus, potassium, total sugars, iron, manganese, copper, zinc and total free amino acid content were recorded at monthly intervals. Among the cultivars Philippine ordinary, Malayan Yellow Dwarf x West Coast Tall and Tall x Dwarf hybrid were found to have appreciable amount of nut water during seventh month after fruit set (350-500ml). The cultivars also had appreciable amount of sugars during that time (3.2 - 3.3%). These cultivars were suggested to grow for tender nut water under West Bengal conditions.

Ratnambal (1999) opined that a large 7 month old nut may contain about 600 ml water with 30g sugar and 2g of potassium. The volume of water was maximum (795 ml/nut) in cultivars Karkar. The total sugar content ranged from 5.0 g/100ml in cultivars Tiptur Tall to 7.0g/100 ml each in cultivars Cameroon Red Dwarf and Surinam Dwarf. The free amino acid content was

maximum (28 mg/100ml) in Tiptur Tall. The sodium content varied from 20ppm each in West African Tall and Chowghat Green Dwarf to 40 ppm in Cultivars Tiptur Tall. The potassium content was maximum (3700 ppm) in Blanchissues and minimum (1931 ppm) in Gangabodam.

Attri et. al., (1999) evaluated the physico-chemical characteristics of tender nut with the age of 7-8 months maturity. The total weight of the coconut varied from 1.31 kg in Malayan orange Dwarf to 28.5 gin Andaman Tall. The length recorded was the highest (21.02 cm) in Dwarf x tall whereas the breadth was maximum (16.34 cm) in Andaman Tall. The volume of water varied significantly and it was recorded maximum (649.0ml) in Dwarf x tall. The specific gravity of water and TSS were found to vary among different cultivars but the variation was recorded as non significant. The highest brix acid ratio (20.73) was observed in Malayan orange Dwarf coconut.

2.3 Storage of Tender coconuts:

Manoto and Aspiras (1970) studied the effect of various preservatives like benzoic acid, sodium metabisulphite, sorbic acid and ascorbic acid on the shelf-life and organoleptic qualities of bottled 'buko' (coconut water) and reported that the stored products (eight to twelve weeks samples) had better acceptability with sodium metabisulphite than the samples treated with

benzoic acid, sorbic acid and ascorbic acid. This was attributed to the development of a slightly rancid and sour taste in the product during the storage.

Mohandas (1974) reported that pasteurisation at 80°C for 25 minutes was found to be most effective for the preservation of fresh coconut sap. The samples were stored for six months without any change in their quality and flavour.

Consignado et. al., (1976) conducted storage studies on young coconut (buko) and found that in the sixth and seventh month old young coconuts (whole and husked) stored for 28 days at 0°C, 17°C and at ambient temperatures, the total soluble solids in all samples decreased with storage except those stored at 0°C. Total sugars and nitrogen increased initially but decreased further after 24 days. Titrable acidity, sugar to acid ratio and pH showed fluctuations. In general, they concluded that the whole buko stored at 17°C were better in acceptability because of their acceptable colour and flavour.

Ramanandan (1980) studied on the storage of tender coconut by keeping them in water, open, sand and buried. He reported that the volume of nut water and weight of kernel portion varies from nut to nut in the same bunch and between different bunches of different trees. The water of the tender nuts kept in the open was good to taste only up to 88 hrs and those

remaining developed sour taste. The water of the nuts kept in water was found to be sour after 40 hours of storage. Nuts stored in sand remained good till 112 hours. The nuts stored in pits were good upto 40 hrs.

Maciel et. al., (1992) studied the effect of different storage condition on preservation of coconut water to determine. The proper storage conditions for preservation of green coconuts for refreshing purpose with various temperatures (4, 12, 22 and 28°C), time and type of packing (with or without polyethylene) for a period of five weeks. A total of 133 dwarf fruits were used. On day 1 (zero time) and on weeks 2, 3, 4, and 5 of the experiment the water was collected at random from six samples from wrapped and six from unwrapped coconuts for physico chemical (brix, total acidity, pH and weight) micro-biological and sensory analyses. Treatments were repeated twice to minimise statistical error. The data was analysed with a standard statistical procedure. The data showed that the best treatment for storage of tender coconut depends on maintenance of temperature at 12°C. Further type of packing and time of packing are very important.

Jiang et. al., (1995) studied on the effects of poly phenol oxidase (Catechol oxidase) (PPO) and Peroxidase (POD) on the phenolic content of coconut fruits during processing and storage using spectrophotometry and HPLC. Poly phenol oxidase was able to oxidise monophenols, diphenols and polyphenols. The main phenolics substances present in the coconut peel (epicarp

and part of mesocarp) were chlorogenic acid and dopamine. After a 10 min soak in boiling water followed by treatment in iced water containing 1% sodium sulphite and 0.02% citric acid, inhibited PPO and POD activity compared with untreated fruits. Reduction in phenolic contents coincident with a milky white colour and good fruit quality when stored for 40 days at 10°C. It was concluded that there was possibility of controlling browning of coconut by inhibiting the activities of PPO and POD during transportation and storage.

Jayaraman et. al., (1998) studied on extending shelf life of fresh coconut gratings at ambient storage using hurdle technique and reported that grated coconut kernel becomes rancid quickly and is highly prone to microbial spoilage within 2-3 days. A simple minimal processing technique based on the combination of preservation (handle) techniques was developed and assessed for preservation of fresh gratings with a combination of additives comprising sodium chloride (to reduce equilibrium RH to 94%), citric acid (to reduce pH to 4.5) and sodium citrate and sodium benzoate (as anti-microbials), equilibrating and packing in flexible polymeric pouches. Stability of the product was monitored and product quality evaluated during storage for 6 months at different temperatures. Sensory evaluation indicated that the product remained acceptable till one month at ambient temperature. Mild heat treatment (in pack pasteurisation at 85°C for 16 min) on treatment with BHA (0.02% on fat content) (3-

ditertbutyl-4-hydroxyanisole) extended the stability and acceptability of the product for period of three months.

Attri et. al., (1999) reported that tender coconut water can be kept fresh without any adverse effect on its quality for two months at low temperature (3-4°C). At ambient temperature (25-30°C) it was found to ferment after 8-10 hours. Further it can be preserved with the help of potassium metabisulphite (KMS) @ 600 ppm but for consumption the preserved water has to be heated upto boiling point to remove excess SO₂ present in the water.

It is evident from the literature that physical and chemical parameters of coconut are greatly influenced by climatic conditions, maturity, type of storage and method of handling. Nuts stored at ambient temperatures under tropical conditions tend to spoil and change the delicate composition compared to water preserved in cans or laminated pouches as reported by Srivastava et. al., (1998).

2.4 Fabrication:

Toh et. al., (1984) made an attempt at fabricate United Plantations. Bernhard (UPB) dehusking machine which was a prototype. The dehusking process involves cutting off a piece of husk at the stalk end of the coconut with a circular saw and tearing the husk from the nut, with the help of a rotating spring loaded fingers of a cone. Dehusking tests carried out at the workshop gave an encouraging capacity of nuts per hour. Further modifications are necessary to improve the efficiency.

Sudaria (1987) studied on the quasi-static mechanical properties of coconut shell of husked mature nut. The range of parameters assessed are as follows: Cracking strength of coconut shell, 3, 345, 0.83, 2.5, 379, 28.3 kg / m², shearing force of the coconut shell, 574, 984.9 - 1, 258, 830.9 kg/m², bending stress of the coconut shell, 61, 801.9 - 289, 003.3 kg/m²; hardness of the coconut shell, 150651.1 - 156657.6; and the cracking stress of the husked mature nut, 280,104.0 - 440,277.7 kg/m². The combined average stresses on bending, shearing, tensile, cracking of coconut shell and cracking of husked mature nut revealed no significant difference on stresses at any position of the husked mature nut. This suggests that nut could be split at any position without significant difference on power expenditure. For design of splitter machine, cracking stress of the coconut shell should be viewed very critically since this parameter requires maximum force.

Sudaria (1994) conducted a study to design, fabricate and evaluate an electric motor driven coconut husk fibre extractor. These were three cylinder teeth configurations tested by using unsoaked and 1-month soaked coconut husks. The three Cylinders teeth configurations were pointed (No. 2.5 nails without heads); a combination of pointed and non pointed (Barbwire nails). Each cylinder teeth configuration was evaluated using the soaked and unsoaked coconut husks with three replications. Results were analysed using the split - plot

technique with randomised block design. Results revealed that the non-pointed cylinder teeth configuration using the 1-month soaked coconut husks, had the highest capacity of 20g/min and gave better quality fibre. However, statistical analysis showed that only the soaking of husks was significant interaction effect and the different cylinder teeth configuration were negative.

A prototype decorticating machine driven by a 10 hp, 3-phase electric motor was designed, fabricated and evaluated based on its performance to defiberize coconut husks. Its main features included among others, quarter cubic meter capacity cylindrical case which encloses the 16 blades rotary assembly to decorticate the husks, and two hoppers which serve as separate passages for coir fibers and dusts existing from the cylinder. Its design consideration was primarily based on the following criteria (1) affordability, mobility and adaptability of the machine to a village - level operation (2) reasonable production output with acceptance quality of fibers and (3) safe to operate. The estimated production cost of coir fibers was 0.90 paise per kilogram (Palomar et. al. 1996).

Sadakathulla et. al., (1993) designed and fabricated a new gadget - coconut measures for simultaneous measurement of both the polar length and equatorial width of coconut. This device can also be used to measure the length and width of fruits of horticultural crops.

A manual coconut husking tool was developed at the Kerala Agricultural University, India. The design, construction and operation of the coconut husking tool has many advantages over traditional tools, producing a mechanical advantage which reduces the force required from 20-35 to 10-20 kg. The mode of application of the force, pulling as opposed to pushing is also easier to apply. The time taken to husk coconuts, 8-220 s/nut, is as fast as other equipment made for this purpose. It is totally flexible for husking all types of coconut, fresh or dry, large or small, and in at least as safe as any other coconut husking tool. The tool can be handled even for domestic use by untrained women, children, and commercial production of the same was started during 1998 (Jacob, 1998).

A manually operated coconut punching device was developed at the Kerala Agricultural University, India. The device consists of punch which moves up and down, actuated by a slider crank mechanism powered by a hand lever requiring about 18 kg of force. The coconut rests on a ring stand on the base of the device. It takes around 5 seconds to punch each coconut and eliminates the risk of using a cutter to husk and chop coconuts.

Shamsudeen. et. al., (1999) have attempted to develop simple tender coconut cutter for easy opening of nuts. They reported with this equipment it takes 2-3 seconds by using a mechanical strength of 15-25 kg of force through hand lever.

**MATERIAL &
METHODS**

3 - MATERIAL AND METHODS

The experiment was conducted at division of Agricultural Engineering, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore, during the year 1999-2000.

The coconut bunches of variety Tiptur tall were harvested from a plantation at Ramanagaram near Bangalore and brought to the laboratory for further studies. Fifteen bunches were selected each with a minimum of 10 nuts of same maturity with similar physical parameters like shape, size and colour. The selected nuts were carefully graded and sorted to study physical and chemical composition.

3.1 Storage of Tender coconuts:

The harvested bunches from the main field were immediately brought to the laboratory by road. The tender nuts were separated from the bunch and divided into three groups of 50 nuts for storage.

The three different methods of storage were as follows:

- 1) **Open**: The selected tender coconuts were placed at ambient conditions.
- 2) **Stored in Water**: Selected number of 50 nuts were immersed in plastic drums containing water & water was changed everyday to prevent fermentation & fungal growth.

- 3) **Storage of nuts in zero energy cool chamber:** The cool chamber was constructed in a well ventilated place with sufficient shade. The cool chamber was constructed as per the recommended procedures using bricks, sand, soil mortar and thatched cover made out of arecanut leaves coconut leaves.

The tender nuts were kept in two crates (25 each) and stored in the cool chamber. The crate had an inner dimension of 763x521x410 mm and an outer dimension of 810x568x425mm.

3.2 The basic hypothesis and construction:

The zero energy cool chamber is based on the principle of evaporative cooling. It is simple brick structure made from cheap and locally available raw materials with a limited water resource. The raw materials required for construction of cool chamber are bricks, sand, bamboo and thatched cover.

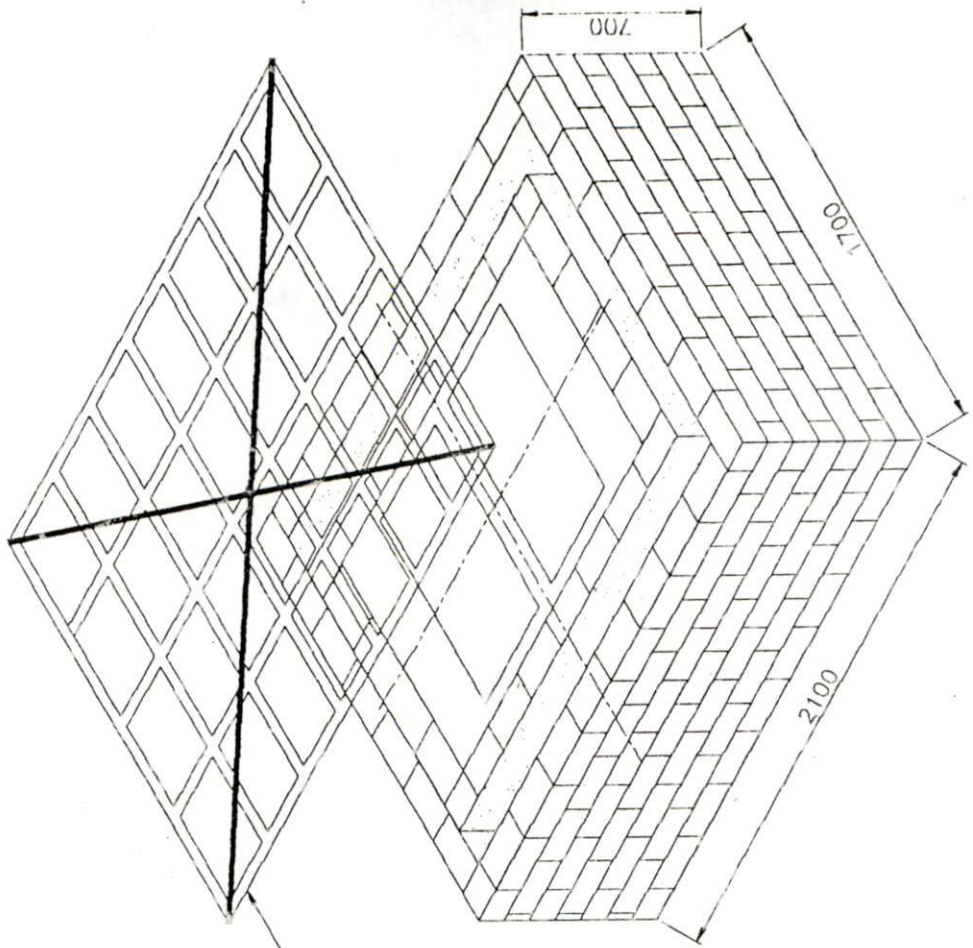
The cool chamber was constructed with following specifications and it is as shown in Figure - 1.

A) External Dimensions:

- 1) Length : 2.1 m (7')
- 2) Breadth: 1.7 m (5'6")
- 3) Height : 0.7 m (2' 2")

B) Internal Dimensions :

- 1) Length : 1.5 m (5')
- 2) Breadth: 1.0 m (3'3")
- 3) Height : 0.8 m (2' 5")



THATCHED TOP COVER MADE
OUT OF ARECANUT LEAVES

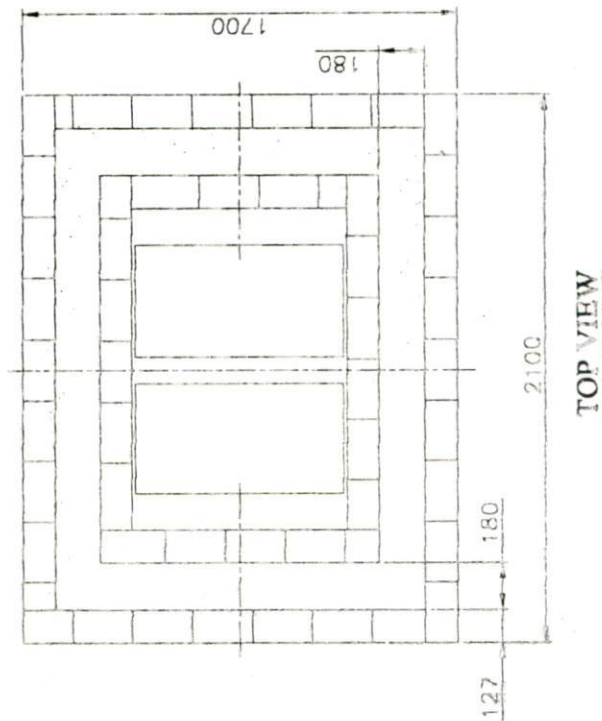


FIGURE - 1
Pictorial view of zero energy cool chamber

NOTE: All dimensions are in mm.

C) Bricks required for the construction:

- 1) Length : 8 layers of each 10 bricks total 160 bricks
- 2) Breadth: 8 layers of each 7 bricks total 112 bricks
- 3) For Floor: Single layer of bricks to cover the entire floor

The side walls are erected with a double layer of bricks leaving approximately 18 cms. (7") space between the bricks to a height of 0.7 meters. The space between the two layers of bricks was filled with clear sand layer by layer to maintain moisture. The top of the chamber was covered with a thatched roof made out of arecanut leaves. The entire cool chamber was thatched to prevent direct sunlight. Before storing the cavity between the bricks was saturated. The cool chamber was wetted by sprinkling water once in the morning and evening to maintain temperature and humidity.

Precautions to be taken:

- a) Use only clean, unbroken and uniform bricks.
- b) The sand should be free from organic matter, clay and other particles.
- c) Prevent contact of chamber to open sun.
- d) Periodically remove all the rotten material and keep the chamber clean.
- e) To maintain low temperature and high humidity inside the chamber bricks and layers should be saturated depending upon weather conditions.
- f) Keep away pests, insect and rodents from the chamber.

PLATE NO. 1

PHOTOGRAPHIC VIEW OF ZERO ENERGY COOL CHAMBER

PLATE NO. 2

**INTERNAL VIEW OF ZERO ENERGY COOL CHAMBER WITH
NUTS IN PLASTIC CRATES.**



3.3 Observation Recorded:

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The selected tender coconuts were stored in different conditions as outlined above for a period of 90 days. For analysis 7 nuts were randomly selected from each lot every time with an interval of 15 days. The nuts were used for determining various physico-chemical parameters.

3.3.1 Physical Parameters:

- 1) Weight of the whole nut (kg/nut)
- 2) Volume of water (ml/nut)
- 3) Weight of shell (kg/nut)
- 4) Weight of fibre (kg/nut)
- 5) Weight of kernel (kg/nut)

3.3.1.1 Weight of the Whole nut:

The average weight of seven individual nut was recorded and expressed as kilogram per nut by using balance - model number 1103CC manufactured by Avery India Limited.

3.3.1.2 Volume of Water:

The total volume of water was determined by measuring total water content of seven nuts and data was recorded in millilitres per nut by using a measuring cylinder.

3.3.1.3 Weight of Shell:

The average shell weight of seven individual nuts was recorded in Kg. by using Tulaman balance.

3.3.1.4 Weight of Fibre:

The average weight of fibre content of seven individual nuts was recorded in Kg. by using Tulaman balance.

3.3.1.5 Weight of Kernel:

The average kernel weight of seven individual nuts was recorded in Kg. by using Tulaman balance.

3.3.2 Chemical Parameters:

The following chemical quality parameters were analysed for the stored nut water of different storage conditions. The average of seven nuts from each lot was taken at an interval of 15 days for a period of 90 days.

- 1) Total soluble solids (°B)
- 2) pH of water
- 3) Total acidity as citric acid (%)
- 4) Reducing sugars (%)
- 5) Nitrogen (%)
- 6) Potassium (mg/100ml)
- 7) Sodium (mg/100ml)
- 8) Calcium (mg/100ml)
- 9) Brix-acid Ratio.

3.3.2.1 Total Soluble Solids:

The total soluble solids of water was recorded by using Bosch and Lamb ABBE-3L refractometer and expressed as °B after calibrating the readings to room temperature.

3.3.2.2 pH

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pH of coconut water was determined using ELICO pH meter model LI-105.

3.3.2.3 Acidity

Total titrable acidity of the coconut water was measured by titrating the sample against 0.1N sodium hydroxide using phenolphthaline indicator and expressed as percentage of citric acid.

3.3.2.4 Reducing Sugars

Reducing sugars in the tender coconut water was estimated by following the method of Nelson-Somogyi (Nelson,1944).

Preparation of reagents:

Reagent 'A':

Twenty eight grams of anhydrous di-sodium phosphate, 40g of Rochelle salt were dissolved in 700 ml of distilled water. To this 100ml of 1N NaOH solution was added. 80ml of 10% $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, solution was added to this mixture, with constant stirring. Finally 180 g of anhydrous sodium sulphate was added and the volume was made upto 100 ml. After two days of incubation, the clear solution was decanted and stored in amber coloured bottle.

25g of ammonium molybdate was dissolved in 450ml of water. To this, 21ml of concentrated H_2SO_4 was added with constant stirring. 3g of sodium arsenate was dissolved in 25ml of water and mixed thoroughly with earlier solution. The reagent was incubated at $37^\circ C$ for 48 hours and stored in amber coloured bottle.

Estimation of reducing sugars:

Two millilitre of sample was taken in a test tube. To this 2ml of reagent 'A' was added and mixed thoroughly. The tubes were covered with rubber stopper and heated in water bath for 10 minutes. It was cooled to room temperature and one millilitre of reagent 'B' was added and mixed immediately. The intensity of blue colour was measured by using spectrophotometer at wavelength of 520nm.

3.3.2.5 Nitrogen:

Five millilitre of sample was digested in a digestion system of 1016 digester with the addition of kjeltech digestion tablets and concentrated sulphuric acid (5ml) at $700^\circ C$ for five hours. The digested samples were diluted and the nitrogen content was measured using auto analyser (Tecator Kjeltch 1030). The total nitrogen content was recorded as percentage.

3.3.2.6 Potassium & Sodium:

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Potassium and sodium content of coconut water was estimated by diluting the samples suitably with double distilled water and concentrations were measured with the help of flame photometer. The colour intensity was measured and further calculated as mg/100ml of the sample (AOAC, 1965).

3.3.2.7 Calcium:

Calcium content of coconut water was estimated by precipitating calcium as calcium oxalate. The precipitate is dissolved in hot dilute H_2SO_4 and titrated with standard potassium permanganate solution. The concentration was measured in terms of mg/100 ml of sample (Ranganna, 1976).

3.3.2.8 Brix - acid Ratio:

The brix acid ratio of the coconut water was obtained by dividing the total soluble solids with the acidity of the sample.

3.4 Sensory Evaluation:

The tender coconut and its water stored at different conditions were organoleptically evaluated for following quality attributes after every 15 days intervals.

- 1) Colour
- 2) Appearance
- 3) Flavour
- 4) Taste
- 5) Overall acceptance

Organoleptic evaluation of the tender coconut and tender coconut water was carried by a panel of five trained judges. Hedonic rating scale was followed for the evaluation outlined by Amerine et. al., (1965). Quality attributes were judged by ranking the samples as follows:

QUALITY	SCORES
Very poor	2
Poor	4
Average	6
Good	8
Very good	10
Excellent	12

3.5 Methods of statistical analysis:

Analysis of variance was done according to the methods obtained by Cochran and Cox (1952) and F-test was applied at 0.05 probability level of significance.

3.6 Designing and Fabrication of tender coconut water dispensing system:

Concept – To dispense easily tender coconut water from 7-8 months old nuts by piercing and punching through hand and foot operated sterile vacuum pump.

Design: The basic design of the system is elaborately tested and fabricated by using mild steel (MS) and stainless steel for piercing to achieve desired functions.

The system is as shown in the Figure - 2.

3.6.1 Basic Components:

- Stand assembly
- Coconut clamping system
- Coconut piercing system
- Coconut water dispensing system

Brief description of the basic components:

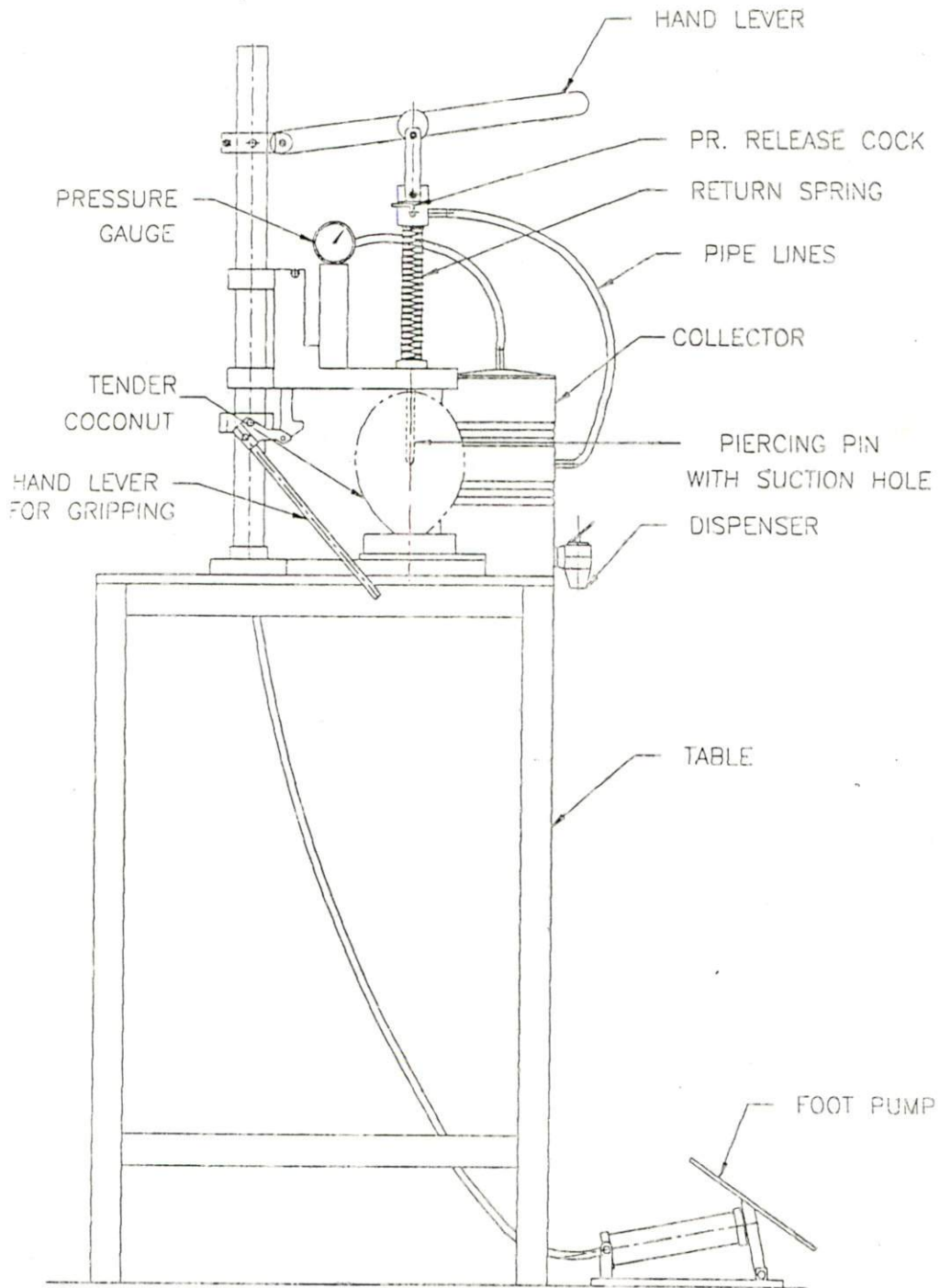
Stand Assembly:

Stand assembly is mounted on to a platform at a convenient height made out of cast iron and carbon steel, machined precisely and assembled with coconut clamping fixture, coconut punching tool and piping for vacuum dispensing of coconut water.

Coconut clamping system:

The above system is a machined construction mounted on column of the stand assembly which slides up and down to clamp and to orient with the piercing punch and also to accommodate different sizes of coconut.

TENDER COCONUT WATER DISPENSER



The above unit is a spring actuated piercing punch capable of being moved up and down made out of food grade stainless steel raw material, machined and assembled with a slider crank mechanism mounted on to the column of the slide assembly and also having provision of inlet and outlet holes for dispensing water from the shell.

Coconut water dispensing system:

The above system is a foot operated vacuum pump which works under vacuum suction principle connected to inlet and outlet port of the piercing punch system by actuation of the bellows by foot pedal. Vacuum is created and water is sucked through inlet pipe and discharged by outlet pipe of the system.

The above subunits assembled on the stand assembly are duly surface treated, powder coated considering the basic parameters of hygienic conditions.

3.6.2 Function of the system:

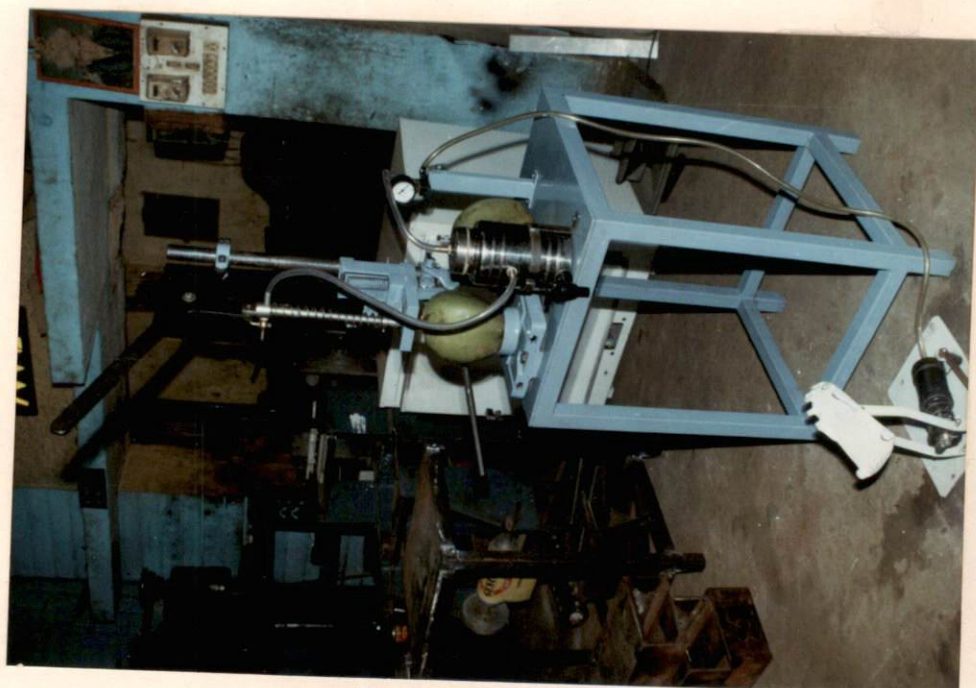
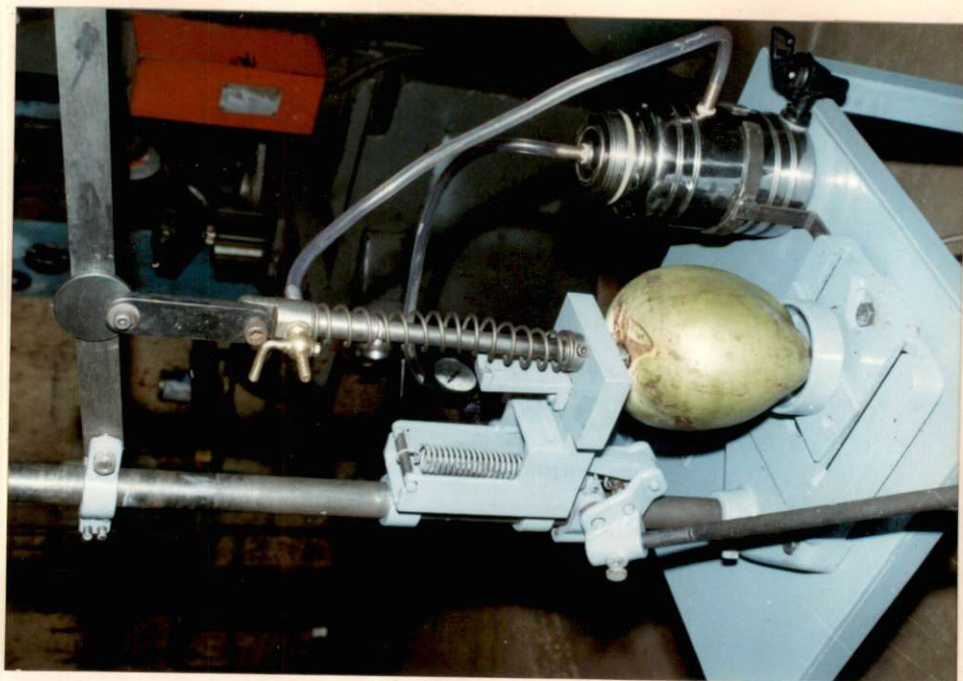
- 1) Tender coconut is placed on to the clamping system and rigidly secured and oriented to the piercing punch.
- 2) The punch is pierced by a handle so as to break open the tender shell, the nozzle enters the liquid endosperm and by actuation of foot pump water is sucked from the coconut and discharged through outlet and a filter hygienically.

PLATE NO. 3

CLOSE VIEW OF TENDER COCONUT WATER DISPENSER

PLATE NO. 4

DESIGN VIEW OF TENDER COCONUT WATER DISPENSER



3.6.3 Operational Sequence:

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- Tender coconut is placed on the clamping fixture so that the pedicel end is turned upwards.
- Clamping handle is operated to hold the coconut rigidly and oriented with the piercing tool assembly.
- On actuation of the main handle lever, the piercing punch moves downwards.
- Piercing nozzle of the tool punctures and breaks open the tender shell and moves to the bottom end of the coconut.
- Vacuum pump pedestal, operated by foot continuously creates vacuum and sucks the water through the outlet hole of the punching tool into a reservoir through a filter.
- From the reservoir water is dispensed and served.

PLATE NO. 5
VIEW OF THE DISPENSER IN OPERATION



EXPERIMENTAL RESULTS

4 - EXPERIMENTAL RESULTS

The results obtained from the investigation on the research problem of "Processing and preservation of tender coconut" (*Cocos nucifera. L*) carried out during the year 2000 are presented in this Chapter.

This research was conducted to find out the effect of storage conditions on the quality and composition of tender coconut water.

The tender coconuts stored at different storage conditions did not keep well beyond 15 days of storage. However, some replications were stored upto 30 days to record different parameters. The initial readings on the day of imposing treatments were recorded for physico-chemical characters.

4.1 Physico-chemical Composition of tender coconut.

4.1.1 Physical Characters:

The physical parameters such as (1)Weight of nut, (2)Weight of fibre, (3)Weight of shell, (4)Volume of water, (5)Weight of kernel were recorded by adopting standard methods. The data recorded was tabulated in Table - 1. The recorded average weight of tender coconut was 2.40 kg/nut and the volume of water per nut was 375 ml whereas, the average weight of the shell was 1.30kg. The average weight of fibre was 0.80 kg and that of kernel was 0.70 kg.

4.1.2 Proximate composition of tender coconut water: 43

The chemical components such as total soluble solids, pH, acidity, brix acid ratio, reducing sugars, nitrogen, potassium, sodium, calcium were analysed and results obtained are presented in the Table - 2.

The total soluble solids of tender coconut water was 4.00°B while acidity, pH and brix acid ratio were 0.93, 4.9 and 4.30 respectively.

The tender coconut water had 2.8 per cent reducing sugars and 0.15 per cent nitrogen. The concentration of potassium, sodium and calcium were 310, 142 and 43 mg / 100 ml of water respectively.

4.2 Storage of tender coconuts:

The changes in the physical constituents such as weight of nut, volume of water, weight of shell, weight of fibre and weight of kernel of tender coconuts and the changes in the chemical composition of nut water such as pH, acidity, TSS, Brix-acid ratio, reducing sugars, nitrogen, potassium, calcium and sodium were recorded for tender nuts stored in different conditions such as open, water immersed and zero energy cool chamber at an interval of 15 days upto 30 days was analysed and results recorded.

TABLE - 1

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**OBSERVATIONS RECORDED FOR DIFFERENT PHYSICAL
PARAMETERS FOR TENDER COCONUT**

Weight of Green Coconuts (kg)	2.40 Kg
Volume of Water (ml)	400 ml
Shell weight (kg)	1.30 Kg
Weight of Fibre (kg)	0.80 Kg
Weight of kernel (If developed)	0.70 Kg

TABLE - 2**OBSERVATIONS RECORDED FOR DIFFERENT CHEMICAL
PARAMETERS IN TENDER COCONUT WATER**

TSS °B	4.00
Acidity %	0.93
pH	4.90
Potassium (mg/100 ml)	310
Sodium (mg/100ml)	142
Calcium (mg/100ml)	43
Nitrogen (%)	0.15
Reducing Sugar (%)	2.8
Brix Acid Ratio	4.30

4.2.1 - Weight of nut (kg)

Table - 3 evidently shows changes in the weight of nut stored in different conditions of storage. The weight of the nut significantly decreased from 2.40 kg on the 1st day to 1.94 kg on the 15th day which further declined to 1.46 kg on the 30th day of storage when nuts were stored under ambient condition.

Nuts stored in water exhibited a light variation in the weight of nut, it was observed that the weight of nut decreased from 2.40kg on the 1st day to 1.88 kg on the 15th day of storage. A slight increase to 1.90 kg was noticed on the 30th day.

The nuts stored in Zero energy cool chamber recorded weight of 2.40 kg on the 1st day further reduced to 2.38 kg on the 15th day which decreased to 2.29 kg on the 30th day.

4.2.2 : Volume of water (ml)

Volume of liquid endosperm in the nuts exhibited variation in its quantity for nuts stored in different conditions. The data is tabulated in Table - 4.

The volume of water decreased from 400ml on the 1st day to 360ml on the 15th day further to 262.85 ml on the 30th day in case of nuts stored in ambient condition.

WEIGHT OF THE GREEN COCONUTS (Kg) ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	1.94	1.46	1.70
T ₂	1.88	1.90	1.89
T ₃	2.38	2.29	2.33
Average	2.07	1.88	-

	T	D	TxD
F. VALUE	*	*	NS
SEM ±	0.07	0.06	0.10
CD at 5%	0.22	0.18	-

TABLE- 4

VOLUME OF WATER PER NUT (ml) ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	360.00	262.85	311.42
T ₂	320.00	415.71	367.85
T ₃	358.57	367.85	363.21
Average	346.19	348.80	-

	T	D	TxD
F. VALUE	*	NS	*
SEM ±	7.48	6.10	10.57
CD at 5%	21.59	-	30.54

T₁ – Ambient storage conditionT₂ – Stored in waterT₃ – Zero Energy cool chamber storage

The volume of water showed variation for the nuts immersed in water. The volume decreased from 400 ml on the 1st day to 320 ml on the 15th day of storage.

In case of nuts stored in zero energy cool chamber the volume of liquid endosperm decreased from 400 ml on the 1st day to 358.57 ml on the 15th day and then there was a slight increase to 367.85 ml on the 30th day of storage.

4.2.3 Weight of shell (kg)

The changes in the shell weight of the tender coconuts stored in different conditions are presented in Table - 5.

The weight of the shell on 1st day was 1.30 kg which slightly decreased to 1.29 kg on 15th day further decreased to 0.74 kg on the 30th day. This results are recorded when the nuts were stored under ambient conditions. The nuts sunk in water recorded 1.30 kg on the 1st day and reduced to 1.26 kg on the 15th day while it was increased to 1.45 kg on the 30th day of storage.

In case of nuts stored in zero energy cool chamber the weight of the shell decreased from 1.56 kg to 1.49 kg from 15th day to 30th day respectively.

SHELL WEIGHT PER NUT (Kg) ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	1.29	0.74	1.01
T ₂	1.26	1.45	1.36
T ₃	1.56	1.49	1.52
Average	1.37	1.23	-

	T	D	TxD
F. VALUE	*	NS	*
SEM ±	0.06	0.05	0.08
CD at 5%	0.017	-	0.25

TABLE- 6

WEIGHT OF THE FIBRE PER NUT (Kg) ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	0.98	0.64	0.81
T ₂	0.96	1.28	1.12
T ₃	1.17	0.86	1.01
Average	1.04	0.93	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.04	0.03	0.06
CD at 5%	0.12	0.10	0.17

T₁ – Ambient storage conditionT₂ – Stored in waterT₃ – Zero energy cool chamber storage

PLATE NO. 6

**NUTS SHOWING INITIATION OF SPOILAGE AFTER 15 DAYS
UNDER AMBIENT CONDITIONS.**

PLATE NO. 7

**NUTS SHOWING SIGNS OF SPOILAGE AFTER 15 DAYS OF STORAGE IN
WATER.**



4.2.4 Weight of Fibre (kg)

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The data on the fibre content of the nut stored in different conditions are presented in Table - 6.

It was observed that the weight of fibre recorded on the 1st day was 0.80 kg. The fibre weight decreased significantly from 0.98 kg to 0.64 kg from 15th day to 30th day for nuts stored in ambient condition.

The fibre content was found to increase from 0.96 kg to 1.28 kg for nuts stored in water from 15th day to 30th day of storage. The weight of fibre for nuts stored in zero energy cool chamber showed a decreasing trend. It decreased from 1.17 kg to 0.86 kg from the 15th day to the 30th day of storage respectively.

4.2.5 Weight of Kernel (kg)

The changes in the weight of the kernel of the tender coconuts stored in different conditions is presented in Table - 7.

The weight of kernel decreased from the 1st day to the 30th day in all the three storage conditions. In case of ambient condition the weight decreased from 0.80 kg to 0.75 kg on the 30th day. The weight of kernel decreased from 0.84kg on the 15th day to 0.73 kg on the 30th day in case of nuts stored in water.

In case of zero energy cool chamber stored the weight decreased from 0.90kg on the 15th day to 0.78 kg on the 30th day of storage.

WEIGHT OF THE KERNEL (kg) ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	0.80	0.75	0.78
T ₂	0.84	0.73	0.78
T ₃	0.90	0.78	0.84
Average	0.85	0.75	-

	T	D	TxD
F. VALUE	NS	*	NS
SEM ±	0.02	0.02	0.04
CD at 5%	-	0.06	-

TABLE- 8

TSS °B OF NUT WATER FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	4.02	3.90	3.96
T ₂	3.70	2.98	3.34
T ₃	4.08	4.02	4.05
Average	3.93	3.63	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.03	0.02	0.04
CD at 5%	0.09	0.07	0.13

T₁ – Ambient storage conditionT₂ – Stored in waterT₃ – Zero energy cool chamber storage

4.2.6 Total soluble solids:

Changes in the total soluble solid of tender coconut water during 30 days of storage are presented in Table - 8. The mean values for total soluble solids did not show much change during storage period. The value was 4.00°B on the 1st day of storage. This was taken as reference value.

The mean values of brix decreased slightly from 4.02 to 3.90 from 15th day to 30th day of storage for nuts stored in open condition. Similarly, for nuts stored in zero energy cool chamber no significant difference was observed. The value recorded on 15th day of storage was 4.08 and that on the 30th day was 4.02 in case of nuts stored in water there was a decrease from 3.7 from the 15th day to 2.98 on the 30th day of storage.

4.2.7 pH

Table-9 indicates the changes in pH values of nuts stored in different conditions. The values for pH showed a significant increase in all the three types of storage conditions. Initially pH value of 4.90 was recorded on the 1st day of storage. There was an increase in the value of pH from 1st day to 15th day (5.13) and 5.46 on the 30th day of storage for the nuts stored under ambient conditions.

An increasing trend was observed in case of nuts immersed in water i.e. 5.07 on the 15th day to 6.58 on the 30th day.

Similarly, for the nuts stored in zero energy cool chamber the pH increased from 5.07 to 5.50 on the 15th and 30th day respectively.

TABLE- 9
pH VALUES OF NUT WATER FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	5.13	5.46	5.29
T ₂	5.07	6.58	5.82
T ₃	5.07	5.50	5.29
Average	5.09	5.84	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.04	0.03	0.05
CD at 5%	0.11	0.09	0.16

TABLE- 10
TOTAL TITRABLE ACIDITY (%) OF NUT WATER
FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	0.83	0.72	0.78
T ₂	0.84	0.67	0.75
T ₃	0.79	0.72	0.75
Average	0.82	0.70	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.006	0.005	0.009
CD at 5%	0.019	0.016	0.028

T₁ – Ambient storage condition
T₂ – Stored in water
T₃ – Zero energy cool chamber storage

4.2.8 Total titratable acidity:

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Total titratable acidity of tender coconut water from the nuts stored in different conditions are furnished in Table - 10. It was observed that the total acidity of water decreased from the 1st day which decreased upto 30th day of storage under different storage conditions. The initial reading of 0.93 per cent was recorded on the 1st day.

There was a significant decrease from 0.83 per cent on the 15th day to 0.72 per cent on the 30th day for nuts stored in ambient condition.

In case of nuts stored in water a decrease from 0.84 to 0.67 per cent was observed on the 15th and 30th day respectively.

The nuts held in zero energy cool chamber also showed similar trend in values of total acidity from 15th day to 30th day which was 0.79 and 0.72 per cent respectively.

4.2.9 Brix acid ratio:

The data for brix acid ratio is presented in Table 11. The brix acid ratio on the 1st day of storage was 4.30.

The brix acid ratio for the nuts stored in open and zero energy cool chamber showed an increasing trend whereas it decreased for the nuts stored in water from the 15th to 30th day

of storage. The least value of brix acid ratio was 4.06 for nuts stored in water for 30 days and the highest value of brix acid ratio was 5.59 for nuts stored in zero energy cool chamber for 30 days.

4.2.10 Reducing Sugars:

Data furnished in Table - 12 shows changes in the reducing sugar level of tender coconut water during the period of 30 days, an decreasing trend was seen in all the three cases of storage conditions.

Storage period had a positive effect on reducing sugar levels of tender coconut water. The initial reducing sugar of 2.80 per cent was recorded on the 1st day and 1.52 per cent on the 30th day for nuts stored in ambient condition.

The reducing sugars decreased significantly for the nuts stored in water from 1.68 per cent on the 15th day to 0.63 per cent on the 30th day.

The nuts stored in zero energy cool chamber also showed a decreasing trend from 3.09 to 1.60 per cent from 15th to 30th day respectively.

TABLE-11
BRIX-ACID RATIO OF NUT WATER
FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	4.78	5.29	5.04
T ₂	4.39	4.06	4.22
T ₃	5.11	5.59	5.35
Average	4.76	4.98	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.05	0.04	0.08
CD at 5%	0.16	0.13	0.23

TABLE-12
REDUCING SUGAR (%) OF NUT WATER
FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	1.89	1.52	1.71
T ₂	1.68	0.63	1.16
T ₃	3.09	1.60	2.35
Average	2.22	1.25	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.010	0.008	0.015
CD at 5%	0.030	0.020	0.043

T₁ – Ambient storage condition
T₂ – Stored in water
T₃ – Zero energy cool chamber storage

4.2.11- Nitrogen

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Results obtained on the nitrogen content of nut water stored under different conditions are tabulated in the Table - 13.

Nuts stored in open showed an increase in nitrogen content from 0.15 per cent on the 1st day to 0.20 per cent on the 15th day of storage and then decreased to 0.02 per cent on the 30th day of storage. The nitrogen content of coconut water decreased significantly from 0.14 per cent to 0.03 per cent on 15th day to 30th day respectively in case of nuts stored in water.

In case of nuts stored in zero energy cool chamber the nitrogen content was decreased from 0.24 per cent on the 15th day to 0.04 per cent on the 30th day. It was also observed that the nitrogen content increased from 0.15 per cent to 0.24 per cent from 1st day to 15th day of storage.

4.2.12 Potassium:

The data tabulated in Table-14 reveals that there was decreasing trend of potassium (mg/100ml) in the coconut water of the tender nuts stored in ambient conditions, immersed in water and zero energy cool chamber from the 1st day of 310mg/100 ml to the 30th day of storage.

There was a significant decrease from 287.14 mg/100 ml to 155.57 mg/100 ml from 15th to 30th day of storage in case of nuts stored in ambient conditions.

PLATE NO. 8

**NUTS SHOWING SIGNS OF SPOILAGE
AFTER 30 DAYS OF STORAGE IN WATER**

PLATE NO. 9

**NUTS INDICATING FUNGAL INFECTION
AFTER 30 DAYS OF STORAGE IN ZERO ENERGY COOL CHAMBER**



TABLE-13

NITROGEN (%) OF NUT WATER
FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	0.20	0.02	0.11
T ₂	0.14	0.03	0.08
T ₃	0.24	0.04	0.14
Average	0.19	0.03	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.001	0.001	0.002
CD at 5%	0.005	0.004	0.007

TABLE- 14

POTASSIUM (mg/ 100ml) OF NUT WATER
FOR NUTS ON STROAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	287.14	155.57	221.35
T ₂	309.18	303.81	306.50
T ₃	302.85	196.08	249.47
Average	299.72	218.49	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.22	0.18	0.31
CD at 5%	0.63	0.52	0.90

T₁ – Ambient storage condition

T₂ – Stored in water

T₃ – Zero energy cool chamber storage

Similarly, the potassium content of water decreased in case of nuts stored in water from 309.18 mg/100 ml on the 15th day to 303.81 mg/100 ml when analysed on the 30th day.

There was a significant decrease in the potassium content from 302.85 mg/100 ml on the 15th day to 196.08 mg/100 ml on the 30th day of storage of nuts under zero energy cool chamber.

4.2.13 Sodium:

The changes in sodium content of coconut water for the nuts stored in different conditions are as recorded in Table - 15.

The sodium content of coconut water decreased significantly in the water from the nuts stored at ambient conditions as well as in zero energy cool chamber when analysed on 1st, 15th and 30th day of storage. The sodium content increased in case of nuts stored in water.

The highest amount of sodium was recorded for the nuts stored in water on 30th day which was 179.61 mg/100 ml and the lowest for the nuts stored in zero energy cool chamber on 30th day which was 100.42 mg/100ml.

TABLE-15

SODIUM CONTENT (100 mg / ml) OF NUT WATER
FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	139.78	130.04	134.91
T ₂	149.87	179.61	164.74
T ₃	140.41	100.42	120.42
Average	143.35	136.69	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.21	0.17	0.29
CD at 5%	0.61	0.49	0.86

TABLE-16

CALCIUM CONTENT (mg/100gm) OF NUT WATER
FOR NUTS ON STORAGE

Treatment	Duration (D)		Average
	15 th Day	30 th Day	
T ₁	40.71	35.42	36.57
T ₂	51.14	55.42	53.28
T ₃	41.85	31.00	36.42
Average	44.57	39.61	-

	T	D	TxD
F. VALUE	*	*	*
SEM ±	0.35	0.28	0.49
CD at 5%	1.01	0.82	1.43

T₁ – Ambient storage condition
T₂ – Stored in water
T₃ – Zero energy cool chamber storage

4.2.14 Calcium:

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There was a significant decrease in the calcium concentration in the nut water stored in different storage conditions such as ambient and zero energy cool chamber. However there was an increase in the content of calcium from the nuts immersed in water (Table 16).

For nuts stored in ambient, the calcium content was 40.71mg/100ml, on 15th day which decreased to 35.42mg/100ml.

There was an increase from 51.14 mg/100ml on the 15th day to 55.42 mg/100 ml on the 30th day in case of nuts stored in water. The calcium content decreased from 41.85 mg/100 ml to 31.00 mg/100 ml for nuts stored in zero energy cool chamber from 15th to 30th day of storage.

4.3 Sensory Evaluation:

Coconut water (endosperm) inside the tender coconut was analysed to determine the quality of the samples by sensory procedures. The relative desirable quality is difficult to measure only by chemical or physical procedures. Hence, it is desirable to go in for organoleptic assessment of the quality. The coconut water was evaluated for its overall quality based on the colour, flavour, appearance, taste and general acceptance by ranking the samples.

The tender coconut was also evaluated for its appearance to assess the quality. The scores relating to sensory evaluation of coconut water differed with different storage conditions and storage period.

The effect of different storage treatment on organoleptic quality of stored coconut water is as shown in the Table-17 and Table-18 respectively. Tender coconuts were stored for 15 days and 30 days respectively in all the 3 storage conditions before subjecting it to sensory evaluation.

Results indicated that the coconut water overall acceptance scores were slightly affected by the storage systems, zero energy cool chamber for the first fifteen days, it was also observed that the overall acceptance scores were very poor in case of samples stored in water and average when stored in ambient air for the analysis after 15 days. The acceptability of coconut water after 30 days of storage in all the three conditions of storage was very poor.

The external appearance of green coconuts stored in zero energy cool chamber and ambient air received higher scores were compared to those stored in water for the same period of storage. The external appearance score was good upto 15 days of storage for tender nuts stored in zero energy cool chamber, average for tender nuts stored in ambient air and very poor for tender nuts stored in water.

TABLE - 17

STORAGE EFFECT ON ORGANOLEPTIC EVALUATION
OF TENDER COCONUT WATER

Treatment	Colour		Flavour		Appearance		Taste		Overall Acceptability	
	15 days	30 days	15 days	30 days	15 days	30 days	15 days	30 days	15 days	30 days
T ₁	6.80	3.20	6.00	2.40	6.40	3.20	6.00	3.60	6.00	2.40
T ₂	2.80	2.80	3.60	2.40	3.20	2.40	2.80	2.00	2.40	2.40
T ₃	10.80	6.80	10.40	5.60	10.00	5.20	10.00	4.40	8.40	3.20

TABLE - 18

SCORES FOR EXTERNAL APPEARANCE FOR TENDER COCONUTS
STORED IN DIFFERENT STORAGE CONDITIONS FOR 15 AND 30 DAYS

Treatment	External Appearance	
	15 days	30days
T ₁	6.00	2.00
T ₂	2.00	2.00
T ₃	8.00	3.20

T₁ - Ambient storage condition

T₂ - Stored in water

T₃ - Zero energy cool chamber storage

4.4 Designing and Fabrication of tender coconut water dispensing system

This device is operated manually by one person. The punching of coconut irrespective of size and maturity, and the withdrawal of punch after punching is made easier and quicker by this invention. The number of unit operations is also reduced to minimum. Above all, it makes the operation safer because the punching method eliminates the need for removing the husk with the machete which otherwise is needed in the traditional method. This specific advantage is likely to encourage women also.

The total time of clamping, piercing, sucking and discharge of coconut water from the shell is around 15 seconds.

DISCUSSION

5 - DISCUSSION

Tender coconuts are valued for their excellent refreshing liquid endosperm. The tender nuts are completely filled with sweet water provides a cool, rejuvenating sweet drink.

Quantity and quality of the nut water goes on changing according to maturity and storage conditions. During this period the sweet water is usually subjected to many chemical changes attributing towards the quality of the water. Therefore, it is necessary to understand the change in the quality of water during storage and for consumer acceptability of the tender water from the stored nuts.

The water from the stored tender nuts were subjected to chemical analysis periodically during storage and evaluated by sensory method for the quality attributes. Results obtained are critically discussed in this chapter.

5.1 Physico-chemical constituents of tender coconut water.

The tender coconuts used in this investigation, recorded nut weight of 2.40 kg, fibre content of 0.80 kg with kernel weight of 0.70kg and of shell weight 1.30 kg. The volume of water was 400 ml. These results are in good agreement with the findings of Ratnambal (1999).

The recorded total soluble solids of tender coconut water was 4.00°B, while acidity was 0.93 and with a pH of 4.90. The data obtained was similar to observations made by Chikkasubbanna et.al., (1990).

The concentration of reducing sugar was 2.80 per cent and nitrogen was 0.15 per cent. These results are similar to observations made by Chikkasubbanna et. al., (1990).

The calcium, sodium and potassium concentrations were 43mg, 142mg and 310 mg/100 ml of nut water. Similar findings were reported by Jaylekshmy et. al., 1986.

5.2 Changes in physical and chemical composition of stored tender coconut water.

5.2.1 Weight of nut (kg)

The weight of nuts decreased during storage under ambient conditions and zero energy cool chamber. This decrease might be due to the loss of water from the nuts during storage. While investigating the weight of the nut Maciel et. al., (1992) made similar observations. The weight of nut declined from the 1st day of storage to the 15th day and further increased slightly towards 30th day. This variation in the nuts immersed in cold water may be due to differential size of the nuts used in the investigation as well as it might be attributed to imbibitions of water into the mesocarp.

5.2.2 Volume of water (ml).

Volume of water showed variations in nuts which were in different storage conditions. Water content of the nut was influenced by season and stage of maturity. The quantity of water ranged from 300 to 590 ml per nut (Subramanian and Vasudevan 1977). Similar observations were made in this investigation also.

5.2.3 Weight of the shell and fibre (kg)

Results are clearly evident that the weight of the shell and fibre decreased during the storage of the nuts for 30 days for nuts stored in ambient condition and in zero energy cool chamber whereas it increased from the 15th to the 30th day of storage in the nuts stored in water.

The variation in the relative weights of coconut shell and fibre generally changes during phases of maturity (Pillai et. al., 1960, Dolendo, 1967).

5.2.4 Weight of Kernel (kg):

The weight of kernel decreased from the 1st day to the 30th day in all the three storage conditions. This may be attributed to the loss of surface moisture in the fibre leading to dryness. Further influencing loss of moisture from the kernel (Jayalekshmy, 1986).

Tender coconuts stored in different conditions recorded very scant variation in the total soluble solids. Maciel et. al., (1992) also found similar variations.

5.2.6 pH:

An upward trend during storage of tender coconut was noticed. A corresponding decrease in acidity during storage could be responsible for change in pH. Analogous observations were recorded by Maciel et. al., (1992). Similar, observation that pH of stored tender coconut water recorded fluctuations irrespective of maturity was recorded by Consignado et. al., (1976).

5.2.7 Total titrable acidity(%).

Acidity of the tender coconut water reduced significantly from the 1st day to the 30th day of storage in all the three conditions. The reduction of acidity of water is in agreement with Maciel et. al., (1992) and Consignado et. al., (1976). The reduction in total titrable acidity could be due to precipitation of acids with potassium and sodium salts forming carbonates and bicarbonates. Thus leading to decline in the amount of free organic acids.

5.2.8 Brix acid ratio:

The brix-acid ratio of water showed fluctuations in different storage conditions. The findings are in line with Consignado et.al., (1976).

5.2.9 : Reducing Sugar:

An decreasing trend in reducing sugars was noticed from the 1st day to 30th day of storage in all the three storage conditions. This might be due to the inversion of sugars by acid causing a decrease in the reducing sugars. (Manoto & Aspiras 1970, Mohandas 1974).

5.2.10: Nitrogen

The nitrogen content increased initially but decreased further in case of nuts stored in ambient air and zero energy cool chamber whereas, the nitrogen content decreased from the 1st day to the 30th day in case of nuts stored in water. These are in line with the findings of Consignado et. al., (1976).

5.2.11: Potassium

The potassium concentration of tender coconut water showed decreasing trend during storage of nuts in all the three conditions of storage. The decrease in potassium in the stored samples might be due to formation of respective salts in the presence of acids.

5.2.12: Sodium and Calcium

The sodium and calcium content also showed a decreasing trend in case of nuts stored in zero energy cool chamber and as well as at ambient condition. But there was an increase in the case of nuts stored under water. This may be attributed to the absorption of salts from the water.

Maciel et. al., (1992) explained that very little is known about the storage conditions that cause change in chemical composition of tender green nuts.

SUMMARY

6 - SUMMARY

The investigations on storage stability of tender coconuts, the organoleptic evaluation of external appearance of tender coconut and stored nut water was carried out at Division of Agricultural Engineering, University of Agricultural Sciences, G.K.V.K, Bangalore during the year 1999-2000. Important findings of the investigations are summarized below.

Tender coconut water (liquid endosperm) is present in the central cavity of the nut enclosed by the kernel and the shell. It can be processed into delicious and refreshing soft drink. It can be made available as a preserved product in places where it is not available. Physico-chemical composition and changes that take place during storage of tender nut under different conditions were investigated. Physical constituents of the tender coconut were studied for period of 30 days with observation taken at every 15 days for the nuts stored in different storage conditions viz., ambient, immersed in water and zero energy cool chamber. Weight of the nut, weight of shell, weight of fibre and weight of kernel decreased in the nuts stored in ambient air and zero energy cool chamber whereas, increased for nuts in water. Volume of water in the nuts showed fluctuations in all three storage conditions.

Among the chemical constituents TSS showed very little variations with respect to storage period. An increase in pH with a corresponding decrease in the total titrable acidity was noticed. The brix acid ratio showed variations during storage. Reducing sugars decreased during the storage period for the nuts stored at different storage conditions.

Nitrogen content increased initially but decreased further in case of nuts stored in ambient air and zero energy cool chamber whereas it decreased for nut stored in water.

Potassium showed a decrease in all the three conditions of storage. The concentration of sodium and calcium varied with nuts stored in zero energy cool chamber and at ambient condition while it increased for nuts stored in plain water.

Tender coconut water stored for 30 days were subjected to various chemical analysis to find out the change in their composition and quality. Most of the chemical constituents of tender coconut water showed a decrease in trend over a period of storage compared to fresh samples irrespective of the stage of their harvest. Sensory evaluation of the tender coconut for nuts stored in zero energy cool chamber scored higher ranking, than the samples stored in other conditions. The acceptability of tender nut water for nuts stored in zero energy cool chamber was the best when compared to nuts stored in ambient air and water.

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The consumer acceptability of tender nut water for those stored in water was the least among the three conditions of storage. The tender nut water stored for a period of 15 days showed better acceptability in respect of quality than the water sample from the nuts stored for 30 days. The tender nut water samples were not subject to microbial examination since the nut water was sterile and free from any type of microbial contamination.

Designing and Fabrication of tender coconut water dispensing system:

Use of tender coconut water as a substitute to artificially flavoured soft drink has become common phenomenon during summer months in the coconut growing areas of the country. In certain areas exclusive tender coconut parlours have been established.

Cutting, piercing and extraction of liquid endosperm free from husk is an art in the tender coconut parlours. It is very difficult to handle heavy knife or machete cutting to open nut into two halves but involves serious risks in this craft. Therefore, it is intended to develop efficient tender coconut punch to open the nuts without much energy involvement and a trained person to minimise wastage of water while opening.

The designed and fabricated coconut punch has shown a promising performance for commercial manufacturing and utilization for punching and piercing of tender coconuts in the growing regions of the country.

However, the above fabricated system is only a conceptual design and could be improved for mass production as per requirement of hygienic standards.

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7 - REFERENCES

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* Originals not seen.

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