Research Article

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Studies on the physico-chemical composition of tender coconut water during development in selected varieties

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Abstract

An experiment was carried out with ten coconut germplasms at Horticultural Research Station, AICRP on Palms, Mondouri, BCKV for two consecutive years (2003-2005) to identify the ideal stage of harvesting of tendernut. Nuts of four stages of maturity (5th, 6th, 7th and 8th months) were evaluated, based on ten parameters. Maximum volume of water (268.0 ml), with the highest reducing sugar (4.26 g/100 ml), potassium (353.90 mg/100 ml) and the least acidity were observed at 7th month but maximum pH, TSS, total sugar, non-reducing sugar, nitrogen and phosphorus were observed at 8th month of maturity. Though some ingredients were slightly higher in the 8th month of maturity, harvesting at 7th month of maturity is ideal for volume of nut water, sweetness and potassium content.

Keywords: Nitrogen, phosphorus, potassium, reducing sugar, tender coconut water

Introduction

Coconut (*Cocos nucifera* L.) is a very versatile and an important commercial palm of the humid tropics grown in over 11 million hectares in 86 countries. It provides not only edible products but also fuel, shelter, medicine and employment to millions of people in the tropics, playing a vital role in the socio-economic condition of India. Tender coconut water (TCW) is the most nutritious wholesome beverage that nature has provided. Around 80 per cent of the production in West Bengal is harvested at tender nut stage (Guha, 1998). Now tender nut is getting popular with the younger generation. Government institutions have already undertaken promotional measures for TCW.

TCW is a natural isotonic beverage with almost the identical levels of electrolytic balance as human blood (Suresh *et al.*, 1968) and is readily accepted by the body (Suresh and Hegde, 1971). The major chemical constituents of TCW are sugar and minerals. The composition of TCW changes with the progress of nut maturation. Potassium decreases and sodium increases during maturation (Vijayan *et al.*, 1977). The present investigation was undertaken to identify the ideal stage of harvesting of tender nut for consumption, with respect to its physico-chemical composition.

Materials and Methods

The investigation was carried out in a 23 years old plantation at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during September, 2003 to September, 2005. The experiment was laid out in "Two factor randomized block design" with four replications and single palm in each replication. Ten germplasm namely B. S. Island, East Coast Tall, FMS Big, Gonthembilli, Hazari, Jamaican Tall, Java, San Ramon, St. Vincent and Zanzibar were included. The inflorescences, which emerged during the months of September to December in the year 2003 and 2004 from each palm under experiment, were marked separately and properly labelled at button nut stage. According to the maturity, 5, 6, 7 and 8 months old nuts were harvested, two from each bunch, during subsequent months of April to May for both the years of the study.

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The observations and estimations included the parameters viz. volume of water, pH, TSS, acidity, total sugar, reducing sugar, non-reducing sugar, total nitrogen, phosphorus and potassium content.

Standard procedures were adopted for the different estimations like total sugars and reducing sugar (A.O.A.C., 1984), non-reducing sugar (Thimmaiah, 1999), total nitrogen and potassium (Jackson, 1973) and phosphorus (Koeing and Johnson, 1942).

Well rotten FYM @ 25 kg/palm/year was applied 1.8-2.0 m away from coconut trunk and thoroughly mixed with soil. Recommended dose of fertilizer (NPK @ 500: 320: 1200 g/palm/year) was applied in two splits *i.e.*, one third in pre-monsoon (June) and two-third in post-monsoon period (September). Urea, single super phosphate and muriate of potash were used as inorganic sources of nitrogen, phosphorus and potassium, respectively.

The analysis of variance over the month was done as per Gomez and Gomez (1984). The analysis was done for two different years separately and to have an overall idea, combined analysis of variance over the years was also taken up.

As the volume of water and sweetness are the two major components of tender nut water from the consumer point of view, the harvesting time of tender coconuts should be standardized in such a way that the volume of water becomes maximum along with the maximum reducing sugar content. It is expected that both the characters increase until a certain maturity level and then decrease, so there is a need to optimise the time period for which these two characters would be maximum. We adopted time trend analysis with volume of water, reducing sugar as dependent variable of time. Second degree polynomial,

$$V_t = \alpha + \beta t + \gamma t^2$$

where V_t = volume at time period t

α, β and γ, the parameters of the model, will be fitted with the pooled data, using ordinary least square technique. The equation will then be differentiated with respect to t and as per min.-max. theory of differential calculus 1st derivative is to be equated with 0, to get the value of t, at which the V_t is maximum,

$$i.\ e. \frac{d\,(vt)}{dt} \quad \beta + 2\,\gamma\, t = 0$$

$$\Rightarrow t = \frac{\beta}{2\,\gamma}$$

for known β and γ, t can be worked out with the help of the above relationship; let it be t', that means at time t', the volume of water in tender nut would be maximum. The same procedure will be followed to ascertain the optimum period at which reducing sugar will be maximum.

Results and Discussion

The data presented in Table 1 clearly indicates that the volume of water was influenced by stage of maturity. The maximum volume was recorded at 7th month (268.0 ml) followed by 6th month of maturity (267.1 ml) and both were at par. The nut at 8th month of maturity exhibited the minimum volume (201.06 ml). The volume of water increased by 30.58% between 5th and 6th months of maturity and declined by 24.77% between 7th to 8th months of maturity. This decline in volume of water is due to the absorption of water by the developing endosperm as well as minor evaporation losses, according to Jayalekshmy *et al.* (1986). However, there are no reports on the exact nature of the loss from the cavity. The stage of maturity has been reported to influence the water content (Jayalekshmy, *et al.*, 1988 and Poduval *et al.*, 1998). These findings are in good agreement with the observations of Damodaran *et al.* (1976) who also obtained maximum volume (451 ml) of water at 7th month of maturity with Philippines Ordinary.

Table 1. Influence of maturity on volume and pH of tender nut water irrespective of varieties

Maturity	Volume of water (ml)			pH of water		
	2003	2004	Pooled	2003	2004	Pooled
5th month	207.5	201.7	204.6	4.38	4.43	4.41
6th month	270.4	263.8	267.1	4.57	4.62	4.60
7th month	273.5	262.6	268.0	4.82	4.87	4.85
8th month	204.3	198.9	201.6	5.05	5.09	5.07
S.Em (±)	3.31	1.59	1.84	0.036	0.044	0.029
CD (P=0.05)	10.83	5.10	5.46	0.116	0.141	0.085

From the above discussion, we have seen that the volume of water in the germplasms under study reaches it is maximum at 6th to 7th month of maturity but it is not definite at which particular time of maturity a specific germplasm reaches its maximum with respect to the volume of water. So, trend analysis with the help of regression technique (OLS=Ordinary least square) was employed to find out the particular age at which the volume of water attains its maximum. The trend in volume of water in different germplasms of coconut along with their relationship with the nut maturity is presented in Table 2.

Table 2. Relationship of volume of water with maturity in different varieties of coconut

Varieties	Equation	R2	Optimum age (month)	Maximum volume (ml)
Java	$y = -34.2x^2 + 437.94x - 1116.5$	0.8778	6.40	285.5
San Ramon	$y = -37.675x^2 + 479.96x - 1253.3$	0.8964	6.37	275.3
St. Vincent	$y = -23.6x^2 + 303.72x - 713.38$	0.9389	6.43	263.8
Gonthembilli	$y = -37.18x^2 + 482.55x - 1287.9$	0.9388	6.49	278.1
FMS Big	$y = -26.25x^2 + 360.87x - 1005.7$	0.7777	6.87	243.6
Jamaican Tall	$y = -35.18x^2 + 438.95x - 1049.2$	0.9719	6.24	320.2
B.S. Island	$y = -20.93x^2 + 265.27x - 605.6$	0.9461	6.34	235.1
Zanzibar	$y = -33.93x^2 + 446.96x - 1184.0$	0.6600	6.59	288.2
East Coast Tall	$y = -35.93x^2 + 469.8x - 1230.3$	0.9755	6.54	305.6
Hazari	$y = -37.65x^2 + 498.49x - 1371.7$	0.9993	6.62	278.3

It is clear for regression equations that the relationships are efficient enough to explain the variation in volume of water by these relationships to the extent of 66% in germplasm Zanzibar to a maximum 99% in germplasm Hazari. From these regression equations by taking first derivatives with respect to nut maturity, the optimum age at which maximum volume of water for different germplasms could be obtained. From this study, it was deduced that nut maturity at which optimal nut water volume is reached is 6.24 months for Jamaican Tall, 6.34 months for B. S. Island, 6.37 months for San Ramon and 6.40 months for Java. Depending on these results, tender coconut should be harvested at these maturities for the different germplasm, provided that the volume of water is the only consideration for harvesting.

There was an increasing trend in pH from 5th to 8th month of maturity. The maximum (5.07) and minimum pH (4.41) were noticed at 8th and 5th months of maturity, respectively irrespective of germplasm under study (Table 1). The findings are also in good agreement with the observations of Jayalekshmy *et al.* (1988) and Ganesamurthy *et al.* (2002) who observed steady increase of pH in the initial stage of nut development (upto 7th month).

Concordant with changes in pH with nut maturity, the maximum acidity (0.927%) was noticed at 5th month maturity, compared to the 6th month maturity (0.903%) and minimum acidity (0.715%) at the 7th month (Table 3). A sharp decline of acidity from 6th (0.903%) to the 7th (0.715%) months stage was observed. Acidity in 6th and 7th month maturity was statistically significant. Chikkasubbanna *et al.* (1990) also noticed the declining trend of acidity (0.21-0.12%) with the progress of maturity. Acidity in nut water of eight months maturity (0.717%) showed a slight increase over seven months (0.715%), the latter exhibited the lowest acidity percentage irrespective of germplasm under study, indicating the qualitative acceptance of tender nut water with its maximum volume of water during six to seven months of maturity.

A gradual increase in total soluble solid content of nut water was noticed in all four stages of nut maturity. The maximum (6.00 °brix) and minimum (3.18 °brix) TSS were registered at eight and five months of maturity, irrespective of germplasms (Table 3). The present finding is also supported by Poduval *et al.* (1998) who observed steady increase in TSS with the germplasms under study upto 7th months except in Andaman Ordinary where there was a continuous increase till eight month.

A steady increase in total sugar content was observed from 5th to 8th months of maturity but rate of increase was more (26.59%) from 6th to 7th month as compared to 5th to 6th month (21.68%) and 7th to 8th month (7.98%) irrespective of the germplasm. The tender nut at 8th month maturity contained maximum total sugar (5.14 g/100 ml water) followed by 7th month maturity (4.76 g/100 ml of water). A steady increase in reducing sugar content was noticed from 5th to 7th month old nuts and thereafter decreased at 8th month of age (Table 4). The findings of both total sugar and reducing sugar are in good conformity with the observations of Chikkasubbanna *et al.* (1990) and Ganesamurthy *et al.* (2002). This decline in sugar level could be attributed to the incorporation of sugars

Table 3. Influence of maturity on total soluble solids and acidity of tender nut water irrespective of varieties

Maturity	Total soluble solids (°Brix)			Acidity (%)		
	2003	2004	Pooled	2003	2004	Pooled
5th month	3.15	3.22	3.18	0.933	0.922	0.927
6th month	4.51	4.54	4.52	0.891	0.914	0.903
7th month	5.54	5.54	5.54	0.707	0.722	0.715
8th month	5.98	6.03	6.00	0.723	0.712	0.717
S.Em (±)	0.050	0.044	0.033	0.0156	0.0175	0.0117
CD (P=0.05)	0.158	0.141	0.098	0.0499	0.0560	0.0348

into the developing endosperm. The developing endosperm might therefore, be utilizing these sugars as precursors for fat synthesis. The physiological significance of conversion of reducing sugars into sucrose on maturation is not clearly understood. The fall in sugar content can be directly correlated with the loss of sweetness during maturation (Jayalekshmy *et al.*, 1988).

Trend analysis with the help of regression (OLS = Ordinary least square) was employed to deduce the specific stage at which the reducing sugar content was maximum. It is clear from equations (Table 5) that the relationships are efficient enough to explain the variation in reducing sugar content by these relationships to the extent of 73% in germplasm FMS Big to a maximum 100% in germplasm Java. From the regression equations by taking first derivatives with respect to the stage of maturity, the optimum age at which maximum reducing sugar content of water for different germplasms was worked out. It is clear that minimum time period of 6.95 months is required to have maximum reducing sugar content of (4.81 g/100ml) in case of Zanzibar followed by 7.10 months for 4.20 mg/100ml of reducing sugar content for East Coast Tall, 7.10 months for 4.11 mg/100 ml of reducing sugar content for FMS Big. On the other hand, optimum maturity of 8.81 months is required for the germplasm B.S. Island to have a maximum reducing sugar content of 4.50 g/100ml followed by 8.40 months in Hazari for 4.70 g/100ml of reducing sugar and 7.59

Table 4. Influence of maturity on total sugar, reducing sugar and non-reducing sugar tender nut water irrespective of varieties

Maturity	Total sugar (g/100 ml)			Reducing sugar (g/100 ml)			Non-reducing sugar (g/100 ml)		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
5th Month	3.09	3.08	3.09	3.08	3.05	3.07	0.008	0.009	0.009
6th Month	3.75	3.78	3.76	3.82	3.70	3.76	0.068	0.075	0.071
7th Month	4.71	4.81	4.76	4.18	4.34	4.26	0.389	0.395	0.392
8th Month	5.10	5.19	5.14	4.05	4.10	4.07	1.051	1.069	1.06
S.Em(±)	0.022	0.029	0.018	0.068	0.030	0.037	0.0198	0.0167	0.0129
C.D. (P=0.05)	0.069	0.093	0.054	0.217	0.096	0.110	0.0633	0.0534	0.0383

Table 5. Relationship of reducing sugar with maturity in different varieties of coconut

Varieties	Equation	R^2	Optimum age (month)	Maximum reducing sugar (g/100 ml)
Java	$y=-0.1525x^2+2.3035x-4.6315$	0.9996	7.55	4.13
San Ramon	$y=-0.237x^2+3.394x-7.995$	1	7.16	4.16
St. Vincent	$y=-0.187x^2+2.838x-6.886$	0.979	7.59	3.88
Gonthembilli	$y=-0.257x^2+3.682x-9.362$	0.925	7.16	3.83
FMS Big	$y=-0.25x^2+3.552x-8.503$	0.7344	7.10	4.11
Jamaican Tall	$y=-0.2925x^2+4.1675x-10.593$	0.9999	7.12	4.25
B.S. Island	$y=-0.1x^2+1.762x-3.168$	0.9999	8.81	4.50
Zanzibar	$y=-0.3775x^2+5.2505x-13.444$	0.9406	6.95	4.81
East Coast Tall	$y=-0.245x^2+3.479x-8.151$	0.9524	7.10	4.20
Hazari	$y=-0.105x^2+1.765x-2.715$	0.8824	8.40	4.70

months in St. Vincent for 3.88 g/100ml of reducing suger content. But most of the germplasms recorded maximum reducing sugar content between 6.95 to 7.16 months except B.S. Island, Hazari and Java and St. Vincent. Based on these results, tender coconuts should be harvested at the maturities worked out for different germplasms provided that the reducing sugar (sweetness) is the only consideration for harvesting.

Maximum non-reducing sugar (1.06 g/100 ml) was recorded in the 8th month of maturity followed by 7th month of maturity (0.392 g/100 ml) irrespective of germplasm, and the lowest non-reducing sugar (0.009 g/ 100 ml) at 5th month of maturity followed by 6th month (0.071 g/100 ml) maturity (Table 4).

An increasing trend was noticed in nitrogen content from 5th to 8th month of maturity. The maximum nitrogen was found in 8th month nut (0.099%) followed by 7th month (0.064%) and 6th month (0.035%) and the lowest value in the 5th month (0.013%). Similar changes in nitrogen have been observed by Jayalekshamy *et al.* (1986) and Chikkasubbanana *et al.* (1990). The increase in nitrogen could be due to the synthesis of amino acids and nucleic acids. Pillai *et al.* (1959) recorded the highest concentration of nitrogen in nut water when maximum volume of water was present in nut and it decreased subsequently. The maximum (8.86 mg/100 ml) phosphorus content was observed at 8th month of maturity followed by 7th month of maturity (7.21 mg/100 ml). The minimum value (4.45 mg/100 ml) was found at 5th month maturity (Table 6). These findings are in good agreement with the observations of Poduval *et al.* (1998) and Mali *et al.* (2004).

Potassium amounts for nearly half of the total mineral water in the nut. The potassium in coconut water was found to be rather stable exhibiting very little change, during maturation of the nuts (Chikkasubbanna *et al.,* 1990).

The pleasant taste of tender coconut water could be attributed mainly to the sugar and mineral content. At the same time the volume of water is also important from the consumers' point of view as it is a thirst quenching drink. Irrespective of types of germplasm, the maximum volume of nut water, with the highest reducing sugar and potassium and the least acidity were observed at 7th month of maturity. Harvesting at 7th month maturity is ideal from quality of nut water and from the point of view of total harvest of nut per year per palm.

Table 6. Influence of maturity on nitrogen, phosphorus and potassium tender nut water irrespective of varieties

Maturity	Nitrogen (%)			Phosphorus (mg/ 100 ml)			Potassium (mg/ 100 ml)		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
5th Month	0.013	0.013	0.013	4.43	4.47	4.45	295.8	300.0	297.9
6th Month	0.034	0.036	0.035	5.57	5.63	5.60	334.6	336.9	335.8
7th Month	0.064	0.064	0.064	7.20	7.23	7.21	351.8	356.1	353.9
8th Month	0.099	0.100	0.099	8.74	8.98	8.86	316.0	322.3	319.1
S.Em(±)	0.0005	0.0010	0.0005	0.033	0.030	0.022	2.843	1.120	1.528
C.D. (P=0.05)	0.0016	0.0032	0.0015	0.104	0.097	0.066	9.093	3.581	4.539

The maximum potassium content was (353.9 mg/ 100 ml) at 7th month of maturity followed by 335.8 mg/ 100 ml of potassium at 6th month maturity (Table 6). The minimum potassium (297.9 mg/100 ml) was associated with nuts of 5th month maturity. The increasing trend of potassium upto 6th or 7th month maturity was reported by Poduval *et al.* (1998) and Ganesamurthy *et al.* (2002).

References

A.O. A. C. 1984. *Official Methods of Analysis* (14 th Ed.)., Association of Official Agricultural Chemist, Washington, D. C.

Chikkasubbanna, V., Jayaprasad, K.V., Thilak Subbaiah and Poonacha, N.M. 1990. Effect of maturity on the chemical composition of tender coconut (*Cocos nucifera* var. Arsikere Tall) water. *Indian Coconut J.* **20**(12) : 10-13.

Damodaran, S., Ratnambal, M.J., Chempakam, B., Pilliai, R.V. and Viraktamath, B.C. 1976. Evaluation of tender nut water in coconut cultivars. pp. 123-128. In: *Advances in Coconut Research and Development* (Ed.) M.K. Nair, H.H. Khan, P. Gopalasundaram and E.V.V. Bhaskara Rao. Oxford & IBH Co. Pvt. Ltd., New Delhi,

Ganesamurthy, K., Natarajan, C., Vaithilingam, R., Giridharan, S. and Hameed Khan, H. 2002. Screening of coconut germplasms for tender coconut water. *Indian Coconut J.* **33**(8) : 31-34.

Gomez and Gomez 1984. *Statistical Procedure for Agricultural Research* (2nd edition), John wiley and Sons, New York.

Guha, S. 1998. Tender coconut market in Calcutta. *Indian Coconut J.* **23**(10) : 11-13.

Jackson, M.L. 1973. *Soil Chemical Analysis*. 2nd Edition. Prentice Hall of India Pvt. Ltd., New Delhi, pp.111-182.

Jayalekshmy, A.C., Arumugham, S., Narayanan, C. and Mathew, A.G. 1986. Changes in the chemical composition of coconut water during maturation. *J. Food Sci. Tech.* **23**: 203-207.

Jayalekshmy, A.C., Arumugham, S., Narayanan, C. and Mathew, A.G. 1988. Changes in chemical composition of coconut water during maturation *Oleagineux.* **43**: 403-414.

Koeing, R.A. and Johnson, C.R. 1942. Colorimetric determination of phosphorus in biological materials. *Indian J. Eng. Chem.* **14**: 155-156.

Mali, P. C., Desai, A.G. and Joshi, G.D. 2004. Evaluation of coconut (*Cocos nucifera* L.) cultivars for tender nut water. *Indian Coconut J.* **34**(11) 5-12.

Pillai, N.G., Sukumaran, C.K. and pandalai, K.M. 1959. Studies on the changes in the chemical composition during different stages in the developing coconut. pp. 132-151. In: *Proc. Ist Conf. Cocon. Res. Workers,* Trivandrum, India.

Poduval, M., Hasan, Md. Abu and Chattopadhyay, P.K. 1998. Evaluation of coconut cultivars for tender nut water for West Bengal. *Indian Coconut J.* **29**(1): 3-6.

Suresh, T.P. and Hegde, V.R. 1971. Tender coconut water as a plasma volume extender II. Studies on physiological responses. *Mysore J. Agri. Sci.* **5**: 410-422.

Suresh, T.P. Raviverma, V.H., Setty, S.V. and Rangachar, T.R.S. 1968. Fluid therapy by tender coconut water in veterinary practice. *Indian Vet. J.* **48**: 829-837.

Thimmaiah, S.K. 1999. *Standard methods of bio-chemical analysis,* Kalyani Publisers, India. pp. 112.

Vijayan, K.P. Louis, I.H., Chandrasekar. N.R., and Jayaraman, C. 1977. Potassium content in nut water of 31 coconut varieties and hybrids. *J. Plantn. Crops* **5**(2): 123-124.