Research Article

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Quality optimization for membrane concentrated tender coconut water

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Abstract

Tender coconut water is the most nutritious wholesome beverage, which will get detoriated within 6-8 h at normal atmospheric conditions. A study was undertaken to improve the shelf life with minimum change to its nutritional and other sensory attributes. Reverse osmosis technique was used as a preservation method to concentrate the tender coconut water. Trials were made for dummy solution and coconut water to optimize the processing conditions based on their chemical compositions and sensory attributes. The total soluble solid content of concentrated juice was increased from 4.5 to 14.0 %. Apart from this, other nutrients also increased 2-2.5 times of its original content. Storage studies were carried out for membrane concentrated tender coconut water, 25 and 50 % upgraded tender coconut water concentrate as control, tender coconut water packed in sterile container and with chemical preservative (500 ppm of sodium benzoate). The samples were stored at 30 ± 2° C and at 12° C. No changes were observed in the samples kept at 12° C up to 43 days. At the same time, increase in the acidity, decrease in reducing sugar content and pH were noticed in the samples kept at 30 ± 2° C within 22 days. Out of all these samples, 14 % membrane concentrated tender coconut water and 25 % upgraded tender coconut water without preservative in the sterile container at 12° C with minimum changes in chemical composition was accepted by panelists.

Keywords: Cocos nucifera, dummy solution, reverse osmosis, sensory attributes, total soluble solid

Introduction

Though India is the largest producer of coconut in the world, pervasive market forces and price fluctuation influence Indian coconut market and to be competitive in the International market, new technology developments in coconut related products is necessary. About 48 % of the total production of coconut in the country is used for edible and religious purposes, 31 % for conversion into mill copra, 8 % for the production of edible copra, 11 % as tender coconut water and balance is used for the manufacture of desiccated coconut powder, coconut cream and other coconut products (Woodroof, 1970; Arumughan *et al*., 1995). Coconut water, a byproduct in all coconut related industries, is rich in energy sources and can be consumed as a drink. It is one of nature's perfect packages. Around 50 percentage of the production of coconut in West Bengal and Maharashtra is harvested at tender stage for consumption as a refreshing natural drink (George *et al*., 1991) but proper technology development is needed in order to reduce the product contamination. The liquid endosperm of coconut is a nature's pure, nutritious and wholesome beverage. Development of techno-economically viable method to process and preserve tender coconut water is essential for soft drink industries and also for coconut cultivators(Woodroof, 1970).

Now technologies are available for the processing of tender coconut water into packed soft drinks. Defense Food Research Laboratory (DFRL), Mysore under a sponsored project of the Coconut Development Board (CDB) has developed a technology for packaging of tender coconut water. It can be packed in aluminum cans and retortable pouches and subjected to minimum heating by the use of additives like nisin to achieve commercial

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sterility. Also stability was reported to be three months at ambient conditions and six months under refrigerated condition (Thampan, 1992).

Regional Research Laboratory (RRL), Trivandrum, Kerala has developed a process for the upgradation and preservation of mature coconut water. The main operations involved are collection, upgradation, pasteurization, filtration and bottling. The drink can be carbonated and marketed as a beverage. Even though the technology was transferred to some entrepreneurs, the commercial production is limited to two to three units. The CDB has done the consumer acceptability study of the product in major cities and was found acceptable to the majority of the selected consumers. Most of the commercial production done at present is carried out using high temperature and short time pasteurization.

Thermal processing not only eliminates the risk of harmful microbe but also some of its nutrients and almost all of its delicate flavour. This problem has been over come by the technique developed in Philippines, wherein Tender Nut Coconut water (TCW) was concentrated by reverse osmosis to reduce transportation cost and to improve product stability. The concentrate is then frozen or canned, which in turn can be used as base for the manufacture of coconut beverages. Coconut water concentrate is spray dried as instant juice and instant coconut water drink and is a technological breakthrough that is expected to augment the income of coconut farmers and provide right incentive to the ailing coconut industry (Singh and Subburaj, 2003). The special feature of fruit juice production by spray evaporation technique is that the product retains all the original characteristics of juice such as retention of vitamins and enzymes, aroma, colour, taste etc which is not possible in the conventional methods of processing (Thomas Mathew,1991). In the present study attempt was made for the preservation of tender coconut water with minimal lose of nutritional and sensory attributes.

Materials and Methods

Collection of Tender Nut Coconut water (TCW)

Coconut at the age of six to eight months were collected from nearby farm at Thiruvananthapuram and cleaned thoroughly with water. The young nut was trimmed off at the side, the bottom and the top and purged at the center. The water was collected and filtered through muslin cloth. This TCW was used for further reverse osmosis studies.

Membrane Separation Process

A number of novel methods are available for the separation of various solutes from solution of liquid food stuffs. Ultra filtration, nano filtration and reverse osmosis are pressure activated membrane separation techniques in which solutes of different molecular weights are separated from solution (Shallo *et al*., 2001).

Reverse osmosis (RO)

PCI, 4416 manual 1.0 doc –tubular membranes, made of polyamide film of 1.8 x 12.7 mm tubes in 0.9 m^2 area was used for this purpose. The cut off, concentrate flow rate, maximum pressure and temperature during operation was 99 % rejection, 1080-1300 l/hr, 50 bar and 60^o C, respectively. It is not advisable to run the unit upto its maximum conditions, which may cause damage to the polyamide thin membranes (Ould Eleya and Gunasekaran, 2002). TCW from the collection point was poured into the feed tank. The sample was pumped to RO membrane. Pressure in the membrane unit was set for maximum flow rate in tubular membranes and samples were collected from both concentrate side and permeate side at regular intervals. Operating conditions were recorded while concentrating dummy solution. For coconut water, optimized pressure for starting the operation was 23 bar for 20 lit/bar flow rate. Flux, trans membrane pressure, percentage rejection and concentration ratio were calculated. The performance of a membrane filtration system is measured in terms of its ability to produce large volume of filtrate in a short period of time and the degree of purity of filtrate with respect to the solute concentrate. Permeate flux and percentage rejectionare the two parameters used for this purpose.

Permeate Flux

The permeate flux is the volume of permeate flow through the unit area in a unit time period ($l/m^2/h$).

$$\text{Permeate flux} = \frac{\text{Permeate volume}}{\text{Membrane area x Time}}$$

Percentage rejection

The proportion expressed as a percentage rejection is that a particular component that does not pass through the membrane, instead being retained or rejected.

$$\text{Rejection (\%)} = \frac{\text{Permeate concentration of component}}{\text{Feed concentration of that component}} \times 100$$

Trans membrane pressure (TMP)

It is the difference in pressure between the average pressure on the concentrate side of the membrane (P_{Av}) and the permeate pressure (P_p).

$$TMP = P_{Av} - P_p$$

$$P_{Av} = \frac{P_{in} + P_{out}}{2}$$

Where

P_{in} - Inlet pressure

P_{out} - Outlet pressure

P_{Av} - Average pressure

P_p - Permeate side pressure

Permeate pressure is zero in the case of polyamide thin membrane.

Concentration ratio (C/R)

It is the overall extent to which feed has been concentrated by a membrane separation unit.

$$CR = \frac{V_F}{V_C}$$

Where

V_F - Feed volume

Vc - Concentrate volume; $V_C = V_F + V_{HU} - V_P$

V_{HU} - Hold up volume

V_P - Permeate volume

Trials were carried out to optimize the membrane system for TCW concentration. Dummy sample was prepared based on the basic composition of the TCW by mixing 4 % sugar and 0.5 % potassium chloride in water. The solution was passed through reverse osmosis spiral membrane module and tubular membrane made of polyamide film and was used for TCW concentration. The optimized osmotic pressure was used to operate the unit for matured coconut water and the same was used for TCW concentrate.

Quality analysis of TCW concentrates

Proximate composition of TCW concentrate was analyzed based on the standard methods such as moisture content, TSS, crude lipids, ash content, titrable acidity. The crude protein content was obtained by multiplying total nitrogen (micro Kjeldhal method) with 6.25, a constant (Ranganna, 1979). Total carbohydrates was determined by using anthrone reagent and reducing sugar by Dinitro salicylic acid (AOAC,1995). Minerals like Na, K and Ca were measured using Flame Photometer (ESICO). P content of the sample was measured by Spectrophotometer (ESICO) at 620 nm absorbance. Fe content was measured at the absorbance of 420 nm. pH of TCW concentrate was measured by digital pH meter with pH 7 buffer solution.

Tender coconut water concentrate upgradation

Upgradation of TCW concentrate was based on sugar and mineral content of tender coconut water as shown in Table 1. Based on the data obtained, food graded sucrose (45 %), glucose (50 %), maltose (4.5 %) and potassium chloride (0.5 %) were mixed to increase the concentration of 14 % MCTCW into 25 and 50 % of final total solid content on dry basis (Chikka Subbanna *et al.*, 1990). Storage studies were carried out for these concentrates and further analysis were made.

Table 1. Proximate Composition of TCW

Sl. no.	Composition	Content (%)
1	Moisture	95.54
2	Total solid	4.45
3	Total fat	0.12
4	Total N	0.014
5	Crude protein	0.02
6	Ash	0.52
7	Total carbohydrate	4.07
8	Reducing sugar	2.35
	Minerals	**Content (ppm)**
1	Sodium	197.67
2	Potassium	2999.58
3	Calcium	520.68
4	Phosphorous	76.75
5	Iron	4.00

Sensory evaluation

Sensory attributes for the three different concentrates were noted based on 9 point Hedonic Scale. Fifteen members (7 male and 8 female) were selected from the laboratory as panelists. The average value of flavour, appearance and overall acceptance were collected and average were taken according to the rating for category numerical scales with negative scale for dislike category and positive scale for liking category vary from like extremely to dislike extremely (Ranganna., 1979).

Shelf life evaluation

Different concentration of TCW was transferred under sterile condition into sterilized screw capped glass jars of 30 ml capacity provided with one inch head space (Shallo *et al.*, 2001). The titrable acidity, pH and reducing sugar changes were recorded at weekly intervals. The samples were reconstituted and sensory evaluation was carried out and results were compared with control. Storage studies were conducted in two conditions at 30

± 2° C and at 12° C. Storage studies were performed for three sets of samples in all three concentrations (14 % TCW concentrate, 25 and 50 % upgraded tender coconut water concentrate) with and without addition of 500 ppm sodium benzoate and control. The analysis was carried out thrice and means value was taken for discussion.

Results and Discussion

Proximate composition of TCW

Proximate composition of TCW is given in the Table 1. The percentage of total solid, total fat and total N contents were 4.45, 0.12, 0.014, respectively. Among the minerals, Na, K, and Ca were 197.67,2999.58 and 520.68 ppm, respectively. Jayalakshmi *et al*. (1986) and Subramaniyan and Swaminathan (1959) also reported similar values for TCW at the age of six to seven months.

Optimization of the reverse osmosis process

Process optimization was done by step-by-step manner. In the first part of the operation dummy solution was used for the concentration. The solution was concentrated to two fold of its single strength within 60 min. Percentage rejection was calculated based on the result as 99.48 %, since small amount of soluble solids passed through the membrane. In this step input pressure was optimized to be 23 bars. The maximum permeate flow of 23 l/h at the initial stage of the operation was noticed. Coconut water was concentrated within 120 min during which the temperature was increased to 47° C at 31 bars, the sensory quality was altered due to the rise in the temperature as mentioned by Neelofar Iulliaskutty *et al*. (2002). It was concentrated to its two fold strength within 120 min. The maximum percentage rejection for coconut water was of 99.79 % at the end of the process. During TCW concentration, the temperature of the membrane was controlled by cold water circulation at 4° C and final three fold concentration was obtained with rise in all the constitutes within 120 min. Percentage rejection of the processing is 99.88 % while negligible amount of smaller molecular weight solids passes through the permeate side as given in Table 2.

Changes in chemical composition of TCW during reverse osmosis membrane concentration

Figure 1(a) and 1(b) indicate that the proximate composition of TCW concentrate increased gradually to its 3-fold level. All the chemical composition except protein and pH increased to its 3-fold level whereas protein increased only to its 2.5 fold level and pH reduced from 5.16 to 4.95 as some amount of minerals come along with permeate side (Table 2). From the Fig 1 (b) it was observed that minerals were increased to its 2.5 fold level. The analysis was carried out thrice and mean values are presented in the Table 2. Same type of processing was carried out for lemon juice by Kakoli Roy *et al*. (2003), milk concentration (Sunil Sachdeva *et al.*, 2002) and kuji fruit juice by Wilson (1986).

Table 2. Optimization of process parameters

Parameters	Dummy solution Before RO	Dummy solution After RO	Matured coconut water Before RO	Matured coconut water After RO	Tender coconut water Before RO	Tender coconut water After RO
Temperature (°C)	30	45	30	47	30	31
Pressure (bar)	22	25	22	31	22	31
Concentrate side flow rate (l/h)	3	0.776	2.87	2.72	2.76	2.74
Permeate side flow rate (l/h)	23	7	22	5	22	4
TSS on concentrate side (%)*	4.48	11.26	5.29	11.97	4.46	13.98
TSS on permeate side (%)*	0.012	0.97	-	0.18	-	0.09
Permeate flux (l/ m2/h)	-	15.56	-	11.11	-	15.28
Transmembrane pressure (bar)	-	24.73	-	30.08	-	31.25
Percentage rejection	-	99.48	-	99.78	-	99.88
Time (min)	-	60	-	120	-	120
Feed volume (l)	-	25	-	40	-	40

*Mean value of the TSS taken from the triplicate of the sample analyzed.
TSS - Total Soluble Solids, RO-Reverse osmosis.

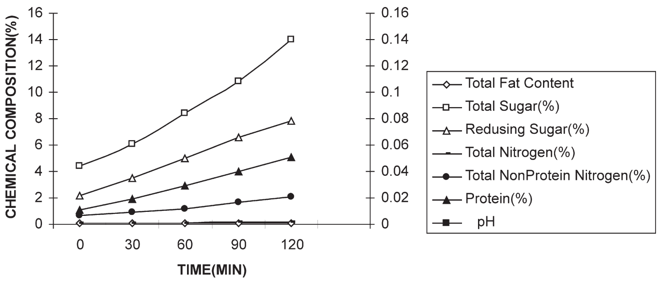

Fig. 1(a). Changes in chemical composition of tender coconut water during membrane concentration

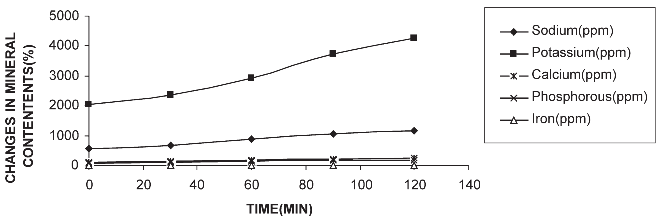

Fig. 1(b). Changes in mineral content of tender coconut water during membrane concentration

Changes in proximate composition and sensory evaluation of TCW Concentration during storage study

In the storage study, all the parameters were observed at seven days interval. Membrane concentrated samples kept at room temperature became turbid within 22 days. Similarly 25 and 50 % upgraded samples kept at room temperature also became turbid within 29 days. After three to four weeks, the samples were not usable. At the same time, the pH of the samples at 12º C remained same throughout the storage period (Fig 2 (a), 3 (a) and 4 (a)). It was same in the case of 14, 25 and 50 % concentration of the samples' acidity and reducing sugar as shown in Fig 2 (b), 3 (b), 4 (b) and Fig 2 (c), 3 (c), 4 (c). Similar type of results were observed for mango, guava, orange and watermelon juice by Das Gupta *et al.* (1996), Kaveri *et al.* (2001) and Das Gupta (2002), respectively. Overall acceptability (OAA) of the 14 % MCTCW was less on the first day of the storage study.

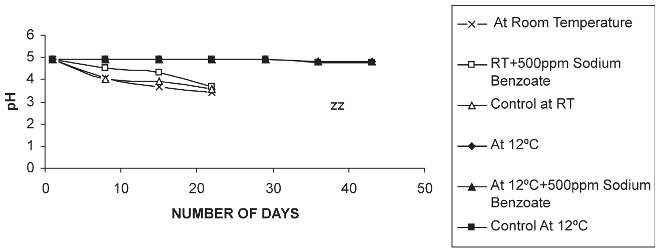

Fig. 2(a). Changes in pH of membrane concentrated tender coconut water (14 %) at different storage condition

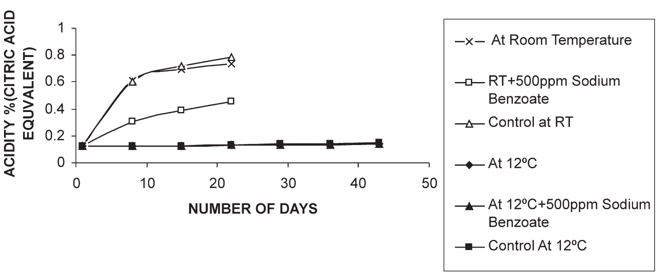

Fig. 2(b). Changes in acidity of membrane concentrated tender coconut water (14 %) at different storage conditions

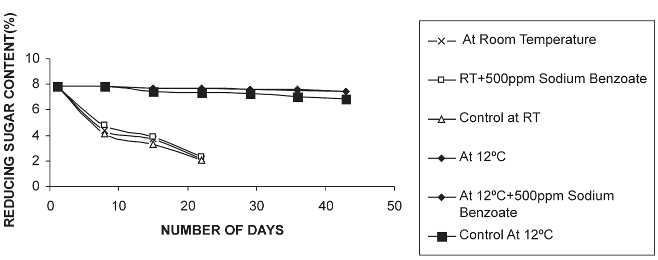

Fig. 2(c). Changes in reducing sugar content of membrane concentrated tender coconut water (14 %) at different storage conditions

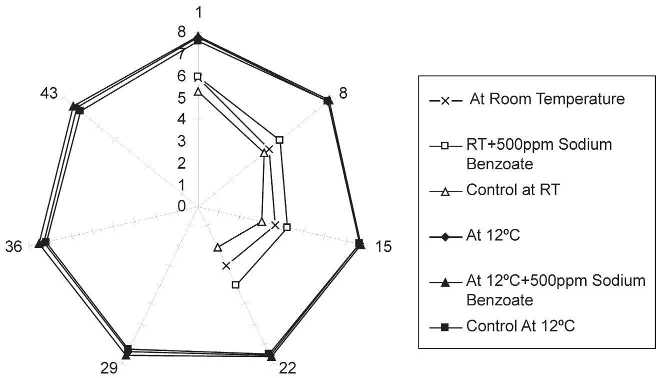

Fig. 2(d). Over all acceptance score of membrane concentrated (14 %) tender coconut water at different storage conditions

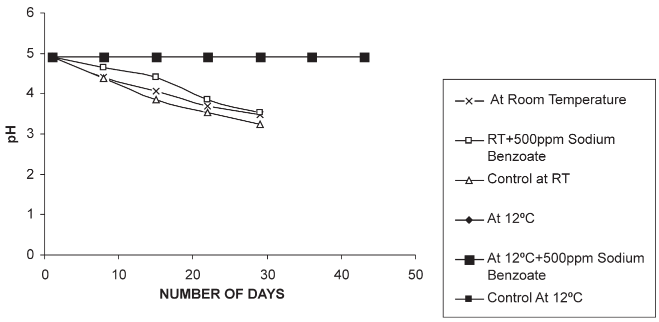

Fig. 3(a). Changes in pH of 25 % upgraded tender coconut water concentrate at different storage conditions

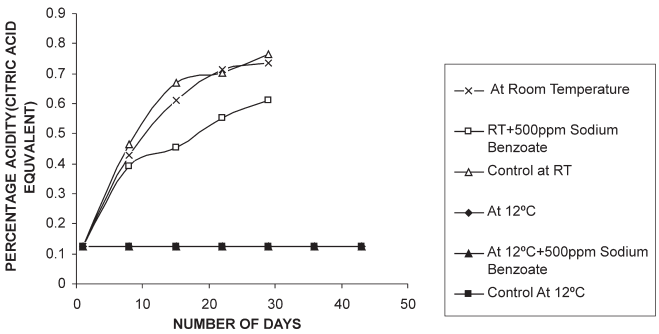

Fig. 3(b). Changes in acidity of 25 % upgraded tender coconut water concentrate at different storage conditions

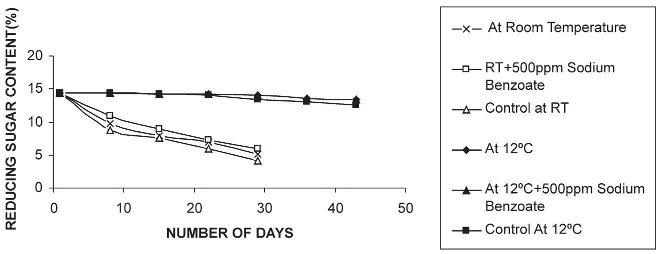

Fig. 3(c). Changes in reducing sugar content of 25 % upgraded tender coconut water concentrate at different storage conditions

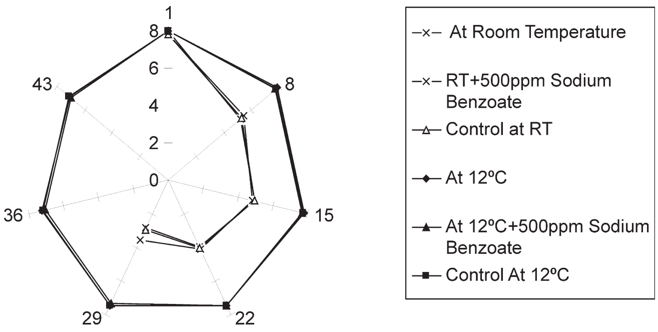

Fig. 3(d). **Over all acceptance of 25 % upgraded tender coconut water at different storage conditions**

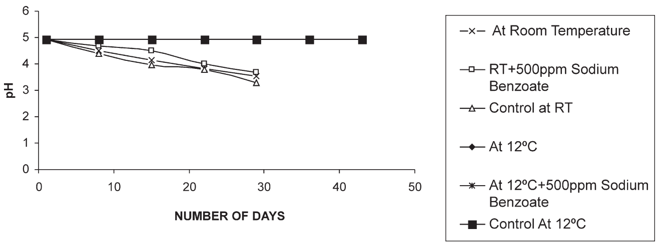

Fig. 4(a). **Changes in pH of 50 % upgraded tender coconut water concentrate at different storage conditions**

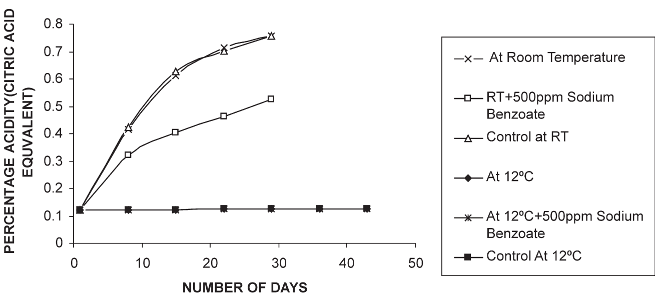

Fig. 4(b). **Changes in acidity of 50 % upgraded tender coconut water concentrate at different storage conditions**

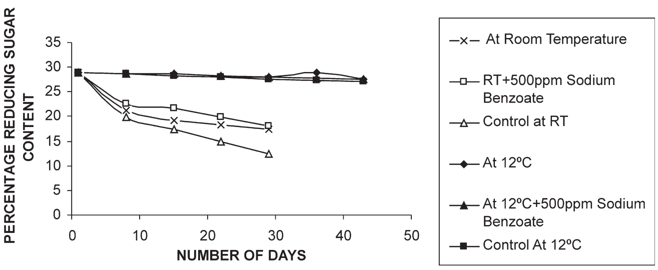

Fig. 4(c). **Changes in reducing sugar content of 50 % upgraded tender coconut water concentrate at different storage conditions**

But OAA for upgraded samples on the first day was indicated that it was moderately liked by the panelists. Membrane concentrated and upgraded samples at room temperature were not liked at the end of the 15th and 22nd day, respectively. Based on changes in chemical composition and sensory scores, the samples kept at 12ºC were accepted without much change in flavour, taste and

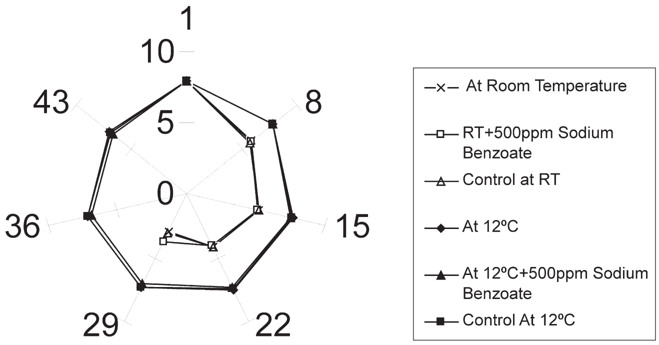

Fig. 4(d). **Over all acceptance score for 50 % upgraded tender coconut water at differnt storage conditions**

aroma of the fresh TCW. Over acceptability of TCW concentrate is comparable with that of fresh coconut water.

Conclusion

The attempt to retain the delicate flavour of TCW was achieved by reverse osmosis using tubular membrane made of polyamide. The concentration of TCW was increased to its three fold level with less overall acceptability. In this study 25 % upgraded TCW sample without preservative at 12º C was considered to be the best natural ready- to- serve TCW for more than 48 days. A dilution of tender coconut water concentrate with water in the ratio of 1:2 (TCW concentrate: water (ml)) at the time of serving is recommended. The cost per 100 ml TCW concentrate was estimated as Rs. 45.50.

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