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ORIGINAL ARTICLE

Effect of storage temperatures and humidity on proximate composition, peroxide value and iodine value of raw cashew nuts

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Abstract The equilibrium moisture content (EMC) of raw cashew nuts (RCN) were determined using the standard static gravimetric method at 30 °C, 40 °C and 50 °C for relative humidity (RH) ranging from 43 to 90 %. The proximate composition analysis, peroxide value and iodine value of RCN were assessed at this equilibrium stage. The RCN kept under the humidity of 86 and 90 percentage at all studied temperatures developed mold growth within 24–48 h of time. The better storage condition assessed for raw cashew nut is 67 % of RH at 30 °C and the values obtained for EMC, proximate composition analysis, peroxide value and iodine value are within the same range as observed with harvested RCN.

Highlights

- Raw cashew nut storage condition identified
- It was analysed with different temperature (30°C, 40°C and 50°C) and relative humidity (43 %–90 %)
- Better storage condition for raw cashew nut is in 67 % of RH at 30°C
- In this condition the EMC was 8.11 % as within the range of moisture in harvested RCN

Keywords Raw cashew nut · Moisture · Protein · Carbohydrate · Fat · Peroxide value · Iodine value

Introduction

Cashew tree (*Anacardium occidentale*) is a native of Brazil and the Lower Amazons and has been introduced in the Americas, the West Indies, Madagascar, India and Malaysia (Frankel 1991). It is an important nut crop that provides food, employment and hard currency to many in developing nations. India, Mozambique, and Tanzania are the three biggest exporters of cashew nuts (Rosengarten 1984). Cashew nuts are high value edible nuts and are usually dried immediately after harvesting to avoid adverse changes due to metabolic processes as well as microbial deterioration. About 47 % of the total weight of cashew nuts constitutes its fat and has the right combination of fat; the ratio of saturated to monounsaturated and polyunsaturated is 1:2:1 which is ideal for human consumption (Achal 2002).

Cashews are more prone to become rancid due to fat degradation and protein coagulation. Nagaraja (1998) reported that any bruise makes the fats liable to become rancid, and as such the integrity of kernels is lost. Environmental factors like temperature, moisture, light, gaseous composition, pressure within the storage atmosphere influence changes in lipid, protein and carbohydrate content of stored seeds. The primary product formed by oxidation of oil is a peroxide or hydroperoxide and are measured as a peroxide value. The secondary products are aldehydes and ketones. These secondary oxidation products, especially aldehydes, have the off-flavours associated with rancid oils Improper post-harvest handling and storage of nuts, such as high moisture, temperature and insect or mechanical damage can influence the incidence of the fungus that produces toxins like afflatoxin and deterioration of kernel nutrients and rancidity can be occurred (Salunkhe and Desai 1986).

Traditional method of sun drying and storage has been followed in cashew processing industries for RCN storage. Storage life of cashew kernels can be increased up to 2 months by using 50 ppm (0.005 %) of BHA applications (Sabna et al. 2011). Shelf life determination can be carried out in the laboratory by assessing the quality of the cashew nuts when stored under specific storage condition and no scientific studies has been conducted so far to determine the shelf life of

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RCN. Hence the present study is aimed to assess the effect of humidity and temperature on physical and chemical changes in raw cashew nuts during storage and to recommend suitable conditions for storage of raw cashew nuts.

Materials and methods

Sample collection

Raw cashew nuts (RCN) of Ivory Coast variety, obtained from the Kerala State Cashew Development Corporation (Ayathil Unit, Kollam, Kerala) were used for the experiment. The reagents used were of analytical grade. The proximate analysis, peroxide value and iodine value of the RCN samples were estimated immediately after sampling.

Sorption method

In the present work, the equilibrium moisture content was determined using the standard static, gravimetric method; this method is based on the use of saturated salt solutions at 30 °C, 40 °C and 50 °C to maintain a fixed relative humidity. The mass transfer between the product and ambient air is done by natural diffusion of the water vapour. The atmosphere surrounding the product has fixed RH or air moisture content for every working temperature imposed by the salt solution.

Experimental procedure

Six salts were chosen (K_2CO_3, NaBr, $CuCl_2$, NaCl, KCl, and BaCl2) so as to have a range of RH 43 %, 57 %, 67 %, 75 %, 86 % and 90 % respectively. The preparations of saturated salt solutions were done by using the data reported by Louis (1960); Wexler and Hasegawa (1954). The experimental apparatus consisted of 18 desiccators (6 salts of 3 groups) and temperature controlled incubators. Saturated salt solutions were prepared at 3 different temperatures and filled to 200 ml in each group of desiccators. Each desiccator was occupied with triplicate samples of raw cashew nut weighed 30 g. Finally the desiccators of each group with 6 saturated salt solutions and RCN samples were put in the incubators at constant temperature of 30 °C, 40 °C and 50 °C respectively. The weight of triplicate samples of RCN in each experimental set up was noted daily. Equilibrium was reached when three consecutive weight measurements showed a difference less than the balance accuracy 0.0001. The time required for equilibrium was 3 weeks or more depending on RH and temperature of the RCN sample. At the equilibrium stage RCN samples were analyzed for changes in moisture content, carbohydrate, protein, fat, peroxide value (PV) and iodine value (IV).

Proximate composition analysis, peroxide value and iodine value of RCN

The recommended methods of the Association of Official Analytical Chemists (AOAC 1984) were employed in determining the levels of moisture, crude fat, iodine value and peroxide value. Moisture content was analyzed by toluene distillation. The iodine value is defined as the weight of iodine absorbed by 100 g of oil or fat. Iodine value (g I2/100g) of raw cashew kernel oil or fat was determined by AOAC Official Methods of Analysis (1984). Rancidity caused by oxidation of fat was particularly noticeable in shelled cashew nuts. In comparison with hydrolytic rancidity, oxidative rancidity is also important to define the shelf life of cashew nuts. It is clearly caused by oxidation of fat. The primary product formed by oxidation of oil is a peroxide or hydroperoxide and are measured as peroxide value. Peroxide value of raw cashew kernel oil or fat was determined by titration method and expressed as milli equivalents of oxygen per kilogram of the extracted fats or oil (meq O_2/kg oil). Crude fat estimations were done exhaustively by extracting fat from powdered cashew kernel in a Soxhlet apparatus using petroleum ether (boiling range 40–60 °C) as the extractant.

The defatted kernel samples were used for estimation of protein and carbohydrates by dry weight basis method. Lowry's method (Sadasivam and Manickam 1992) was used to estimate protein content and carbohydrate was estimated by anthrone method (Sadasivam and Manickam 1992) by using glucose standard curve. Estimation of proximate composition, PV and IV of RCN samples were done immediately after collecting the samples from cashew industry.

Statistical analysis

Analysis of variance (ANOVA) *F*-test (value of test) was used to compare the data obtained from different estimations (moisture content, carbohydrate, protein, fat, peroxide value and Iodine value) at particular temperature and between temperatures for each relative humidity. *F*-value was calculated at 0.01 levels of significance. In ANOVA interaction was found to be significant which implies that the difference in the mean value of each estimation at different temperature was not the same for different RH. So it was compared with the values obtained for RCN stored in different RH at a particular temperature and between temperatures for each RH. The results of comparison are presented in Table 2 to 7.

Results and discussion

Initially (immediately after sample collection) estimated proximate composition, PV and IV of RCN samples are presented in Table 1.

Table 1 Proximate composition, PV and IV assessed from RCN samples collected immediately from the industry

Moisture (%)	Carbohydrates (%)	Protein (%)	Total fat (%)	Peroxide value(milli equivalent)	Iodine value(milli equivalent)
8.2	22	12. 9	37.73	3.98	56.60

Effect of relative humidity and temperature on moisture percentage

The estimation results of equilibrium moisture content at each RH represent the mean value of three replications. As expected, higher equilibrium moisture content (EMC) were found at lower temperature at the same RH. The reason is probably that an increase in temperature the water molecules get activated due to an increase in their energy level. Activation of the water molecules due to the increase in temperature causes them to break away from the water binding sites, which helps in removing bound water from the product (Rozis 1997; McMinn and Magee 2003), thus decreasing in the degree of water sorption with increasing temperature at a given relative humidity. Similar results for many crops have been reported in the literature of Lahsasni, et al. 2003. The EMC range of RCN stored in 67 % and 75 % of RH at 30 °C, 40 °C and 50 °C of temperatures were found to be in between 7 and 8.4 %. The increase in humidity conditions, the organoleptic characteristics deteriorated and is known to foster mold growth. It has been observed that the RCN kept under the humidity of 86 and 90 percentage at all studied temperatures developed mold growth within a very short period of time (24–48h) (Table 2). In roasted cashew kernels having 11 % of moisture content has developed mold growth within 10 days of time period (Balasubrahmanyam et al. 1985). Fungi dominate the microflora of stored products due to their ability to grow at low water activity (Deible and Swanson 2001). These results revealed that to avoid the growth of fungi/mold the RCN moisture should be maintained below 10 %. Decrease in moisture content inversely affects the weight and economic cost of RCN and therefore the present study reveals the appropriate conditions for storage of RCN.

Effect of humidity and temperatures on carbohydrates and protein

Presence of moisture in food stuffs has been reported to cause a decrease in the concentration of nutrients (Labuza 1973). The rapid growth of microorganisms which results from high moisture content also brings about decrease in concentration of protein and carbohydrates etc. (Clausi 1973). Carbohydrate contents of RCN stored in 57 % and 67 % of RH showed significant variation between temperatures and was increased with increase in temperature. Activation of the water molecules due to the increase in temperature causes them to break away from the water binding sites, which helps in removing bound water from the product (Rozis 1997; McMinn and Magee 2003). Same result happened in drying process also, the sugar content of the samples generally increased with increase in drying temperature due to the elimination of more water from the sample with increase in temperature leading to concentration of the product (Adebayo and Diyaolu 2003). This same trend was also observed by Prichavudhi and Yamamoto (1987), who reported that higher dying temperature increases the level of sugar in the nuts. At 86 % of RH

Table 2 Equilibrium moisture percentage of RCN in different relative humidity and temperature

Saturated salt solution	Relative humidity (%)	Moisture (%)		
		30 °C	40 °C	50 °C
K_2CO_3	43	5.85^{aE}	5.115^{bF}	5.015^{bF}
NaBr	57	6.65^{aD}	6.635^{abE}	5.71^{bE}
$CuCl_2$	67	8.11^{aC}	7.515^{bD}	7.305^{bD}
NaCl	75	8.40^{aC}	8.365^{aC}	8.00^{aC}
KCl	86	$10.67^{aB}{}_m$	$10.45^{abB}{}_m$	$10.10^{bB}{}_m$
$BaCl_2$	90	$13.65^{aA}{}_m$	$12.535^{bA}{}_m$	$12.665^{bA}{}_m$

** significant at 0.01 levels, m represents fungi/mold growth observed within 48h

Means with same small letter as superscript are not significantly different within a row

Means with same capital letter as superscript are not significantly different within a column

Table 3 Carbohydrate content of RCN in different humidity and temperature

Saturated salt solution	Relative humidity (%)	Carbohydrate (mg %)		
		30 °C	40 °C	50 °C
K_2CO_3	43	25.66^{aB}	25.40^{aB}	26.76^{aB}
NaBr	57	$21.1\ °C^{C}$	25.35^{bB}	29.19^{aA}
$CuCl_2$	67	20.42^{cC}	22.57^{bC}	26.28^{aBC}
NaCl	75	26.10^{bB}	31.57^{aA}	24.90^{bC}
KCl	86	28.64^{aA}	26.53^{bB}	23.24^{cD}
$BaCl_2$	90	21.57^{bC}	20.23^{bD}	25.63^{aBC}

** significant at 0.01 levels

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Table 4 Protein content of RCN in different humidity and temperature

Saturated salt solution	Relative humidity (%)	Protein (mg %)		
		30 °C	40 °C	50 °C
K_2CO_3	43	13.40^{aA}	12.60^{bA}	11.25^{cAB}
NaBr	57	12.65^{aB}	12.74^{aA}	10.59^{bC}
$CuCl_2$	67	12.85^{aB}	12.08^{bB}	10.96^{cBC}
NaCl	75	12.05^{aB}	11.62^{abB}	11.34^{bA}
KCl	86	12.81^{aB}	12.33^{aAB}	10.18^{bC}
$BaCl_2$	90	12.61^{aB}	11.86^{bB}	10.82^{cABC}

** significant at 0.01 levels

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carbohydrate content decreased with increase in temperature and values showed significant variation between temperatures (Table 3). These results indicate an inversion point that depends on the sugar size distribution, composition and solubility of sugars (Weisser 1985). In 43 % of RH the values obtained were non significant between temperatures and in 75 % and 90 % of RH the carbohydrate content values shows non significant between two temperatures such as 30 °C and 50 °C; 30 °C and 40 °C respectively. In the case of 30 °C, the mean carbohydrate content obtained for 57 %, 67 % and 90 % of RH was not significantly different. The mean value obtained for 43 % and 75 % RH was also not significantly different. But the value obtained for 86 % of RH have showed significant difference between other mean values. Considering 40 °C, mean value for carbohydrates in 43, 57 and 86 % of RH is not significantly different and the mean values obtained in 67, 75and 90 % of RH are significantly different. The mean values of carbohydrate content obtained from RCN in 67, 75 and 90 % of RH at 50 °C were not significantly different. The highest value (31.57 %) obtained was at 40 °C and 75 % of RH (Table 3).

Table 5 Percentage of total fat in RCN stored in different humidity and temperature

Saturated salt solution	Relative humidity (%)	Fat (mg %)		
		30 °C	40 °C	50 °C
K_2CO_3	43	33.88^{cC}	35.47^{bC}	40.78^{aB}
NaBr	57	30.99^{bE}	39.34^{aA}	40.15^{aC}
$CuCl_2$	67	33.33^{cC}	35.46^{bC}	39.42^{aD}
NaCl	75	35.54^{cA}	37.20^{bB}	42.88^{aA}
KCl	86	32.59^{bD}	32.64^{bD}	35.14^{aE}
$BaCl_2$	90	34.64^{aB}	32.71^{bD}	30.92^{cF}

** significant at 0.01 levels

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Table 6 Iodine value of RCN stored in different humidity and temperature

Saturated salt solution	Relative humidity (%)	Iodine value (mg %)		
		30 °C	40 °C	50 °C
K_2CO_3	43	38.49^{cD}	46.95^{bD}	68.74^{aA}
NaBr	57	106.24^{aA}	92.85^{bA}	52.75^{cB}
$CuCl_2$	67	61.25^{aC}	54.75^{bC}	48.75^{cC}
NaCl	75	25.65^{bE}	20.75^{cF}	55.40^{aB}
KCl	86	13.60^{bF}	31.75^{aE}	29.30^{aE}
$BaCl_2$	90	82.69^{aB}	84.33^{aB}	35.45^{bD}

** significant at 0.01 levels

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The crude protein content of RCN was decreased with increase in temperature except in 57 % of RH at 40 °C. Maximum amount of protein content (13.40 %) was obtained in 43 % of RH at 30 °C. In the case of 30 °C, mean value protein content in 43 % of RH was significantly different from other group of mean protein values of RCN. In 40 °C the mean values obtained for RCN group from 43 to 57 % of RH was significantly different. But in the case of 50 °C, there was no significant difference between the mean value of protein in 57 and 86 % of RH (Table 4).

Changes observed in protein and lipid content during storage may have been due to leaching out of some extractable soluble protein fraction and hydrolysis of some of the lipid fractions (Emokpae 1979). There was reduction in the

Table 7 Peroxide value of RCN stored in different humidity and temperature

Saturated salt solution	Relative humidity (%)	Peroxide value (mEq/kg)		
		30 °C	40 °C	50 °C
K_2CO_3	43	2.75^{cE}	14.28^{bB}	29.03^{aD}
NaBr	57	61.62^{bA}	70.87^{aA}	20.89^{cE}
$CuCl_2$	67	8.84^{aD}	8.38^{abC}	7.06^{bF}
NaCl	75	49.81^{bB}	5.17^{cD}	58.07^{aA}
KCl	86	14.11^{bC}	3.54^{cE}	46.46^{aB}
$BaCl_2$	90	60.81^{aA}	7.76^{cC}	41.01^{bC}

** significant at 0.01 levels

Means with same small letter as superscript are not significantly different within a row

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percentage of crude protein of the species during the period of storage. This could be due to gradual degradation of the initial crude protein to more volatile products such as Total Volatile Bases (TVB), Hydrogen sulphide and Ammonia (Eyo 2001). Here the protein content in each experimental equilibrium was in acceptable range since degradation of protein to TVB is a long process and in the present study period of exposure for getting each experimental equilibrium was maximum up to 4 weeks.

Effect of humidity and temperatures on total fat, Iodine value and peroxide value of raw cashew nuts

The mean value percentage of the total fat estimated from RCN was found to be high (42.88 %) at 50 °C and 75 % of RH. Aremu et al. (2006) reported 36.7 % of crude fat in cashew nut flour. This was described in earlier studies that susceptibility of fats to oxidative changes is propotional to the degree of unsaturation of fatty acid in the fat (Rzhavskaya et al. 1977). The total fat content from RCN was found to be low (30.92 %) in 90 % of RH at 50 °C, where higher EMC (12.665 %) was observed with mold growth (Table 2). It was observed that the oxidative rancidification was effected by humidity. The high moisture content increases the enzyme activity and facilitates the degradation of oils by lipase which produces free fatty acids and lipoxygenase oxidizes polyunsaturated compounds and produce undesirable flavours and odour (Salunkhe and Desai 1986). Rapid mold growth was also observed with high moisture content and humidity. The moisture content was reported to increase the above enzyme activities (Booth 1984) and therefore influence rancidification. At 30 °C, the total fat content obtained from RCN in 43 % and 67 % of RH was not significantly different. At 40 °C, the fat content in 43 % and 67 % as well as in 86 % and 90 % of RH were also shown to be non significant but at 50 °C, all the values obtained were significantly different (Table 5).

Iodine value is the measure of unsaturation of fats and oils and expresses the amount of absorbed iodine (Hrayati et al. 1998). The low iodine value indicates that the oil has a low content of unsaturated fatty acid. The acid value/free fatty acid revealed the degree of fat that has degraded due to rancidity or by other means. Higher IV was recorded from the RCN stored in 57 % of RH at 30 °C and 40 °C respectively as 106.24 and 92.85 and least IV was recorded from RCN in 86 % of RH at 30 °C (Table y6). Decrease in iodine value is an indicator of lipid oxidation (Naz et al. 2004).

PV values obtained from RCN stored in different RHs are found to be significantly different between temperatures and less value was estimated (2.45) from RCN stored in 43 % of RH at 30 °C and highest value (60.81) was found in 90 % of RH at 30 °C. Peroxide value is widely used as a measure of the primary lipid oxidation indicating the amount of peroxides formed in fats and oils during oxidation (Ozkan et al. 2007). Fat is considered to be rancid at a peroxide value of 10. Rancidity caused by oxidative fat cleavage is particularly noticeable in the case of shelled cashew nuts. In comparison with hydrolytic rancidity, oxidative rancidity is also important to define the shelf life of cashew nuts and it is clearly caused by oxidation of fat. So it is presumed that the peroxide value of cashew kernel oil depends on relative humidity as well as temperature.

Conclusion/recommendation

The present study revealed that the proximate composition, peroxide value and iodine value of raw cashew nuts that are significantly affected by ambient humidity during storage. The suitable storage conditions for raw cashew nut are in the relative humidity of 67 % at 30 °C where the proximate composition, peroxide value and iodine value were not affected during storage.

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