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Shelf-life of Roasted Cashew Nuts as Affected by Relative Humidity, Thickness of Polythene Packaging Material and Duration of Storage

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Abstract: The effect of relative humidity, thickness of polythene packaging material and duration of storage on the shelf life of roasted cashew was determined to provide information for packaged roasted cashew nuts marketers. For this study, split plot in Randomized Complete Block Design was used with a total number of 180 observations (3 relative humidity x 4 polythene thicknesses x 5 duration levels of storage x 3 replications) each for moisture content, microbial count and quality index, which were measured using standard procedures. The initial mean moisture content, total fungal counts and percentage quality index of the nuts were found to be 1.17%db, 30CFU/g and 100% respectively, which were all deemed appropriate in comparison with the set acceptable storage moisture content of 5.8%db, tolerable fungal levels of 10^3 and 10^4/g and acceptable percentage quality index of 45% for roasted cashew nuts which did not exceed its shelf-life and still deemed fit for human consumption. The results of the study indicates that relative humidity, polythene thickness and duration of storage have a highly significant effect ($P \leq 0.01$) on moisture content and quality index while for the microbial count, polythene thickness and duration of storage has significant effect ($P \leq 0.05$) with relative humidity showing non-significance. For all levels of relative humidity and polythene thickness, moisture content and microbial count increased with increase in duration of storage while quality index decreased with increase in duration of storage. As the polythene thickness increased at constant storage duration, the moisture content decreased. The moisture content of all the samples increased with increase in duration of storage at constant polythene thickness level. As the thickness of the polythene packaging material increased, the amount of moisture absorbed over time (in days) decreases; the total fugal growth decreases, and the percentage quality index increases. It is recommended that for the packaged roasted cashew nuts industry for poverty alleviation, the most favourable polythene thickness of 0.95mm should be used. The best storage relative humidity was determined in the study to be 47.2% under which conditions, storage period should not exceed 14 days for best quality and value for money.

Key words: Polythene thickness, packaging material, roasted cashew nuts and shelf-life

INTRODUCTION

Worldwide, cashew nuts are an esteemed and highly priced food delicacy because of their pleasant taste and flavour. The post-harvest processing, packaging and marketing have been commercialized and modern technology and regulations adopted in major producing countries like India and Tanzania. In Nigeria however, despite the cultivation of cashew in plantations and the establishment of cashew-processing factories (Esuruoso, 1974), peasant processing and packaging methods are still commonly adopted. The latter predisposes the nuts to mould contamination especially during hawking of the product, which usually are packaged in hand-knotted thin polyethylene bags. There are no labels to indicate vital information such as the name and address of producer, nutritional contents, recommendations for storage and the best-before-date for human consumption. However, mycotoxicoses are becoming increasingly implicated in human and animal pathology (Bacha *et al.*, 1988). The situation is worsened by consumers' reluctance to discard fairly mouldy food samples such as cashew nuts. Cashew seeds have no dormancy. They remain viable for one year if dried to 9% moisture content and stored properly. The kernels rank third after almonds and hazelnuts in the international trade of tree nuts. The kernels constitute a valuable export product for confectionery and dessert purposes (Jaffe and Morton, 1995).

Shelf life is that length of time that food, drink, medicine and other perishable items are given before they are considered unsuitable for sale or consumption. Shelf life is different from expiration date; the former relates to food quality, while the latter refers to food safety. A food that has passed its shelf life is still safe, but optimal quality is no longer guaranteed. Shelf life is most influenced by several factors: exposure to light and heat, transmission of gases including humidity, mechanical stresses, and contamination by such things as micro-organisms. Product quality is often mathematically modelled around a single parameter (concentration of a chemical; compound, a microbiological index, or a physical parameter), though this approach can miss relevancy. Preservatives and antioxidants may be incorporated into some food and drug products to extend

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their shelf life. Some companies use induction sealing and vacuum pouches to assist in the extension of the shelf life of their products. The principal factors that affect shelf life are the nature of the food and the mechanisms by which it undergoes deterioration; the size of package in relation to volume; the atmospheric condition which the package is required to withstand during transit and before use and the overall resistance of the package of moisture, atmospheric gases and odours, including the closures and folded areas (Dwem, 1997). The shelf life of processed food is determined by the type of food, the degree of microbial destruction or inactivation achieved by the process, control of hygiene during processing and packaging, the barrier properties of the packaging materials and the temperature during distribution and package (Adebajo and Diyaolu, 2003).

Roasted cashew nut can be consumed either directly, or used as a raw material. In whichever form, the excess has to be preserved for future use. The greater value of this product is lost to spoilage after a period of time due to improper handling and storage conditions and this result in great loss of product and investment. Roasted cashew nut is vulnerable to deterioration over time and this result from improper packaging to adverse storage conditions. The rate of this spoilage is dependent on moisture content of stored nuts; relative humidity of storage environment; permeability of packaging material; ambient temperature and insect infestation. Based on these effects, roasted cashew nuts deteriorate by mould growth, rancidity and insect attack (Ayikoye, 2004).

Since the society and most importantly investors suffer great losses as a result of the deterioration of polythene-packaged cashew nuts, it becomes imperative to study and analyze the effect of the thickness of the polythene used as the packaging material on the spoilage rate under environmental condition with a view to making recommendations based on the result of the experiment.

MATERIALS AND METHODS

Materials: The roasted cashew nuts used for this study were procured in Obollo-Afor in Enugu State, Nigeria. Packaging films (polythene) of three different thicknesses: 0.91mm, 0.93mm and 0.95mm and mosquito net. Plastic air-tight containers were used as storage containers. Equipment and machines used include GallenKamp vacuum oven, desiccators, autoclave, incubator, weighing scale, sealing machine, test tubes, petri dishes, pipettes, mortar and pestle, crucibles (moisture test cans). Chemicals and reagents include diluted tetraoxosulphate VI acid (sulphuric acid), distilled water, potato dextrose agar.

The cashew nuts were roasted in open pans (FAO, 2000). Twenty five grammes (25g) of roasted sample seeds were tied in polythene bags of three different thicknesses (0.91mm, 0.93mm, and 0.95mm) and a control set using mosquito net, all purchased from Modern Market, Makurdi, Benue State as its packaging material. Each of the samples were suspended in the airspace containers containing solution of dilute tetraoxosulphate VI acid (sulphuric acid) of different levels of dilution thus creating three relative humidity environments of 47.2%, 70.4% and 88.8% in accordance with Weast and Astle (1989). After insertion of the samples and the solutions, the containers were closed and exposed to ambient temperature. The set up was monitored daily for four weeks (28 days). On the first day, i.e. day zero (0), the moisture content, microbial count and organoleptic tests were carried out. These tests were repeated on day 7, day 14, day 21, and day 28. Three replications were performed for each set up for the samples.

Moisture content: The Gallen Kamp vacuum oven-air method was used for moisture content test. About 10g of sample was crushed in a mortar and about 5g bits was measured into a crucible whose weight had been zeroed. The crucible with the samples was then put into the oven and dried at 103ºC for 4.5 hours. The weight of the sample was taken again after they were cooled in the desiccators. The percentage moisture content on dry basis was calculated using % moisture content (dry basis) = (change in weight/weight of dry matter) x 100.

Microbial count: The pour plate technique was used to obtain the microbial count. Nine (9) ml of distilled water was measured using a pipette into each of the sterile test-tubes and were sterilized in an autoclave at 121ºC for 15 minutes after which they were brought out and cooled to about body temperature. The roasted cashew nuts were cut into small pieces with a sterile scalpel and 1g was mixed with 9ml of distilled water and then properly shaken. The serial dilution was carried out to 10^{-4} dilution i.e. 1ml of the solution was drawn out using a pipette and was introduced into a second test-tube containing 9ml of distilled water and this was done serially until the last tube was reached. A fresh pipette was used at each stage. The potato dextrose agar was melted and cooled. Sterile petri dishes were set out for each dilution and they were labelled with the dilution number. 1ml of each dilution was pipetted into the centre of the appropriate dishes, using a fresh pipette for each dilution. Potato dextrose agar was poured into each of the plates, enough to cover the 1ml solution in them. The medium was allowed to solidify, then inverted and incubated at 37ºC for 24 hours. The numbers of colonies were counted with the use of a colony counter.

Quality index: Three students of the University o Agriculture, Makurdi were trained to chew and report on the overall acceptability in terms of taste, crispiness and visible mould incidence of the samples in percentages. Each person's decision was independent of the other. The cashew nuts were tasted on days 0, 7, 14, 21, and 28. The nuts were reported as being very good (80% and above), good (60-79%), fairly good (45-59%), fairly bad (40-

44%), bad (30-39%) and very bad (below 30%) to indicate the degree of quality.

Experimental Design: The experimental design for the study is split plot in Randomized Complete Block Design (RCBD) made up of three levels of packaging films (polythene) of three different thicknesses: 0.91mm, 0.93mm and 0.95mm and mosquito net; three levels of relative humidity environments: 47.2%, 70.4% and 88.8% and five levels of days of storage (0, 7, 14, 21 and 28 days). The analysis of variance (ANOVA) and Fishers Least Significant Difference (F-LSD) were carried out using Genstat statistical package.

RESULTS AND DISCUSSION

Table 1 shows the results of the mean moisture content, total fungal counts and the percentage quality index as affected by relative humidity, polythene thickness and days of storage. The various F-LSDs are indicated for the purpose of mean comparisons while the Analysis of Variance (ANOVA) is shown in Table 2. The ANOVA table shows highly significant relative humidity, polythene thickness and days of storage effect ($P \leq 0.01$) for moisture content and quality index while for the microbial count, there was significant effect ($P \leq 0.05$) for polythene thickness and days of storage with relative humidity showing non-significance. For all the shelf-life parameters measured, interaction was non-significant.

Effect of Relative Humidity: For all the relative humidity and at all polythene thickness levels, moisture content and microbial count increased with increase in days of storage while quality index decreased with increase in days of storage (Table 1). For example, for relative humidity of 47.2% and polythene thickness of 0.91mm, moisture content increased from 1.17 %db on day 0 to 9.61 %db on day 28, microbial count increased from 30 to 2100 CFU/g while quality index decreased from 100 to 61.67%. Also for all the relative humidity and at all days of storage levels, moisture content and microbial count decreased with increase in polythene thickness while quality index increased with increase in polythene thickness. Considering 47.2% relative humidity and storage day 14, moisture content decreased from 4.54 for the control to 2.11%db at polythene thickness of 0.95mm, microbial count decreased from 1100 to 120 CFU/g while quality index increased from 63 to 80.25%.

The analysis off variance (Table 2) shows highly significant ($P \leq 0.01$) relative humidity (RH) effect on moisture content and quality index while microbial count is non-significant. In terms of moisture content, a 2-tailed F-LSD test at 5% level of significance between 7-28 days of storage and four levels of polythene thicknesses representing 16 mean comparisons shows that between 47.2 and 70.4 %RH, 31.25% of the mean comparisons were non-significant. Similarly, 43.75% non-significance was observed in the mean comparisons between 70.4 and 80.5%RH while comparisons between 47.2 and 80.5%RH were all statistically different. In the case of the microbial count, 81.25, 37.5 and 50% non significance was observed between 47.2 and 70.4, 47.2 and 80.5, and 70.4 and 80.5%RH respectively whereas for quality index, 50, 0 and 6.25% non-significance was similarly observed. In general, the greater the non significance percentage difference, the closer the similarities between the levels of measured parameters being compared.

Effect of Polythene Thickness: The results show that as the polythene thickness increased at constant storage day, the moisture content decreased (Table 1). For example, at storage day 14, the moisture content decreased from 4.54 to 2.11%db for 47.2%RH, 5.63 to 2.78%db for 70.4% RH and from 6.84 to 3.39%db for 80.5%RH. Similarly microbial count decreased from 1100 to 120, 2700 to 200 and 12400 to 500 CFU/g for 47.2, 70.4 and 80.5% RH respectively whereas quality index increased from 63 to 80.5, 60 to 76.25 and 50 to 71% at same %RH values.

The analysis of variance (Table 2) shows highly significant ($P \leq 0.01$) polythene thickness effect on moisture content and quality index while microbial count is considered significant ($P \leq 0.05$). A 2-tailed F-LSD test at 5% level of significance shows that in the case of 47.2% RH, the 10 mean moisture content comparisons were found to be statistically different for control but 10, 20 and 30% non-significance for 0.91, 0.93 and 0.95mm respectively. Again 10% non-significance was observed for 0.91, 0.93 and 0.95mm at 70.4%RH and 0.91 and 0.95mm at 80.5%RH while all other comparisons were statistically different. In the case of microbial count, all 10 comparisons at 47.2%RH were non-significant while 40, 60, 60 and 100% non-significance was observed at 70.4%RH for control, 0.91, 0.93 and 0.95mm respectively. Similarly, 10% non-significance for control and 40% for 0.91, 0.93 and 0.95mm at 80.5%RH was observed. For quality index, 10 and 30% non-significance was observed for control and 0.91mm while 20% was observed for 0.93 and 0.95mm at 47.2%RH. The quality index was also 10% non-significant for control and 20% for 0.91, 0.93 and 0.95mm at 70.4%RH while 10, 20, 30 and 20% non-significance was recorded at 80.5%RH for control, 0.91, 0.93 and 0.95mm respectively.

Effect of Duration of Storage: The results show that the moisture content of all the samples increased with increase in duration of storage at constant polythene thickness level (Table 1). For storage days range of 0 to 28 at constant polythene thickness of 0.95mm, moisture content at 47.2% RH increased from 1.17 to 8.65, 70.4% RH from 1.17 to 9.70 and for 80.5%RH from 1.17 to 10.75%db. Similarly, microbial count increased from 30 to 1060, 30 to 3130 and 30 to 14600 CFU/g for 47.2, 70.4 and 80.5%RH respectively whereas quality index decreased from 100 to 69.34, 100 to 67.17 and 100 to 63.16% at same %RH values.

Table 1: Mean values for moisture content, microbial count and quality index as affected by relative humidity, polythene thickness and duration of storage*

Relative Humidity, %	Polythene Thickness, mm	Duration of Storage (Days)				
		0	7	14	21	28
Moisture Content (%db)						
47.2	Control	1.17	2.77	4.54	9.25	14.76
	0.91	1.17	2.56	3.01	6.00	9.61
	0.93	1.17	2.24	2.87	5.60	9.42
	0.95	1.17	1.97	2.11	5.50	8.65
70.4	Control	1.17	3.41	5.63	9.63	15.97
	0.91	1.17	3.00	3.08	7.18	10.95
	0.93	1.17	2.67	3.07	6.30	10.86
	0.95	1.17	2.65	2.78	6.18	9.70
80.5	Control	1.17	4.15	6.84	9.89	17.02
	0.91	1.17	3.41	3.81	7.19	11.75
	0.93	1.17	3.16	3.78	6.80	11.00
	0.95	1.17	3.13	3.39	6.74	10.75
Microbial count (CFU/g)						
47.2	Control	30	700	1100	2800	3660
	0.91	30	400	520	1800	2100
	0.93	30	300	487	1100	1580
	0.95	30	120	120	1000	1060
70.4	Control	30	850	2700	8500	21950
	0.91	30	500	800	1900	15790
	0.93	30	425	500	1530	12350
	0.95	30	180	200	1200	3130
80.5	Control	30	950	12400	22600	31860
	0.91	30	580	9700	15400	16400
	0.93	30	500	2500	14800	15100
	0.95	30	310	500	10700	14600
Quality Index (%)						
47.2	Contro	l100	67.67	63.00	56.00	48.00
	0.91	100	75.50	71.00	65.34	61.67
	0.93	100	79.00	74.25	68.00	65.33
	0.95	100	82.00	80.25	70.33	69.34
70.4	Control	100	63.00	60.00	52.00	40.00
	0.91	100	73.00	67.34	65.00	56.67
	0.93	100	76.50	70.50	66.67	61.66
	0.95	100	80.00	76.25	68.00	67.17
80.5	Control	100	57.00	50.00	35.00	32.00
	0.91	100	68.00	63.45	59.50	52.17
	0.93	100	70.00	66.25	62.50	60.00
	0.95	100	74.00	71.00	64.67	63.16

*Values are means of three replications

Fishers Least Significant Difference (F-LSD) **Moisture Content (%db)** F-LSD (P=0.05) of the difference between two relative humidity means = 0.547; F-LSD (P=0.05) of the difference between two polythene thickness means = 0.843; F-LSD (P=0.05) of the difference between two duration of storage means = 1.346 **Total fungal count (CFU/g)** F-LSD (P=0.05) of the difference between two relative humidity means = 6355.3; F-LSD (P=0.05) of the difference between two polythene thickness means = 2192.9; F-LSD (P=0.05) of the difference between two duration of storage means = 6853.0 **Quality Index (%)** F-LSD (P=0.05) of the difference between two relative humidity means = 3.179; F-LSD (P=0.05) of the difference between two polythene thickness means = 3.451; F-LSD (P=0.05) of the difference between two duration of storage means = 5.848

Table 2: Summary of ANOVA for moisture content, microbial count and quality index

Source of Variation	Degree of Freedom	Moisture Content (%db)	Microbial Count (CFU/g)	Quality Index (%)	5%	1%
Duration of Storage	4	371.36**	3.80*	183.41**	2.78	4.22
Relative Humidity	2	10.74**	3.81^{NS}	14.79**	5.14	10.19
Error (a)	8					
Polythene Thickness	3	17.42**	8.21*	34.06**	4.76	9.78
Interaction	6	0.03^{NS}	1.46^{NS}	0.62^{NS}	2.36	3.36
Error (b)	36					

**Highly significant difference (1%), * Significant difference (5%), NS Non significant

The analysis of variance (Table 2) shows highly significant ($P \leq 0.01$) duration of storage effect on moisture content and quality index while microbial count is considered significant ($P \leq 0.05$). A 2-tailed F-LSD test at 5% level of significance from 0-28 days of storage shows that for the 6 mean moisture content comparisons, all comparisons were different on day 7 while 33.33, 50 and 33.33% non-significant differences were observed on days 14, 21 and 28 respectively at 47.2%RH. However, at 70.4%RH, 100, 50, 16.67, 16.67 and for 80.5%RH, 66.67, 50, 50, 33.33% mean comparisons were found to be non-significant on days 7, 14, 21 and 28 respectively. In the case of the microbial count, all the comparisons at 47.2%RH were statistically different except on day 28 between control and 0.95mm where non-significance was observed. In the case of 70.4%RH, 100, 66.67, 50, 100 and for 80.5%RH, 100, 16.67, 16.67, 50% non-significance was recorded for control, 0.91, 0.93 and 0.95mm respectively. For quality index, 16.67% non-significance was observed on days 7, 14 and 28 at 47.2%RH with 33.33% on day 21. At 70.4%RH, the index was 16.67% and 50% non-significant on days 14

and 21 respectively while on days 7 and 28, all the differences were statistically different. In the case of 80.5%RH, quality index indicated 16.67% non-significance difference on days 7, 14 and 28 while on day 21, 66.67% non-significant difference was observed.

Practical Industry Applications: From the results obtained from the moisture content on each test day and at all %RH values, taking 5.8%db as the moisture content threshold value which is considered as the maximum permissible percentage amount of moisture for safe storage of roasted cashew nuts (Henderson, 1985; Pixton, 1986), the shelf life of the nuts was deduced to be less than 21 days irrespective of the storage %RH and thickness of the polythene packaging material excluding that packaged in mosquito net (control) which had a shelf life of less than 21 days at storage %RH of 47.2 and less than14 days at storage %RHs of 70.4 and 80.5. With reference to quality, irrespective of the polythene thickness excluding the control, the stored roasted cashew nuts still remained edible after 28 days as the percentage quality index did not drop below 45% which was set as the lowest acceptable percentage quality index. In accordance to ICMSF(1986), the maximum set fungal tolerance acceptable for packaged nuts fit for human consumption is 10^4/g. Based on the results, the shelf-life of the nuts stored in polythene thicknesses of 0.91, 0.93 and 0.95mm was 14 days as the results beyond day 14 exceeded the tolerable fungal count. Conversely the nuts stored under the control had a shelf-life of 7 days. The nuts stored in 0.95mm, which is the thickest polythene, absorbed the least amount of moisture; had the smallest total fugal count, and the highest percentage quality index at all %RH and day of storage levels in comparison with the values obtained from the other less thicker polythene. This is followed by nuts stored in 0.93mm, 0.91mm and control in that order. The results further show that the rate of deterioration of the nuts increased with higher storage RH. Considering the three storage RH used in the study, the most favourable storage RH irrespective of the thickness of the packaging material is 47.2%. Adebajo (1992) found out that the highest tolerable RH for polythene packaged foods (including nuts) is 70%, if the moisture content is to be maintained below 5.8%db for a reasonable length of time.

CONCLUSIONS

Based on the results obtained in this study the following conclusions are drawn:

- There is highly significant effect of relative humidity, polythene thickness and duration of storage ($P \leq 0.01$) on moisture content and quality index while for the microbial count, polythene thickness and duration of storage has significant effect ($P \leq 0.05$) with relative humidity showing non-significance.
- For all levels of relative humidity and polythene thickness, moisture content and microbial count increased with increase in duration of storage while quality index decreased with increase in duration of storage. As the polythene thickness increased at constant storage duration, the moisture content decreased. The moisture content of all the samples increased with increase in duration of storage at constant polythene thickness level.
- For packaged roasted cashew nuts industry for poverty alleviation, the most favourable storage relative humidity is 47.2% with polythene thickness of 0.95mm. Storage period should not exceed 14 days for best quality and value for money.

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