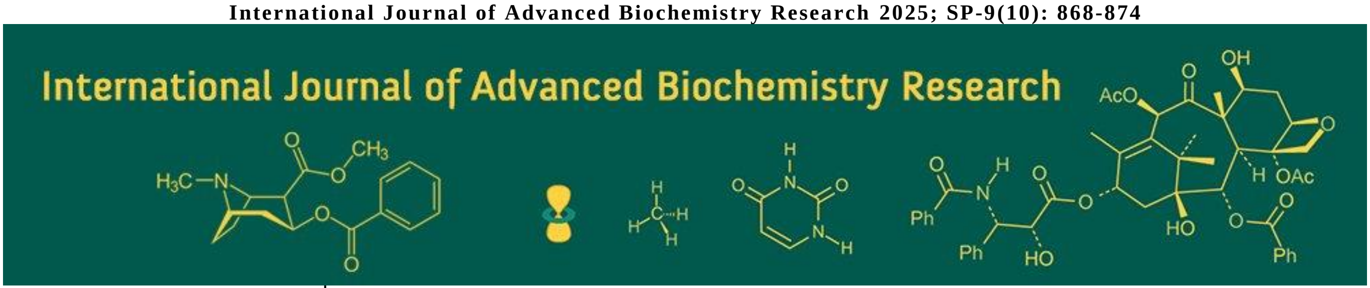

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Studies on packaging of dehydrated tender cashew (*Anacardium occidentale* L.) kernel

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Abstract
This study investigated the effects of different packaging materials on the storage stability of dehydrated tender cashew kernels. Five packaging treatments were evaluated: T_1: 51+µ LDPE without nitrogen flushing (control), T_2: 50+ µ with nitrogen flushing (one-way aluminum foil), T_3: 60 µ with nitrogen flushing (both-side aluminum foil), T_4: 100 µ with nitrogen flushing (transparent granular), T_5: 120 µ with nitrogen flushing (both-side aluminum foil).The experiment followed a Factorial Completely Randomized Design (FCRD) with observations recorded at 0, 30, 60, 90, and 120 days of storage. Parameters assessed included physicochemical properties (moisture, fat, protein, ash, fiber, carbohydrates, peroxide value) Results indicated that T_5 (120 µ both-side aluminum foil with nitrogen flushing) provided the best preservation, maintaining quality for 120 days with minimal degradation.

Keywords: Cashew kernel, dehydration, nitrogen flushing, packaging, shelf life

Introduction

The cashew, which belongs to the genus Anacardium of the family Anacardiaceae, is one of the major dollar-earning plantation crops in India (Vergara *et al.* 2010) [23]. According to Rodrigues *et al.* (2018) [24], cashew trees are grown all over the world, but particularly in Brazil, Vietnam, India, Nigeria, Indonesia, Philippines, Benin, Guinea-Bissau and Ivory Coast. In the 16th century, the Portuguese introduced the cashew tree in India after it had originally been domesticated in Eastern Brazil. Cashews are currently one of India's top dollar-earning crop but initially they were primarily consider as a crop for afforestation and soil binding to prevent erosion. In 1558, Thevet, a French monk and scientist, were the first to describe cashew as a wild plant that grows widely throughout Brazil**.** He related that they ate cashew apples and their juice, roasted the nuts in a fire and then ate the kernels.

The world's largest producer of raw cashew nuts, accounting for 20% of total production, is India. Maharashtra has the most cashew production and productivity. The state of Maharashtra offers 170,000 hectares of cashew land, with an estimated 199.70 thousand MT produced (Anon., 2023- 24 b) [5]. One of the biggest cashew-growing belts is the Konkan region on Maharashtra's western coast, which has 173,601 hectares of cashew agriculture. Cashew farming is mostly concentrated in the Konkan region of Maharashtra, which includes the districts of Thane (10,783 ha), Raigad (19,088 ha), Ratnagiri (89,999 ha) and Sindhudurg (53,731 ha) (Anon. 2023-24 b) [5]. Maharashtra's Konkan region is especially well-suited for this crop because of the climate. The ground in this area is often undulating and has a hilly terrain. The area receives between 2000 and 4000 mm of rainfall annually, although during the summer months, there is a serious water deficit. Its benefit is that this plantation crop grows well in light soils and rainfed environments on sloping hillsides. (Gajbhiye *et al.* 2015) [10].

This region's historic cashew groves yield little fruit. Thus, nine high-yielding cashew varieties - Vengurla 1, Vengurla 2, Vengurla 3, Vengurla 4, Vengurla 5, Vengurla 6, Vengurla 7, Vengurla 8 and Vengurla 9 have been developed by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (Gajbhiye *et al.* 2018) [9].

These types are gaining popularity and turning into an important cash crop for Konkan farmers as a result of the rising demand for cashew kernels in global markets. Due to increases in price, cashew cultivation is becoming more and more important. India began research on cashew kernels in the early 1950s and was the first nation to take advantage of the global cashew kernel commerce in the early 20th century. These varieties are becoming more and more popular and profitable cash crops for farmers in the Konkan region due to the growing demand for cashew kernels in international markets. The importance of cashew cultivation has increased due to price increases and India was the first country to take advantage of the international cashew kernel trade in the early 20th century and the first to start research on the subject in the early 1950s.

The occurrence of the fungus that creates toxins like aflatoxin can be influenced by incorrect post- harvest handling and storage of nuts, including excessive moisture levels from improper drying, temperature changes, and insect or mechanical damage. This can lead to rancidity and loss of kernel nutrients. Extension activities that improve harvest and post-harvest handling practices will boost Nigerian cashew's international acceptance and improve its price. The supply of high-quality cashews for both domestic and international markets has been hampered by post-harvest cashew management. Poor packaging practices have caused moisture to seep into already-dried cashew nuts, which has resulted in low-quality cashew. Due to a lack of information, cashew growers have mostly been selling the nuts without considering the benefits of processing them into kernels, which may also be stored in big quantities using a minimum amount of storage space. In order to improve cashew post-harvest management, this study was conducted to address the packaging issues with both the nuts and the kernels. Thus, the purpose of this study was to evaluate how various packaging techniques affected the cashew nut's shelf life and kernel quality.

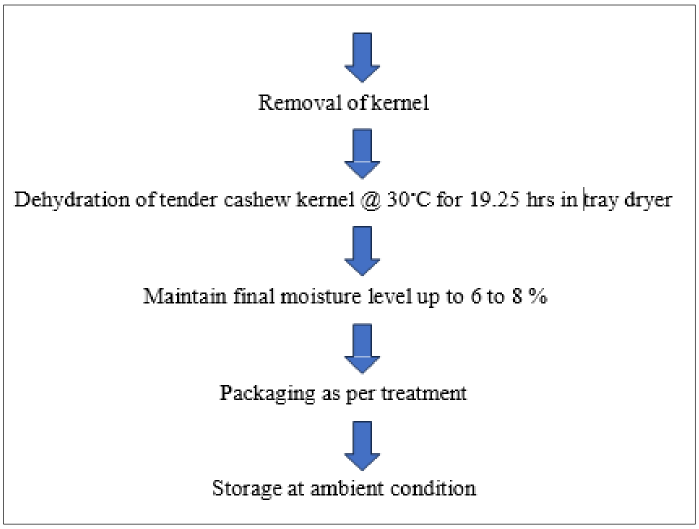
Material and Methods

Material Required

The tender cashew kernel was produced from local market Roha Dist Raigad, other material produced to different packaging material in roha market

Methods

Flow Chart: Harvesting of tender cashew nut 50 to 55 days after flowering



Chemical parameters of dehydrated tender cashew kernel in different packaging.

Dehydrated tender cashew kernel in different packaging The chemical parameters like moisture, ash, peroxide value, fatty acid, crude fiber, protein, fat and carbohydrate were analysed with the methods as described under 3.3.2 initially (0 day) and thereafter at an interval of 30,60,90 days for a period of 120 days during storage at ambient condition.

Moisture (%)

Moisture content was estimated by drying 5 g sample in pre weighed aluminium moisture boxes in hot air oven at 130 ± 1 °C for 2 hours till constant weight. Dried samples were cooled down to room temperature by keeping the boxes in desiccator prior to weighing (AOAC, 2002) [2] and the difference in weight was expressed as per cent moisture content and was calculated as per the given formula:

$$\text{Percentage}\ (\%) = \frac{\text{Value Obtained (V)}}{\text{Total Value (T)}} \times 100$$

Ash (%)

Ash was determined by taking 5 g of sample in pre-weighed silica crucibles followed by incineration over hot plate under open atmosphere to make it smoke free and ashing in muffle furnace at 550 °C for 4 to 6 hours. The crucibles were allowed to cool down. The crucibles, along with the ash were taken out, kept in desiccator and weighed till constant weight. The difference between the weight of empty silica crucible and with ash was the amount of total ash (AOAC, 2002) [2]. The per cent ash was calculated using the following formula:

$$A\% = \frac{\text{Measured Value (M)}}{\text{Total Value (T)}} \times 100$$

Crude Fibre (%)

Two g fat free dried sample was taken in a 500 ml beaker to which 200 ml of 0.128 M
(1.25%) sulphuric acid was added. Beaker along with contents was placed on hot plate and boiled for 30 minutes. After boiling, the contents of tshe beaker were filtered

through muslin cloth and then transferred to the same beaker and 200 ml of 0.313 M (1.25%) NaOH was added. After boiling for 30 min, the mixture was filtered through muslin cloth. The residue was washed with hot water till free from alkali, followed by washing with alcohol or ether. It was then transferred to crucible, dried in hot air oven 100℃ and weighed. The crucibles were then kept in muffle furnace and ignited for 2-3 hrs at 525℃ followed by cooling and weighing. The difference in weights represented the weight of crude fiber (Rangana, 1986).

$$\text{Crude Ash (\%)} = \frac{\text{Weight of sample before ashing (g)} - \text{Weight of sample after ashing (g)}}{\text{Weight of sample (g)}} \times 100$$

Protein (%)
Protein was estimated by micro-Kjeldahl method, using the factor 6.25 for converting nitrogen content into crude protein. Weighed sample of 2 g was digested with concentrated sulphuric acid (2 ml) and 2 g of catalyst mixture (K2SO4, CuSO4 and SeO2) in a long neck Kjeldahl flask for 2 hours till free from carbon. The contents were cooled and transferred to a 100 ml volumetric flask and the volume was made to 100 ml with distilled water. Measured aliquot was distilled with 40 per cent sodium hydroxide and liberated ammonia was collected through a condenser in a flask containing 10 ml 4 per cent boric acid solution and a few drops of mixed methyl red and bromocresol green indicator (A.O.A.C, 2020) [1] and was titrated against standardized 0.1 N sulphuric acid and protein content was calculated using the equation as given below. A blank sample was also run along with the sample.

$$\text{Moisture (\%)} = \frac{\text{Weight of sample before drying (g)} - \text{Weight of sample after drying (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

Fat was estimated as crude ether extract of the dry material. The dry sample (5 g) was weighed accurately into the thimble and plugged with cotton. The thimble was then placed in a Soxhlet apparatus and extracted with anhydrous ether for 3 hrs. The ether was then evaporated and the flask with the residue dried in the oven at 80℃ to 100℃, cooled in desiccator and weighed. The fat content was expressed as g/100g (A.O.A.C, 2020) [1].

$$\text{Fat (\%)} = \frac{\text{Weight of sample after extraction (g)}}{\text{Weight of sample (g)}} \times 100$$

Carbohydrate (%)
Amount of carbohydrate was calculated by difference method as subtracting the total sum of moisture content, crude protein, crude fat, ash and crude fiber from 100 (A.O.A.C, 2020) [1].

Peroxide value (meq/kg)
To evaluate the oxidative stability of packaged cashew kernels, a peroxide value determination was conducted. Approximately 5.00 ± 0.05 g of cashew kernel sample was accurately weighed into a 250 mL conical flask and a blank was prepared simultaneously for reference. 30 mL of acetic acid-chloroform solution was added to the flask and the mixture was gently swirled to dissolve the sample. Following this, 0.5 mL of saturated potassium iodide (KI) solution was introduced, resulting in the formation of a dark yellow colour, indicating the release of iodine. 30 mL of distilled water was then added to the mixture. The solution was titrated slowly with 0.01 N sodium thiosulfate ($Na_2S_2O_3$) until the dark yellow colour turned light yellow. At this point, 0.5 mL of 1% starch solution was added as an indicator, turning the solution blue. The titration was continued until the blue colour just disappeared, marking the endpoint. This procedure was employed to determine the peroxide value in cashew kernels stored in different packaging materials, such as nitrogen-flushed aluminum foil pouches, to assess the lipid oxidation during storage and evaluate the effectiveness of each packaging method in maintaining kernel quality.

$$\text{Peroxide Value (meq/kg)} = \frac{V_{\text{sample}} \times N \times 1000}{\text{Weight of sample (g)}}$$

Experimental details
The experiment was conducted in Factorial Completely Randomized Design (FCRD). The treatments comprised of 5 main treatments of different packaging with 5 storage periods as sub treatments. The observations were recorded at the 0, 30, 60, 90 and 120 days of storage period was taken for the statistical analysis.

Statistical analysis
The data collected on chemical parameters such as moisture, ash, fat, protein, crude fiber, carbohydrate, peroxide value and Fatty acid were represented as mean values. The data collected on the changes in chemical parameters of dehydrated tender cashew during storage were statistically analysed by standard procedure given by (Panse and Sukhatme 1985) [19] using Factorial Completely Randomised Design and valid conclusions were drawn only on significant differences between treatment mean at 5 per cent level of significance.

Results and Discussion
Changes in different packaging material on chemical parameters of dehydrated tender cashew kernel during storage.

Moisture (%)
It is clear from the Table 1 that the maximum (6.739%) moisture content was noticed in the treatment T_1 51+ µ LDPE without nitrogen flushing (control). The treatment T5 (120 µ with nitrogen flushing (both-side aluminum foil)) observed minimum moisture content (6.399%). The minimum mean value of moisture content of dehydrated tender cashew kernel i.e. 6.161per cent was noticed initially

at 0 day of the storage, which was increased to 7.251 per cent at the end of storage period of 120 days. The moisture content of dehydrated tender cashew kernel increased significantly. Similar observations are reported by (Kosoko *et al.* 2009) [11] in cashew nuts. During the storage of 12 weeks, moisture content affected by the difference between packaging materials may be due to their thermal conductance properties which affects the decomposition reactions in the product during storage. Identical findings of increasing moisture content during storage observed by (Silva and Marsaioli. 2006) [22] in macadamia nut kernels during 6 months of storage period. Reis *et al.* (2019) also reported increasing trend of moisture content during 120 days storage period in cashew kernel. Identical findings in accordance with increasing moisture content during storage were noticed by (Shakerardekani and Karim 2013) [20] in pistachios nut.

Ash (%)

It noticed from the Table 2 that the maximum mean ash content (2.131%) was found in the treatment T_5 120 µ with nitrogen flushing (both-side aluminum foil) and the treatment T_1 51+

µ LDPE without nitrogen flushing (control). lowest minimum ash (2.113%) ash content. The maximum value of ash content of dehydrated tender cashew kernel was recorded 2.171 per cent at 0 day of the storage, which was decreased to 2.061 per cent at end of 120 days of storage period. Similar reports were noticed by (Lawal and Fogbound 2014) [12] they reported decreasing ash content in cashew nut. (Bello *et al.* 2019) [6] also recorded decreasing trend in freshly roasted groundnut. The ash content of dehydrated cashew kernel changed significantly during 120 days of storage period.

Fat (%)

The Table 3 clearly shows that the treatment T5 120 µ with nitrogen flushing (both-side aluminum foil) recorded maximum mean fat (45.727%), while it was minimum in the 51+ µ LDPE without nitrogen flushing (control) treatment T_1 (45.703%). Regarding to the duration of the storage period, there was decrease in the fat content during the storage. The highest mean fat content 45.733 per cent was observed initially at 0 day of the storage, while the lowest mean fat content 45.676 per cent was observed at 120 days of the storage period. It is clear from the data that which could be due to an increase in moisture content in the tender cashew kernel. A similar trend of decrease in fat content is observed during storage and recorded by (Padehban *et al.* 2018) [18] that the overall mean crude fat content significantly decreased as storage times. Similar findings are observed by (Fagbohun and Faleye 2012) [8] groundnut fat content during storage.

Protein (%)

Table 4 clearly indicates that among all the treatments, the highest mean protein content was found in the treatment T_5 120 µ with nitrogen flushing (both-side aluminum foil) (18.564%). The lowest mean protein content (18.528%) was noticed in the treatment T_1 51+ µ LDPE without nitrogen flushing (control). At initial stage i.e. 0 day, the highest mean protein content 18.639 per cent of the dehydrated tender cashew kernel was noticed, while the lowest mean protein content 18.408 per cent was recorded at 120 days of storage. There was a significant effect of different packaging of dehydrated tender cashew kernel on protein content. It was apparent from the data that the protein content of tender cashew kernel. Similar results were reported by (Ajith *et al.* 2015) [3], elevated humidity and temperature during storage accelerate chemical reactions that compromise nutritional quality, including protein levels. Additionally, the Maillard reaction where proteins interact with reducing sugars can occur over time, especially under suboptimal packaging temperatures, leading to non-enzymatic browning and reduced bioavailability of proteins. Liu *et al.* (2023) [14] also emphasize that packaging materials with low barrier properties may fail to protect against oxidative stress, further contributing to protein loss. (Padehban *et al.* 2018) [18] in processed almond kernels; and Bello *et al.* (2019) [6] in raw and roasted groundnut.

Crude fiber (%)

It is noticed from the Table 5 that the mean crude fibre content of the dehydrated tender cashew kernel was highest in treatment T_5 120 µ with nitrogen flushing (both-side aluminum foil) (2.221%). Among all the treatments, significantly lowest mean crude fibre content was noticed in the treatment T_1 51+ µ LDPE without nitrogen flushing (control) (2.199%). It was also noticed from the data that the mean crude fibre content was significantly decreased from 0 day 2.311 to 2.119 per cent up to 120 days of storage period. The decrease in crude fiber content may be attributed to the change in moisture content. Fagbohun and Faleye. (2012) [8] groundnuts (Arachis hypogea) throughout storage. It found that samples at the twentieth week. The identical result for a decrease in crude fiber content was recorded by (Bello *et al.* 2019) [6] in raw and roasted groundnut; Lawal and Fagbohun, (2014) [12]; Padehban *et al.* (2018) [18] decrease in crude fiber content in almond kernels.

Carbohydrate (%)

It is clear from the Table 6 that the mean carbohydrate content of the dehydrated tender cashew kernel was highest in treatment T_5 120 µ with nitrogen flushing (both-side aluminum foil) (24.964%). Among all treatments, the significantly lowest mean Carbohydrate was recorded in the treatment T_1 51+ µ LDPE without nitrogen flushing (control) (24.718%). The mean carbohydrate was changed during 120 days of storage period. Initially, the mean carbohydrate content decreased from 25.004 to 24.649 per cent from the initial day to 120 days of storage. of storage. When nuts lose some of water 78 molecules that are bound to carbohydrate which can make carbohydrate more susceptible enzymatic breakdown and the Millard reaction. Similar findings by Bello *et al.* (2019) [6] in roasted groundnut;

Peroxide value (%)

Table 7 indicates that among the treatments, the treatment T_1 51+ µ LDPE without nitrogen flushing (control) was significantly superior to other treatments and showed maximum (0.192%) mean peroxide value content, while treatment T_5 120 µ with nitrogen flushing (both-side aluminum foil) showed minimum (0.141%) mean peroxide value content in the dehydrated tender cashew kernel.

Initially, the mean peroxide value content decreased from 0.113 to 0.316 per cent from the initial day to 120 days of storage under ambient conditions. It is clear from the data, the peroxide value of tender cashew kernel showed significant variations according to the treatments and storage period According to Das, *et al.* (2013) [7] the absence of peroxide value in kernels stored under nitrogen-flushed temperatures across various packaging materials over 4 months is a result of controlled oxidative environment and barrier protection respectively. These findings agrees well with the earlier study on packed kernel Akinhanmi *et al.* (2013) [4] raw cashew kernel storage study; Olowookere *et al.* (2021) [16]; Lima and Borges. (2004) [13]; Shojaee *et al.* (2023) [21] almond kernel; Peroxide values were lower in the gas filled samples than in the control samples. This is in line with the results of (Mexis, Riganakos, & Kontominas, 2011) [15]. Ajith *et al.* (2015) [3] demonstrated that improper storage temperatures, such as high relative humidity and temperature, accelerate peroxide formation and compromise oil stability.

Table 1: Changes in the moisture (%) content of dehydrated tender cashew kernels during storage at ambient temperature

Treatments	**Moisture (%)**					
	Storage period (Days)					
	0	**30**	**60**	**90**	**120**	**Mean A**
T_1	6.161	6.516	6.730	7.038	7.251	6.739
T_2	6.161	6.434	6.622	6.853	7.036	6.621
T_3	6.161	6.291	6.468	6.772	6.905	6.519
T_4	6.161	6.491	6.713	6.947	7.144	6.691
T_5	6.161	6.245	6.370	6.515	6.703	6.399
Mean B	6.161	6.395	6.580	6.825	7.008	
		S.E. m±			CD 5%	
Treatment (T)		0.001			0.001	
Storage (S)		0.001			0.001	
Interaction (T×S)		0.001			0.002	

Table 2: Changes in the Ash (%) content of dehydrated tender cashew kernels during storage at ambient temperature

Treatments	**Ash (%)**					
	Storage period (Days)					
	0	**30**	**60**	**90**	**120**	**Mean A**
T_1	2.163	2.135	2.117	2.088	2.061	2.113
T_2	2.166	2.143	2.128	2.102	2.081	2.124
T_3	2.165	2.146	2.131	2.107	2.083	2.126
T_4	2.168	2.149	2.128	2.097	2.075	2.123
T_5	2.171	2.153	2.132	2.108	2.089	2.131
Mean B	2.167	2.145	2.127	2.100	2.078	
		S.E. m±			CD 5%	
Treatment (T)		0.001			0.001	
Storage (S)		0.001			0.001	
Interaction (T×S)		0.001			0.002	

Table 3: Changes in the Fat (%) content of dehydrated tender cashew kernels during storage at ambient temperature

Treatments	**Fat (%)**					
	Storage period (Days)					
	0	**30**	**60**	**90**	**120**	**Mean A**
T_1	45.732	45.714	45.704	45.688	45.676	45.703
T_2	45.733	45.718	45.712	45.704	45.697	45.713
T_3	45.734	45.731	45.723	45.713	45.704	45.721
T_4	45.730	45.717	45.709	45.698	45.690	45.709
T_5	45.733	45.735	45.732	45.723	45.715	45.727
Mean B	45.732	45.723	45.716	45.705	45.696	
		S.E. m±			CD 5%	
Treatment (T)		0.002			0.005	
Storage (S)		0.002			0.005	
Interaction (T×S)		0.004			0.011	

Table 4: Changes in the protein (%) content of dehydrated tender cashew kernels during storage at ambient temperature

Treatments	**Protein (%)**					
	Storage period (Days)					
	0	**30**	**60**	**90**	**120**	**Mean A**
T_1	18.631	18.590	18.524	18.488	18.408	18.528
T_2	18.638	18.600	18.545	18.511	18.464	18.551
T_3	18.639	18.598	18.549	18.513	18.465	18.553

T_4	18.634	18.598	18.534	18.505	18.428	18.540
T_5	18.632	18.608	18.558	18.515	18.492	18.564
Mean B	18.637	18.599	18.542	18.506	18.451	
		S.E. m±			CD 5%	
Treatment (T)		0.001			0.001	
Storage (S)		0.001			0.001	
Interaction (T×S)		0.001			0.002	

Table 5: Changes in the crude fiber (%) content of dehydrated tender cashew kernels during storage at ambient temperature

Treatments	**Crude fiber (%)**					
	Storage period (Days)					
	0	**30**	**60**	**90**	**120**	**Mean A**
T_1	2.307	2.250	2.193	2.148	2.098	2.199
T_2	2.315	2.254	2.209	2.166	2.122	2.213
T_3	2.314	2.259	2.214	2.169	2.127	2.216
T_4	2.311	2.256	2.204	2.164	2.116	2.210
T_5	2.309	2.269	2.219	2.175	2.131	2.221
Mean B	2.311	2.257	2.207	2.164	2.119	
		S.E. m±			CD 5%	
Treatment (T)		0.001			0.001	
Storage (S)		0.001			0.001	
Interaction (T×S)		0.001			0.003	

Table 6: Changes in the carbohydrate (%) content of dehydrated tender cashew kernels during storage at ambient temperature.

Treatments	**Carbohydrate (%)**					
	Storage period (Days)					
	0	**30**	**60**	**90**	**120**	**Mean A**
T_1	25.006	24.795	24.732	24.551	24.507	24.718
T_2	24.987	24.851	24.785	24.666	24.601	24.778
T_3	25.031	24.975	24.915	24.726	24.715	24.872
T_4	24.995	24.791	24.712	24.589	24.550	24.727
T_5	25.003	24.991	24.989	24.966	24.870	24.964
Mean B	25.004	24.881	24.826	24.699	24.649	
		S.E. m±			CD 5%	
Treatment (T)		0.001			0.001	
Storage (S)		0.001			0.001	
Interaction (T×S)		0.001			0.003	

Table 7: Changes in the peroxide value (meq/kg) content of dehydrated tender cashew kernels during storage at ambient temperature.

Treatments	**Peroxide value (MEQ/kg)**					
	Storage period (Days)					
	0	**30**	**60**	**90**	**120**	**Mean A**
T_1	ND	0.121	0.211	0.272	0.357	0.192
T_2	ND	0.113	0.168	0.247	0.316	0.169
T_3	ND	0.110	0.145	0.218	0.298	0.154
T_4	ND	0.117	0.202	0.254	0.346	0.184
T_5	ND	0.105	0.138	0.199	0.265	0.141
Mean B	ND	0.113	0.173	0.238	0.316	
		S.E. m±			CD 5%	
Treatment (T)		0.001			0.001	
Storage (S)		0.001			0.001	
Interaction (T×S)		0.001			0.003	

Conclusion

It is concluded that the tender cashew kernel could be stored for four months in a good acceptable temperature at ambient temperatures by using the treatments T_1 (51+µ LDPE without nitrogen flushing), T_2 (50µ One-way aluminum foil), T_3 (60µ both side aluminum foil) T_4 (100µ Transparent granular) and T_5 (120µ both side aluminum foil).

In conclusion, T_5 (120µ both sides aluminum foil) is the best way to maintain quality and increase shelf life, allowing the tender cashew kernel to be consumed for up to 120 days. The aluminum pouch offers a strong barrier against moisture, light and air and this treatment efficiently displaces oxygen, reducing oxidative rancidity and microbiological growth.

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