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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(8): 1770-1775

www.thepharmajournal.com
Received: 13-05-2022
Accepted: 29-06-2022

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Effect of drying techniques and packaging material on shelf life of tender jackfruit powder

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Abstract
The study was conducted to find out suitable drying technique and packaging material for the storage of tender jackfruit powder. Tender jackfruit slices were blanched for one minute at 100 °C and dried in three drying methods *viz.*, sun drying (D_1), solar drying (D_2) and tray drying (D_3) and then milled into powder. Among three drying methods, maximum powder recovery percentage was recorded by tray drying method (20%) followed by solar drying (14%) and sun drying (13%). The tender jackfruit powder was packed in LDPE (Low Density Polyethylene) (P_1), HDPE (High Density Polyethylene) (P_2) and aluminium foil pouch (P_3) and stored for 90 days. It was observed that, among all treatment combinations tray dried powder packed in aluminium foil pouch recorded the minimum moisture content (%) and water activity (a_w), maximum ascorbic acid (mg/100g), protein (%), fibre (%) and ash content (%).

Keywords: Tender jackfruit powder, drying methods, packaging materials

Introduction
Jackfruit (*Artocarpus heterophyllus* L.) is known as the largest tree-borne fruit in the world and it is a tropical climacteric fruit belongs to the family *Moraceae.* Origin of jackfruit is rainforests of the Western Ghats of Southern India. It is popularly known as the national fruit of Bangladesh and Sri Lanka and the state fruit of the Indian states of Kerala and Tamil Nadu.
The compound fruit of jackfruit is made of three parts *viz.*, bulb (30-32%), seeds (18%) and the rind (50-55%) (Srivastava *et al.*, 2017, Srivastava and Anu 2020) [1, 2]. Tender, ripe fruits as well as seeds of jackfruit are rich in minerals and vitamins. Hundred grams of edible jackfruit contains water ranged from 76.2 to 85.2 g, protein ranged from 2.0 to 2.6 g, fat ranged from 0.1 to 0.6 g, carbohydrate ranged from 9.4 to 11.5 g**,** fibre ranged from 2.6 to 3.6 g, calcium ranged from 30.0 to 73.2 mg, phosphorus ranged from 20.0 to 57.2 mg, potassium ranged from 287 to 323 mg, sodium ranged from 3.0-35.0 mg, iron ranged from 0.4 to 1.9 mg, Vitamin-A 30 IU, Thiamine ranged from 0.05 to 0.15 mg, Riboflavin ranged from 0.05 to 0.2 mg, Vitamin C (12.0-14.0 mg) and Energy (50-210 KJ) (Ranasinghe *et al.*, 2019) [2] and it also contains useful antioxidants which are regarded as compounds able to delay or retard or prevent oxidation process, whereas ripe fruits are rich in vitamin-A which maintain good vision. Jackfruits are eaten unripe at 25-50% full size as vegetables or ripe as a fruit, different parts of jack tree such as fruits, leaves and bark have been extensively used in traditional medicine due to its anti-carcinogenic, anti-microbial, anti-fungal, anti-inflammatory, wound healing and hypoglycemic effects. Jackfruit could be very useful in the treatment of dreaded disease like AIDS. “Jacaline”, an extract of jackfruit inhibited growth of HIV infection *in vitro* and also it has significant role in cancer treatment (Ambily and Anitha, 2016) [1].
In Srilanka, people believed that consumption of tender jackfruit will increase breast milk production in nursing mothers and it is also an excellent source of complex carbohydrate and dietary fiber, making it a great energy food (Ambily and Anitha, 2016) [1].
The seasonal nature of the fruit with short storage life, even under low temperature conditions, necessitates processing of the ripe and tender jackfruit. A number of products have been developed from unripe as well as ripe fruits.

Materials and Methods

Raw material collection

Raw material for this study were procured from jackfruit orchard located at Horticultural Research Station (HRS), Venkataramannagudem. Disease and pest free tender jackfruits without any physical damage weighed 3 kg to 4 kg were selected for this experiment.

Sample preparation

The collected tender jackfruits were thoroughly cleaned with 0.1% KMS to remove any dirt or dust particles adhered to the surface. Outer green rind was removed and tender jackfruit was made into slices of desired thickness.

Pre-treatment

Tender jackfruit slices were blanched for one minute at 100 °C.

Dehydration

The tender jackfruit slices were dried by using three different drying methods *viz*., sun drying, solar drying and tray drying.

Sun drying

Tender jackfruit slices were spread on a dust free cloth kept under sunlight. The floor area selected for sun drying was cleaned thoroughly and made it free from dirt and foreign material. The ambient temperature during sun drying ranged from 25 °C to 32 °C. The relative humidity varied from average minimum of 50% to average maximum of 75%.

Solar drying

The tender jackfruit slices were spread on the trays of solar drier. The sample loaded trays were kept in the solar drier available at Postharvest Technology Research Station, Dr.Y.S.R Horticultural University, Venkataramannagudem. During drying, the temperature inside the solar drier (45 °C - 55 °C) was warmer than outside and relative humidity ranged from 60% to 80%.

Tray drying

The tray drier in the Postharvest Technology Research Station (PHTRS), was used for drying. The tender jackfruit slices were spread on perforated aluminium trays and kept in drier. The drying was carried out at a temperature of 60 °C.

Packaging

Dehydrated tender jackfruit powder were packed in three different packaging materials *viz*., LDPE, HDPE, aluminium foil pouch and kept for storage studies.

Physioco-chemical analysis

The main objective was to study the effect of drying techniques and packaging material on shel life of tender jackfruit powder in terms of physico-chemical analysis. observations were recorded on parameters like powder recovery (%), moisture content (%), water activity (a_w), ascorbic acid (mg/100g), protein (%), fibre (%) and ash content (%) from initial day of storage to 90th day of storage.

Results and Discussion

Powder recovery (%)

The data pertaining to the per cent powder recovery of tender jackfruit was presented in table 1. Among different drying methods tray drying (D_3) method has recorded the high powder recovery percentage with 20%, followed by solar drying (D_2) with powder recovery percentage of 14% and least powder recovery percentage was observed in sun drying (D_1) with 13% (Parveen *et al.,* 2022) [5].

Table 1: Effect of drying methods on powder recovery (%) of tender jackfruit

Drying methods (D)	Powder recovery (%)
Sun drying	13
Solar drying	14
Tray drying	20

Moisture content (%)

The data pertaining to the moisture content of the tender jackfruit powder recorded at 30 days intervals after packing and storage in ambient conditions were presented in table 2.

From the data, it was observed that drying methods significantly influenced the moisture content of tender jackfruit powder. sun dried tender jackfruit powder (D_1) recorded the lowest moisture content *i.e.,* 5.80, 7.22, 8.45 and 7.80% on initial day, 30th, 60th and 90th day of storage respectively whereas solar dried tender jackfruit powder (D_2) recorded the highest moisture content *i.e.,* 6.83, 8.40, 9.51 and 11.77% on initial, 30th, 60th and 90th day of storage respectively.

The results indicated that moisture content was significantly influenced by packaging material up to 90th day of storage period. Tender jackfruit powder packed in aluminium foil pouch (P_3) recorded the lowest moisture content *i.e.,* 6.18, 7.39, 8.04 and 8.59% on initial, 30th, 60th and 90th day of storage respectively. Tender jackfruit powder packed in LDPE (P_1) recorded highest moisture content *i.e.,* 6.42, 7.96, 9.83 and 11.96% on initial, 30th, 60th and 90th day of storage respectively.

It was evident from the data that there was a significant difference in the interaction (D x P) on moisture content of tender jackfruit powder after 30th day of storage, the moisture content was found to increased up to 90th day of storage. sun dried tender jackfruit powder packed in aluminium foil pouch (D_1P_3) recorded the lowest moisture content *i.e.* 5.60, 7.09, 7.39 and 7.80% was recorded on initial, 30th, 60th and 90th day of storage respectively whereas solar dried tender jackfruit powder packed in LDPE (D_2P_1) recorded the highest moisture content *i.e.,* 6.91, 8.70, 10.23 and 13.19% on initial, 30th, 60th and 90th day of storage respectively.

The moisture content increased steadily during the storage which might be due to hygroscopic nature of the tender jackfruit powder. The moisture content of sun dried tender jackfruit powder was found to be less when compared to other drying methods (D_1). Tender jackfruit powder packed in aluminium foil pouch recorded the lowest moisture content (P_3) due to lower permeability of packaging material (Sarker *et al.,* 2014) [6].

Table 2: Effect of drying methods and packaging material on moisture content (%) of tender jackfruit powder during storage

Drying methods (D)	Packaging materials (P)															
	Days of storage															
	Initial ('0' day)				30th day of storage				60th day of storage				90th day of storage			
	P1	P2	P3	Mean	P1	P2	P3	Mean	P1	P2	P3	Mean	P1	P2	P3	Mean
D1	5.91	5.89	5.60	5.80	7.32	7.25	7.09	7.22	9.63	8.32	7.39	8.45	11.69	9.29	7.80	9.59
D2	6.91	6.83	6.76	6.83	8.70	8.63	7.88	8.40	10.23	10.10	8.19	9.51	13.19	13.04	9.09	11.77
D3	6.44	6.23	6.19	6.29	7.85	7.65	7.19	7.56	9.62	8.73	8.55	8.97	11.01	9.72	8.89	9.87
Mean	6.42	6.32	6.18	6.31	7.96	7.84	7.39	7.73	9.83	8.87	8.04	8.98	11.96	10.68	8.59	10.41
Factor	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
(D)	0.056		0.168		0.054		0.161		0.079		0.238		0.064		0.191	
(P)	0.056		0.168		0.054		0.161		0.079		0.238		0.064		0.191	
Interaction (D x P)	0.097		NS		0.09		0.278		0.138		0.412		0.111		0.331	

Drying methods: D_1: Sun drying D_2: Solar drying D_3: Tray drying
Packaging materials: P_1: LDPE P_2: HDPE P_3: Aluminium foil pouch

Water activity (a_w)

The data pertaining to the water activity (a_w) of the tender jackfruit powder recorded at 30 days intervals after packing and storage in ambient conditions were presented in table 3.

From the data, it was observed that drying methods significantly influenced the water activity of tender jackfruit powder. Sun dried tender jackfruit powder (D_1) recorded the lowest water activity *i.e.*, 0.40, 0.46, 0.54 and 0.55 a_w on initial day, 30th, 60th and 90th day of storage respectively whereas solar dried tender jackfruit powder (D_3) recorded the maximum water activity *i.e.*, 0.42, 0.50, 0.59 and 0.60 a_w on initial, 30th, 60th and 90th day of storage respectively whereas The results indicated that water activity was significantly influenced by packaging material up to 90th day of storage period. Tender jackfruit powder packed in aluminium foil pouch (P_3) recorded the lowest water activity *i.e.*, 0.40, 0.46, 0.54 and 0.55 a_w on initial, 30th, 60th and 90th day of storage respectively whereas tender jackfruit powder packed in LDPE (P_1) recorded highest water activity *i.e.*, 0.43, 0.50, 0.58 and 0.59 on initial, 30th, 60th and 90th day of storage respectively whereas It was evident from the data that there was no significant difference in the interaction (D x P) on water activity of tender jackfruit powder up to 90th day of storage. Sun dried tender jackfruit powder packed in aluminium foil pouch (D_1P_3) recorded the minimum water activity *i.e.*, 0.39, 0.44, 0.52 and 0.53 a_w was recorded on initial, 30th, 60th and 90th day of storage respectively whereas solar dried tender jackfruit powder packed in LDPE (D_2P_1) recorded the maximum water activity *i.e.*, 0.44, 0.52, 0.60 and 0.63 a_w on initial, 30th, 60th and 90th day of storage respectively.

The water activity increased steadily during the storage which might be due to increase in moisture content of the tender jackfruit powder. The minimum water activity was recorded by sun dried tender jackfruit powder when compared to other drying methods (D_1). Tender jackfruit powder packed in aluminium foil pouch recorded the minimum water activity (P_3) due to lower permeability of packaging material to water vapour (Shishir *et al.*, 2017) [7].

Table 3: Effect of drying methods and packaging material on water activity (a_w) of tender jackfruit powder during storage

Drying methods (D)	Packaging materials (P)															
	Days of storage															
	Initial ('0' day)				30th day of storage				60th day of storage				90th day of storage			
	P1	P2	P3	Mean	P1	P2	P3	Mean	P1	P2	P3	Mean	P1	P2	P3	Mean
D1	0.42	0.40	0.39	0.40	0.48	0.46	0.44	0.46	0.56	0.53	0.52	0.54	0.56	0.54	0.53	0.55
D2	0.44	0.42	0.41	0.42	0.52	0.50	0.48	0.50	0.60	0.59	0.57	0.59	0.63	0.60	0.57	0.60
D3	0.43	0.41	0.40	0.41	0.49	0.47	0.45	0.47	0.58	0.56	0.52	0.55	0.58	0.56	0.54	0.56
Mean	0.43	0.41	0.40	0.41	0.50	0.48	0.46	48	0.58	0.56	0.54	0.56	0.59	0.57	0.55	0.56
Factor	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
(D)	0.003		0.01		0.003		0.01		0.003		0.01		0.003		0.01	
(P)	0.003		0.01		0.003		0.01		0.003		0.01		0.003		0.01	
Interaction (D x P)	0.006		NS		0.006		NS		0.006		NS		0.006		NS	

Drying methods: D_1: Sun drying D_2: Solar drying D_3: Tray drying
Packaging materials: P_1: LDPE P_2: HDPE P_3: Aluminium foil pouch

Ascorbic acid content (mg/100g)

The data pertaining to the ascorbic acid content of the tender jackfruit powder recorded at 30 days intervals after packing and storage in ambient conditions were presented in table 4

From the data, it was observed that drying methods significantly influenced the ascorbic acid content of tender jackfruit powder. Tray dried tender jackfruit powder (D_3) recorded the maximum ascorbic acid content *i.e.*, 7.29, 6.85, 5.58 and 5.57 mg/100g on initial, 30th, 60th and 90th day of storage respectively where as the sun dried tender jackfruit powder (D_1) recorded the minimum ascorbic acid content *i.e.*, 5.88, 5.55, 4.78, 4.57 mg/100g on initial day, 30th, 60th and 90th day of storage respectively.

The results indicated that ascorbic acid content was significantly influenced by packaging material up to 90th day of storage period. Tender jackfruit powder packed in aluminium foil pouch (P_3) recorded the maximum ascorbic acid content *i.e.*, 6.86, 6.44, 5.34 and 5.27 mg/100g on initial, 30th, 60th and 90th day of storage respectively. Tender jackfruit powder packed in LDPE (P_1) recorded minimum ascorbic acid content *i.e.*, 6.36, 6.00, 4.99 and 4.91 mg/100g on initial, 30th, 60th and 90th day of storage respectively.

It was evident from the data that there was no significant difference in the interaction (D x P) on ascorbic acid content

of tender jackfruit powder from 30th day to 90th day of storage period. Tray dried tender jackfruit powder packed in aluminium foil pouch (D_3P_3) recorded the maximum ascorbic acid content *i.e.,* 7.53, 6.93, 5.84 and 5.83 mg/100g was recorded on initial, 30th, 60th and 90th day of storage respectively whereas sun dried tender jackfruit powder packed in LDPE (D_1P_1) recorded the minimum ascorbic acid content *i.e.,* 5.69, 5.43, 4.67 and 4.43 was recorded on initial, 30th, 60th and 90th day of storage respectively.

The ascorbic acid content decreased steadily during the storage might be due to the oxidation of L- ascorbic acid into dehydroascorbic acid. The maximum ascorbic acid content was recorded by tray dried tender jackfruit powder (D_1) when compared to other drying methods (Naikwade 2014) [8]. Tender jackfruit powder packed in aluminium foil pouch recorded the maximum ascorbic acid content (P_3) which might be due lower rate of oxidation process (Hymavathi and Kader 2014) [9].

Table 4: Effect of drying methods and packaging material on ascorbic acid content (mg/100 g) of tender jackfruit powder during storage

Drying methods (D)	Packaging materials (P)															
	Days of storage															
	Initial ('0' day)				30th day of storage				60th day of storage				90th day of storage			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
D_1	5.69	5.83	6.12	5.88	5.43	5.51	5.72	5.55	4.67	4.71	4.96	4.78	4.43	4.51	4.76	4.57
D_2	6.32	6.69	6.92	6.64	5.83	6.27	6.68	6.26	5.07	5.19	5.21	5.15	5.07	5.19	5.21	5.14
D_3	7.06	7.29	7.53	7.29	6.73	6.88	6.93	6.85	5.24	5.67	5.84	5.58	5.24	5.67	5.83	5.57
Mean	6.36	6.60	6.86	6.60	6.00	6.22	6.44	6.22	4.99	5.19	5.34	5.17	4.91	5.12	5.27	5.10
Factor	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
(D)	0.059		0.175		0.055		0.165		0.031		0.093		0.031		0.093	
(P)	0.059		0.175		0.055		0.165		0.031		0.093		0.031		0.093	
Interaction (D x P)	0.101		NS		0.096		0.286		0.054		0.161		0.054		0.161	

Drying methods: D_1: Sun drying D_2: Solar drying D_3: Tray drying
Packaging materials: P_1: LDPE P_2: HDPE P_3: Aluminium foil pouch

Protein content (%)

The data pertaining to the protein content of the tender jackfruit powder recorded at 30 days intervals after packing and storage in ambient conditions were presented in table 5.

From the data, it was observed that drying methods significantly influenced the protein content of tender jackfruit powder. Tray dried tender jackfruit powder (D_3) recorded the maximum protein content *i.e.,* 3.29, 3.18, 3.07, 2.96% on initial, 30th, 60th and 90th day of storage respectively where as the sun dried tender jackfruit powder (D_1) recorded the minimum protein content *i.e.,* 2.31, 2.16, 1.97, and 1.88% on initial day, 30th, 60th and 90th day of storage respectively.

The results indicated that protein content was significantly influenced by packaging material up to 90th day of storage period. Tender jackfruit powder packed in aluminium foil pouch (P_3) recorded the maximum protein content *i.e.,* 2.98, 2.85, 2.68 and 2.58% on initial, 30th, 60th and 90th day of storage respectively. Tender jackfruit powder packed in LDPE (P_1) recorded minimum protein content *i.e.,* 2.73, 2.63, 2.45 and 2.35% on initial, 30th, 60th and 90th day of storage respectively.

It was evident from the data that there was a significant difference in the interaction (D x P) on protein content of tender jackfruit powder up to 90th day of storage. Tray dried tender jackfruit powder packed in aluminium foil pouch (D_3P_3) recorded the maximum protein content *i.e.,* 3.38, 3.22, 3.16 and 3.04% on initial, 30th, 60th and 90th day of storage respectively whereas sun dried tender jackfruit powder packed in LDPE (D_1P_1) recorded the minimum protein content *i.e.,* 2.13, 1.98, 1.83 and 1.72% was recorded on initial, 30th, 60th and 90th day of storage respectively.

The protein content decreased steadily during the storage. The maximum protein content was recorded by tray dried tender jackfruit powder (D_1) when compared to other drying methods (Sarker *et al.,* 2014) [6]. Tender jackfruit powder packed in aluminium foil pouch recorded the maximum protein content (P_3) due to differential permeability of packaging material (Pavani and Priyanka 2018) [10].

Table 5: Effect of drying methods and packaging material on protein content (%) of tender jackfruit powder during storage

Drying methods (D)	Packaging materials (P)															
	Days of storage															
	Initial ('0' day)				30th day of storage				60th day of storage				90th day of storage			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
D_1	2.13 (1.77)	2.25 (1.80)	2.55 (1.88)	2.31 (1.82)	1.98 (1.73)	2.08 (1.76)	2.43 (1.85)	2.16 (1.78)	1.83 (1.68)	1.94 (1.72)	2.14 (1.77)	1.97 (1.72)	1.72 (1.65)	1.84 (1.69)	2.07 (1.75)	1.88 (1.70)
D_2	2.86 (1.97)	2.97 (1.99)	3.02 (2.01)	2.95 (1.99)	2.77 (1.94)	2.76 (1.94)	2.89 (1.97)	2.80 (1.95)	2.53 (1.88)	2.49 (1.87)	2.74 (1.93)	2.59 (1.89)	2.44 (1.86)	2.32 (1.82)	2.62 (1.90)	2.46 (1.86)
D_3	3.19 (2.05)	3.29 (2.07)	3.38 (2.09)	3.29 (2.07)	3.14 (2.04)	3.17 (2.04)	3.22 (2.06)	3.18 (2.04)	2.98 (2.00)	3.07 (2.02)	3.16 (2.04)	3.07 (2.02)	2.89 (1.97)	2.96 (1.99)	3.04 (2.01)	2.96 (1.99)
Mean	2.73 (1.93)	2.84 (1.95)	2.98 (1.99)	2.85 (1.96)	2.63 (1.90)	2.67 (1.91)	2.85 (1.96)	2.71 (1.92)	2.45 (1.65)	2.50 (1.87)	2.68 (1.92)	2.54 (1.88)	2.35 (1.83)	2.37 (1.83)	2.58 (1.89)	2.43 (1.85)
Factor	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
(D)	0.006		0.019		0.006		0.019		0.004		0.012		0.006		0.017	
(P)	0.006		0.019		0.006		0.019		0.004		0.012		0.006		0.017	
Interaction (D x P)	0.011		0.033		0.011		0.032		0.007		0.021		0.01		0.03	

Drying methods: D_1: Sun drying D_2: Solar drying D_3: Tray drying
Packaging materials: P_1: LDPE P_2: HDPE P_3: Aluminium foil pouch

Fibre content (%)

The data pertaining to the fibre content of the tender jackfruit powder recorded at 30 days intervals after packing and storage in ambient conditions were presented in table 6.

From the data, it was observed that drying methods significantly influenced the fibre content of tender jackfruit powder. Tray dried tender jackfruit powder (D_3) recorded the maximum fibre content *i.e.,* 2.47, 2.42, 2.36 and 2.24% on initial, 30th, 60th and 90th day of storage respectively whereas the sun dried tender jackfruit powder (D_1) recorded the minimum fibre content *i.e.,* 2.25, 2.21, 2.15 and 2.04% on initial day, 30th, 60th and 90th day of storage respectively.

The results indicated that fibre content was not significantly influenced by packaging material up to 90th day of storage period. Tender jackfruit powder packed in aluminium foil pouch (P_3) recorded the maximum fibre content *i.e.,* 2.38, 2.33, 2.28 and 2.49% on initial, 30th, 60th and 90th day of storage respectively. Tender jackfruit powder packed in LDPE (P_2) recorded minimum fibre content *i.e.,* 2.33, 2.28, 2.22 and 2.09% on initial, 30th, 60th and 90th day of storage respectively.

It was evident from the data that there was no significant difference in the interaction (D x P) on fibre content of tender jackfruit powder up to 90th day of storage. Tray dried tender jackfruit powder packed in aluminium foil pouch (D_3P_3) recorded the maximum fibre content *i.e.,* 2.50, 2.44, 2.40 and 2.27% on initial, 30th, 60th and 90th day of storage respectively whereas sun dried tender jackfruit powder packed in LDPE (D_1P_1) recorded the minimum fibre content *i.e.,* 2.21, 2.17, 2.12 and 1.99% was recorded on initial, 30th, 60th and 90th day of storage respectively.

The fibre content decreased steadily during the storage. The maximum fibre content was recorded by tray dried tender jackfruit powder (D_1) when compared to other drying methods (Gupta and Sukhla 2017) [11]. Tender jackfruit powder packed in aluminium foil pouch recorded the maximum fibre content (P_3) due to differential permeability of packaging material (Pavani and Priyanka 2018) [10].

Table 6: Effect of drying methods and packaging material on fibre content (%) of tender jackfruit powder during storage

Drying methods (D)	Packaging materials (P)															
	Days of storage															
	Initial ('0' day)				30th day of storage				60th day of storage				90th day of storage			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
D_1	2.21 (1.79)	2.27 (1.81)	2.28 (1.81)	2.25 (1.80)	2.17 (1.78)	2.22 (1.79)	2.24 (1.80)	2.21 (1.79)	2.12 (1.77)	2.16 (1.78)	2.18 (1.78)	2.15 (1.78)	1.99 (1.73)	2.05 (1.75)	2.08 (1.74)	2.04 (1.73)
D_2	2.32 (1.82)	2.34 (1.83)	2.36 (1.83)	2.34 (1.83)	2.27 (1.81)	2.29 (1.82)	2.31 (1.82)	2.29 (1.82)	2.21 (1.79)	2.24 (1.80)	2.25 (1.80)	2.24 (1.80)	2.09 (1.76)	2.11 (1.76)	2.13 (1.77)	2.11 (1.76)
D_3	2.45 (1.86)	2.47 (1.86)	2.50 (1.87)	2.47 (1.86)	2.40 (1.84)	2.42 (1.85)	2.44 (1.86)	2.42 (1.85)	2.33 (1.83)	2.35 (1.83)	2.40 (1.84)	2.36 (1.83)	2.20 (1.79)	2.24 (1.80)	2.27 (1.81)	2.24 (1.80)
Mean	2.33 (1.82)	2.36 (1.83)	2.38 (1.84)	2.35 (1.83)	2.28 (1.81)	2.31 (1.82)	2.33 (1.83)	2.32 (1.82)	2.22 (1.80)	2.25 (1.80)	2.28 (1.81)	2.25 (1.80)	2.09 (1.76)	2.13 (1.77)	2.49 (1.78)	2.24 (1.76)
Factor	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
(D)	0.006		0.017		0.004		0.011		0.005		0.016		0.005		0.016	
(P)	0.006		NS		0.004		NS		0.005		NS		0.005		NS	
Interaction (D x P)	0.01		NS		0.007		NS		0.009		NS		0.009		NS	

Drying methods: D_1: Sun drying D_2: Solar drying D_3: Tray drying

Packaging materials: P_1: LDPE P_2: HDPE P_3: Aluminium foil pouch

Ash content (%)

The data pertaining to the ash content of the tender jackfruit powder recorded at 30 days intervals after packing and storage in ambient conditions were presented in table 7.

From the data, it was observed that drying methods significantly influenced the ash content of tender jackfruit powder. Tray dried tender jackfruit powder (D_3) recorded the maximum ash content *i.e.,* 1.44, 1.36, 1.30 and 1.26% on initial, 30th, 60th and 90th day of storage respectively where as the sun dried tender jackfruit powder (D_1) recorded the minimum ash content *i.e.,* 1.26, 1.20, 1.14 and 1.05% on initial day, 30th, 60th and 90th day of storage respectively.

The results indicated that ash content was significantly influenced by packaging material up to 90th day of storage period. Tender jackfruit powder packed in aluminium foil pouch (P_3) recorded the maximum ash content *i.e.,* 1.40, 1.35, 1.26 and 1.20% on initial, 30th, 60th and 90th day of storage respectively. Tender jackfruit powder packed in LDPE (P_1) recorded minimum ash content *i.e.,* 1.32, 1.23, 1.18 and 1.12% on initial, 30th, 60th and 90th day of storage respectively.

It was evident from the data that there was no significant difference in the interaction (D x P) on ash content of tender jackfruit powder up to 90th day of storage. Tray dried tender jackfruit powder packed in aluminium foil pouch (D_3P_3) recorded the maximum ash content *i.e.,* 1.49, 1.43, 1.34 and 1.29 on initial, 30th, 60th and 90th day of storage respectively whereas sun dried tender jackfruit powder packed in LDPE (D_1P_1) recorded the minimum ash content *i.e.,* 1.23, 1.17, 1.11 and 1.01% was recorded on initial, 30th, 60th and 90th day of storage respectively.

The ash content was decreased steadily during the storage, this might be due to increase in moisture content during storage. The maximum ash content was recorded by tray dried tender jackfruit powder (D_1) when compared to other drying methods (Gupta and Sukhla 2017) [11]. Tender jackfruit powder packed in aluminium foil pouch recorded the maximum ash content (P_3) due to differential permeability of packaging material to water vapour (Ashura *et al.,* 2021) [12].

Table 7: Effect of drying methods and packaging material on ash content (%) of tender jackfruit powder during storage

Drying methods (D)	Packaging materials (P)															
	Days of storage															
	Initial ('0' day)				30th day of storage				60th day of storage				90th day of storage			
	P1	P2	P3	Mean	P1	P2	P3	Mean	P1	P2	P3	Mean	P1	P2	P3	Mean
D1	1.23 (1.49)	1.27 (1.51)	1.28 (1.51)	1.26 (1.50)	1.17 (1.47)	1.21 (1.49)	1.24 (1.50)	1.20 (1.48)	1.11 (1.45)	1.14 (1.46)	1.17 (1.47)	1.14 (1.46)	1.01 (1.42)	1.05 (1.43)	1.08 (1.44)	1.05 (1.43)
D2	1.33 (1.53)	1.36 (1.54)	1.42 (1.56)	1.37 (1.54)	1.26 (1.50)	1.26 (1.50)	1.37 (1.54)	1.30 (1.52)	1.19 (1.48)	1.21 (1.49)	1.28 (1.51)	1.22 (1.49)	1.12 (1.46)	1.16 (1.47)	1.23 (1.49)	1.17 (1.47)
D3	1.39 (1.55)	1.44 (1.56)	1.49 (1.58)	1.44 (1.56)	1.27 (1.51)	1.38 (1.54)	1.43 (1.56)	1.36 (1.54)	1.25 (1.50)	1.31 (1.52)	1.34 (1.53)	1.30 (1.52)	1.22 (1.49)	1.26 (1.50)	1.29 (1.51)	1.26 (1.50)
Mean	1.32 (1.52)	1.36 (1.54)	1.40 (1.55)	1.36 (1.53)	1.23 (1.49)	1.28 (1.51)	1.35 (1.53)	1.29 (1.51)	1.18 (1.48)	1.22 (1.49)	1.26 (1.50)	1.22 (1.49)	1.12 (1.46)	1.16 (1.47)	1.20 (1.48)	1.16 (1.47)
Factor	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
(D)	0.004		0.012		0.003		0.009		0.003		0.009		0.003		0.01	
(P)	0.004		0.012		0.003		0.009		0.003		0.009		0.003		0.01	
Interaction (D x P)	0.007		NS		0.005		0.014		0.005		NS		0.006		NS	

Drying methods: D_1: Sun drying D_2: Solar drying D_3: Tray drying
Packaging materials: P_1: LDPE P_2: HDPE P_3: Aluminium foil pouch

Conclusion

Results of this study revealed that the moisture content (%) and water activity (a_w) followed a increasing trend whereas ascorbic acid content (mg/100 g), protein content (%), fibre content (%) and ash content (%) followed a decreasing trend from the day of storage to 90 days after storage. The present experimental study was focused on investigating the effect of drying techniques and packaging materialon shelf life of tender jackfruit powder. Among different drying methods, tray drying and different packaging materials aluminium foil pouch found superior for maximum retention of physic-chemical parameters.

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