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Studies on storage stability of different coloured Jackfruit flakes for quality traits

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Abstract
A multi-target or combination preservation technique of freshly cut Jackfruit flakes was done by osmo-balancing the ripe flakes by using osmotic solution of 68.9 º Brix sugar syrup concentration with a immersion time of 180.6 min. The percentage of ash ranged from 2.87% to 6.43% among the eight treated genotypes. The TSS value of the eight genotypes ranged from 21.17 to 32.5º Brix. The L value ranged from +51.45 to +61.67, a value ranged from +10.16 to +25.12, b value ranged +31.77 to +39.69. Changes in pH and the moisture content revealed that the treatments such as T2PP, T4PP and T7PP with polypropylene pouches and similarly the treatments such as T2AP, T4AP and T7AP with aluminium pouches were better packaging material for storage of pre-treated Jackfruit flakes both at ambient and 4 °C temperatures conditions. Similarly organoleptic evaluation and the self-life revealed that the osmotic dewatered flakes storage duration can be increased up to 78 hrs in ambient temperature, when packed in polypropylene pouches. Whereas, the shelf life was only up to 42hrs when packed in aluminium pouches. But the storage of osmotic dewatered flakes at the 4 °C, self-life can be increased up to 25 days in polypropylene pouches and 16 days in aluminium pouches.

Keywords: Indian mustard, path coefficient analysis

Introduction
Jackfruit (*Artocarpus heterophyllus* Lam.) is an evergreen tropical tree species, grown wild in tropical rain forests of Western Ghats. It belongs to the family Moraceae and is the biggest tree borne edible fruit in the world. The jackfruit has spread from heavy rainfall zone to hot dry climates in plains of Karnataka, Tamil Nadu and Andhra Pradesh. It is commonly grown in South Asian countries such as India, Malaysia, Thailand, Vietnam, and China, as well as in Brazil and Queensland. In India it is widely grown in Southern, Eastern, and North-Eastern states. The cross pollinated nature of the crop has led to huge diversity. The largest tree-borne fruit is produced by an evergreen, monoecious tree that produces latex. The tree will have a canopy diameter of 3.5-7.0 m and a height of 8-25 m when it is 10-25 years old. The leathery, glossy, deep green leaves are oblong, oval, or elliptic in shape and measure 4-25 cm long and 2-12 cm wide. Jackfruit is a multiple fruit, botanically known as sorosis, that develops from the modification of pistillate flowers. The pulp of the fruit is made from the perianth of individual flowers. Fruits can be found on the main trunk, mature branches, and at the tree's base. It usually weighs between 0.5 to 80 kg and is made up of both edible (pulp and seed) and non-edible (rind and skin) parts. Jackfruit has two different textures when it is ripe: soft fleshed (Ambali or Ghila), with a soft and pulpy perianth, and firm fleshed (Bakke, Khaja, or Karcha), with a hard, thick, and highly fleshy perianth. Dorosha is another kind that has the characteristics of both ghila and khaja (Naik, 1949; Sturrock, 1959; Rahman *et al*., 1999) [8, 14, 10].

Jackfruit (*Artocarpus heterophyllus* L.) is an aggregate or multiple fruit, like other citrus fruits, it deteriorates quickly after ripening. The fruit contains 35-40% edible (flakes and seeds) portions remaining portion is rind and core. The marketing of whole fruits involves high transportation and packaging costs. The fruit should be marketed in pre-cut form after the bulbs have been separated from the pericarp. Adding value to Jackfruit pulp has resulted in the creation of products such as a fruit bar, fruit leather, and canned juice. The pitted bulbs have also been subjected to blast or cryo-freezing to extend the shelf-life (Chulaki *et al.*, 2017) [5].
Saxena *et al*. (2009) [12] described a process protocol for extending the shelf-life of Jackfruit bulbs by combining minimal processing with modified-atmosphere storage. The minimally processed Jackfruit has a shorter shelf life and is still in a respiratory state. As a result, the product recorded a limited shelf life.

Because of the physiologically active conditions, the shelf life was limited. A multi-target preservation technique or hurdle technology could be used to keep the product viable for more than six months under ambient conditions. The bulbs were firm with no tissue disintegration and an acidic pH, making them ideal for multi-target preservation.

Materials and Methods

The three flake colours of Jackfruit (Yellow, Orange and Red) and a control (cream colour) were subjected to pre-treatment at ripe (fresh) stage. The pre-treated flakes were packed in two types of packaging material and was stored at 4 °C and at ambient temperature, till the flakes deteriorate in quality. The number of days with good shelf life was recorded.

Pre-treatment

It includes Osmotic dewatering, it was done by osmo-balancing the bulbs using osmotic solution of 68.9 ° Brix concentration with an immersion time of 180.6 min (Alok *et al*. 2008) [15].

Main Treatments

It included four types of Jackfruit flake colours (3 coloured flake + 1 cream flake) with pre-treatment and without the pre-treatment (control) and storing at two temperatures such as 4 °C and at ambient temperature.

Sub treatments

It included two types of packaging material such as
PP: Polypropylene pouches
AP: Aluminum pouches

Sample quantity

100gm of each sample per replication was packed after the pre-treatment, in such a way that each coloured flakes contained two different types of genotypes randomly collected from the various regions of Karnataka such as
T1 (PP and AP): Yellow colour flake-1
T2 (PP and AP): Yellow colour flake-2
T3 (PP and AP): Coppery red colour flake-1
T4 (PP and AP): Coppery red colour flake-2
T5 (PP and AP): Orange colour flake-1
T6 (PP and AP): Orange colour flake-2
T7 (PP and AP): Cream colour flake-1
T8 (PP and AP): Cream colour flake-2
TC (PP and AP): Flakes without pre-treatment

Observations recorded for the following quality parameters

a) pH

pH was determined before the pre-treatment i.e for the fresh flakes as well as after the packing of osmotic dewatered flakes in polypropylene pouches (PP) and aluminium pouches (AP) at the regular intervals as follows:

Table 1: Observation recorded during the storage

Temperature condition	Observation recorded			
4 °C (PP+AP)	Before pre-treatment	1st week	3rd week	5th week
27 °C (PP+AP)	Before pre-treatment	1st day	3rd day	5th day

b) Moisture content

The moisture content of each sample was calculated before the pre-treatment i.e osmotic dewatering and it was determined as described by Ranganna (1986) [11] using the formula

$$\% \text{ MC } = \frac{\text{W1} - \text{W2 x 100}}{\text{W1}}$$

Where, W_1 = initial weight of the crucible; W_2 = final weight of sample+ crucible; 100 – constant figure

c) Colour

The instrumental measurement of flake colour was carried out with a Hunter Lab Mini Scan XE Plus colorimeter (HAL, USA, Model 45/0-L). The color was determined in terms of 'L', 'a' and 'b' values by positioning the nose cone in the surface of fruit directly such that the light thrown by the colorimeter is not leaked.
'L' denotes the lightness or darkness.
'a-'denotes greenness while 'a+' for redness.
'b-' denotes blueness while 'b+' for yellowness colour of the samples.

Care was taken to put a "clean" colour part of the flake on the colorimeter diaphragm. The colour was measured in four places of each sample and average values were recorded for the study. Before measuring, the colorimeter was standardized with black and white calibration tiles provided with the instrument.

d) Organoleptic quality

The organoleptic evaluation for assessing sensory attributes of the samples was conducted by a panel of twenty judges. The samples were rated on the 9-point Hedonic Rating Scale (Amerine *et al*., 1965) [1].

Results and Discussion

A multi-target or combination preservation technique has been extensively applied to develop minimally processed as well as completely stabilized shelf-stable fruit products. In the present study, freshly cut Jackfruit flakes were taken and subjected to pre-treatment such as Osmotic Dewatering. It was done by osmo-balancing the bulbs using osmotic solution of 68.9° Brix sugar syrup concentration with an immersion time of 180.6 min. Flakes with higher thickness were used for osmotic dewatering process, after dipping in sugar solution for 180.6 min, excess amount of sugar syrup was removed using the muslin cloth. Then the pre-treated flakes were packed in two types of packaging material such as polypropelene pouches and aluminium pouches and was stored at 4 °C and at ambient temperature, till the flakes deteriorate in quality. Prior to packaging the moisture content, Ash percentage, TSS, pH were estimated and subsequently after the treatment pH, moisture content, shelf days and organoleptic evaluation was carried out and the results of these parameters are given below.

Physico-chemical evaluation

The percentage of ash ranged from 2.87% to 6.43% among

the eight treated genotypes. The TSS value of the eight genotypes ranged from 21.17 to 32.5º Brix. The colour values were also estimated using colorimeter and the values were represented in the form L, a and b. The L represents lightness or darkness, a+ "for redness**,** b+" for yellowness colour of the samples. The L value ranged from +51.45 to +61.67, a value ranged from +10.16 to +25.12, b value ranged +31.77 to +39.69 (Table 1).

Table 2: Physico-chemical properties such as Ash%, TSS, and Lab values

Flake colour	Ash%	TSS	L	a	B
Yellow 1	3.27	23.58	60.67	12.57	36.97
Yellow 2	6.43	21.17	61.67	18.05	38.69
Orange 1	6.02	26.17	34.67	25.12	37.85
Orange 2	3.13	32.50	37.98	22.75	34.50
Coppery red 1	5.75	32.17	42.28	18.95	31.67
Coppery red 2	2.87	25.17	49.94	17.04	31.59
Cream 1	4.03	24.00	55.65	11.24	36.05
Cream2	5.19	26.67	51.45	10.16	31.77
Mean	4.59	26.42	49.28	16.98	34.89
CD @ 5%	1.29	1.81	1.46	1.32	1.43
SEM±	0.13	1.32	1.09	1.11	1.28
CV	2.31	3.11	7.69	8.54	3.44

Flakes with very thick flesh and with no tissue disintegration, along with a relatively lower moisture content can be used for multi-target preservation. In our present study only firm fleshed flake types were used, thus there was no higher percent of moisture content i.e. more than 85% in the studied genotypes. So Moisture content less than 65% can be used widely used for further storage. pH, moisture content and organoleptic evaluation was done at 1, 3, 5 days' interval for those which have been stored at ambient temperature. Whereas readings on pH, moisture content and organoleptic evaluation was taken at 1st, 3rd, 5th week interval for those which was stored at 4 °C.

Changes in pH and moisture content over a period of storage

After the treatment of Jackfruit flakes with multi-target preservation technique, the pH exhibited changes (Table 2). From our present findings, we can see that there was a gradual increase in the pH of the product over a period of storage. When packed in polypropylene pouches and stored at ambient temperature, the initial pH was 5.13 in T1PP, 5.43 in T2PP, 5.13 in T3PP, 5.47 in T4PP, 5.07 in T5PP, 5.00 in T6PP, 5.30 in T7PP and 5.20 in T8PP. Whereas there was a gradual increase in the pH during the storage at ambient temperature (27 °C). Among treatments T2PP showed lesser change in the pH from 5.43 (initial pH) to 5.55 (day 5 pH) followed by the treatment T4PP showed from 5.47 (initial pH) to 5.68 (day 5 pH) and T7PP with 5.30 (initial pH) to 5.41 (day 5 pH) respectively. When packed in aluminium pouches and stored at ambient temperatures (27 °C), among the treatments T2AP showed lesser change in the pH from 5.43(initial pH) to 5.56(day 5 pH) followed by the treatment T4PP showed from 5.47(initial pH) to 5.63(day 5 pH) and T7PP with 5.30(initial pH) to 5.51 (day 5 pH) respectively.

But when the treated flakes were stored at 4 °C in polypropylene pouches, there were a gradual increase in the pH up to 3 weeks of storage, but when the storage period increased up to the 5th week, the pH was also increased. Among treatments T2PP showed lesser change in the pH from 5.45 (pH at 1 week) to 5.56 (pH at week 5) followed by the treatment T4PP showed from 5.45 (pH at 1 week) to 5.68 (pH at week 5) and T7PP with 5.34 (pH at 1 week) to 5.43 (pH at week 5) respectively.

But when the treated flakes were stored at 4 °C in aluminium pouches, among treatments T2AP showed lesser change in the pH from 5.45 (pH at 1 week) to 5.58 (pH at week 5) followed by the treatment T4AP showed from 5.55 (pH at 1 week) to 5.68 (pH at week 5) and T7AP with 5.34 (pH at 1 week) to 5.40 (pH at week 5) respectively.

When packed in polypropylene pouches and stored at ambient temperature, the initial moisture content was 69.40 in T1PP, 68.33 in T2PP, 67.90 in T3PP, 66.83 in T4PP, 68.65 in T5PP, 67.58 in T6PP,68.90 in T7PP and 67.83 in T8P. Whereas there was a gradual increase in the moisture content during the storage at ambient temperature (27 °C). Among treatments, moisture content in T2PP changed from 69.08% (initial) to 71.58% (day 5) followed by the treatment T4PP changed from 66.83% (initial) to 70.08% (day 5) and in the T7PP with 68.90% (initial) to 72.15% (day 5) respectively. But when packed in aluminium pouches and stored at ambient temperature, moisture content in T2AP changed from 65.33%(initial) to 68.58% (day 5) followed by the treatment T4AP changed from 63.83% (initial) to 67.08% (day 5) and in the T7AP with 65.70% (initial) to 68.95% (day 5) respectively.

When packed in polypropylene pouches and stored at 4O C temperature, among treatments, moisture content in T2PP changed from 68.83% (1 week) to 69.58% (5th week) followed by the treatment T4PP changed from 67.33% (initial) to 68.08% (5th week) and in the T7PP with 69.40% (1week) to 70.15% (5th week) respectively. But when packed in aluminium pouches and stored at 4 °C, moisture content in T2AP changed from 65.83% (1week) to 66.58% (5th week) followed by the treatment T4AP changed from 64.33% (1week) to 65.08% (5th week) and in the T7AP with 66.20% (1week) to 66.95% (5th week) respectively.

Table 3: Changes in pH over the period of storage at ambient and 4 °C storage

	Ambient (27 °C)				4 °C		
Treatments	**Initial (pH)**	**Day 1(pH)**	**Day 3(pH)**	**Day 5(pH)**	**pH at 1 week**	**pH at 3rd week**	**pH at 5th week**
T1PP	5.13	5.43	5.54	5.61	5.23	5.38	5.54
T2PP	5.43	5.49	5.50	5.55	5.45	5.50	5.56
T1AP	5.13	5.46	5.51	5.53	5.23	5.41	5.55
T2AP	5.43	5.46	5.53	5.56	5.45	5.51	5.58
T3PP	5.13	5.35	5.52	5.60	5.35	5.52	5.60
T4PP	5.47	5.55	5.65	5.68	5.45	5.55	5.68
T3AP	5.13	5.35	5.41	5.54	5.35	5.52	5.60
T4AP	5.47	5.50	5.54	5.63	5.55	5.65	5.68
T5PP	5.07	5.40	5.51	5.56	5.40	5.50	5.56

T6PP	5.00	5.33	5.53	5.57	5.33	5.49	5.57
T5AP	5.07	5.38	5.41	5.45	5.40	5.49	5.56
T6AP	5.00	5.53	5.60	5.62	5.33	5.51	5.57
T7PP	5.30	5.34	5.39	5.41	5.34	5.36	5.43
T8PP	5.20	5.25	5.29	5.36	5.25	5.30	5.49
T7AP	5.30	5.45	5.48	5.51	5.34	5.37	5.40
T8AP	5.20	5.53	5.55	5.59	5.25	5.31	5.42
TCPP	5.19	5.50	5.70	5.80	5.25	5.30	5.45
TCAP	5.30	5.48	5.65	5.80	5.38	5.51	5.65
Mean	5.219	5.42	5.51	5.63	5.33	5.44	5.56
CD @ 5%	0.192	0.080	0.146	0.239	0.21	0.42	0.31
SEM±	0.063	0.057	0.048	0.079	0.068	0.085	0.091
CV	2.211	1.792	1.557	2.629	1.12	1.45	1.54

Based on the results we could say that the treatments such as T2PP, T4PP and T7PP with polypropylene pouches and similarly the treatments such as T2AP, T4AP and T7AP with aluminium pouches were better packaging material for storage of pre-treated Jackfruit flakes both at ambient and 4 °C temperatures conditions (Table 3).

Increase in acidity coupled with decrease in pH might be due to the addition of acids which increases the acidity and decreases the pH of the produce (Bieganska-Marecik and Czapski, 2007) [4]. Similar observations have been reported by Damasceno *et al*. (2005) [6], Lima *et al*. (2010) [7], and Antoniolli *et al*. (2012) [2] for honey dew melon, guava and pineapple respectively. Various treatment combinations have a significant influence on the activity of polygalacturonase enzyme. An increasing trend was observed in polygalacturonase activity in terms of enzyme activity and specific activity. There is a possible role of ethylene in increasing polygalacturonase activity.

Organoleptic evaluation

Organoleptic evaluation based on sensory method was done at regular intervals to know the overall acceptability of the products. Sensory scores were high at 1st day for those stored at ambient temperatures in polypropylene pouches. Whereas sensory scores were high up to 3rd week when stored at 4 °C. From the findings we can conclude that the osmotic dewatered flakes can be stored up to 3 days at ambient temperature and up to 3 weeks in 4º c conditions (Table 4).

Ashok *et al.* (2021) [3], during minimal processing for short-term preservation of Jackfruit bulbs, sensory quality, *viz.* colour, texture, flavour, and overall acceptability, was studied, and the higher scores were in treatment solutions containing ascorbic acid, citric acid, and calcium chloride, the bulbs were exposed to on the 3rd, 6th, and 9th days' observations. Regarding the sensory quality of the produce, better retention of the sensory score in terms of colour, flavour, taste, texture, and overall acceptability was observed.

Table 4: Changes in moisture content over the period of storage at ambient and 4 °C storage

Treatments	Ambient temperature				4º C temperature		
	Initial (MC)	Day 1(MC)	Day 3(MC)	Day 5(MC)	MC at 1 week	MC at 3rd week	MC at 5th week
T1PP	69.40	70.15	71.40	72.65	69.90	70.15	70.65
T2PP	68.33	69.08	70.33	71.58	68.83	69.08	69.58
T1AP	66.20	66.95	68.20	69.45	66.70	66.95	67.45
T2AP	65.33	66.08	67.33	68.58	65.83	66.08	66.58
T3PP	67.90	68.65	69.90	71.15	68.40	68.65	69.15
T4PP	66.83	67.58	68.83	70.08	67.33	67.58	68.08
T3AP	64.70	65.45	66.70	67.95	65.20	65.45	65.95
T4AP	63.83	64.58	65.83	67.08	64.33	64.58	65.08
T5PP	68.65	69.40	70.65	71.90	69.15	69.40	69.90
T6PP	67.58	68.33	69.58	70.83	68.08	68.33	68.83
T5AP	65.45	66.20	67.45	68.70	65.95	66.20	66.70
T6AP	64.58	65.33	66.58	67.83	65.08	65.33	65.83
T7PP	68.90	69.65	70.90	71.15	69.40	69.65	70.15
T8PP	67.83	68.58	69.83	71.08	68.33	68.58	69.08
T7AP	65.70	66.45	67.70	68.95	66.20	66.45	66.95
T8AP	64.83	65.58	66.83	68.08	65.33	65.58	66.08
TCPP	65.00	69.50	72.00	73.50	65.70	66.90	67.00
TCAP	63.00	65.80	69.70	75.10	63.80	65.40	66.80
Mean	63.33	66.	68.87	70.31	66.86	67.24	67.77
CD @ 5%	2.19	2.25	2.02	2.30	3.03	2.22	2.34
SEM±	2.02	1.58	1.15	1.90	1.43	1.25	1.53
CV	6.02	6.13	6.08	6.21	6.33	6.18	6.24

Shelf life

The shelf life of the osmotic dewatered flakes revealed that the storage duration of the flakes can be increased up to 78 hrs. When packed in polypropylene pouches and stored at ambient temperature, the shelf life was increased up to 78hrs.The treatments such as T7PP recorded a maximum shelf life of 78 hrs and T2PP, T4PP recorded 72hrs respectively. But when treated flakes packed in aluminium pouches and stored at ambient temperature, the shelf life was increased up to 42 hrs. The treatment such as T4AP recorded a shelf life of 42 hr, followed by T2AP (32 hrs) and T7 (30 hrs). But the control treatment recorded a shelf life of 16 hrs.

and 12 hrs. at ambient temperature when packed in PP and AP, respectively (Table 5).

Similarly, when packed in polypropylene pouches and stored at 4 °C temperature, the shelf life was increased up to 25 days. The treatments such as T7PP recorded a maximum shelf life of 25 days and T2PP (23 days), T4PP (21 days). But when treated flakes packed in aluminium pouches and stored at 4 °C temperature, the shelf life was increased up to 16days.The treatment such as T4AP recorded a shelf life of 12 days, T2AP (16 days) and T7 (12 days). But the control treatment recorded a shelf life 6 and 4 days at 4 °C when untreated flakes packed in PP and AP respectively (Table 5).

The observations on various physic chemical and microbial parameters were recorded both prior to storage and at periodic intervals during the study of Influence of pre-treatment on quality and shelf life of fresh cut jack fruit (*Artocarpus heterophyllus* L.) bulbs. Jack fruit bulbs pre-treated with 1% $CaCl_2$ along with 0.25% ascorbic acid registered better in terms of maintaining quality with extended shelf life. The treatment recorded lower PLW, better retention of ascorbic acid, total carotenoids, total antioxidants and lower microbial load at the end of the experiment up to 3 weeks (Prathiba *et al.*, 2019) [16].

Table 5: Influence of pre-treatment on Overall acceptability of fresh Jackfruit flakes in ambient and refrigerated storage

Treatments	Day 1	Day 3	Day 5	1st week	3rd week	5th week
T1PP	9	8	6	9	7	6.5
T2PP	9	8.5	7	9	8	7.5
T1AP	9	6	6	9	7	6.5
T2AP	9	7	6.5	9	8.5	8
T3PP	9	6.5	5.5	9	6.5	6
T4PP	9	8.5	7	9	8	7.5
T3AP	9	6.8	6	8.5	6	5.5
T4AP	9	8	7.0	8.8	6.4	6
T5PP	9	8	6	9	7.5	7
T6PP	9	7.5	6.5	9	7.5	7
T5AP	9	7.5	6	9	6	6
T6AP	9	6.4	6	9	6.5	6
T7PP	9	8	7.5	9	8.5	8
T8PP	9	8	6.5	9	7	6.5
T7AP	9	8.5	8	9	8.5	8
T8AP	9	6.8	5.9	9	6.5	5.9
TCPP	6	5	4.5	7	6	5
TCAP	5	3.5	2	6.5	5	4
Mean	8.61	7.14	6.11	8.71	7.02	6.49

Table 6: Influence of pre-treatment on shelf life of fresh Jackfruit flakes in ambient and refrigerated storage

Treatments	Shelf life (hrs)at ambient temperature	Shelf life (in days) at 4^0 temperatures
T1PP	48	14
T2PP	72	23
T1AP	24	7
T2AP	32	16
T3PP	48	14
T4PP	72	21
T3AP	36	10
T4AP	42	12
T5PP	60	17
T6PP	54	15
T5AP	30	8
T6AP	18	5
T7PP	78	25
T8PP	48	11
T7AP	30	12
T8AP	28	9
TCPP	16	6
TCAP	12	4
Mean	41.55	12.72
CD @ 5%	4.739	1.474
SEM±	1.646	0.512
CV	6.859	6.969

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