International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 20-06-2025, Accepted: 21-07-2025, Published: 05-08-2025
Volume 10, Issue 4, 2025, Page No. 41-46

Preparation of ready-to-cook tender jackfruit chunks using hot air drying

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Abstract
A nutritious and convenient ready-to-cook (RTC) tender jackfruit product was developed by optimizing pretreatments and drying temperatures. Three pretreatments *viz*. 0.3% KMS, 0.3% citric acid and 0.5% salt were given to pre-processed jackfruit chunks for 10 min to prevent enzymatic browning. After pretreatments, the chunks were blanched at 80ºC for 3 minutes in hot water and dried at 50ºC. The dried chunks pretreated with KMS showed more color retention which is further dried at 50ºC, 60ºC and 70ºC (T1, T2 and T3 samples). Processing parameters including cooking time, rehydration ratio, pH, and water activity and proximal analysis were determined for the RTC jackfruit chunks. Texture profile and sensory analysis were also conducted. The results showed that T3 (chunks pretreated with KMS and dried at 70ºC) exhibited most favorable outcomes in terms of color retention, shortest drying time (9h, shortest cooking time (7.5 min), higher rehydration ratio (4.22), lowest water activity (0.43), optimal pH (6.00), soft texture and desirable sensory attributes. The optimal conditions of 0.3% KMS pretreated and 70ºC drying temperature preserved jackfruit's nutritional and textural properties.

Keywords: Tender jackfruit, hot air dryer, Ready-to-cook (RTC), Sensory evaluation

Introduction
Jackfruit (*Artocarpus heterophyllus Lam*) is a tropical fruit belonging to the Moraceae family. It is widely distributed across tropical regions, particularly in Asia, Africa, and South America. It is notably abundant in countries such as India, Bangladesh, Malalaysia, Indonesia, Thailand, Philippines, Sri Lanka, and various Southeast Asian nations (Rajneesh & Anu, 2020) [15]. Often referred to as the "poor man's fruit" due to its widespread availability and nutritional value, jackfruit is a versatile and underutilized fruit with significant potential for value addition. The tree is known for its high productivity, with reports of yielding between 10 to 200 fruits per tree, equating to approximately 25.71 tons per hectare. In India, jackfruit is consumed as a staple for centuries, with diverse culinary and medicinal applications.
Jackfruit is rich in carbohydrates, proteins, vitamins, and minerals, contributing to its high nutrition value. It possesses immune-boosting properties and has demonstrated anti-cancer, anti-ulcer, and anti-hypertension effects, along with protective properties against HIV/AIDS. The fruit is utilized in a variety of products such as beverages, nectar, clarified juice, wine, vinegar, canned products, candied fruit, dehydrated flakes, biscuits, pickles, sweets, jackfruit bulbs and leather. Unripe jackfruit is frequently used in curries and other savory dishes. Despite its potential, jackfruit faces significant postharvest losses due to lack of proper storage facilities and mishandling during harvesting and distribution. The fruit is highly perishable, with a shelf life of only three to ten days depending on maturity, ambient temperature, and relative humidity (Srinivasa, 2019) [17]. This short shelf life, coupled with the seasonal nature of the fruit, often leads to market gluts during peak seasons, resulting in economic losses for growers. Preservation techniques, such as drying, can help extend shelf life of jackfruit and reduce postharvest losses. Drying removes moisture, inhibiting microbial growth, enzymatic activity, and spoilage, thus prolonging the shelf life (Taib *et al.*, 2013) [19].
In Addition to drying, other preservation methods can be employed to process ripe jackfruits into various products such as canned fruit, dried fruit, pulp, jackfruit jam, and chips (Rajneesh & Anu, (2020) [15]. While much research has focused on the preservation of ripe jackfruits, there is limited study on the preservation of unripe or tender jackfruit, which is primarily used as a plant-based meat substitute due to its fibrous texture. This gap in knowledge necessitates research on the preservation of tender jackfruit. The present study aims to explore the preparation of ready-to-cook tender jackfruit chunks using hot air drying, with a focus on color retention, textural properties, proximal composition, and sensory evaluation.

Materials & Methods
1. Raw materials
Raw tender jackfruits *(Artocarpus heterophyllus Lam.)* of the varikka variety were purchased from the Maddilapalem market in Visakhapatnam district, Andhra Pradesh, India. Edible-grade KMS salt, citric acid, table salt, and seasonings were procured from local market in Bapatla, Andhra Pradesh, India.

2. Pretreatments
The tender jackfruits were washed thoroughly to remove dirt and dust. The outer skin was peeled, seeds were removed, and the tender portions were cut into 15-20 mm chunks using knives coated with vegetable oil to prevent sticking. The tender jackfruit chunks were subjected to three different pretreatments in a solution containing 0.3% KMS,

0.3% citric acid, and 0.5% salt for 10 minutes to prevent enzymatic browning as shown in Table1. Subsequently they were blanched in hot water at 80ºC for 3 minutes to inactivate polyphenol oxidase enzymes, which preserved the color and texture of the chunks before drying. The pretreatment with the best color retention was selected for further experiments. The pre-treated chunks were dried in a hot air dryer at 50ºC until completely dried.

Table 1: Pretreatments and treatments for the RTC Jackfruit chunks

S. No	Pre-treatments	Details
1	P1	0.3% KMS
2	P2	0.3% Citric acid
3	P3	0.5% Salt (NaCl)
S. No	**Treatments**	**Details**
1	T0 (Control sample)	Tender chunks without pretreatment and drying
2	T1	Chunks pre-treated with 0.3% KMS & dried at 50ºC
3	T2	Chunks pre-treated with 0.3% KMS & dried at 60ºC
4	T3	Chunks pre-treated with 0.3% KMS & dried at 70ºC

3. Color Measurement

The color of the dried jackfruit chunks was measured using a Hunter Lab colorimeter, calibrated with black and white tiles based on the CIE color space system. Measurements include

L* value: Lightness (0 = black, 100 = white)

a* value: Redness (positive) or greenness (negative)

b* value: Yellowness (positive) or blueness (negative)

4. Preparation of RTC tender jackfruit chunks

The standardized pre-treatment (0.3% KMS) with superior color retention (P1) was used for further trails. The jackfruit chunks were pre-treated and dried at three different temperatures (50, 60 and 70˚C) in a tray dryer as detailed in Table.1. Jackfruit chunks without any pretreatments are taken as control. Figure 1 show various steps involved in preparation of tender jack fruit chunks.

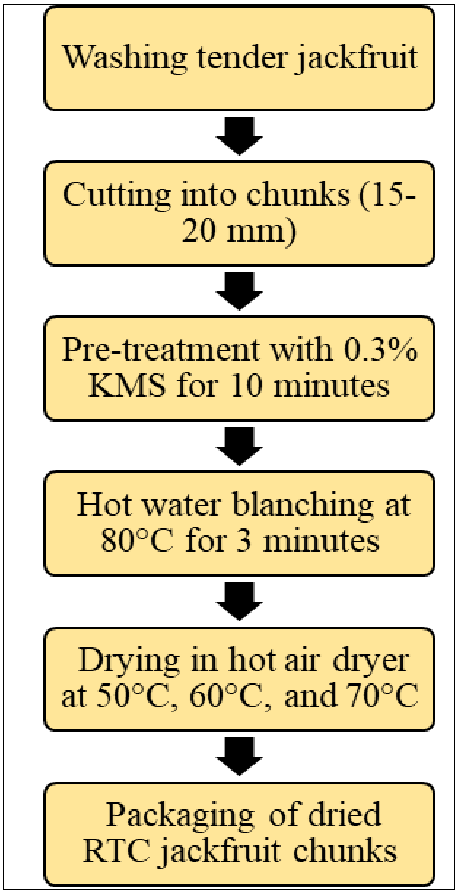

Fig 1: Flow chart for preparation of RTC tender jackfruit chunks

5. Drying kinetics

5.1 Drying time: Samples T1, T2, and T3 were dried in a tray dryer at 50°C, 60°C, and 70°C, respectively and the drying time was recorded.

5.2Moisture ratio: The moisture ratio (MR) was calculated using equation given by Alessandra *et al*., (2020) [2]

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad \ldots \text{(Eq.1)}$$

Where,

MR= Moisture ratio,

M_t = Moisture content at time t,

M_0 = Initial moisture content of the sample,

M_e = equilibrium moisture content.

6. Processing parameters of RTC Jackfruit chunks

6.1 Cooking time: Approximately 10g of each sample was cooked in 200 ml of water until and the cooking time was recorded (Purwandari *et al*., 2014) [13].

6.2 Rehydration ratio: Dried tender jackfruit chunks (4g) were soaked in 75 ml distilled water at 80–100°C for 30 minutes. Rehydration ratio (RR) was calculated using equation given by Mufjar and Lov, (2016) [12].

$$\text{Rehydration ratio (RR)} = \frac{b}{a} \quad \ldots \text{(Eq.2)}$$

Where,

a = weight of rehydrated sample, g

b = weight of dehydrated sample, g

7. Determination of physicochemical composition

PH of the samples was determined using calibrated pH meter. Moisture content, crude fiber and ash content were determined using the methods of AOAC (2000) [4]. Crude protein was determined using method of Raghuramulu *et al*., (2003) [14]. Carbohydrate content was determined using method described by *BeMiller (2010)* [6] .

7.1 Determination of water activity (a_w)

The water activity of the samples was determined using water activity meter (Rotronic Hygrolab C-1). The experiments were conducted in triplicates. The water activity meter is first calibrated at 25ºC room temperature and then the required grinded sample (1-2g) is placed into the cup provided with meter for the measurement of its water activity.

8. Total flavonoid content (TFC) and DPPH assay

Total flavonoid content (TFC) was measured by aluminum chloride method, with absorbance recorded at 415 nm as given by Chang *et al.*, (2002) [8]. Antioxidant activity was assessed using DPPH solution with absorbance recorded at 517nm as given by Brand-Williams *et al.*, (1995) [7].

9. Texture analysis

Rehydrated chunks were analyzed using texture analyzer consisting of cylindrical probe with a 75 mm base diameter, spaced by an interval of 5 seconds between cycles and the compression distance of 5mm. The texture attributes such as hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience were calculated from the graphs. (Babji *et al.*, 1993) [5].

10 Sensory evaluation

The sensory attributes were performed based on the procedure of Ranganna, 1996 [16]. Jackfruit 65 was prepared as showed in Figure 2, and sensory attributes (appearance, texture, aroma, taste) were evaluated by 15 panelists using a 9-point hedonic scale, i.e. 9= like extremely, 8= like very much, 7= like moderately, 6= like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much, 1= Dislike extremely.

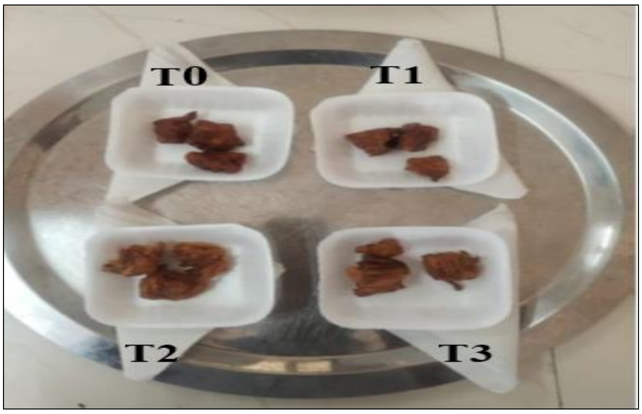

Fig 2: Jackfruit 65

11. Statistical analysis

Data obtained for each analysis were expressed in triplicates ± standard deviation. Data were analyzed by one-way ANOVA in Minitab Statistical software (v21.4.1). The significance was defined at the 95% confidence level.

Results and discussions

1. Effect of pre-treatment on color retention of jackfruit chunks:

The color attributes of jackfruit chunks were measured in terms of L* (lightness), a* (red-green), and b* (yellow-blue) values as shown in table 2. The L* values varied from 60.59±0.82 to 77.56±1.86, while the a* values ranged from 11.05±0.61 to 13.43±3, and b* values ranged from 15.66±1.42 to 20.79±4.92 (Table 2). P1 exhibited the highest L* value (77.56), indicating superior lightness compared to P2 (61.61) and P3 (60.59). No significant differences were observed in a* and b* values among the samples. The higher L* value of P1 suggests it is most suitable for hot air drying to prepare ready-to-cook (RTC) jackfruit chunks. These results align with findings by *Khan et al., 2021* [10].

Table 2: Color values of pretreated & dried RTC jackfruit chunks

Samples	L*	a*	b*
P1	77.56±1.86[a]	13.43±3[a]	20.79±4.92[a]
P2	61.61±1.06[b]	13.24±1.11[a]	20.87±1.88[a]
P3	60.59±0.82[b]	11.05±0.61[a]	15.66±1.42[a]

All values are means of triplicate determinations ± standard deviation (SD). Means within columns with different letters a, b, c, d indicates significant result at $p<0.05$.

2. Drying kinetics

2.1 Drying time: The drying times varied with temperature. T1(50°C) required 15 hours, T2 (60°C) took 11 hours, and T3 (70°C) dried within 9 hours as shown in Figure.4. The results of drying time are in agreement with Abraham *et al.*, (2004) [1].

2.2 Moisture ratio: Moisture ratio decreased with rising temperature and shorter drying time. T1, T2, and T3 exhibited progressively lower moisture ratios, with T3 showing the most efficient moisture removal (Figure 3). The findings suggest that higher temperatures effectively reduce moisture, which is essential for shelf stability. Similar observations were reported by *Abraham et al. (2004)* [1].

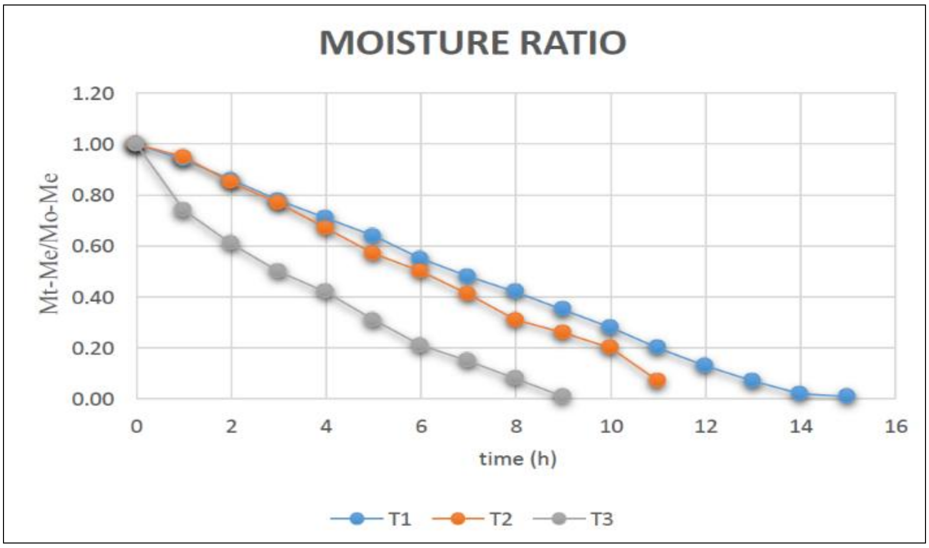

Fig 3: Moisture ratio of the dried RTC jackfruit chunks

3. Processing parameters of RTC Jackfruit chunks

3.1 Cooking time

Cooking time ranged from 7.5±0.6 minutes (T3) to 11.6±0.3 minutes (T1). Sample T3 exhibited the shortest cooking time, attributed to its reduced drying time and porous structure as shown in table 3. This observation aligns with Elamin (2014) [9].

3.2 Rehydration ratio

Rehydration ratios varied from 3.82±0.05 to 4.22±0.27, with T3 showing the highest rehydration ratio (4.22) as shown in table 3. The increased porosity of T3 due to higher drying temperatures facilitated water absorption during rehydration. These findings are in consistent with Elamin (2014) [9].

Table 3: Cooking time and rehydration ratio of dehydrated jack fruit samples

Samples	Cooking time (min)	Rehydration Ratio
T0	9.10±0.10^{b}	-
T1	11.6±0.3^{a}	3.82±0.05^{a}
T2	8.3±0.3^{bc}	4.00±0.15^{a}
T3	7.5±0.6^{c}	4.22±0.27^{a}

All values are means of triplicate determinations ± standard deviation (SD). Means within columns with different letters a, b, c, d indicates significant result at p<0.05.

4. Physicochemical composition of RTC jackfruit chunks

4.1 pH, water activity, moisture content and crude fiber

The pH ranged from 6.00±0.01 (T3) to 6.50±0.17 (T0), with T3 showing the lowest value (Table 5). The reduction in pH with increasing drying temperature is attributed to thermal degradation of organic acids. Similar trends were reported by *Khan et al. (2021)* [10].

Water activity decreased from 0.98±0.01 (T0) to 0.43±0.02 (T3) (Table 4). The significant reduction in water activity with higher drying temperatures indicates improved stability and reduced susceptibility to spoilage. These results corroborate findings by *Khan et al. (2021)* [10].

Moisture content ranged from 10.49±0.13% (T3) to 81.57±0.95% (T0) (Table 4). The significant reduction in moisture content with increasing drying temperatures ensures better shelf life. T3 (70°C, 9 hours) was the most effective condition. Similar trends were reported by *Elamin et al. (2014)* [9].

Crude fiber content increased from 3.09±0.23% (T0) to 4.94±0.22% (T3) (Table 4). Higher drying temperatures and shorter drying times resulted in higher fiber concentration due to more moisture removal. Similar results were observed by Galvez *et al.*, (2014).

4.2 Crude protein, fat content, ash content and carbohydrate content

Crude protein content decreased from 2.89±0.03% (T0) to 2.38±0.03% (T3) (Table 4). The reduction is attributed to protein denaturation during drying, with minimal variations among samples. Haruna *et al.* (2018) [11] reported similar findings. Crude fat content decreased from 0.41±0.02% (T0) to 0.21±0.01% (T3) (Table 4). The reduction in fat content is due to lipid volatilization at higher temperatures. Similar observations were made by Stewart *et al.* (2003) [18]. Ash content increased from 0.67±0.21% (T0) to 1.77±0.31% (T3) (Table 4). The increase is attributed to mineral concentration due to moisture removal. Haruna *et al.* (2018) [11] noted similar results. The carbohydrate content of the samples ranged from 13.03±0.92% to 78.75±0.92% (Table 4). Among the treatments, T1 exhibited the highest carbohydrate content (75.67±1.29%), followed by T2 (75.09±0.61%) and T3 (73.12±0.64%). Statistical analysis showed no significant difference between T1 and T2, whereas T3 was significantly different from both. T0 (control) had the lowest carbohydrate content and was significantly different from all other treatments. The observed decline in carbohydrate content from T1 to T3 can be attributed to the breakdown of starches and other carbohydrates during the drying process, particularly at higher temperatures. This finding aligns with previous research by Haruna *et al.* (2018) [11].

Table 4: Quality and nutritional composition of RTC jack fruit chunks

Samples	pH	aw	Moisture%	Crude fiber %	Crude protein %	Fat content %	Ash %	Carbohydrates %
T0 (Control)	6.5±0.17^{a}	0.98±0.01^{a}	81.57±0.95^{a}	3.09±0.23^{c}	2.89±0.03^{a}	0.41±0.02^{a}	0.67±0.21^{b}	13.03±0.92^{c}
T1	6.14±0.03^{b}	0.52±0.03^{b}	12.15±0.11^{b}	3.90±011^{b}	2.66±0.10^{b}	0.36±0.01^{ab}	1.37±0.31^{a}	75.67±1.29^{a}
T2	6.08±0.02^{b}	0.46±0.02^{c}	11.31±0.55^{bc}	4.25±0.13^{b}	2.55±0.03^{b}	0.31±0.04^{c}	1.47±0.21^{a}	75.09±0.61^{ab}
T3	6.00±0.01^{b}	0.43±0.02^{c}	10.49±0.13^{c}	4.94±0.22^{a}	2.38±0.03^{c}	0.21±0.01^{c}	1.77±0.31^{a}	73.12±0.64^{b}

All values are means of triplicate determinations ± standard deviation (SD). Means within columns with different letters a, b, c, d indicates significant result at p<0.05.

4.2 Total flavonoid content (TFC) and DPPH assay

The TFC of the samples varied from 39.37±2.44 μg/rutin eq to 143±0.82 μg/rutin eq (Figure 5). T0 exhibited the highest mean flavonoid content (143.00±0.82 μg/rutin eq) and was significantly different from all other treatments. T1, T2, and T3 demonstrated progressively lower TFC values of 70.97±2.59, 54.75±2.46, and 39.37±2.44 μg/rutin eq, respectively. The significant decrease in TFC with increasing drying temperatures is attributed to the degradation of flavonoid compounds, which are sensitive to heat, oxygen, and water. These results are consistent with findings by *Tagou et al. (2017).*

The antioxidant activity of the samples determined by DPPH assay ranged from 21.93±0.25% to 38.63±0.83% (Figure. 4). T0 showed the highest antioxidant activity (38.63±0.83%) and was significantly different from all other treatments. T1, T2, and T3 exhibited lower activities of 21.93±0.25%, 20.93±0.21%, and 19.03±0.32%, respectively. The decline in antioxidant activity with increasing temperature can be attributed to the degradation of bioactive compounds such as flavonoids and phenolic acids. This trend corroborates the results of *Alessandra Fratinni et al. (2020)* [2].

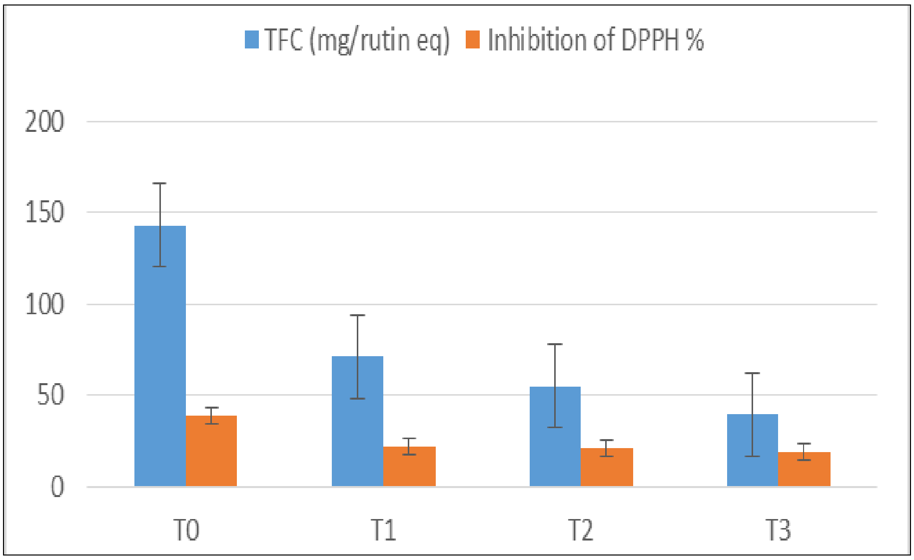

Fig 4: TFC and DPPH of the RTC jackfruit chunks

4.3 Color measurement of RTC jackfruit chunks

Color parameters (L*, a*, b*) of RTC jackfruit chunks are shown in Figure 5. Lightness (L*) values ranged from 65.37±1.44 to 72.43±0.65, with T0 and T3 showing the highest lightness and no significant difference between them. Redness (a*) values were higher for T1, T2, and T3 compared to T0, with no significant differences among the three treatments. T0 exhibited the highest yellowness (b* value of 17.47±0.91), which was significantly different from other samples. T3 demonstrated improved color retention among the treatments, indicating better preservation of visual quality. These results are in consistent with Elamin *(*2014) [9].

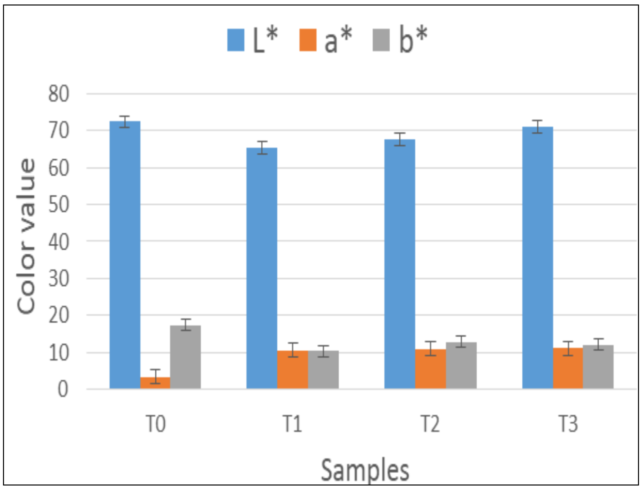

Fig 5: Color values of RTC jackfruit chunks

4.4 Texture profile analysis (TPA)

The TPA results for rehydrated jackfruit chunks are presented in Table 5. T1 exhibited the highest hardness (68.16 N), gumminess (46.20 N/cm²), and chewiness (39.86 N/cm), indicating a firmer texture. Conversely, T3 showed the lowest hardness (65.09 N) and chewiness (21.98 N/cm) and higher fracturability (14.32 N), suggesting a softer and more desirable texture. Additionally, T3 had the highest springiness (0.86 cm), indicating a better ability to return to its original shape after compression. These findings align with the results of Galvez *et al.* (2014).

Table 5: Texture profile of RTC jackfruit chunks

Parameter	Samples			
	T0	T1	T2	T3
Hardness (N)	51.93	68.16	66.78	65.09
Fracturability (N)	15.52	11.67	12.29	14.32
Adhesiveness (cm)	-0.54	-0.92	-0.86	-0.68
Springiness (cm)	0.82	0.82	0.84	0.86
Cohesiveness (cm)	0.83	0.60	0.64	0.58
Gumminess (N/cm^2)	43.25	46.20	45.33	42.39
Chewiness (N/cm)	20.03	39.86	26.57	21.98
Resilience (N/cm)	0.51	0.315	0.32	0.25

5. Sensory analysis

Sensory evaluation results (Figure. 6) showed that T3 had the highest overall acceptability (7.6), followed by T2 (7.4). T3 scored the highest across color, appearance, texture, and making it the most preferred sample. T1 received the lowest scores due to its higher hardness and chewiness, which were less desirable. The hedonic scale ratings align with the superior texture and color retention properties observed in T3.

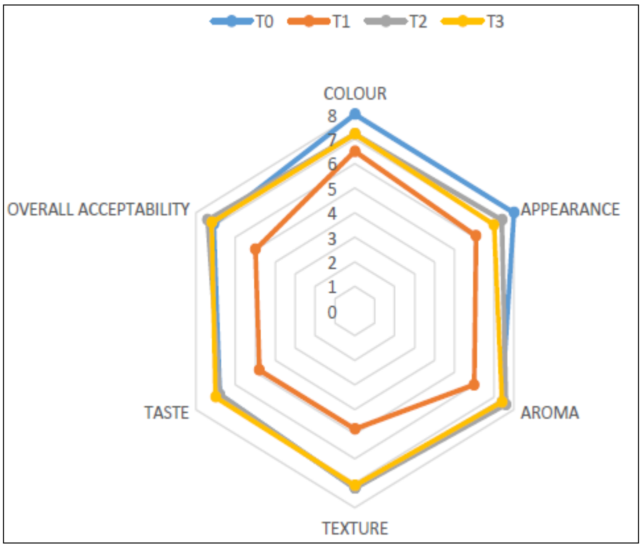

Fig 6: Graphical representation of sensory evaluation of RTC jackfruit chunks

Conclusions

The results revealed that the optimal treatment involved pre-treating with 0.3% KMS and drying at 70ºC (i.e., T3) showed superior quality attributes of jack fruit chunks. The dried jackfruit chunks of T3 sample exhibited optimal processing parameters such as water activity, pH, rehydration ratio, cooking time. Additionally, T3 showed excellent color retention and a favorable texture profile, characterized by lower hardness, chewiness, and adhesiveness. Sensory evaluation confirmed T3 as the most acceptable sample after T2, with the optimal scores for color, appearance, texture, taste, and overall acceptability (7.6). These results indicate that tender jackfruit chunks pre-treated with 0.3% KMS and dried at 70ºC are optimal for developing RTC products with enhanced shelf stability, appealing sensory attributes, and desirable nutritional and physicochemical properties.

Acknowledgement

The authors acknowledge the Principle Scientist and Head, Post Harvest Technology Centre, Acharya N.G. Ranga Agricultural University, Bapatla for providing laboratory facilities for the sample analysis.

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