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PHYSICO-CHEMICAL CHARACTERISTICS, BROWNING AND SHELF LIFE OF OIL-BASED IMMATURE JACKFRUIT (*Artocarpus heterophyllus* LAM.) PICKLE PREPARED USING DIFFERENT FORMULATIONS

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ABSTRACT

Jackfruit (*Artocarpus heterophyllus* Lam.) is a nutritionally rich but highly perishable fruit with considerable potential for value addition through processing. This study aimed to the preparation of an oil-based immature jackfruit pickle that suits the South Indian palate using natural acidulants and evaluate its physicochemical characteristics, browning and shelf stability. The experiment comprised 13 treatments with different combinations of amchur powder or acid lime juice, chilli powder, crystal salt and mustard powder in a Completely Randomized Design with three replications. Amchur powder-based treatments maintained lower pH, higher titratable acidity and reduced browning than acid lime juice-based and control treatments. All treatments remained free from visible spoilage up to 90 days. T_1 revealed superior physicochemical stability, indicating that the proportion of amchur powder used was suitable for producing a stable oil-based immature jackfruit pickle.

***Key words*:** Jackfruit, pickle, amchur powder, acid lime juice, physicochemical characteristics, browning, shelf stability.

Introduction

Artocarpus heterophyllus Lam. (jackfruit) is an important tropical fruit crop native to the Western Ghats of India and widely cultivated in India, Bangladesh and other tropical countries. It produces the largest edible tree-borne fruit and is valued for its high productivity, nutritional richness and diverse dietary, medicinal and economic uses. It is a good source of dietary fibre, carbohydrates, protein, minerals, vitamin C and bioactive compounds such as carotenoids and lutein, which contribute to its nutritional and functional value (Ranasinghe *et al.*, 2019).

Tender (immature) jackfruit is widely consumed as a vegetable, making it a popular plant-based alternative in curries, salads and pickles (Jagtap *et al.*, 2010). However, its high moisture content and active metabolism make it highly perishable, resulting in considerable post-harvest losses and necessitating value addition through processing (Babu and Sudheer 2020).

Although several studies have reported pickles prepared from various fruits and vegetables, limited information is available on oil-based tender jackfruit pickle prepared with natural acidulants. Therefore, the present investigation was undertaken to evaluate the effect of different natural acidulants on the physicochemical characteristics, browning and shelf life of oil-based immature jackfruit (*Artocarpus heterophyllus* Lam.) pickle at 0, 30, 60 and 90 days.

Materials and Methods

The experiment was conducted in the Fruit Science Laboratory, PGIHS, SKLTGHU, Mulugu, Siddipet, India. The study was laid out in a Completely Randomized Design (CRD) comprising 13 treatments with three replications. Treatments consisted of different combinations of amchur powder and acid lime juice as natural acidulants with different quantities of chilli powder, crystal salt and mustard powder, while groundnut oil, turmeric powder and fenugreek powder were common to all treatments. A treatment without acidulant served as the control (Table 1).

Fresh, healthy, tender jackfruits were washed, peeled and cut into uniform pieces after removing the seeds while retaining the edible core. The pieces were blanched in hot water containing salt and turmeric for 10 min, drained and dried in a hot-air oven at 80°C for 2 h. Acid lime juice was exposed to sunlight for two days before use to reduce its moisture content. The jackfruit pieces were mixed with the required quantities of chilli powder, crystal salt, mustard powder, fenugreek powder, the respective acidulant and groundnut oil, filled in clean, dry airtight glass jars, covered with a thin layer of oil and stored at ambient temperature.

Physicochemical Analysis

The physicochemical parameters were analysed on the 0^{th}, 30^{th}, 60^{th} and 90^{th} days of storage.

pH:

he pH of homogenized pickle samples was measured using a digital pH meter (FiveEasy Plus, Mettler Toledo),

Table 1: Treatment details.

Treat-ment	JP	TT	AP	CP	CS	MP
T_1	250	Amchur	25.00	75.00	56.25	75.00
T_2	250	Amchur	25.00	62.50	45.00	62.50
T_3	250	Amchur	25.00	50.00	33.75	50.00
T_4	250	Amchur	18.75	75.00	56.25	75.00
T_5	250	Amchur	18.75	62.50	45.00	62.50
T_6	250	Amchur	18.75	50.00	33.75	50.00
T_7	250	Lime juice	18.75	75.00	56.25	75.00
T_8	250	Lime juice	18.75	62.50	45.00	62.50
T_9	250	Lime juice	18.75	50.00	33.75	50.00
T_{10}	250	Lime juice	15.00	75.00	56.25	75.00
T_{11}	250	Lime juice	15.00	62.50	45.00	62.50
T_{12}	250	Lime juice	15.00	50.00	33.75	50.00
T_{13}	250	-	-	75.00	56.25	75.00

JP: Jackfruit Pieces(g); TT: Treatment type; AP: Amchur powder(g)/Acid Lime Juice(ml); CP: Chilli Powder(g); CS: Crystal Salt(g); MP: Mustard powder(g)



Plate 1: Overall view of all treatments.

calibrated with pH 4.0 and 7.0 buffer solutions (Cornell University, 2022).

Titratable acidity (%):

itratable acidity was determined according to Ranganna (2001). A 5 g sample was homogenized with 50 mL of distilled water and filtered. A 10 mL aliquot of the filtrate was titrated against 0.1 N sodium hydroxide (NaOH) using phenolphthalein as an indicator. Acidity was expressed as a percentage of acetic acid.

Moisture content (%):

Oisture content was determined by the hot-air oven

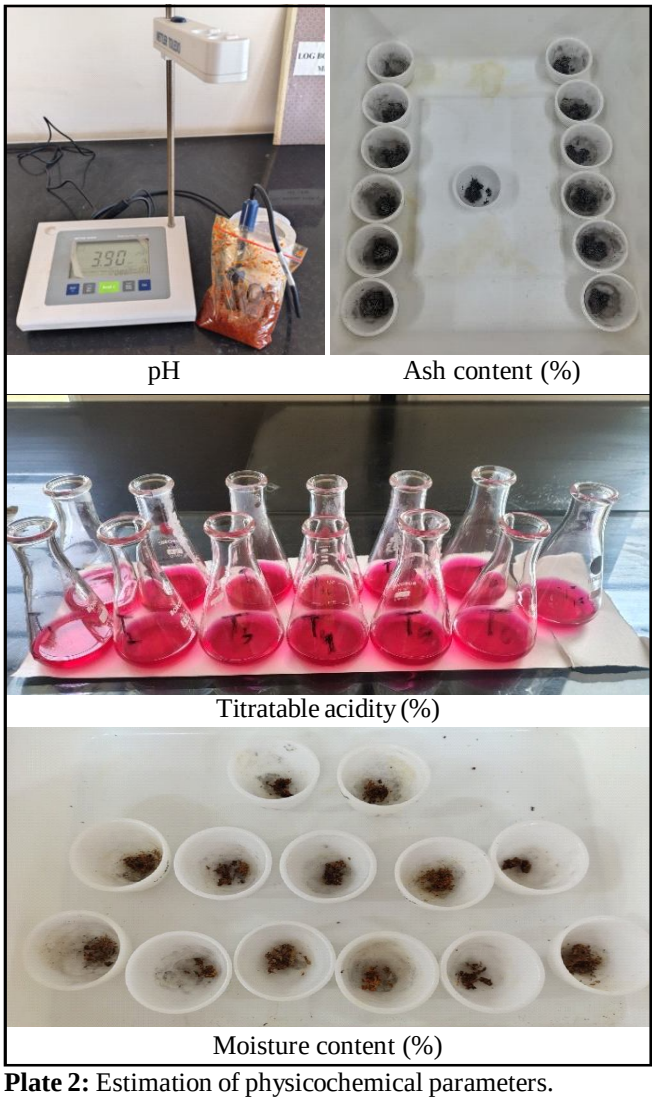


Plate 2: Estimation of physicochemical parameters.

Table 2: Effect of different concentrations of acidulants, chilli powder, crystal salt and mustard powder on the pH and titratable acidity of jackfruit pickle.

Treatments	pH				Titratable acidity (%)			
	0th day	30th day	60th day	90th day	0th day	30th day	60th day	90th day
T_1	3.84^{h}	3.53^{fg}	3.43^{j}	3.39^{fg}	0.67^{a}	0.85^{a}	1.03^{a}	1.07^{a}
T_2	3.88^{g}	3.47^{g}	3.41^{jk}	3.30^{g}	0.63^{ab}	0.85^{a}	0.98^{ab}	1.03^{a}
T_3	3.79^{i}	3.54^{g}	3.40^{k}	3.30^{g}	0.58^{abc}	0.76^{ab}	0.89^{abc}	0.98^{ab}
T_4	4.04^{f}	3.58^{f}	3.53^{h}	3.42^{ef}	0.54^{bcd}	0.71^{bc}	0.85^{bcd}	0.89^{abc}
T_5	4.08^{e}	3.52^{g}	3.48^{i}	3.45^{e}	0.54^{bcd}	0.67^{bcd}	0.82^{bcd}	0.85^{bcd}
T_6	4.08^{e}	3.66^{e}	3.57^{g}	3.55^{d}	0.49^{cde}	0.63^{cde}	0.76^{cde}	0.85^{bcd}
T_7	4.14^{d}	3.86^{d}	3.72^{f}	3.70^{c}	0.45^{def}	0.58^{def}	0.71^{def}	0.98^{ab}
T_8	4.17^{c}	3.91^{c}	3.76^{e}	3.74^{bc}	0.40^{efg}	0.54^{efg}	0.67^{efg}	0.71^{cde}
T_9	4.13^{d}	3.93^{c}	3.80^{d}	3.76^{bc}	0.39^{fg}	0.54^{efg}	0.60^{efgh}	0.63^{e}
T_{10}	4.22^{b}	4.01^{b}	3.91^{ab}	3.84^{b}	0.36^{fgh}	0.49^{efg}	0.58^{fgh}	0.71^{cde}
T_{11}	4.23^{b}	4.05^{b}	3.86^{c}	3.80^{bc}	0.31^{gh}	0.45^{ghi}	0.54^{gh}	0.67^{de}
T_{12}	4.25^{a}	3.96^{c}	3.80^{d}	3.75^{bc}	0.27^{hi}	0.40^{hi}	0.54^{gh}	0.58^{e}
T_{13}	4.26^{a}	4.20^{a}	3.90^{a}	4.04^{a}	0.18^{i}	0.39^{i}	0.49^{h}	0.54^{e}
SE(m) (±)	**0.01**	**0.02**	**0.01**	**0.04**	**0.03**	**0.04**	**0.05**	**0.06**
C.D @ 5%	**0.02**	**0.05**	**0.02**	**0.11**	**0.10**	**0.10**	**0.14**	**0.18**

Note : Mean values followed by the same superscript letter(s) within a column are not significantly different (P* < 0.05) according to Duncan's Multiple Range Test (DMRT); means with different superscript letters differ significantly.

method following FSSAI (1966). Approximately 5 g of sample was dried at 105°C for 2 h, and moisture content was calculated from the loss in weight.

Ash content (%):

Total ash was determined by the dry-ashing method (AOAC, 2000). Approximately 5 g of sample was dried, charred and incinerated in a muffle furnace at 600°C for 5 h. Ash content was expressed as a percentage of the initial sample weight.

Sodium chloride content (%):

Sodium chloride content was determined by the Mohr titration method using standardized 0.1 N silver nitrate ($AgNO_3$) and 5% potassium chromate as an indicator. The sample extract was titrated to a reddish-brown endpoint, and NaCl content was expressed as a percentage of the sample weight.

Browning (absorbance at 440 nm):

Browning intensity was determined according to

Table 3: Effect of different concentrations of acidulants, chilli powder, crystal salt and mustard powder on the moisture content (%) and ash content (%) of jackfruit pickle.

Treatments	Moisture content (%)				Ash content (%)			
	0th day	30th day	60th day	90th day	0th day	30th day	60th day	90th day
T_1	33.83^{f}	27.16^{g}	26.12^{f}	24.88^{g}	13.84^{a}	13.60^{a}	13.32^{a}	13.15^{a}
T_2	34.26^{ef}	28.53^{fg}	26.00^{f}	25.39^{fg}	13.45^{ab}	13.21^{bc}	13.00^{ab}	12.82^{ab}
T_3	34.61^{ef}	28.65^{fg}	27.64^{e}	25.97^{def}	12.98^{bc}	12.80^{de}	12.66^{bc}	12.45^{bc}
T_4	33.92^{f}	28.47^{fg}	25.95^{f}	25.03^{g}	13.50^{ab}	13.36^{ab}	13.23^{a}	12.99^{a}
T_5	34.11^{f}	32.35^{bcd}	27.62^{e}	25.52^{efg}	13.15^{bc}	12.97^{cd}	12.76^{bc}	12.51^{bc}
T_6	34.68^{def}	29.66^{ef}	28.15^{de}	26.10^{cdef}	12.85^{cd}	12.70^{de}	12.55^{bc}	12.40^{c}
T_7	35.22^{de}	28.53^{fg}	28.58^{de}	26.21^{cde}	12.68^{cde}	12.51^{ef}	12.35^{cd}	12.20^{cd}
T_8	36.33^{c}	31.06^{cde}	29.40^{bcd}	26.83^{bc}	12.38^{def}	12.22^{fg}	12.06^{de}	11.90^{de}
T_9	38.61^{ab}	33.17^{abc}	30.17^{abc}	27.10^{ab}	12.13^{fg}	11.89^{ghi}	11.55^{fg}	11.43^{fg}
T_{10}	35.75^{cd}	30.52^{def}	28.87^{cde}	26.27^{cde}	12.40^{def}	12.12^{gh}	11.89^{def}	11.67^{ef}
T_{11}	37.59^{b}	33.02^{abc}	30.64^{ab}	26.77^{bcd}	12.21^{efg}	11.96^{ghi}	11.75^{efg}	11.55^{efg}
T_{12}	38.83^{a}	34.12^{ab}	30.64^{ab}	27.53^{ab}	11.96^{fg}	11.78^{hi}	11.56^{fg}	11.43^{fg}
T_{13}	38.61^{ab}	34.79^{a}	30.79^{a}	27.65^{a}	11.82^{g}	11.64^{i}	11.41^{g}	11.25^{g}
SE(m) (±)	**0.37**	**0.81**	**0.46**	**0.28**	**0.18**	**0.12**	**0.16**	**0.13**
C.D @ 5%	**1.07**	**2.36**	**1.34**	**0.82**	**0.52**	**0.36**	**0.46**	**0.38**

Note : Mean values followed by the same superscript letter(s) within a column are not significantly different (P* < 0.05) according to Duncan's Multiple Range Test (DMRT); means with different superscript letters differ significantly.

Table 4: Effect of different concentrations of acidulants, chilli powder, crystal salt and mustard powder on the NaCl (%) and browning of jackfruit pickle.

Treatments	NaCl (%)				Browing			
	0th day	30th day	60th day	90th day	0th day	30th day	60th day	90th day
T_1	6.11^{a}	6.35^{a}	6.62^{a}	6.96^{a}	0.79^{efg}	0.90^{de}	0.98^{def}	1.12^{efg}
T_2	5.61^{bc}	5.82^{cd}	5.96^{def}	6.42^{bcd}	0.76^{g}	0.87^{e}	0.95^{f}	1.08^{g}
T_3	5.01^{e}	5.69^{de}	5.84^{efg}	6.32^{cd}	0.77^{fg}	0.94^{de}	0.96^{ef}	1.10f^{fg}
T_4	6.09^{a}	6.22^{abc}	6.33^{abc}	6.81^{ab}	0.86^{c}	0.90^{de}	1.02^{cde}	1.17^{cde}
T_5	5.84^{abc}	6.04^{abcd}	6.20^{bcd}	6.48^{bcd}	0.82^{de}	0.96^{cd}	1.04^{bcd}	1.15^{def}
T_6	5.46^{cd}	5.69^{de}	5.87^{def}	6.17^{de}	0.87^{bc}	1.03^{abc}	1.05^{bc}	1.19^{bcd}
T_7	6.16^{a}	6.37^{a}	6.42^{ab}	6.48^{bcd}	0.90^{b}	0.98^{bcd}	1.08^{abc}	1.23^{ab}
T_8	5.57^{c}	5.66^{de}	5.78^{efg}	6.17^{de}	0.87^{bc}	0.97^{cd}	1.12^{a}	1.22^{abc}
T_9	5.09^{de}	5.41^{e}	5.51^{g}	5.73^{e}	0.90^{b}	1.06^{ab}	1.09^{ab}	1.21^{abc}
T_{10}	6.01^{ab}	6.23^{ab}	6.41^{ab}	6.73^{abc}	0.82^{de}	0.92^{de}	0.98^{def}	1.13^{defg}
T_{11}	5.83^{abc}	5.9^{bcd}	6.02^{cde}	6.38^{bcd}	0.85^{cd}	0.95^{cde}	0.94^{f}	1.17^{cde}
T_{12}	5.09^{de}	5.37^{cde}	5.62^{fg}	6.26^{d}	0.80^{ef}	0.91^{de}	1.04^{bcd}	1.12^{efg}
T_{13}	6.08^{ab}	6.20^{abc}	6.32^{abc}	6.46^{bcd}	0.97^{a}	1.09^{a}	1.09^{ab}	1.27^{a}
SE(m) (±)	**0.14**	**0.14**	**0.12**	**0.16**	**0.01**	**0.03**	**0.02**	**0.02**
C.D @ 5%	**0.42**	**0.40**	**0.34**	**0.47**	**0.03**	**0.08**	**0.06**	**0.06**
C.V. (%)	**4.39**	**4.05**	**3.38**	**4.39**	**2.25**	**5.22**	**3.52**	**3.20**

Note : Mean values followed by the same superscript letter(s) within a column are not significantly different (P* < 0.05) according to Duncan's Multiple Range Test (DMRT); means with different superscript letters differ significantly.

Ranganna (1986). Approximately 500 mg of pickle sample was macerated in 60% ethyl alcohol, transferred to a volumetric flask, and made up to 250 mL with distilled water. The mixture was left overnight and filtered through Whatman No. 1 filter paper. The absorbance of the filtrate was measured at 440 nm using a UV- Vis spectrophotometer (Evolution One, Thermo Scientific), with 60% ethyl alcohol as the blank. Browning intensity was expressed as optical density (OD) at 440 nm.

Shelf-Life Assessment

The shelf life of jackfruit pickle was evaluated during 90 days of ambient storage by periodically examining samples for visible fungal growth, off-odour, gas formation and surface deterioration.

Statistical Analysis

The data for each storage interval were analysed separately using analysis of variance (ANOVA) appropriate for a Completely Randomized Design (CRD). Treatment means were compared using the Critical Difference (CD) test at the 5% significance level. The standard error of the mean (SEm) was also calculated.

Results and Discussion

Titratable acidity

The highest titratable acidity was recorded in T_1 (1.07%), followed by T_2 (1.03%), while the lowest was observed in the control (T_{13}) (0.54%). The higher titratable acidity observed in the amchur powder-based treatments may be attributed to the higher acidity of amchur powder compared to acid lime juice. There was an increase in titratable acidity on 90th day compared to the initial day. Similar reports were made by Saroj *et al.*, (2018) and Meena *et al.*, (2023) in mango pickle and by Jadhav *et al.*, (2022) in lemon pickle.

pH

The pH of jackfruit pickle was lowest in T_2 and T_3 (both 3.30), whereas the highest pH was observed in the control (4.04). Amchur powder-based treatments exhibited lower pH compared to the acid lime juice-based treatments and control. The higher titratable acidity of amchur powder, compared with acid lime juice, may have contributed to the lower pH observed in the amchur-based treatments. The decline in pH at 90th day may be attributed to the corresponding increase in titratable acidity during storage. Similar observations were reported by Saroj *et al.*, (2018) and Meena *et al.*, (2023) in mango pickle.

Moisture content

At the 90th day, the lowest moisture content was recorded in T_1 (24.88%), whereas the highest was observed in the control (T_{13}) (27.65%). All the amchur powder-based treatments maintained lower moisture content than the acid lime juice-based treatments. The decline in moisture content on the 90th day may be attributed to repeated jar openings during sampling, which may have increased moisture loss through evaporation. A similar reduction in moisture content during storage was reported by Anna Anandh (2020) in chicken pickle.

Ash content

The highest ash content was recorded in T_1 (13.15%), followed by T_4 (12.99%) and T_2 (12.82%), whereas the lowest was observed in the control (T_{13}) (11.25%) on the 90th day. Treatments containing higher levels of chilli powder, crystal salt and mustard powder maintained comparatively higher ash content. Similar reports were submitted by Wani and Majeed (2014) in chicken gizzard pickle.

NaCl

The highest NaCl content was recorded in T_1 (6.96%), followed by T_4 (6.81%) and T_{10} (6.73%), whereas the lowest was observed in T_9 (5.73%) on the 90th day. It was observed that the treatments containing higher levels of crystal salt maintained higher NaCl content than those with lower salt levels.

Browning

The browning (recorded as OD at 440 nm) of jackfruit pickle was highest in the control (T_{13}) (1.27), followed by T_7 (1.23) and T_8 (1.22), whereas the lowest was observed in T_2 (1.08). The increase in browning may be attributed to non-enzymatic browning reactions, including the Maillard reaction and oxidation of phenolic compounds, occurring gradually during storage (van Boekel, 2001; Chen *et al.,* 2025). The lower browning observed in amchur powder-based treatments may be associated with the lower pH, as acidic conditions can retard Maillard browning reactions compared to neutral or alkaline conditions (Martins *et al.,* 2001; van Boekel, 2001). Similar cases of browning during storage were reported by Rajendra Kumar (2021) in aonla pickle and Saroj *et al.,* (2018) in mango pickle.

Shelf life

All treatments remained free from visible spoilage signs, including fungal growth, off-odour and surface deterioration, throughout the 90 days evaluation period. The absence of spoilage may be attributed to the combined preservative effects of salt, acidulants, spices and the protective oil layer, which inhibited microbial growth and maintained product stability. The acidic environment may have further contributed to the product's extended shelf life, consistent with observations by Usaga *et al.,* (2017), who reported that acidification extended the shelf life of commercially prepared pickled eggs.

Conclusion

The study demonstrated that immature jackfruit can be successfully utilized for preparing stable oil-based pickle using natural acidulants. Amchur powder-based treatments exhibited better acidity maintenance, lower pH and reduced browning intensity compared with acid lime juice-based and control treatments. The combined effects of salt, acidulants, spices and oil contributed to product stability, with all treatments remaining free from visible spoilage up to 90 days. Among the formulations, T_1 showed better physicochemical stability, indicating the better suitability of amchur powder as a natural acidulant for developing an oil-based jackfruit pickle suitable for the South Indian palate.

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