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Preparation and Storage of Tomato (*Lycopersicon esculentum* Mill.) *Kammarakattu* in Different Packaging Materials

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ABSTRACT

In order to reduce the post-harvest losses of tomato during glut period and when there is no minimum support price, it is an important to go for value addition of tomatoes to provide entrepreneurial opportunities at rural and urban level. A sweet item, *kammarakattu* was developed by using the traditional preparation method which gained popularity in South India by incorporating the tomato pulp. The tomato pulp with an addition of jaggery and desiccated coconut powder, processed until achieving a TSS of 85^0 Brix, thereafter molded into sheets (thickness 4–6 mm), cut into a uniform size and kept for storage studies in different packing materials under different treatments *viz.,* low-density polyethylene, high-density and polypropylene containers and studied the shelf life of the product at ambient temperatures. The findings revealed that the lycopene content and anti-oxidant activity were increased in the developed product. It is a low cost and nutritious sweet item and had a lot of scope to create entrepreneurship opportunities among the rural women and youth. Similarly, it will reduce the post-harvest losses of the tomato during the period of glut.

Key words: Iron, Jaggery, Kammarakattu, Lycopene, Tomato pulp, Vitamin C.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill., or *Solanum lycopersicum* L.) is well known for its diverse and high-quality nutritional contents, as well as its versatility in terms of usage both as a fresh product and in industrial processing. Post-harvest technologies find wide application from the point of view of the food processing sector in transforming fresh ripe tomatoes into numerous value-added foods like tomato juice, paste, puree, ketchup, sauces, and pickles. These products are stabilized through thermal processing, pasteurization and acidification methods that not only increase their shelf life but also provide food safety. Tomatoes are essential for human nutrition and culinary variety, a key raw material in food processing and agro-industrial operations, thus making valuable contributions to the agro-economy and nutritional security (Jayathunge *et al,* 2012).

Tomatoes are a good source of key phytonutrients and bioactive compounds like ascorbic acid (vitamin C), β-carotene (pro-vitamin A), vitamin K (phylloquinone), folic acid, and potassium (K^+). One of the main phytochemicals found in tomatoes is lycopene, a red carotenoid pigment with strong antioxidant potential. Lycopene has a key function to decrease the chances of non-communicable diseases like cardiovascular diseases and various cancers by scavenging for damaging reactive oxygen species (ROS) (Adhau *et al,* 2013). The tomato fruit is mostly water and organic solids, and the skin and seeds account for around 10% of the fruit's weight. There is evidence to show a positive relationship between soluble solids and sugar content in tomato fruit, such that soluble solids measurement can be used as a rough gauge of sugar content. (Turhan and Seniz, 2009) noticed that the fructose and glucose are the major sugars present in tomatoes, representing approximately 65% of the total expressed tomato juice soluble solids. During technological processing like sauce and ketchup manufacturing, lycopene yield is not only preserved but can increase, thus increasing the nutritional value of processed tomato items (Jasmina *et al*, 2017). Therefore, tomatoes and processed foods are still essential carotenoids (lycopene) and vitamin C sources.

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Andhra Pradesh is the number one producer among Indian states and provides close to 36% of the country's tomato production. The state generates around 1,473.5 thousand metric tons of tomatoes from about 54.2 thousand hectares of cultivated land, attaining a high productivity level of 27.2 Mt/ha (Madhuri, 2017). Even with large-scale production, Indian tomatoes suffer huge post-harvest losses, estimated at 25.5%. The main causes of these losses are improper handling, poor storage facilities, and market inefficiencies. Countering such post-harvest losses requires the implementation of appropriate processing techniques. Processing raw tomatoes into varied value-added food products like pickles, curries, powders, jams, ketchup, and other types minimizes wastage and yields better economic returns. The world market's increasing demand for varied snack foods has resulted in the popularity of novel tomato-based snack foods like instant tomato pickles, chips, sauces, powders, and other dried foods. Such value-added tomato commodities with distinct sensory qualities and flavors created using salt, sugar, spices, and natural flavors find wide acceptance and are consumed on a number of social and cultural events (Manjula *et al,* 2023). Value addition not only aids in minimizing post-harvest losses but also increases income generation, thus enhancing agro-industrial development and food security.

A tomato *kammarakattu*, a unique chewable sweet confectionery item, can be consumed by people of all ages, particularly among children, can be a potential area for enhancing its nutritional value by adding more vitamins and minerals. The study was carried out with an aim to develop the tomato value added products, shelf-life of the developed product and popularization of technology for entrepreneurship development.

MATERIALS AND METHODS

The present investigation on development of Tomato *kammarakattu* was undertaken at Krishi Vigyan Kendra, Kalikiri, Annamayya district, Andhra Pradesh during the year 2022-23. The locally leading tomato variety “Saho” was selected for the product development. Other ingredients like, Jaggery was procured from the farmers field and dry coconut powder was procured from the local super market at Kalikiri.

Extraction of pulp from the tomatoes

Fresh, well matured tomatoes were hand-picked and cleaned thoroughly under running tap water to clear surface contaminants. Whole fruits were blanched in boiling water at 70-80°C for 5 minutes to inactivate browning enzymes. The fruits were peeled manually after blanching, and the inner seed-bearing section was removed with a knife or spoon. The rest of seed-free pulpy portion was chopped into small fragments and pulped with a mixer grinder. Embedded seeds in the pulp were removed by either rubbing it through a wire mesh screen or grinding it lightly with a mixer grinder to remove seed grit. This eliminated the loss of good fruit pulp from the entire fruits.

Optimization of TSS of the tomato pulp

The fresh tomato pulp was cooked at varied temperatures to standardize the TSS of the tomato pulp for the acceptance of the tomato flavour at various Brix levels of 14°, 16°, 18°, 20°, and 22°. Seven of different Brix stages were experimented with, each having equal proportions of jaggery and coconut (Table 1) to identify the most acceptable stage of brix of the tomato pulp in the final product. Sensory analysis was carried out to standardize the total soluble solids content in the tomato pulp and to evaluate the appearance, color, taste, texture, flavor, and overall acceptability of the developed product on a 9-point Hedonic scale by 45 panelists.

Preparation of tomato *kammarakattu*

The pulped tomato was allowed to cook at a concentration of 14°–16° Brix, and jaggery was then added and dissolved. Dry coconut powder was added, followed by a good blend and cooking in a medium flame until it reached an end concentration of 84° Brix. An amount of 1-2 g of cardamom powder was added to enhance the flavor. The mixture was placed on vanaspati-greased stainless-steel plates and left to cool on the plate surface. After cooling sufficiently, the mass was kneaded to enable exposure of the hot center and assist further cooling. Upon cooling, it was rolled into 4–6 mm thick sheets, cut into equal-sized pieces, and stored in different packing materials at room temperature and studied the shelf life of the developed product.

Tomato pulp was boiled at different brix levels and added equal amount of jaggery (40 g) and dry coconut powder (20 g) and statistical analysis was carried out to optimize the TSS of the tomato pulp and evaluated on the 9-point hedonic scale for sensory characteristics and acceptability by using the SPSS software.

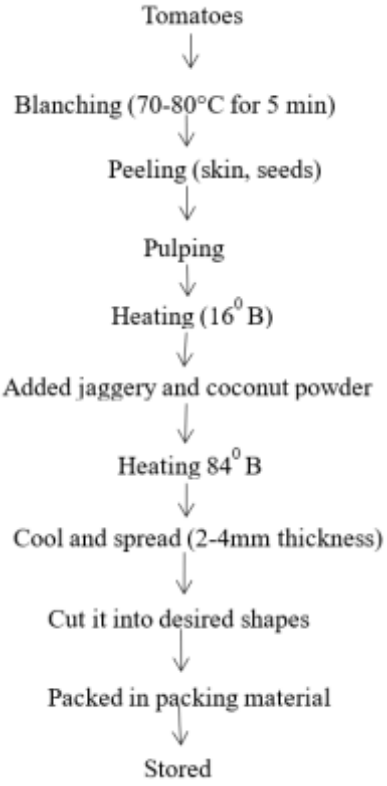


Fig:1-Flow chart on preparation of Tomato Kammarakattu

iv) Storage studies of the developed product:

The product was kept for storage studies in different packaging material (5-treaments, 3-replcation) for 45 days to study the shelf -life of the developed product.

T1-Locally available plastic covers (60µ)

T2 -Low density polythene (LDPE) (200 gauge)

T3-High density polythene (HDPE) (300 gauge)

T4-Poly propylene (plastic container) container

T5- Poly propylene (plastic container) container

+ Aluminum foil

RESULTS AND DISCUSSION

Saho a leading tomato variety in most parts of the Andhra Pradesh contains good pulp rather than juice in the fruit. It is a highly suitable variety to develop the value-added products like tomato powder, ketchup, leather and incorporation in the preparation of sweet items like *kammarakattu*. Hence, this study was taken up with the idea of development of tomato *kammarakattu*, a traditional food recipe. In preparation method, we used the ingredients like jaggery of good quality which is a good source of iron and dry coconut power to improve the shelf life of the product instead of using fresh coconut. The TSS of tomato pulp was standardized to give a good taste to the final product that is 14-16^{0}Brix. The tomato pulp which cooked below or above the standardized TSS level, it was not acceptable by the panel members. Thereafter, the further standardization was taken place to optimize the quantity of jaggery and dry coconut powder and he final TSS of the product until it gave a sheathable consistency.

The findings indicated no significant differences between sensory attributes like appearance, flavor, texture, color, and overall acceptability among treatments, except for taste. The P-value (<0.01) was highly significant showing a strong statistical difference in taste among treatments. This means that TSS had a major influence on taste perception. The taste scores were highest at 14° and 16° Brix, suggested that moderate sugar levels enhanced taste quality, while very low (10°) or high (22°) levels reduced palatability. This was due to the thermal treatment boosted cooked aroma volatiles and diminished fresh green note volatiles, which impacted the general flavor profile of the tomato products (Koltun *et al,* 2022).

Table 1. Summary of the sensory evaluation for the tomato pulp at different TSS levels

Treatment (Brix)	Appearance	Taste	Flavor	Texture	Color	Overall acceptability
10^0	7.27 ± 0.70[a]	6.67±1.11[c]	6.87± 0.83[a]	7.13± 0.83[a]	7.00± 0.65[a]	6.60± 1.88[a]
12^0	7.40 ± 0.73[a]	7.27 ± 0.79[b]	6.53± 1.12[a]	7.40 ± 0.73[a]	7.00 ± 0.84[a]	6.73 ± 1.87[a]
14^0	7.40 ± 0.91[a]	8.47 ± 0.51[a]	6.47 ± 0.99[a]	7.20 ± 0.67[a]	7.20 ± 0.86[a]	7.27 ± 1.03[a]
16^0	7.27 ± 1.10[a]	8.53 ± 0.51[a]	6.27 ± 1.16[a]	6.87 ± 1.06[a]	7.00 ± 1.06[a]	7.00 ± 1.64[a]
18^0	7.07 ± 1.22[a]	6.47 ± 0.915	6.53 ± 1.24[a]	6.73 ± 1.33[a]	7.20 ± 1.08[a]	6.73 ± 1.79[a]
20^0	7.40 ± 0.73[a]	6.33 ± 0.724[c]	6.60 ± 1.40[a]	6.93 ± 0.96[a]	7.27± 0.79[a]	7.00± 0.92[a]
22^0	7.27 ± 1.16[a]	4.27 ± 1.33[d]	6.27 ± 1.48[a]	6.47 ± 1.06[b]	6.93 ± 1.28[a]	6.87 ± 1.18[a]
F-Value	0.237	40.159**	0.448	1.541	0.281	0.322
P-Value	0.963	0.000	0.845	0.173	0.945	0.924

Table 2. Treatments given to develop the Tomato kammarakattu (in grams)

Treatment	Tomato pulp (g)	Jaggery (g)	Dry coconut powder (g)	Remarks
T1	100	60	20	Not acceptable
T2	100	55	40	Not acceptable
T3	100	55	20	Not acceptable
T4	100	50	30	Not acceptable
T5	100	50	25	Not acceptable
T6	100	45	25	Not acceptable
T7	100	40	20	Not acceptable

Table 3. Nutritive value of the developed Tomato kammarakattu (per 100 gms approximately)

Parameter	Fresh tomato	Developed Tomato *kammarakattu*
Lycopene (µg)	2570	6721.77
Total anti-oxidant activity(µmol)	118	1440.74
Ascorbic acid(mg)	13.7	2.65

Source: Quality Control Laboratory, PJTSAU, Hyderabad

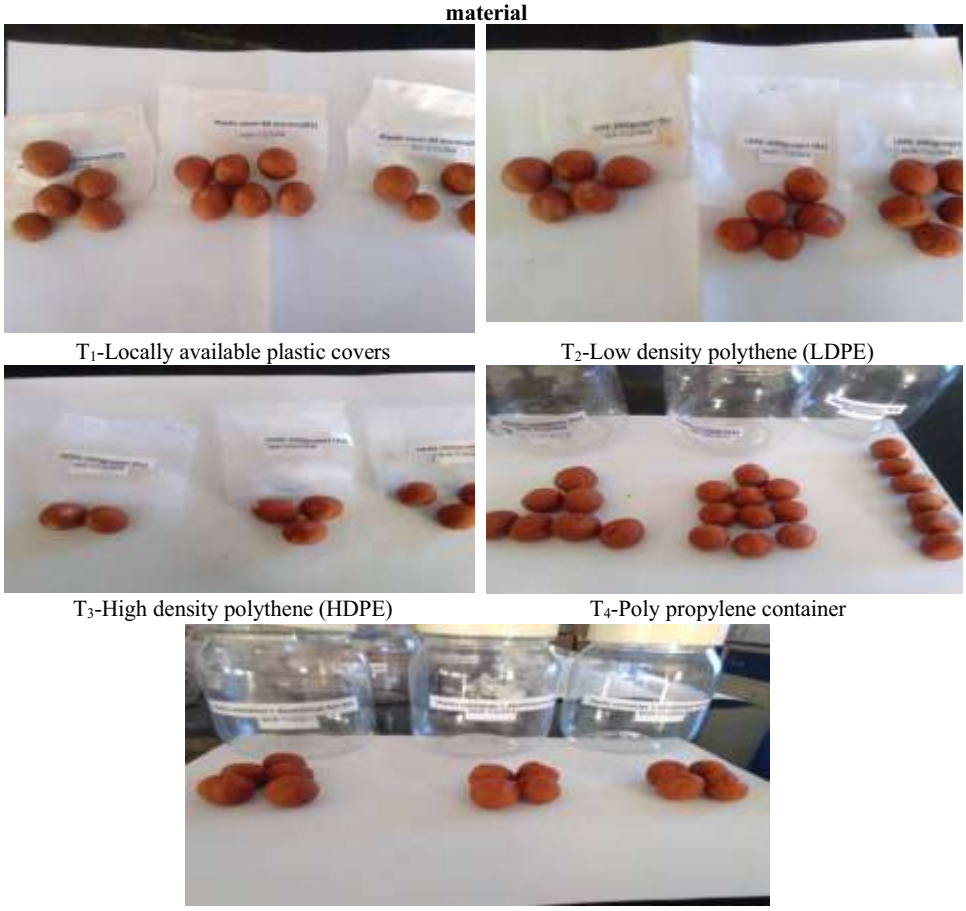
Sensory evaluation of the developed tomato *kammarakattu*

Tomato *kammarakattu* was formulated based on different treatments (Table 2) with standerdized total soluble solids (TSS) of tomato pulp, along with different ratios of jaggery and dry coconut powder and cooked until it reached 84^0 Brix. All the treatments were evaluated sensorially by 45 panelists employing a 9-point hedonic scale for appearance, color, taste, texture, flavor, and overall acceptability. According to panelists' ratings, treatment T7, which consisted of 100 g of tomato pulp, 40 g of jaggery, 20 g of dry coconut powder, and 1–2 g of cardamom at TSS of 84^0 Brix was the highest rated and acceptable product.

The developed product was analyzed for lycopene, ascorbic acid, and total antioxidant activity (Table 3). Results indicated that the thermal processing of tomato pulp significantly enhanced its nutritional profile, resulting in a substantial increase in both lycopene concentration and total antioxidant activity (TAA) in the final product. Lycopene content escalated from 2,570µg to 6,721.77µg per 100 g, with TAA rising sharply from 118µmol to 1,440.74µmol.

Blanching tomatoes at approximately 88 °C for 2–30 min. reduced vitamin C but increased trans-lycopene content and improves overall antioxidant activity (Dewanto *et al*, 2002). (Periago *et al,* 2011) found that thermal concentration of tomatoes

Fig 2. Shelf life studies of the developed tomato kammarakattu under different packaging material



T_1-Locally available plastic covers

T_2-Low density polythene (LDPE)

T_3-High density polythene (HDPE)

T_4-Poly propylene container

T5- Wrapped with Aluminium foil stored in Poly propylene container

increased lycopene, phenolics and flavonoids but decreased ascorbic acid. (Gahler *et al,* 2003) also found that thermal processing decreases vitamin C in tomato products, but increases total phenolics and hydrophilic antioxidant capacity, indicating heat-induced release or formation of phenolics. This enrichment is primarily driven by the thermal isomerization of the less bioavailable all-trans-lycopene into more extractable and bioavailable cis-lycopene isomers. Simultaneously, the high-temperature concentration process induces chromoplast cell matrix disruption, effectively releasing lycopene molecules previously sequestered by proteins and membranes. The dramatic increase in TAA is also attributed to the generation of thermally induced antioxidants. Reactions like the Maillard reaction and carotenoid co-oxidation produce potent radical-scavenging compounds. These compounds collectively enhance the product's free radical scavenging capacity, confirming that controlled heating is a viable strategy for elevating the antioxidant potency of tomato-based foods. The loss of vitamin C confirms the well-established thermal lability of L-ascorbic acid, which undergoes rapid oxidative degradation during high-temperature processing. Lycopene, the predominant tomato carotenoid, functions as a highly effective singlet oxygen quencher and free radical scavenger.The enhanced bioavailability of cis-lycopene isomers, formed through thermal processing, improves physiological absorption and subsequent utilization (Shi and Maguer, 2020).

Tomato processing or cooking, especially in the presence of added oil has been found to enhance lycopene bioavailability which is beneficial in clinical nutrition situations (Burton-Freeman *et al*, 2014). (Jacob *et al*, 2010) reinforced that the concentration process during the production of tomato paste increases lycopene, total phenolics, flavonoids, and single phenolic compounds including quercetin, rutin, chlorogenic, and caffeic acids and decreases ascorbic acid. Generally, processed tomato products provide greater lycopene bioavailability compared to fresh tomatoes (Shi , 2000). (Liang *et al,* 2021) corroborated that some processing techniques, such as thermal

Table 4. Storage studies of the developed product- presence of microbial contamination

Treatment	15 d	20	25 d	30 d	35 d	40 d	45 d
T1 - Locally available plastic covers	√	-	-	-	-	-	-
T2- Low density polythene (LDPE)	Nil	√	-	-	-	-	-
T3 - High density polythene(HDPE)	Nil	Nil	√	-	-	-	-
T4 -Polypropylene container	Nil	Nil	Nil	Nil	√	-	-
T5 - Polypropylene container + Aluminum foil.	Nil	Nil	Nil	Nil	Nil	Nil	√

treatments, enhance both the stability and bio-accessibility of lycopene in tomato pulp. (Martínez-Hernández *et al,* 2020). Human study showing that heat processing (to form cis-isomers of lycopene) improved absorption/bioavailability of lycopene.

Storage studies of the developed product under different packaging materials

Packaging extends the shelf life of fresh vegetables and fruits by reducing physiological decay and weight loss, according to (Maul *et al*, 2000). The success of packaging is based on material properties (Shahnawaz *et al*, 2012). The product was further kept for storage studies under different packaging material which all are locally available in market and affordable by the entrepreneurs at low cost. Among the treatments, the product that were wrapped in aluminum foil and stored in polypropylene containers showed the maximum shelf life of 45 days. Contrary, when products were kept in locally available plastic covers, microbial contamination (*Rizhophus* sp.) was observed within 15d of storage. When compared with locally available covers, LDPE, HDPE, and polypropylene containers offered improved preservation. The combination of aluminum foil covering and storage in polypropylene containers produced the highest shelf stability for the product. The superior barrier properties of aluminium foil namely, low oxygen and moisture permeability, light opacity, and inertness contributed to the suppression of oxidative degradation and microbial growth. These results emphasized that properly chosen packaging materials are important to ensure the quality and safety of tomato-based products during storage. These findings align with previous reports (Shi and Maguer, 2020; Sarker *et al,* 2014) suggesting that Laminated Aluminium Foil (LAF) or PP-based materials offer superior nutrient retention, lower moisture uptake, and minimal microbial proliferation in tomato-based processed products. Thus, for small-scale commercial deployment, PP containers with aluminium foil wrapping are recommended due to their cost-effectiveness, thermal compatibility, and sustainability.

Laminated Aluminum Foil (LAF) is recognized as the best packaging material for tomato powder, providing higher stability of nutrients such as protein, fat, vitamin C, lycopene, and β-carotene, with less moisture absorption and lower microbial growth than HDPE and MDPE. (Sarker *et al*, 2014) suggested keeping tomato powder in LAF pouches at room temperature for six months, as long as there is pretreatment and drying. For fresh tomatoes, (Poudel *et al,* 2022) discovered that perforated plastic packaging, LDPE and HDPE is optimal in maintaining quality and shelf life. Perforated LDPE bags had the longest shelf life of 24 days, followed by a close second for perforated HDPE at 23 days.

Unpackaged tomatoes degraded rapidly with excessive weight loss and drying out. (Afrose *et al*, 2023) showed that different packaging (LDPE, polypropylene, foil) resulted in varying retention of lycopene and vitamin C over storage. (Oladipupo *et al*, 2020) conducted a study in Nigeria, compared black polyethylene, white polyethylene and laminated aluminum foil for tomato powder storage, found laminated aluminum foil best retained vitamin C etc. (Rani *et al,* 2019) conducted packaging study on tomatoes using aluminum foil and polythene covers, found aluminum foil best.

CONCLUSION

Tomato kammarakattu is a nutritious, chewy sweet substitute to prevent the post-harvest losses during glut time. Research shows that boiled tomato pulp enhances lycopene, a potent antioxidant and anti-carcinogenic substance and jaggery a good source of healthy iron to avert anemia in vulnerable groups. Thus, tomato kammarakattu can become a healthier and more attractive choice like other sweet items available in the market.

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