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Physical Characterization of Custard Apple (*Annona squamosa L.*) at Different Stages of Fruit Ripening

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ABSTRACT

Custard apple (*Annona squamosa* L.) is a commercially important fruit crop grown in homesteads of Kerala, which is mostly consumed for its nutritional value. The present investigation aimed to evaluate the genetic variability of custard apple in homesteads of Kerala with respect to quality at different fruit ripening stages *viz*., optimum mature, ripe and at the end of shelf life and compared with the cultivated variety of *Annona squamosa* L. cv. Balanagar. Fruit characters *viz.,* fruit weight, length, diameter, seed weight, fruit firmness, and pulp percentage were recorded higher in Balanagar fruits at all the stages of ripening. However, the number of seeds, fruit rind thickness and fruit colour, pulp colour and pulp texture of fruits of local genotype and Balanagar did not show any variation in all fruit ripening stages. The fruits of local custard apple fruits recorded higher peel percentage and shelf life than Balanagar fruits. The locally collected genotype from Kerala homesteads had promising fruit physical characteristics and was comparable to the commercial variety Balanagar. Hence local genotype selected could be used for the varietal improvement studies for developing promising custard apple variety suitable for humid tropical conditions of Kerala.

Key Words: *Annona squamosa* L. Custard apple, Variability, Physical parameters

INTRODUCTION

Custard apple *(Annona squamosa* L.) is an important fruit crop that belongs to the Annonaceae family and is mainly grown in tropical as well as subtropical regions. It is a multipurpose evergreen tree raised for its nutrient-dense and sweet fruits. Among the annonaceous crops, custard apple is the most favourite and commercially important fruit crop seen in the homesteads of Kerala. It is popularly known as sugar apple, sweetsop, and sitaphal (Jagtap and Bapat, 2012). The fruits are an abundant source of vitamins and minerals, with a moisture content of 73.5%, 23.9 % carbohydrates, 1.6 % proteins, 0.3 % fats, 0.7 % minerals and vitamins A and C and yield about 45% pulp with a TSS of 22.30 ^{0}Brix, pH of 5.6, and tannins of 0.5% (Kolekar and Tagad, 2012).

Since the custard apple fruit is climacteric in nature, the biochemical changes that take place after harvest occur more quickly. After being harvested, mature fruits ripen fast and become too soft and inappropriate for consumption within 3 to 4 days at room temperature (Braily and Kaushik, 2015). Generally, the fruits are consumed fresh and can be utilized for the development of semi-processed and processed products such as juice, squash, nectar, ice cream, sherbets, soft drinks, and milkshakes (Baskaran *et al*, 2016).

To identify the superior genotypes, researchers frequently assess the natural variation that exists within the species. Even though custard apple is a hardy crop with widespread adaptability, only a few varieties, including Balanagar, Island Gem, and Arka Sahan were released for commercial cultivation in the country (Meghana *et al*, 2020). The physical characterization of *Annona squamosa* L. at different stages of ripening is important to understand the quality of fruits and to assess the keeping quality/ shelf life of the fruits. There is relatively meagre information available on the

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physical characteristics of custard apple fruits at different stages of ripening. Hence, the study was undertaken with the objective to evaluate the fruit physical characteristics of locally selected custard apple fruit and in comparison, to that of commercially cultivated variety Balanagar.

MATERIALS AND METHODS

Collection of fruits

Uniformly matured custard apple fruits were collected from preidentified homesteads of Thiruvananthapuram districts and ten independent fruit samples of each were selected for the study. The fruits were analyzed at different fruit ripening stages *viz*., optimum maturity, optimum ripening and at the end of shelf life and was compared with the cultivated variety Balanagar for its physical parameters *viz*., fruit weight, fruit length, fruit diameter, seed weight, number of seeds, fruit firmness, fruit rind thickness, pulp percentage, peel percentage, fruit colour, pulp colour, pulp texture and shelf life. The data obtained were statistically analysed using Analysis of Variance (p=0.05) with Completely Randomised Design.

Fruit Weight (g): The weight of custard apple fruits at different ripening stages was recorded on an electronic weighing balance and expressed in gram.

Fruit Length (cm): Length of individual fruits at different ripening stages was measured from stalk end to stigmatic end and recorded in centimetres.

Fruit Diameter (cm): Fruit diameter at different ripening stages was measured at its widest plane.

Seed Weight (g): Seeds extracted from individual fruits at different ripening stages were weighed in an electronic weighing balance and the recorded weight was expressed in gram per 100 g fruit weight.

Number of Seeds/ 100g: The counted number of seeds per fruit was converted into the number of seeds per 100 g fruit weight.

Fruit Firmness (N): The fruit firmness of individual fruit at different ripening stages was evaluated using a texture analyser TA.HD plus (Stable Microsystems, England) using compression mode and fruit firmness was expressed in Newton (N).

Fruit Rind Thickness (mm): The rind thickness of individual fruit was measured with the help of Vernier Caliper.

Pulp Percentage: Pulp percentage of individual fruit at different ripening stages was calculated by recording the whole fruit weight and pulp weight and its average was expressed in percentage (Kolekar and Tagad, 2012).

$$\text{Pulp (\%)} = \frac{\text{Weight of fruit pulp}}{\text{Fruit weight}} \times 100$$

Peel Percentage: Peel percentage of individual fruit at different ripening stages was evaluated by recording the whole fruit weight and its average was expressed in percentage (Kolekar and Tagad, 2012).

$$\text{Pulp (\%)} = \frac{\text{Weight of fruit peel}}{\text{Fruit weight}} \times 100$$

Fruit Colour : The external surface colour of custard apple fruits at maturity, ripe and end of the shelf life was evaluated using the IPGRI crop descriptor which was categorized as light green, green, dark green, reddish green, reddish yellow, yellowish green, yellow, brownish green, brown and others (IPGRI, 2008).

Fruit Pulp Colour: The fruit pulp colour of custard apple fruits at different ripening stages was characterized as white, cream and other using the IPGRI crop descriptor (IPGRI, 2008).

Fruit Pulp Texture: The fruit pulp texture of custard apple fruits at different ripening stages was characterized as watery, creamy, granular, hard, hard areas in the pulp and others according to the IPGRI crop descriptor (IPGRI, 2008).

Shelf Life (Days): The end of the shelf life was observed when 10% of external fruit surface discolouration occurred and recorded in days.

RESULTS AND DISCUSSION

Fruit Weight (g), Fruit Length (cm) and Fruit Diameter (cm)

The fruit weight, fruit length and fruit diameter of custard apple fruits at different stages of ripening are depicted in Table 1. The custard apple var. Balanagar recorded the highest fruit weight as compared to the locally collected custard apple fruits. At optimum maturity, the highest fruit weight of 186.05 g was recorded by Balanagar fruits which decreased with ripening and recorded 166.46 g at optimum ripe stage which further decreased to 152.08 g at the end of shelf life. The locally collected custard apple fruits recorded 127.23 g at optimum maturity and 114.66 g and 104.41 g at optimum ripe and at the end of shelf life respectively. Fruit weight is a genetically determined trait that varies greatly among landraces (Bhatnagar *et al,* 2012). The cultivated variety Balanagar recorded a maximum fruit length of 7.65 cm and fruit diameter of 7.07 cm whereas fruit length was 5.70 cm and fruit diameter of 6.51 cm was recorded for locally collected *custard apple* fruits. There was no change in fruit length and diameter with the ripening stages for both locally collected and Balanagar fruits. Fruit weight variation is largely due to higher canopy spread, which encourages the accumulation of higher photosynthates in fruit, enabling them to attain optimum size. It is also influenced by the length and breadth of the fruit, as well as the age and vigour of the plant and eco-physiological conditions (Meghana *et al*, 2020).

Bakane *et al* (2015) evaluated the physical attributes of custard apple cv. Balanagar and observed that the average fruit weight ranged from 114.80 g to 231.64 g. Similarly, the fruit weight was highest (330 g) in cultivated variety Balanagar reported by Abdualrahman *et al*, 2016). Jyolsna (2016) assessed the variability of different *Annona* species and reported the average fruit weight of locally collected custard apple fruits was 116.90 g with average fruit length of 6.70 cm and fruit diameter of 4.29 cm. Kachhadiya and Jethva (2017) evaluated the physical and chemical characters of custard apple and revealed that the weight of optimum mature and ripe fruits was 143.57 g and 103.04 g respectively. The fruit length of custard apple cv. Balanagar was non-significantly varied from 5.80 cm to 6.90 cm and average fruit diameter varied from 6.70 cm to 7.90 cm as reported by Jaishanker *et al* (2018). Kumar *et al* (2018) worked on morphological and quality traits in 30 custard apple genotypes and reported that the average fruit weight varied from 98.80 g to 187.50 g, indicating that genotypes of custard apples had enough variation in fruit weight. The variation in fruit diameter might be due to edaphic factors and maximum seed accumulation in the horizontal plain, as well as gibberellin production in seeds (Handique *et al*, 2022).

Seed Weight (g/100 g), Number of Seeds and Fruit Firmness (N)

The seed weight, number of seeds and fruit firmness of custard apple fruits at different stages of ripening are depicted in Table 2. The cultivated variety Balanagar recorded the maximum seed weight (23.17 g 100 g^{-1}) whereas the locally collected custard apple fruits recorded 15.06 g 100 g^{-1} which didn't vary with the fruit ripening stages. The reason for the minimum seed weight of local collection of custard apple fruits might be due to the difference in fruit size, genetic variation, or the accumulation of lesser photosynthates in seeds. The average seed weight of 15 g was found in custard apple fruit (Kad *et al*, 2016) and Yadav *et al* (2017) noticed maximum and minimum seed weight of 7.27 g and 26.12 g in *custard apple fruits.* These findings are in conformity with Kachhadiya and Jethva (2017), Chandel *et al* (2018) and Mahorkar *et al* (2022).

The number of seeds for local collection of custard apple fruits as 27.82 for 100 g of fruit

which did not show significant difference with the Balanagar fruits and no changes was noticed with the different ripening stages. The minimum number of seeds per fruit is usually preferred for table and processing purposes, although data suggests that the number of seeds increased as fruit size increased which might be due to a higher pulp percentage (Meghana *et al*, 2020).

Fruit firmness is an important sensory quality indicator and is used to assess the process of fruit ripening. The fruit firmness was higher in Balanagar fruits (14.78 N) which decreased with ripening and recorded 7.10 N at optimum ripe stage and decreased to 2.53 N at the end of shelf life. The local collection of custard apple fruits recorded a firmness value of 12.96 N at optimum mature stage which decreased to 6.22 N and 2.12 N at optimum ripening and at the end of shelf life respectively. Fruits become soft towards the ripe and senescence stages, which might be related to the activation of enzyme that breaks down cell walls or the production of ripening hormone and custard apple fruit firmness varied from 23.54 N to 24.91 N (Mahorkar *et al*, 2022).

Fruit Rind Thickness (mm), Pulp and Peel

The fruit rind thickness is a crucial factor affecting the fruit's ability to withstand transport. The pulp percentage and peel percentage determine the quality, marketability and consumer acceptability of fruits and these factors play an important role in selection of better genotypes and values of the present study are depicted in Table 3.

The cultivated custard apple variety Balanagar had a maximum fruit rind thickness of 6.15 mm which showed no significant difference with locally collected fruits of *Annona squamosa* L. with a fruit rind thickness of 5.73 mm at the optimum mature stage. During ripening rind thickness decreased for the both locally collected and Balanagar fruits and recorded 2.78 mm for local collection and 3.00 mm for Balanagar without any significant difference. Hiwale (2015) found that the average fruit rind thickness of 'Arka Sahan' an interspecific hybrid of custard apple, as 0.5 cm and Yadav *et al* (2017) analysed the variability in custard apple genotypes for physical attributes and reported that the fruit rind thickness ranged between 4.73 mm and 2.29 mm.

Fruit pulp weight is an important fruit characteristic and is influenced by factors such as the weight and size of the fruit, thin fruit peel, and fewer seeds. At the optimum mature stage, Balanagar fruits recorded higher pulp percentage (29.90 %), and it increased to 56.74 % and 64.13 % at optimum ripening and at the end of shelf life respectively. Local genotype of custard apple fruits recorded a pulp percentage of 23.83 % at optimum mature stage which increased to 52.73 % at optimum ripening and 60.61 % at the end of shelf life. Bhatnagar *et al* (2012) observed that pulp weight varied from 21.25 g to 47.00 g in custard apple races collected from Rajasthan. Kachhadiya and Jethva (2017) observed that the pulp percentage of unripe fruits was found to be 31.98 % and that of ripe fruits of custard apple was 35.08 % and similar values were reported by Jaishanker *et al* (2018).

The peel of custard apple fruits is not edible, so the minimum peel weight is crucial for selecting the genotype for varietal improvement studies. At the optimum mature stage, the custard apple fruits local genotype recorded higher peel percentage of 66.60 % which decreased to 36.78 % and 29.02 % at optimum ripening and at the end of shelf life respectively. Balanagar fruits recorded lower peel percentage in comparison with the local genotype and recorded 58.84 % at optimum mature stage, 30.84 % at optimum ripening and 22.58 % at the end of shelf life. The reduction in peel percentage during ripening might be due to the softening of the peel associated with climacteric fruit ripening. The peel percentage of 48.62 % was reported for Balanagar by Bakane *et al* (2015) and it was 46.77 % for locally collected custard apple fruits (Kad *et al*, 2016; Kachhadiya and Jethva, 2017).

Table 1. Fruit weight (g), fruit length (cm), fruit diameter (cm) of custard apple fruits at different fruit ripening stages

Custard apple (*A. squamosa* L.)	Fruit weight (g)			Fruit length (cm)			Fruit diameter (cm)		
	Optimum mature	Optimum ripe	End of shelf life	Optimum mature	Optimum ripe	End of shelf life	Optimum mature	Optimum ripe	End of shelf life
Local collection	127.23^{a}± 0.968	114.66^{a} ± 0.672	104.41^{a}± 1.248	5.70^{b} ± 0.406_	5.70^{b} ± 0.406_	5.70^{b} ± 0.406_	6.51^{b} ±_ 0.185	6.51^{b} ±_ 0.185	6.51^{b} ±_ 0.185
Balanagar	186.05^{b}± 2.127	166.46^{b}± 1.999	152.08^{b}± 1.967	7.65^{a} ± 0.229	7.65^{a} ± 0.229	7.65^{a} ± 0.229	7.07^{a} ±_ 0.236	7.07^{a} ±_ 0.236	7.07^{a} ±_ 0.236
SE± (m)	0.523	0.472	0.521	SE± (m)	0.104		SE± (m)	0.067	
CD (0.05)	1.553	1.401	1.548	CD (0.05)	0.309		CD (0.05)	0.199	
CV(%)	1.055	1.061	1.285	CV (%)	4.391		CV (%)	3.124	

Table 2. Seed weight (g 100 g^{-1}), number of seeds per 100 g fruit weight and fruit firmness (N) of custard apple fruits at different fruit ripening stages

Custard apple (*A. squamosa* L.)	Seed weight (g 100 g^{-1})			Number of seeds 100 g^{-1}			Fruit firmness (N)			
	Optimum mature	Optimum ripe	End of shelf life	Optimum mature	Optimum ripe	End of shelf life		Optimum mature	Optimum ripe	End of shelf life
Local collection	15.06^{b}±_ 0.030	15.06^{b}±_ 0.030	15.06^{b}±_ 0.030	27.82^{a} ±_ 1.262	27.82^{a} ±_ 1.262	27.82^{a} ±_ 1.262		12.96^{b}± 0.407	6.22^{b}± 0.424	2.12^{b}± 0.272
Balanagar	23.17^{a}±_ 0.147	23.17^{a}±_ 0.147	23.17^{a}±_ 0.147	27.41^{a} ±_ 0.808	27.41^{a} ±_ 0.808	27.41^{a} ±_ 0.808		14.78^{a}± 0.551	7.10^{a}± 0.512	2.53^{a}± 0.271
SE± (m)	0.034			SE± (m)	0.335		SE± (m)	0.153	0.149	0.086
CD (0.05)	0.100			CD (0.05)	NS		CD (0.05)	0.455	0.442	0.255
CV (%)	0.556			CV (%)	3.837		CV (%)	3.491	7.056	11.654

NS-Non significant

Table 3. Fruit rind thickness (mm), pulp percentage and peel percentage of custard apple fruits at different fruit ripening stages

Custard apple (*A. squamosa* L.)	Fruit rind thickness (mm)			Pulp percentage			Peel percentage		
	Optimum mature	Optimum ripe	End of shelf life	Optimum mature	Optimum ripe	End of shelf life	Optimum mature	Optimum ripe	End of shelf life
Local collection	5.73^{a}± 0.751	4.10^{a}± 0.370	2.78^{a}± 0.308	23.83^{b}± 0.164	52.73^{b}± 0.058	60.61^{b}± 0.239	66.60^{a}± 0.164	36.78^{a}± 0.063	29.02^{a}± 0.136
Balanagar	6.15^{a}± 0.316	4.20^{a}± 0.126	3.00^{a}± 0.588	29.90^{a}± 0.224	56.74^{a}± 0.717	64.13^{a}± 0.841	58.84^{b}± 0.261	30.84^{b}± 0.800	22.58^{b}± 0.730
SE± (m)	0.182	0.087	0.148	0.062	0.161	0.195	0.069	0.180	0.166
CD(0.05)	NS	NS	NS	0.184	0.478	0.581	0.205	0.533	0.493
CV (%)	9.702	6.657	16.255	0.730	0.930	0.991	0.348	1.679	2.036

NS-Non significant

Table 4. Fruit colour, pulp colour, pulp texture and shelf life (days) of custard apple fruits at different fruit ripening stages

Custard apple (*A. squamosa* L.)	Fruit colour			Pulp colour			Pulp texture			Shelf life (days)
	Optimum mature	Optimum ripe	End of shelf life	Optimum mature	Optimum ripe	End of shelf life	Optimum mature	Optimum ripe	End of shelf life	
Local collection	Light green	Yellowish green	Yellowish green	White	Cream	Cream	Granular	Granular	Granular	7.89^{a} ± 0.057
Balanagar	Light green	Yellowish green	Yellowish green	White	Cream	Cream	Granular	Granular	Granular	7.33^{b} ± 0.071
										SE±(m) 0.020
										CD (0.05) 0.061
										CV (%) 0.850

Fruit Colour, Pulp Colour, Pulp Texture and Shelf Life (Days)

Fruit sensory characters *viz*., fruit colour, fruit pulp colour and pulp texture and the shelf life of fruits are depicted in Table 4. The fruit colour was light green at optimum maturity which changed to yellowish green at optimum ripening and retained the same colour till the end of shelf life for both the fruits of local genotype and Balanagar variety. The fruit colour of custard apple fruits was reported as light green and green at optimum maturity, while it was yellowish green at ripening was reported by Bakane *et al* (2016) and Handique *et al* (2022).

The custard apple fruits recorded a white pulp colour at maturity and turned to cream colour at the ripe stage and at the end of shelf life in locally collected and Balanagar fruits. Yogesh (2013) studied the morphological characteristics of 52 custard apple genotypes and reported that the fruit pulp colour was white for most of the genotypes. The result of present study was in conformity with the findings of Hiwale (2015) and Handique *et al* (2022). Genotype and edaphic factors play a major role in determining the variation in fruit pulp texture.

The locally collected fruits and the cultivated variety Balanagar fruits recorded a granular pulp texture at its optimum mature, ripe stage, and end of the shelf life. Yogesh (2013) reported that the pulp texture of *custard apple fruits* as granular and Handique *et al* (2022) analysed the physical properties of different custard apple accessions and found that the fruit pulp texture was either soft or granular at the ripening stage.

The shelf life of fruits determines its keeping quality and marketability and the higher shelf life attribute is promising for the new varietal development studies. The fruits from local genotype recorded a higher shelf life of 7.89 days whereas Balanagar fruits recorded a shelf life of 7.33 days at ambient temperature. According to Cheng *et al* (2018), the fruits of *Annona squamosa* L. recorded a shelf life of 4 days at 22 to 28 ^{0}C. The Balanagar variety of custard apple exhibited a shelf life of 4 days at ambient temperature (Pimpalpalle *et al*, 2018) and similar results were also reported by Ambika *et al* (2019).

CONCLUSION

The physical characterisation of custard apple fruits of local genotype collected from homesteads of Kerala and the commercially cultivated variety Balanagar were done at different stages of ripening *viz*., optimum mature, optimum ripening and at the end of shelf life. The study revealed variation in fruit physical attributes and the fruits of Balanagar recorded higher fruit weight of 186.05 g at optimum mature stage which decreased with fruit ripening and recorded 152.08 g at the end of shelf life. The fruit length (7.65 cm), fruit diameter (7.07 cm), and seed weight (23.17 g) was higher in Balanagar fruits which showed no variation with the stages of fruit ripening. The fruit firmness, and pulp percentage were also higher in Balanagar fruits whereas number of seeds, fruit rind thickness, fruit colour, pulp colour, and fruit pulp texture of fruits of local genotype and Balanagar fruits did not recorded any variations. The shelf life which determines the keeping quality and marketability of fruits was higher (7.89 days) in locally collected custard apple fruits. The study indicated that locally collected genotype of custard apple from homesteads of Kerala recorded promising fruit characteristics and could be utilised for the varietal improvement programmes for developing promising custard apple variety suitable for humid tropical conditions of Kerala.

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