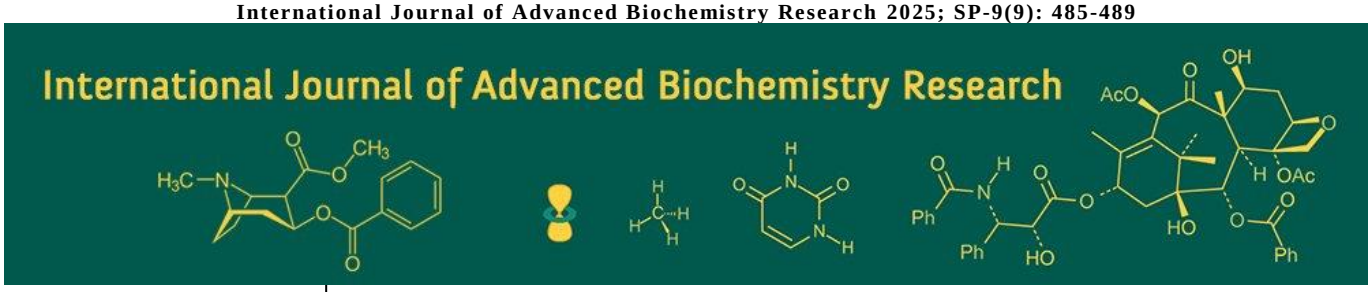

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Impact of pest damage on cashew apple quality for juice and value

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Abstract
Cashew apples are nutritionally rich but highly perishable, with significant potential for juice and value-added processing. However, pest damage, particularly from *Helopeltis*, fruit borers, and stem/root borers, leads to deterioration in fruit quality. A field study was conducted using 13 graded levels of pest damage (0 to >60%) to evaluate effects on physical traits, juice quality, and processing suitability. Results showed a consistent decline in fruit weight, juice yield, vitamin C content, and product acceptability with increasing damage. Conversely, peel discoloration, acidity, and tannins increased. Fruits with damage above 30% were found unfit for premium processing, highlighting the need for effective pest management.

Keywords: Cashew apple, pest damage, juice quality, value addition, *Helopeltis*

1. Introduction
Cashew (*Anacardium occidentale* L.) is a tropical tree crop widely cultivated for its economic importance, primarily for its nuts. However, the cashew apple is the succulent, pseudo-fruit attached to the nut and also holds considerable value due to its high juice content, rich nutritional profile, and potential for processing into various value-added products such as juice, candy, vinegar, and alcoholic beverages. Despite its potential, the cashew apple remains largely underutilized in commercial processing, especially in regions where post-harvest handling and pest management are not optimal.

Pest damage is one of the critical factors influencing the quality and usability of cashew apples. Insect pests such as the Tea Mosquito Bug (*Helopeltis antonii*), Fruit and Nut Borer (*Thylacoceris* sp.), and various borers and sap suckers attack the developing apples, leading to physiological and biochemical deterioration. These infestations can cause visible lesions, internal damage, reduced juice content, increased tannin levels, and susceptibility to microbial spoilage, thereby severely limiting their suitability for processing.

Quality parameters such as juice yield, total soluble solids (TSS), pH, total acidity, vitamin C (ascorbic acid) content, and tannin levels are essential indicators for determining the processing value of cashew apples. Pest-infested apples may exhibit significant deviations in these parameters, which adversely affect both the sensory and chemical qualities of juice and other derived products.

Given the increasing interest in utilizing cashew apples for commercial juice production and other processed goods, it is imperative to understand the extent to which pest damage compromises fruit quality. Such knowledge is essential for both pest management strategies and post-harvest handling systems aimed at minimizing losses and enhancing value addition in cashew production systems.

The present study was undertaken to evaluate the impact of different levels of pest damage on the physicochemical quality of cashew apples, and to assess their suitability for juice extraction and processing into value-added products. The findings aim to bridge the gap between pest management and fruit processing, thereby contributing to the sustainable utilization of cashew apples in the Agro-processing sector.

2. Materials and Methods
The study conducted at Agricultural and Horticultural Research Station Ullal, Mangalore during March-May 2024-2025 using the variety Ullal-1.

A Complete Randomized Block Design (CRBD) followed with 13 treatments and 3 replications. A specific pest damage range classified each treatment in 5% intervals. From each replicate, 10 randomly selected cashew apples were assessed.

Table 1: Treatments details

Treatments	Particulars
T_1	0% Damage (Healthy)
T_2	1-5% Damage
T_3	6-10% Damage
T_4	11-15% Damage
T_5	16-20% Damage
T_6	21-25% Damage
T_7	26-30% Damage
T_8	31-35% Damage
T_9	36-40% Damage
T_{10}	41-45% Damage
T_{11}	46-50% Damage
T_{12}	51-60% Damage
T_{13}	>60% Damage

2.1 Parameters recorded included

Physical attributes: weight, length, diameter, peel discoloration, fruit firmness. Juice quality parameters include juice yield, total soluble solids (°Brix), pH, total acidity, ascorbic acid content and tannin content. Product suitability includes juice acceptability (hedonic score), candy recovery, fermentation rate and shelf life.

3. Results and Discussion

The experimental results clearly reveal the significant effect of pest damage on the quality parameters of cashew apple and its suitability for juice extraction and value-added product preparation. As the level of pest infestation increased, there was a consistent and statistically significant decline in the physical, chemical, and organoleptic characteristics of cashew apples. The data obtained for all 13 treatments under Randomized Block Design (RBD) are analyzed below.

3.1 Physical Properties of Cashew Apples

Pest infestation significantly influenced the physical quality of cashew apples. Fruit weight, length, diameter, and firmness declined consistently with increasing damage, while peel discoloration increased sharply. Healthy fruits (T_1) recorded the highest fruit weight (93.22 g) and firmness (28.71 N), whereas severely damaged fruits (T_{13}) weighed only 54.07 g with a firmness of 16.27 N. Peel discoloration increased from 1.22% (T_1) to 34.11% (T_{13}), showing progressive spoilage. These effects reduce market acceptability and storage potential (Table 2 and Fig 1).

Interpretation: Pest-induced physiological stress results in reduced fruit development and tissue breakdown, which directly compromises the marketability and processing quality of the apple.

Table 2: Study of Morphological and Textural Characteristics of Fresh Cashew Apples

Treatment	Fruit weight (g)	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Firmness (N)	Fruit peel discoloration (%)
T_1	93.22 (9.66)	7.86 (2.8)	5.5 (2.35)	28.71 (5.36)	1.22 (1.1)
T_2	89.83 (9.48)	7.4 (2.72)	5.46 (2.34)	27.45 (5.24)	3.54 (1.88)
T_3	86.87 (9.32)	7.19 (2.68)	5.09 (2.26)	25.95 (5.09)	6.26 (2.5)
T_4	81.29 (9.02)	6.75 (2.6)	4.91 (2.22)	23.85 (4.88)	10.41 (3.23)
T_5	76.33 (8.74)	6.48 (2.55)	4.61 (2.15)	22.54 (4.75)	12.89 (3.59)
T_6	73.67 (8.58)	6.25 (2.5)	4.22 (2.05)	21.37 (4.62)	16.91 (4.11)
T_7	70.1 (8.37)	5.94 (2.44)	4.12 (2.03)	20.09 (4.48)	21.47(4.63)
T_8	66.19 (8.14)	5.54 (2.35)	3.93 (1.98)	19.16 (4.38)	26.52(5.15)
T_9	62.53 (7.91)	5.33 (2.31)	3.86 (1.96)	18.38 (4.29)	27.27(5.22)
T_{10}	59.89 (7.74)	5.24 (2.29)	3.98 (1.99)	17.77 (4.22)	30.79 (5.55)
T_{11}	58.27 (7.63)	5.14 (2.27)	3.84 (1.96)	17.11 (4.14)	31.71 (5.63)
T_{12}	55.95 (7.48)	5.06 (2.25)	3.88 (1.97)	16.79 (4.1)	32.76 (5.72)
T_{13}	54.07 (7.35)	5.12 (2.26)	3.8 (1.95)	16.27 (4.03)	34.11 (5.84)
S Em±	0.6165	0.0682	0.0552	0.4261	0.707
CD (5%)	1.7920	0.1981	0.1606	1.2388	2.0552
CV%	1.92	1.93	2.17	3.48	6.22

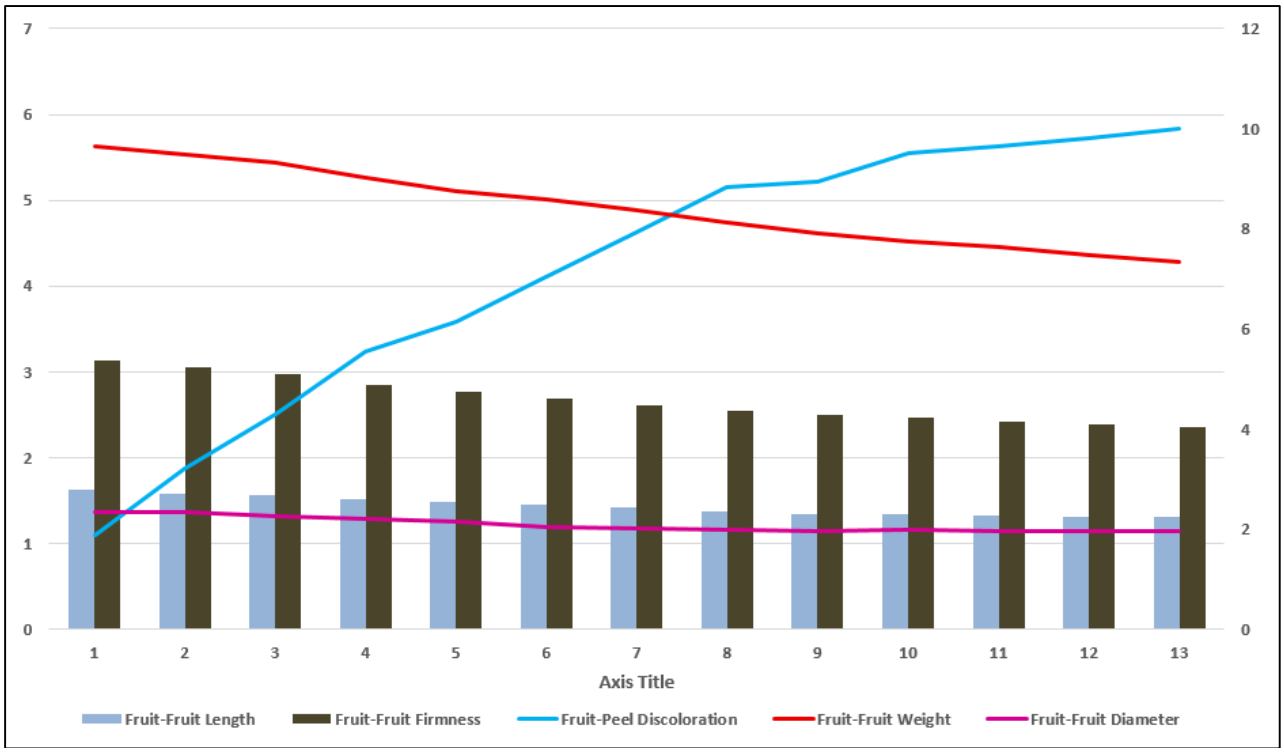

Fig 1: Physical and External Quality Attributes of Fruit Samples

3.2 Juice Quality Parameters.

Juice yield decreased from 72.15% (T_1) to 46.71% (T_{13}). TSS dropped from 13.87 °Brix to 9.17 °Brix, reflecting lower sweetness. Vitamin C content reduced sharply from 263.2 mg/100ml to 154.59 mg/100ml, while tannin content increased (0.16% to 0.50%). pH declined slightly (4.21 to 4.01) while acidity increased (0.42% to 0.51%). These trends indicate nutrient depletion and increased bitterness in damaged fruits, reducing their processing suitability.

Interpretation: Pest damage causes metabolic imbalance and oxidation of cell components, leading to loss of sugars, vitamins, and an increase in bitter polyphenols like tannins, all of which reduce juice quality and processing efficiency (Table 3 and Fig 2).

3.3 Suitability for Value-Added Products

Juice acceptability fell from 8.05 (T_2) to 4.08 (T_{13}). Candy recovery decreased from 60.36% to 33.22%. Fermentation rate dropped from 8.17 g CO_2/day (T_1) to 4.36 g CO_2/day (T_{13}), showing inhibitory effects of high tannins. Shelf stability reduced from 12.79 days (T_1) to 5.31 days (T_{13}), indicating faster spoilage in damaged fruits. These results confirm that severe pest infestation limits cashew apples' suitability for high-value processing (Table 4 and Fig 3).
Interpretation: Severe pest damage reduces the technological and economic feasibility of using cashew apples in high-quality juice and value-added products.

Table 3: Study of Physicochemical Quality Parameters of Cashew Apple Juice

Treatment	Juice yield	Juice-TSS	Juice-pH	Juice acidity	Juice Vit-C	Juice-Tannin Content
T_1	72.15 (8.49)	13.87 (3.72)	4.21 (2.05)	0.42 (0.65)	263.2 (16.22)	0.16 (0.4)
T_2	69.69 (8.35)	13.13 (3.62)	4.19 (2.05)	0.43 (0.66)	238.79 (15.45)	0.2 (0.45)
T_3	70.24 (8.38)	12.57 (3.55)	4.17 (2.04)	0.44 (0.66)	231.89 (15.23)	0.21 (0.46)
T_4	64.12 (8.01)	12.15 (3.49)	4.16 (2.04)	0.45 (0.67)	217.83 (14.76)	0.24 (0.49)
T_5	66.18 (8.14)	11.85 (3.44)	4.13 (2.03)	0.45 (0.67)	209.38 (14.47)	0.28 (0.53)
T_6	62.42 (7.9)	11.4 (3.38)	4.12 (2.03)	0.46 (0.68)	198.1 (14.07)	0.29 (0.54)
T_7	58.74 (7.66)	11.02 (3.32)	4.09 (2.02)	0.47 (0.69)	182.24 (13.5)	0.37 (0.61)
T_8	54.77 (7.4)	10.4 (3.22)	4.08 (2.02)	0.47 (0.69)	188.31 (13.72)	0.37 (0.61)
T_9	52.98 (7.28)	10.12 (3.18)	4.07 (2.02)	0.48 (0.69)	164.79 (12.84)	0.43 (0.66)
T_{10}	49.4 (7.03)	9.42 (3.07)	4.03(2.01)	0.49 (0.7)	159.43 (12.63)	0.45 (0.67)
T_{11}	48.53 (6.97)	9.41 (3.07)	4.02 (2)	0.5 (0.71)	144.71 (12.03)	0.52 (0.72)
T_{12}	46.93 (6.85)	9.09 (3.01)	4.02 (2)	0.5 (0.71)	149.33 (12.22)	0.52 (0.72)
T_{13}	46.71 (6.83)	9.17 (3.03)	4.01 (2)	0.51 (0.71)	154.59 (12.43)	0.5 (0.71)
S E.m±	1.0387	0.172	0.0103	0.0023	4.4259	0.0173
CD (5%)	3.019	0.5024	0.03	0.0066	12.866	0.0502
CV%	3.07	2.71	0.44	0.84	3.98	8.55

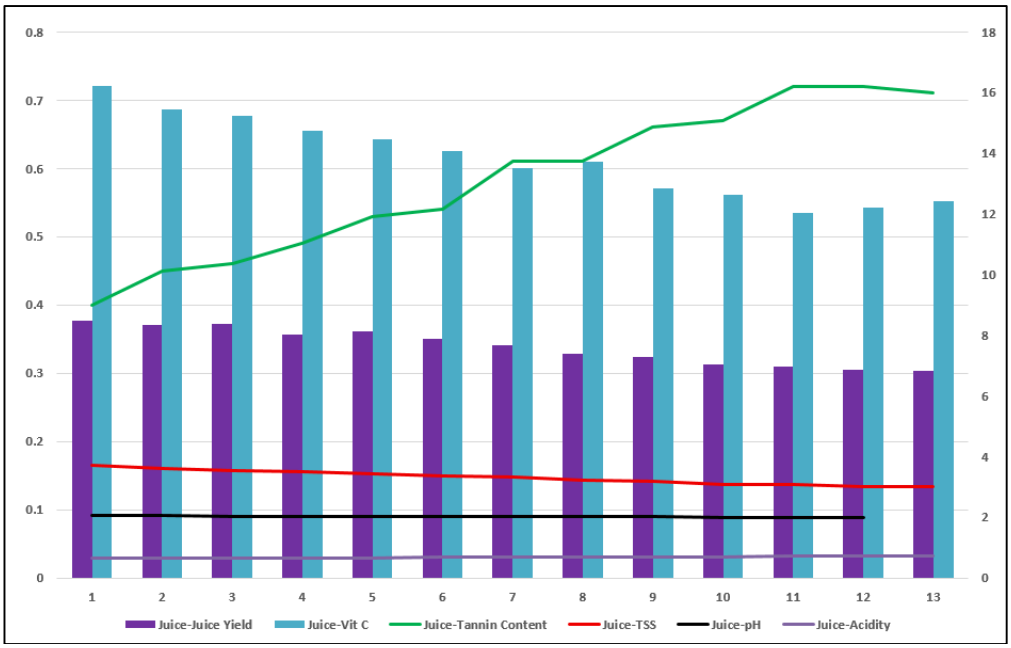

Fig 2: Physicochemical Characteristics of Juice Samples

Table 4: Evaluation of Cashew Apples for Suitability in Various Value-Added Products

Treatment	Value-Juice Acceptability	Value-Candy Recovery (%)	Value-Fermentation Rate (g CO_2/day)	Value-Shelf Stability (days)
T_1	7.52 (2.74)	60.36 (7.77)	8.17 (2.86)	12.79 (3.58)
T_2	8.05 (2.84)	58.23 (7.63)	8.1(2.85)	11.74 (3.43)
T_3	7.44 (2.73)	60.35(7.77)	7.8 (2.79)	11.8 (3.44)
T_4	6.94 (2.63)	58.52(7.65)	7.55 (2.75)	9.93 (3.15)
T_5	6.65 (2.58)	51.2(7.16)	7.16 (2.68)	9.85 (3.14)
T_6	6.47 (2.54)	49.07(7.00)	6.7 (2.59)	9.58 (3.1)
T_7	4.69 (2.17)	42.18(6.49)	5.47 (2.34)	6.63 (2.57)
T_8	4.59 (2.14)	40.54(6.37)	5.5 (2.35)	5.8 (2.41)
T_9	4.34 (2.08)	37.46(6.12)	4.95 (2.22)	6.03 (2.46)
T_{10}	4.18 (2.04)	35.07(5.92)	4.97 (2.23)	5.32 (2.31)
T_{11}	4.26 (2.06)	34.18(5.85)	5.00 (2.24)	5.25 (2.29)
T_{12}	4.16 (2.04)	34.79(5.9)	4.92 (2.22)	5.21 (2.28)
T_{13}	4.08 (2.02)	33.22(5.76)	4.36 (2.09)	5.31 (2.3)
SE.m±	0.1687	1.2615	0.1652	0.2236
CD (5%)	0.4903	3.667	0.4802	0.65
CV%	5.18	4.77	4.61	4.78

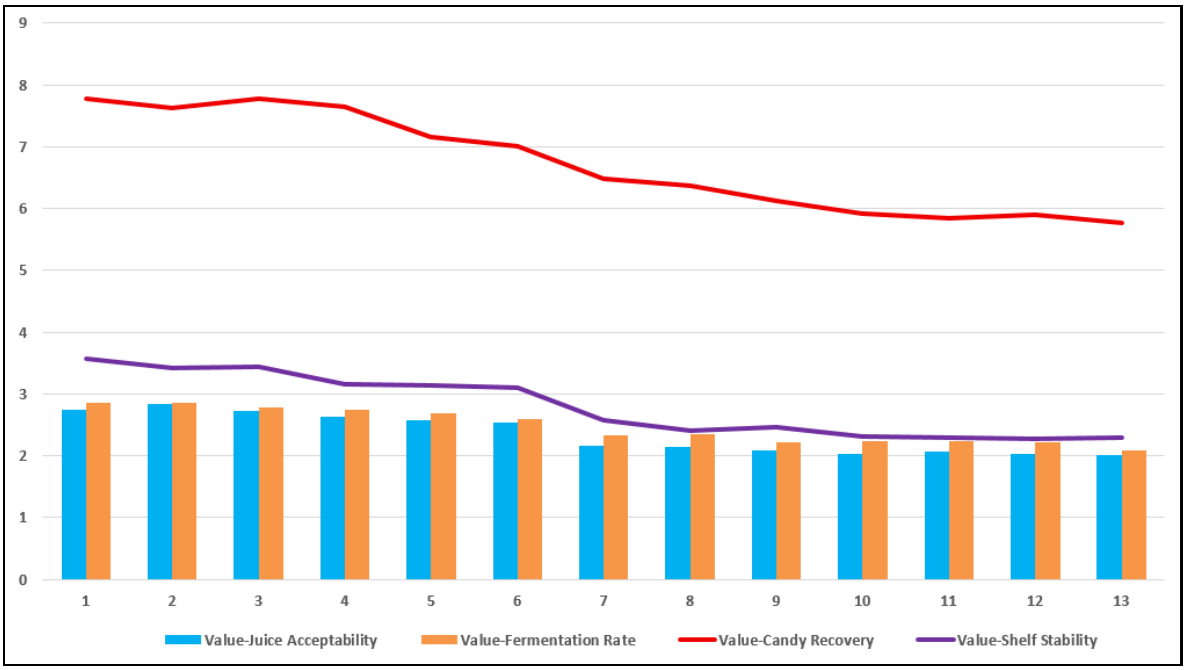

Fig 3: Evaluation of Value-Added Product Quality Attribute

Conclusion

The study demonstrates that pest damage significantly reduces the physical, nutritional, and processing quality of cashew apples. Fruits with up to 15% damage (T_1-T_4) retained acceptable standards for juice and value-added processing. However, fruits with damage exceeding 30% (T_7-T_{13}) were unsuitable for high quality processing due to poor juice yield, lower vitamin C, higher tannins, and reduced stability. Integrated pest management (IPM) during fruiting is essential to minimize losses and ensure the commercial viability of cashew apple processing.

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