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# Evaluation of performance of custard apple (*Annona squamosa* L.) pulp-flakes extractor

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**Abstract**

The designed and developed semi-automatic machine to extract the seeds from the flakes. The scope in custard apple processing is deseeding of pulp and pulp- flakes extraction. Hence, there is need of effective machine which can separate pulp and seed from custard apple. The research was conducted to evaluate the performance of custard apple pulp-flakes extractor. The machine consists of constructional parts such as feeding hopper, central wire mounted roller with shaft, outer perforated casing, housing with seeds/pulp flakes outlet, seed outlet, pulp-flakes outlet, A.C. induction motor drive with gear box and frame on which all the parts were assembled. The effect of roller speed and angle of inclination on core recovery, flakes recovery, working capacity and seed separation was studied. The optimum values of core recovery, working capacity, seed separation efficiency and flakes recovery was 85 per cent, 80 kg/h, 86 per cent and 75 per cent, respectively, for 65 rpm of roller and 38° inclination angle of drum.

**Keywords:** Custard apple, pulp-flakes, roller speed, angle of inclination, core recovery, flakes recovery, working capacity, seed separation efficiency

## Introduction

Custard apple is a popular fruit crop of tropical states of India. In Maharashtra, custard apple crop is grown on 13,470 ha with the production of 85,340 MT. It is widely distributed throughout tropics and subtropics in Maharashtra. This fruit crop is mainly grown in the districts of Beed, Dhule, Pune, Aurangabad, Nagpur and Bhandara (Anonymous, 2017) [1]. It is usually eaten as a dessert fruit and finds immense applications in the preparations of beverages and ice creams (Chikhalikar *et al*., 2000) [3]. Fruit has gained considerable importance because of its sweet pulp being medicinally valuable and it is good source of carbohydrates (23.5%), minerals (0.9%) and proteins (1.6%) as reported by Gopalan *et al*. (1991) [4]. Processed products of custard apple such as jam, jelly, crush, ice-cream etc. has more demand in the market if they have flakes along with pulp. However retention of flakes is more important during pulp extraction to have good organoleptic properties of processed products. Custard apple is considered as a critical fruit for separating the seeds from pulp-flakes with minimum damage to the flakes. A manual separation of pulp-flakes is very cumbersome, time consuming and unhygienic. It also leads to crushing of flakes to some extent. Further, manual separation has constraints in separation of pulp-flakes on large scale (Kad, 2015 and Kad *et al*., 2016) [5, 6]. The scope in custard apple processing is deseeding of pulp and pulp- flakes extraction. Hence, there is need effective machine which can separate pulp and seed from custard apple. The machine was evaluated in the present research work in term of core recovery, flakes recovery and seed separation efficiency.

## Materials and Methods

The custard apple pulp-flakes extracting machine was tested to study the effect of roller speed and angle of inclination on working capacity, core recovery, flakes recovery and seed separation efficiency. The present machine was developed in Agricultural Process Engineering and Post-Harvest Technology Centre, Mahatma Phule Krishi Vidyapeeth, Rahuri and M/s. Sahyadri Farmers Producer Company Ltd., Nashik.

### Independent variables

1. Revolution per minutes of roller
2. Angle of inclination of drum

**Dependent variables**

1. Corerecovery
2. Flakes recovery
3. Seed separation efficiency

All the dependent variables were calculated using procedure given by Kad (2015) [5] and Kad *et al.* (2016) [6].

**Core recovery**

The core recovery is amount of pulp of fruit coming out of the machine after separation. Total material at seed and pulp outlet was collected and weighted.

$$\text{Corerecovery}(\%) = \frac{\text{Materialatpulpoutlet} + \text{Materialatseedoutlet}}{\text{Weightofcorefeedinhopper}} \text{X100}$$

**Flakes recovery**

The flakes recovery is percent weight of extracted pulp.

$$\text{Flakesrecovery}(\%) = \frac{\text{Weightofflakesonly}}{\text{Weightofpulpwithflakes}} \text{X100}$$

**Seed separation efficiency**

The seed separation efficiency for different inclination angle and calculate by using following formula.

$$\text{Seedseparationefficiency } (\%) = \frac{(\text{Totalweightofseedmaterial}) - (\text{Unseparatedseedsfoundatseedoutlet} + \text{Unseparatedseedsfoundatpulpoutlet})}{\text{Totalweightofseedmaterial}} \text{X100}$$

**Response surface methodology (RSM)**

RSM has important applications in design development and formulation of new products, as well as in improvement of existing product design. The goal of RSM is to determine the optimum conditions for the system or to determine a region in the total space of the factors in which certain desirable conditions are satisfied. It defines the effect of independent variables, alone or in combination, on the processes. In addition to analyzing the effects of independent variables, this experimental methodology generates a mathematical model (Kad *et al.*, 2016) [6].

## Results and Discussion

**Performance evaluation of Custard Apple Pulp-Flakes Extractor Machine**

Performance evaluation of the developed machine was carried out to see the effect of roller speed (30, 50, 70 and 90 rpm)and inclination angle of drum (20, 30 and 40°) on core recovery, working capacity, seed separation efficiency and flakes recovery and the results have been presented in Table 1 to 3.

**Response contour for core recovery**

The core recovery was found to be increasing with increase in RPM of roller and inclination angle of drum. Maximum core recovery of 87.57 per cent was found for roller speed of 90 rpm and inclination angle of 40°.The increased core recovery with increase in RPM of roller and inclination angle of drum was due to increased centrifugal force, which forced pulp-flake material away from the roller wires at pulp-flakes outlet and also due to increased vibrations of the machine with increase in roller speed.

**Response contour for working capacity**

The minimum working capacity of 31.61 kg/h was recorded at roller speed of 30 rpm and 20° inclination angle of drum, while maximum of 102 kg/h was for a roller speed of 90 rpm and 40° inclination angle of drum. It was observed that with increase in RPM of roller and inclination angle of drum, the working capacity was increased.

The increased working capacity with increase in RPM of roller and inclination angle of drum was due to increased centrifugal force, which forced pulp-flake material away from the roller wires at pulp-flakes outlet and also due to increased vibrations of the machine with increase in roller speed

**Response contour for seed separation efficiency**

It was found that the seed separation efficiency was decreasing with increase in inclination angle of drum and RPM of roller. A seed separation efficiency of 91.59 per cent was found at 20˚ inclination angle of drum and 70 rpm speed of roller, while it was decreased to 84.27 per cent at an inclination angle of drum of 30˚and 90 rpm of roller.

**Response contour for flakes recovery**

The recovery of the flakes was found to be depending mainly on the RPM of roller, since the clearance between stainless steel wires cylinder and outer perforated casing varying from 7 mm at feed end to 2 mm at the discharge end.

It was observed that the flakes recovery was increasing with increase in inclination angle of drum and was decreasing with increase in RPM of roller. The maximum flakes recovery of 81.05 per cent was found for a roller speed of 30 rpm and 30° inclination angle of drum, whereas minimum flakes recovery of 64.80 per cent was for a speed of 90 rpm and 20° inclination angle of drum. The decrease in flakes recovery was due to increased momentum and inertial forces resulting in more impact action for squeezing out the pulp-flakes.

**Response contour for core recovery, working capacity, seed separation efficiency and flakes recovery**

The custard apple pulp-flakes extractor was tested for core recovery, working capacity, seed separation efficiency and flakes recovery by changing the RPM of roller as 30, 50, 70 and 90 rpm and inclination angle of drum varying from 20 to 40°. The response contours map shown in Fig.1 was drawn for core recovery, working capacity, seed separation efficiency and flakes recovery while considering RPM of roller and inclination angle of drum.

As per the response contours for core recovery, working capacity, seed separation efficiency and flakes recovery, the optimum value of core recovery, working capacity, seed separation efficiency and flakes recovery is 85 per cent, 80 kg/h, 86 per cent and 75 per cent, respectively. The best combination of RPM of roller and inclination angle of drum is 65 rpm and 38°, respectively for said optimum values of core recovery, working capacity, seed separation efficiency and flakes recovery.

The results obtained in the present investigation are in similar line with Kad *et al.* (2016) [6] and Pawar (2012) [7] for the testing of custard apple pulp-flakes extracting machine.

**Table 1.** Effect of roller speed at 20° angle of inclination on core recovery, seed separation efficiency and flakes recovery

| Sr. No | RPM | Time required (min) | Weight of core (g) | Weight of material at pulp-flakes outlet (g) | Weight and number of seeds at pulp-flakes outlet (g) | Weight of seeds at pulp-flakes Outlet (%) | Weight of pulp-flakes at pulp-flakes outlet (g) | Weight of flakes only (g) | Weight of gritty pulp only (g) | Weight of material at seed outlet (g) | Weight of unseparated seeds at seed outlet (g) | Weight of unseparated seeds at seed outlet (%) | Working capacity (kg/h) | Seed Separation efficiency (%) | Core Recovery (%) | Flakes recovery (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 8.16 | 4300 | 1830 | 13.03 (07) | 0.71 | 1827.97 | 1434.40 | 393.57 | 1310 | 170 | 12.97 | 31.61 | 86.86 | 73.02 | 78.47 |
| 2 | 50 | 7.19 | 4500 | 1800.45 | 13.80 (08) | 0.77 | 1798.65 | 1339.99 | 458.66 | 1350 | 130 | 09.63 | 37.55 | 90.23 | 70.01 | 74.50 |
| 3 | 70 | 5.38 | 4500 | 1890.40 | 12.92 (06) | 0.68 | 1888.48 | 1305.13 | 583.35 | 1390 | 115 | 08.27 | 50.18 | 91.59 | 72.90 | 69.11 |
| 4 | 90 | 3.20 | 4500 | 1940.00 | 13.40 (07) | 0.74 | 1938.60 | 1256.21 | 682.39 | 1330 | 130 | 09.77 | 84.37 | 90.12 | 72.67 | 64.80 |

**Table 2.** Effect of roller speed at 30°angle of inclination on core recovery, seed separation efficiency and flakes recovery

| Sr. No | RPM | Time required (min) | Weight of core (g) | Weight of material at pulp-flakes outlet (g) | Weight and number of seeds at pulp-flakes outlet (g) | Weight of seeds at pulp-flakes Outlet (%) | Weight of pulp-flakes at pulp-flakes outlet (g) | Weight of flakes only (g) | Weight of gritty pulp only (g) | Weight of material at seed outlet (g) | Weight of unseparated seeds at seed outlet (g) | Weight of unseparated seeds at seed outlet (%) | Working capacity (kg/h) | Seed Separation efficiency (%) | Core Recovery (%) | Flakes recovery (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 6.16 | 5100 | 3409 | 17.76 (12) | 0.52 | 3391.24 | 2740.49 | 650.75 | 854.50 | 103.82 | 12.15 | 49.68 | 85.77 | 83.60 | 81.05 |
| 2 | 50 | 5.56 | 5100 | 3400 | 10.40 (08) | 0.30 | 3389.59 | 2598.19 | 791.40 | 860.30 | 120.50 | 14 | 55.03 | 84.79 | 83.54 | 78.01 |
| 3 | 70 | 5.16 | 5100 | 3470 | 18.64 (12) | 0.54 | 3451.35 | 2478.69 | 972.66 | 930.00 | 136.90 | 14.67 | 59.30 | 83.33 | 86.33 | 72.30 |
| 4 | 90 | 3.10 | 5100 | 3500 | 10.90 (07) | 0.31 | 3489.10 | 2415.50 | 1073.10 | 994.50 | 145.50 | 14.63 | 98.70 | 84.27 | 88.13 | 69.50 |

**Table 3.** Effect of roller speed at 40°angle of inclination on core recovery, seed separation efficiency and flakes recovery

| Sr. No | RPM | Time required (min) | Weight of core (g) | Weight of material at pulp-flakes outlet (g) | Weight and number of seeds at pulp-flakes outlet (g) | Weight of seeds at pulp-flakes Outlet (%) | Weight of pulp-flakes at pulp-flakes outlet (g) | Weight of flakes only (g) | Weight of gritty pulp only (g) | Weight of material at seed outlet (g) | Weight of unseparated seeds at seed outlet (g) | Weight of unseparated seeds at seed outlet (%) | Working capacity (kg/h) | Seed Separation efficiency (%) | Core Recovery (%) | Flakes recovery (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 5.38 | 5100 | 2677.50 | 13.92 (09) | 0.52 | 2675.58 | 2081.60 | 593.98 | 1450.50 | 180 | 12.40 | 56.88 | 87.46 | 80.94 | 77.80 |
| 2 | 50 | 4.15 | 5100 | 2703 | 12.56 (08) | 0.46 | 2700.44 | 2011.82 | 688.62 | 1500.50 | 188 | 12.52 | 73.74 | 87.30 | 82.42 | 74.50 |
| 3 | 70 | 4.02 | 5100 | 2750.50 | 13.92 (10) | 0.51 | 2748.58 | 1890.47 | 858.11 | 1530.50 | 197.50 | 12.90 | 76.12 | 86.97 | 83.39 | 68.78 |
| 4 | 90 | 3 | 5100 | 2840 | 13.60 (09) | 0.44 | 2838.40 | 1840.13 | 998.27 | 1660.10 | 210 | 13.04 | 102 | 86.85 | 87.57 | 64.83 |

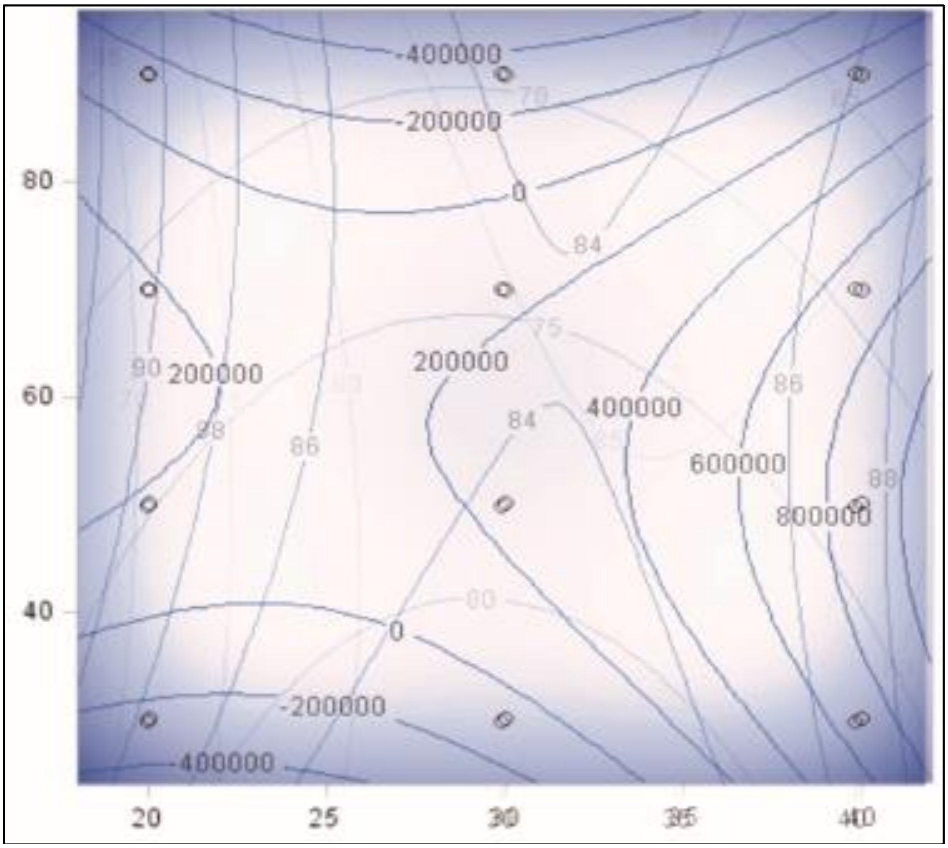


**Fig 1:** Contour map for core recovery, working capacity, seed separation efficiency and flakes recovery

## Conclusion

The best combination of developed custard apple pulp-flakes extractor for core recovery, working capacity, seed separation efficiency and flakes recovery was 85 per cent, 80 kg/h, 86 per cent and 75 per cent, respectively, for 65 rpm of roller and $38^{o}$ inclination angle of drum.

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