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Design, development and evaluation of hand operated Destoner cum Segmenter for Aonla (*Emblica officinalis*)

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Abstract
Aonla is known as Indian gooseberry which is rich in vitamin C and is popular around the world owing to its nutraceutical properties. Aonla is one of the underutilized fruits in India which has huge potential in world market and needs to be popularized. Manual processing of Aonla is very tedious and labour consuming which calls for developing new processing machineries. In the present study, a hand operated destoner cum segmenter was developed and assessed for its performance. The major components of the developed machine were frame, base plate, plunger rod with knives set, plunger rod with guide assembly, fruit holding cup, operating lever, segment scrapper, and seed and segment outlets. The findings of the present investigation revealed that the developed machine could successfully process about 13 kg of Aonla fruits in one hour with 90% pulp recovery efficiency. The developed machine resulted in about 91.3% labour and time saving as compared to manual destoning and segmenting by hand.

Keywords: Aonla, destoner, segmenter, performance evaluation, efficiency

Introduction

Aonla (*Emblica officinalis*) is one of the oldest Indian fruits and considered as "Wonder fruit for health" because of its nutraceutical qualities. It is rich in ascorbic acid content only next to Barbados cherry (*Malpighia glabra* L.). It is one of the three constituents of the famous ayurvedic preparation, triphala, which is prescribed in many digestive disorders (Peterson *et al.*, 2017) [8]. It is known by different names like Amla, Amalakki, Nelli, Indian gooseberry etc. It is an important fruit crop of tropical and subtropical region of India. It is grown in all over Asia for its nutritional, pharmacological and commercial significance. Wild Aonla trees are also found in China, Sri Lanka, Pakistan, USA and in Peurto Rico. The fruit bearing tree is quite hardy and is highly remunerative even without much care. The yield per tree ranges from 100 to 300 kg/year. It is the richest source of ascorbic acid (Vitamin C) and also contains tannin, polyphenol, pectin, gallic acid and fibre. About 600–900 mg of vitamin C is found in 100 g of Aonla pulp (Pokharkar, 2005) [9]. The Aonla fruits are used in medicines for treatment of common cold, gastric troubles, headache, constipation etc. (Gupta *et al.*, 2018) [4].

India is the largest producer of Aonla in the world. According to the recent estimates in 2021-22, Aonla production in India stands at 1206.17 MT (APEDA, 2023) [1]. In recent years, the processing and value addition of Aonla has increased many folds due to increase in its area and production. Aonla has acquired wide popularity all over the world for its medicinal properties. The fruit, due to its sour and astringent taste, has very limited table value (Ganachari *et al.*, 2020) [2]. However, it is processed into a number of products like preserve, candy, pickle, juice, shreds, RTS beverages, dried powder, Aonla supari etc. to increase its value and diversification of consumption (Nayak *et al.* 2012; Kore *et al.*, 2013) [7, 6].

Post-harvest losses in Aonla vary from 30-40 percent due to its perishable nature and glut during harvesting time, which reduce the market value of the fruit. Hence, value addition through processing would be the only effective tool for economic utilization of increased production of Aonla in future. The processes for preparations of different value added products from Aonla are currently limited to cottage and small scale industries which follow indigenous knowledge and processes for these products. Most of these processing operations are still done manually which are laborious, and inefficient with higher drudgery. In addition, small capacity pricking and shredding machines are also used in the processing of Aonla. However, these are less efficient, consume more power and susceptible to numerous breakdowns (Goyal *et al.*, 2008) [3].

Aonla processing operations *viz*., manual destining, pricking, and segmenting/slicing also has safety issues for the processor. Hence, there is need to develop destoning, pricking and segmenting equipment for increasing the processing capacity and safety of the user. In light of the above, the present study was undertaken to develop and evaluate the performance of a hand operated destoner cum segmenter for small scale Aonla processing.

Materials and Methods

In the present study, the Aonla samples were collected from the local market in Delhi, India for evaluation of the physical and mechanical properties of Aonla fruit. The samples were sorted, washed with portable water and stored under refrigeration till further analysis. The Aonla fruits were analyzed for physical and mechanical properties which formed the basis for the design of the Aonla destoner cum fragmenter.

Measurement of physical properties

The principal dimensions *viz*., length (L) and diameter (*D*) of twenty randomly selected Aonla fruits and the seeds were measured by using a digital vernier caliper of 0.01 cm least count. From the principal dimensions, the geometric mean diameter (D_g) was calculated and is expressed as size. The size, sphericity (ϕ) and surface area (S) were computed using the following equations (Kingsly et.al. 2006; Topuz et.al. 2005; Pradhan *et al.*, 2009) [5, 10].

$$D_g = (L \times D^2)^{1/3} \quad (1)$$

$$\varphi = \frac{D_g}{L} \quad (2)$$

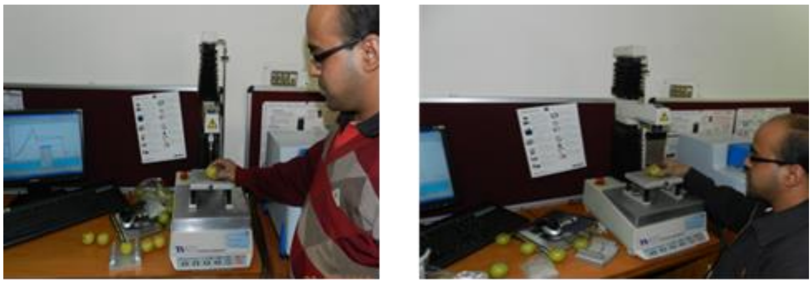
$$S = \pi D_g^2 \quad (3)$$

Fruit mass was determined using an electronic balance of 0.001 g accuracy. To determine the 1000 fruit mass, 20 randomly selected fruits were weighed and extrapolated. The volume and true density of fruits and seeds were measured by liquid displacement method and water was used as the liquid. The fruit volume was measured using a 500 ml measuring cylinder and for seeds a 25 ml measuring cylinder was used because of its smaller size. The true density was calculated as the ratio of fruit mass by the displaced volume of water (Pradhan *et al.*, 2009) [10]. The seed to pulp ratio was also calculated from the fruit and seed masses. Fig. 1 shows the views of the laboratory experiments.

Fig 1: Views of physical properties measurement of Aonla

Measurement of mechanical properties

In the present study the surface hardness (skin strength) of the Aonla fruits was measured using texture analyzer (Stable Microsystems, UK) with 3 mm diameter stainless needle probe (P/2N). Initial peak force in compression, corresponding to the insertion of probe through the surface, was taken as the surface hardness of the Aonla fruits. The skin elasticity was also determined as the displacement of the probe till the skin rupture point. The cutting force was also determined by shearing test using blade set probe (HDP/BS) in the texture analyzer. The tests were conducted for both fresh fruit and blanched fruit. Hot water blanching with three treatment times *viz*., 3 min, 6 min and 10 min were followed. The measurements were made in two orthogonal orientations i.e. vertical and radial, with respect to the stem-calyx axis. Six replications were taken for each test parameter. The test conditions were: pre-test speed=1.5 mm/s, test speed = 1.00 mm/s, post-test speed = 10.00 mm/s, trigger force = 10 g and points per second = 400. The views of the textural measurement are shown in Fig. 2.



Puncture test with needle probe **Shear test with blade set**

Fig 2: Measurement of textural properties with texture analyzer

Development of the Aonla destoner cum segmenter

A hand operated equipment for the removal of seed/stone and cutting of the Aonla fruit into six pieces/segments was designed and developed (Fig. 3). The developed machine consisted of the following major components/assemblies.

Base plate: The base plate of size 200 x 125 mm was made of SS. The base plate was provided a seed hole of diameter 17 mm and a rectangular opening of size 40 x 40 mm for discharge of the cut segments to the outlet trough below. The base plate was provided with channels along the length for sliding movement of the fruit holding plate. Two stoppers at both side ends were provided so as to restrict the movement of the fruit plate and help proper positioning.

Fruit holding cup with plate: To minimize the risk of any hand injury during feeding of fruit and holding the fruit in position a fruit cup was designed. The fruit holding cup was made of SS. The cup has a tapered hole with maximum diameter of 46 mm at top to 35 mm at bottom. The height of the cup was 40 mm. The fruit cup was provided with six longitudinal grooves at 60^0 angular spacing for movement of the cutting blades. The fruit cup was fitted with a base plate of size 125 x 105 mm. The plate was provided with a hole of 35 mm diameter and the cup was fitted exactly above this hole. A handle was provided for holding the plate during operation.

Plunger rod with knives set: The plunger rod was made of SS with diameter 12 mm and the end of the rod was machined in to a V-groove with sharpen edge. The V-groove was provided for easy punching and scouring of seed at discharge. The plunger was fixed with a set of six SS knives at 60^0 angular positions for cutting the fruit in to six pieces. The knives were positioned in line with the grooves of the fruit cup.

Plunger push rod with guide assembly: The plunger was fitted to a push rod of 20 mm diameter. The guide bush of 35 mm diameter and 100 mm length was provided for support and straight to and fro movement of the push rod. The guide bush was rigidly fixed to the frame. The rotation of push rod in the bush was restricted by providing a key on the push rod and a groove in the hole of the bush. This was necessary for exact movement of the blades along the grooves in the fruit cup. A retaining spring was provided for automatic return stroke of the plunger. A socket was fitted at top of the push rod to hold the spring.

Operating lever: A 900 mm long operating lever was provided made of 15 mm square MS rod.

Segment scraper: The cut fruit segments had a tendency to stick to the knives and come out during the return stroke. Therefore, a scraper was designed to scrape out the segments sticking to the knives and dislodge back to the fruit cup. The scraper was fitted above the fruit cup at height of 25 mm. The scraper consists of a SS ring of 70 mm diameter with a set of six radial fingers protruding towards the plunger rod. The fingers were of 24 mm length with the inner edge beveled at 45^0 for pushing the segments towards the center in to the fruit cup. The scraper was so positioned that the fingers lie just in between the line of cutting knives.

Frame: The base frame for holding the base plate was made of 25 x 25 mm MS angle with four legs. The upper frame of the machine was made of 20 mm square MS pipe.

Seed and fruit outlet: Separate out let chutes for seed and fruit segments were provided below the base plate. The seed and fruit segments are discharge separately on either side.

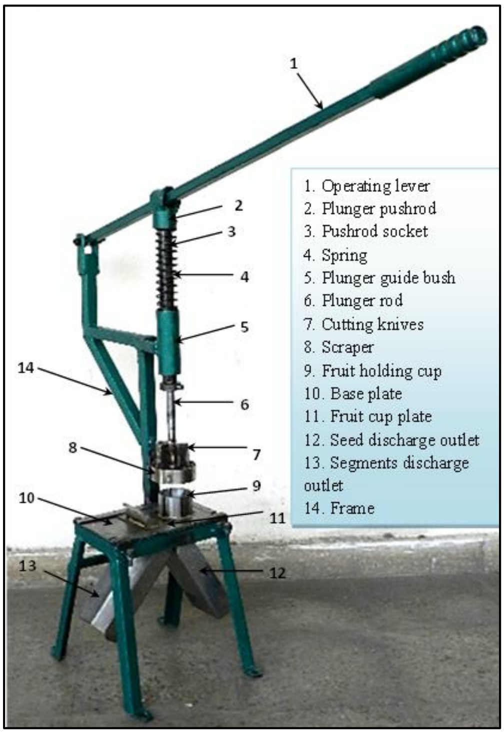


Fig 3: Developed Aonla destoner cum segmenter

Working principle of the machine

The fruit is fed into the fruit cup and then slide towards the left side. Then the operating leaver is depressed. In the downward stroke the plunger end punches the fruit first pushing the seed downward and then cutting takes place by the following knives. The seed is discharged through the seed outlet chute. The fruit segments remain inside the fruit cup. In case the fruit segments stick to the knives, then the scraper dislodges them back in to the fruit cup. Then the fruit cup plate is slide back to left position. At this position the bottom of the fruit cup is open to the fruit opening of the base plate and falls through the fruit outlet chute. Seed and fruit segments are collected separately on either side.

Performance evaluation of the developed machine

The performance evaluation was carried out with 20 numbers of fruits per batch and three replications were taken. The views of the machine operation are shown in Fig. 4. The performance of the developed machine was evaluated in terms capacity in number of fruits/h and kg/h and efficiency of pulp recovery. The pulp recovery was defined as the ratio of the weight of pulp recovered to the total pulp present in the fruit which is the difference in weight of fruit and stone.

Fig 4: Operation of the machine: a & b feeding of fruit, c- punching and cutting, d- fruit segments and seeds

Results and Discussion

Physical properties of Aonla

The physical properties of Aonla fruit and seed/stone are presented in Table 1. The size of the fruit i.e. the geometric mean diameter varies from 37.7- 44.2 mm and that of the seed varies from 13.1-15.4 mm. The sphericity values of 1.09-1.24 for fruit and 0.91-1.03 for stone indicates almost spherical shape of the fruit and seed/stone. However, the seeds are less spherical than fruits. This may be due to the ribbed structure of the seed. All the fruits in the test sample had six segments. The one thousand mass of Aonla fruits and seeds were 32-51 kg and 1.096-1.774 kg respectively. The true density of the Aonla fruit and stone were 0.97-1.36 g/cm^3 and 0.62-1.47 g/cm^3 respectively. The pulp percentage in the Aonla samples were in the range of 95-97%.

Table 1: Physical properties of Aonla

Properties	Maximum	Minimum	Average	SD
Fruit				
Length, mm	39.4	31.5	35.1	1.8
Diameter, mm	46.8	39.5	42.8	1.7
Geometric mean diameter, mm	44.2	37.7	40.1	1.6
Sphericity	1.24	1.09	1.14	0.03
Surface area, cm^2	61.3	44.6	50.5	4.1
1000 Mass, kg	51.0	32.0	38.6	4.6
Volume, cm^3	47.5	30.0	36.3	4.2
True density, g/cm^3	1.36	0.97	1.1	0.1
Seed				
Length, mm	16.4	14.0	15.4	0.8
Diameter, mm	15.1	12.5	14.2	0.7
Geometric diameter, mm	15.4	13.1	14.6	0.6
Sphericity	1.03	0.91	0.95	0.03
Surface area, cm^2	7.4	5.4	6.71	0.6
1000 Mass, g	1.774	1.096	1.442	0.354
Volume, cm^3	2.4	1.0	1.4	0.4
True density, g/cm^3	1.47	0.62	1.10	0.2
No. of segments	6	6	6	-
Pulp percentage, %	97	95	96	-

Mechanical or textural properties

The results of the mechanical properties of fresh, and blanched Aonla fruits are presented in Table 2. The results of texture analysis indicated that the surface hardness (2.043-3.84 N) as well as cutting forces (5.724-13.752 N) are higher in radial direction than axial direction (1.22-3.246 N hardness and 5.162-12.803N cutting force). This may be due to the fiber structure and maturity direction of the fruit. From Table 4, the surface hardness as well as cutting force decreased with the increase in blanching time. This may be due to the softening of fruit caused as a result of higher treatment time. In contrast to the hardness and cutting force, the deformation of the skin increased with the blanching period. This may be attributed to the higher tenderness of the fruit skin upon hot water treatment for longer period. The cutting force and the skin strength obtained from the present study were not too high and hence, can be applied manually by hand with suitable linkage design.

Table 2: Surface hardness and cutting force of fresh and blanched Aonla fruit

Parameter	Axial direction	Radial direction
Surface hardness, N		
Fresh Aonla	3.246	3.840
Blanched (3 min)	2.046	2.537
Blanched (6 min)	1.499	2.446
Blanched (10 min)	1.220	2.043
Cutting force, N		
Fresh Aonla	12.803	13.752
Blanched (3 min)	7.24	7.36
Blanched (6 min)	6.208	6.841
Blanched (10 min)	5.162	5.724
Deformation, mm in puncture test		
Fresh Aonla	2.1	1.6
Blanched (3 min)	3.1	2.4
Blanched (6 min)	2.8	2.5
Blanched (10 min)	3.6	2.7

Performance evaluation of the developed machine

The results of the performance evaluation of the developed machine have been presented in Table 3. The machine showed a pulp recovery efficiency of 89.97 ≈ 90%. The 10% loss was due to the pulp waste sticking to the seed and little juice waste due to compression during punching of the fruit. The pulp recovery efficiency was lower in the developed machine in comparison to manual destoning and segmenting by hand where efficiency was about 99%. Similar type of pulp recovery efficiency has been reported by Swarnakar *et al.* (2018) [11] for a hand operated alma destoning cum slicing machine. However, about 396 fruits/h could be processed by the developed machine as compared to 33 fruits by hand. The machine capacity was about 13.3 kg/h. The capacity of the developed machine is about 13 times higher compared to manual destoning and segmenting by hand. In a day, about one quintal of Aonla fruit can be processed based on 8 hours of operation. Higher capacity can be realized in long operation and with proper practice by the operator. The weight of the machine was about 8.8 kg. Average cost of the machine was ₹1500.00.

Table 3: Performance of the Aonla destoner cum segmenter

Particulars	Developed machine		Manual method	
	Mean value	SD	Mean value	SD
Fruit weight, kg	0.670	0.047	0.661	0.058
Pulp recovery, kg	0.575	0.044	0.622	0.073
Weight of mass collected at seed outlet, kg	0.081	0.006	-	-
Seed weight, g	0.031	0.004	0.035	0.006
Time taken, s	181.67	2.52	2180.85	10.33
Pulp recovery efficiency, %	89.97	1.05	99.36	0.72
Capacity, No. fruits/h	396.37	5.49	33.02	1.11
Capacity, kg/h	13.30	1.01	1.09	0.58
Labour requirement (man-hour/kg)	0.08	0.01	0.92	0.23

Conclusions

The present study aimed to develop a simple hand operated Aonla destoning and segmenting machine. From the findings of the present investigation, the developed machine was found to be superior to manual Aonla destoning and segmenting in terms of capacity and safety. The developed destoner cum segmenter could process about 13 kg of Aonla fruit per hour with a pulp recovery efficiency of about 90%. In addition, the developed destoner would help in drudgery reduction of the workers of Aonla processing units. The developed Aonla destoner cum segmenter is a simple, light and low-cost equipment, which can be recommended to be used in the small /cottage scale industries involved in processing and value addition of Aonla.

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