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Studies on Engineering Properties of Aonla Fruit (*Phyllanthus Emblica* L.) for Design and Development of Aonla Pricking Machine

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Abstract: *The studies on engineering properties of aonla fruit were undertaken for designing and development of low cost manual operated aonla pricking machine. The findings of seventy five fruits taken for observation of various parameters on average basis revealed, unit weight (33.00 grams), size (39.77 mm), spherecity (98.82%), volume (33.70 cm^3), surface area (14.78 cm^2) and volume to surface area ratio (2.32 : 1). The aonla pricking machine designed and developed after exploring engineering properties of fruit consisted of, mild steel (M.S) supporting frame angle (35 L × 35 B × 600 H mm) and plate (300 × 300 × 5 mm thick) and pricking stand of Wolf ES 14. The pricking die unit comprise of die plate, die support, needle support, needle (spike), spring, spindle and allen bolt of various dimension.*

Keywords: *Aonla Pricking Machine, Engineering Properties, Design.*

INTRODUCTION

Aonla fruit is currently grown over 49.60 thousand hectares, with production of 150.5 thousand metric tons (nhb.gov.in; www.apeda.gov.in). Aonla due to less water requirement, least crop protection measures and high market demand has become one of most sought over crop among the farmers of dry land region. The demand for industry is due to its, high processing potential and medicinal properties. High ascorbic acid 450-682 mg/100g in aonla (Shrivastava and Shrivastava, 1964) helps in treating scurvy, a Vit.C deficiency disease (*en.wikipedia.org/wiki/scurvy*). Aonla fruit is having, antiscorbulic, diuretic, laxative, and alternative antibiotic properties (Ray and Mujumdar, 1976) and used in treating jaundice and cough (Burkill,1935). It is used in Ayurvedic and Unani systems of Indian Medicines (Khan and Moheet, 1958, Tripathi *et.al., 1979*). Apart from its medicinal properties aonla is also used for preparation of various household products on commercial scale such as; Juice, Murramba, Pickles, Syrup, Squash, RTS beverages, candies, etc. (Kalra, 1988, Bhosale, 1998).

The physical properties of fruit plays important role in handling fruit during primary processing operations, such as grading, pricking, blanching, syruping, etc. and also for designing the portable equipment for such operations. Aonla fruits are round to oval shape with diameter 3.2 to 4.0 cm, height 2.7 to 3.4 cm. The *Banarsi* cultivar is reputed for its fairly large size fruits upto 4.12 cm. (Singh and Arora, 1967). For preparation of candy from aonla pricking is the primary operation involved. Various workers have studied pricking as an important operation in various fruits such as, grapes (Thorat *et.al.*, 1963), ber (Gharte, 1984) and aonla (Patil, 2001) for rapid moisture loss during preparation of grape raisins, ber and aonla candy respectively.

Perception to various limitation such as, labor, time consumption, hygiene, unevenness in penetration and damage to the fruit, etc. in hand operated pricking fork, an indigenous equipment for pricking, the studies on engineering properties of aonla fruit (*Phyllanthus emblica* l.) Cv. "*Banarsi*" were undertaken for designing and development of aonla pricking machine.

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MATERIAL AND METHODS

A. Engineering Properties of Aonla Fruit

Engineering properties were studied from the observations of seventy five fresh, well matured aonla fruits procured from the orchards of Dept.of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. An average and range were worked out from observation of seventy five fruits for parameters comprising of, size, weight, sphericity, volume, surface area, and its ratio, pulp thickness, pulp weight, seed size, weight and pulp to seed ratio.

1. ***Size of Fruit (mm):*** It is geometric mean of three dimensions *viz.*, length, breadth and thickness, calculated using eq^{n}.1.1. and is elaborated below.

   Size = $(ABC)^{1/3}$

   Where, A = Major diameter

   B = Intermediate diameter

   C = Minor diameter

2. ***Unit Weight of Fruit (grams):*** Weight of fruit was measured by using electronic weighing balance.

3. ***Spherecity (%):*** Isoperimetric property of sphere expresses shape factor of an object. The spherecity was calculated by eq^{n}.1.2, mentioned below.

   Geometric mean diameter (mm) (ABC) $^{1/3}$

   $$\text{Spherecity} = \frac{\text{Geometric mean diameter (mm)}}{\text{Major diameter (mm)}}$$

   i.e. . $\dfrac{(ABC)^{1/3}}{A}$

4. ***Volume (cm^3) and Surface Area (cm^2):*** Volume and surface area of aonla fruit were calculated by using equations given by, Mohsenin, 1970, and is explained in eq^{n}.1.3. and 1.4 respectively.

   Where, $a = \dfrac{A}{2}$ and $b = \dfrac{B}{2}$

   Volume = $\dfrac{4}{3}\pi ab^2$

   Surface Area = $2\pi b^2 + 2\pi \dfrac{ab}{e}\sin^{-1} e$

   Where, $e = \left(\dfrac{1}{a^2} - \dfrac{1}{b^2}\right)^{1/2}$

5. ***Volume to surface area ratio:*** Volume to surface area ratio was calculated by dividing volume by surface area, as mentioned below in eq^{n}.1.5.

   Volume to surface area ratio

   $$= \frac{\text{Volume (cm}^3\text{)}}{\text{Surface area (cm}^2\text{)}}$$

6. ***Pulp thickness (mm):*** Aonla physical structure consists of six pulpy sections enclosing the seed tightly inside. Each of these sections is separated by thin thread like ridge over the surface. Using knife one complete section was cut out and the thickness of pulp was measured at three different places with the help of standard calibrated vernier caliper, and average pulp thickness was calculated.

7. ***Seed size (mm):*** The seed was removed from the raw fruit with the help of knife and its size was calculated using eq^{n}.1.1.

8. ***Weight of Pulp and Seed (grams):*** The pulp and seed weight was measured using standard calibrated electronic balance and average was calculated.

9. ***Pulp to seed ratio:*** The pulp to seed ratio was worked out by dividing the weight of pulp by weight of seed, as mentioned in eq^{n}.1.6.

   $$\text{Pulp to seed ratio} = \frac{\text{Weight of Pulp (grams)}}{\text{Weight of Seed (grams)}}$$

B. Design and Development of Pricking Machine

For simplicity in fabrication point of view the aonla pricking machine was design by dividing into following structural and functional components. The different parts of machine have been depicted in Figure A

(i) Supporting frame

(ii) Pricking Stand

(iii) Three aonla pricking die unit having spikes diameter 1, 2 and 3 mm.

The design consideration and actual fabrication are discussed as below.

1. ***Supporting Frame:*** The supporting frame consisted four legs using mild steel (M.S) angle of 35 × 35 × 600 mm and plate 300 × 300 × 5 mm. The supporting frame or stand was fixed firmly in the ground by using cement concrete and it provided a firm foundation for a machine.
2. ***Pricking Stand:*** The main frame of drill machine stand (Wolf ES-14) was used as pricking stand. The material of stand was mild steel. The stand consisted of ;
   (i) A base plate
   (ii) A vertical arm
   (iii) Pressing handle
   (iv) Sliding plate

The base plate was fixed firmly to the grooves provided in the supporting frame with the help of nuts and bolts.

3. ***Pricking die unit***
   (i) **Die plates:** Two die plates (top and Bottom), of aluminum bar were cut with the help of hack-saw machine, into rectangular shape of dimensions 200 × 50 × 35 mm, and were fabricated to die unit. By taking into account the roundness and average fruit diameter, two hemispherical cavities or round shaped cups of diameter 45 mm each were made to both the die plates (top and bottom) using lathe machine. Nine cylindrical holes were made in each cup using a small precision drill machine. The diameter of holes were according to the needle diameter of 1,2 and 3 mm.
   (ii) **Die support plate:** Two die support plates were fabricated top and bottom side of die unit in rectangular shape with dimension 250 × 75 × 20 mm. The plates were of mild steel and provided firm support to the entire pricking die.
   (iii) **Needle Support Plates:** Two needles support plates were fabricated to top and bottom side of the die unit. The dimensions of support plates were 150 × 50 × 10 mm and material used was mild steel. Nine holes for supporting the spikes/needle were drilled on each single support plate with the help of precision drill machine. The needle supporting holes were drilled with such accuracy that, they were in perfect alignment with the holes of cups in the die-plates. Three sets of needle support plates, with three different needle diameter *viz.*, 1, 2 and 3 mm, supporting total 36 needles were fabricated to three die units. Needle support plates were fixed to die support plates with the help of screws.
   (iv) **Needles or Spikes:** The needles used in the pricking machine were of high speed steel. Two sets each of nine needle top and bottom respectively, and each set of three different needle diameter *viz.*, 1, 2 and 3 mm were used. The length of needle was 70 mm and top and bottom needles were align to each other in the design. The needles were tapering towards the tip for free movement within the holes of the cup. The point of the spikes was sharp for deeper penetration to the fruit surface. Needles were supported to needle support plates with the wedge shape structure. Each needle was placed 10 mm apart from each other.
   (v) **Springs:** The upper and lower die plates were spring loaded. The material used for springs was standard with dimensions 60 h × 2*t* OD Φ 20 mm and ID Φ 16 mm. Two pairs of springs each between die-support plate and die plate were fixed with the help of allen screws.
   (vi) **Die Support Spindle:** Two die support spindles with dimensions 8 mm Φ × 225 mm L of M.S, were used. Two holes of 8 mm Φ on each of above supporting plates were drilled throughout for the purpose of insertion of spindles. After pressing the handle of pricking machine stand, the springs compress and die plates slide over the spindle.
   (v) **Spike Adjustment Allen Bolts:** Four spike adjusting allen bolts of 5 mm Φ and 50 mm length were used for adjusting the

depth of penetration of spikes into the fruit. The allen bolts were fitted between die plates and needles support plates. Maximum depth of penetration that could be achieved with the help of allen bolt. It was equal to the radius of cups (22.5 mm), however, owing to the presence of seed inside the aonla fruit and taking into account the average pulp thickness, the bolt were so adjusted that it could achieve penetration upto 10 mm depth.

(vii) **Crome Plating:** All the parts were crome plated in order to avoid corrosion. After coating was dried the plates were assembled together to form the single unit.

RESULT AND DISCUSSION

A. Engineering Properties of Aonla Fruits

The observations of seventy five fruit for various engineering properties of aonla fruit were recorded and average and minimum and maximum range of dimensions were calculated and presented in table 1.

1. ***Size of Fruit (mm):*** The size of fruit ranged between 35.63 mm to 43.99 mm, whereas average size was measured to be 39.77 mm.
2. ***Unit Weight of Fruit (grams):*** The range of unit weight of fruit was 24.08 grams to 44.92 grams and average weight was 33.00 grams.

Table 1
Some Engineering Properties of Aonla Fruits

Property of fruit	*Range*	*Average*
Unit weight (g)	24.08 to 44.92	33.00
Size (mm)	35.63 to 43.99	39.77
Spherecity (%)	90.30 to 99.99	98.82
Volume (cm)	24.02 to 45.62	33.70
Surface area (cm^2)	11.79 to 18.10	14.78
Volume to surface area ratio	1.76:1 to 2.52:1	2.32:1
Seed size (mm	12.50 to 16.43	14.36
Pulp thickness (mm	11.06 to 15.67	13.44
Seed weight (g)	1.19 to 1.96	1.54
Pulp weight (g)	21.82 to 39.63	31.36
Pulp to seed ratio	15.5 : 1 to 26: 1	19.5:1

3. ***Spherecity (%):*** The spherecity of aonla fruit ranged between 90.30 % to 99.99 % and average spherecity was 98.82 %.
4. ***Volume (cm^3) and Surface Area (cm^2):*** The range of volume of fruit was 24.02 cm^3 to 45.62 cm^3 and average was found to be 33.70 cm^3. The surface area of fruit ranged between 11.79 cm^2 to 18.10 cm^2 and averaged to 14.78 cm^2.
5. ***Volume to surface area ratio:*** Volume to surface area ratio was calculated and ranged between 1.76: 1 to 2.52 : 1 and average was found to be 2.32 :1.
6. ***Pulp thickness (mm):*** The range of pulp thickness of fruit was 11.06 mm to 15.67 mm and average pulp thickness was 13.44 mm.
7. ***Seed size (mm):*** The seed size (mm) of aonla fruit ranged between 12.50 mm to 16.43 mm and average was 14.36 mm.
8. ***Weight of Pulp and Seed (grams):*** Weight of pulp and seed (grams) was calculated and ranged was calculated. The range of seed weight (gms) was 1.19 to 1.96 and average was 1.54 grams. Whereas, range of pulp weight in grams was 21.82 to 39.63 and averages was found to be 31.46 grams.
9. ***Pulp to seed ratio:*** Pulp to seed ratio was calculated and ranged between 15.5 : 1 to 26 : 1 and average was found to be 19.5 :1.

B. Engineering Properties of Aonla Fruit for Design and Development of Pricking Machine

The results of study on engineering properties of aonla fruits concluded average size to be 39.77 mm, while, average spherecity was 98.82%. These parameters helped to design the hemispherical cavities or roundshaped cups of diameter 45 mm to hold the fruit in position for pricking. The cavities were made to both the die plates (top and bottom) using lathe machine.

Average fruit surface area was 14.78 cm^2 which helped to give conclusive evidence for finalizing nine plus nine number of needles fabricated to needle support plate, top and bottom respectively. Needles of diameter of 1, 2 and 3 mm were defined on average fruit surface area and moreover, to investigate percent surface area of fruit to be

pricked. For free movement of needles within the hemispherical cavities nine cylindrical holes were made in each cup using a small precision drill machine. The diameters of holes were according to the needle diameter.

Average pulp thickness 13.44 mm, of aonla fruit helped to determine thelength of needle *i.e.* 70 mm and moreover, to spring load upper and lower die plate with four springs of dimensions 60 h × 2t OD Φ 20 mm and ID Φ 16 mm for deeper penetration of needles into the pulp.

The seed size (mm) of aonla fruit ranged between 12.50 mm to 16.43 mm and average was 14.36 mm. This parameter helped to fixed 10 mm spacing between two needles and to comprise the design of machine with four spike adjusting allen bolts of 5 mm Φ and 50 mm length. These bolts were used for adjusting the depth of penetration of spikes into the fruit and were fitted between die plates and needles support plates. Maximum depth of penetration that could be achieved with the help of allen bolt was equal to the radius of cups (22.5 mm). However, owing to the presence of seed inside the aonla fruit and taking into account the average pulp thickness, the bolt were so adjusted that it could achieve penetration upto 10 mm depth.

C. Functioning of Machine

The functioning of pricking machine is based on the principal of pressure based penetration of needles into the fruits.

Lowering of the pressing handle of the pricking stand causes the upper movable die plate to slide smoothly along the spindle and come in contact with the lower fixed die-plate. As handle was pressed further, springs of both the plates compress. The needle moves through the holes made on the hemispherical cavity onto the die-plate. When aonla fruit was placed into the hemispherical cavity the needle penetrated into the fruit surface through the hole and single pricking operation was completed.

As handle was released slowly, springs expand and penetrated needles into the fruits were automatically released or removed from the fruit. The upper mechanism was lifted further along the rod and pricked aonla were collected. Depending upon the average surface area of fruit to be pricked the pressing handle could be lowered number of times accordingly.

Table 2
Performance of Machine Pricking Method with Different Needles Diameter (mm)

Sr. No.	*Parameter*	*Machine pricking*		
1.	Diameter of holes	1 mm	2 mm	3 mm
2.	No. of aonla fruits pricked at a time	2	2	2
3.	No. of holes per stroke	18	18	18
4	No. of strokes reguired to cover the entire surface	2	2	2
5.	Avg. depth of penetration achieved (mm)	12	10	8
6.	Damage to the fruits (%)	0	0.67	1.30
7.	Capacity (quantity of commodity pricked) kg/hr	10	8.5	5.80
9.	Average percent surface area pricked (%)	1.92 (1.57 to 2.39)	7.20 (6.28 to 9.54)	17.17 (14.05 to 21.48)

Figureureures in bracket are of range.

Table 3
Specifications (dimensions) and quantities of materials used for design and development of aonla pricking machine

Sr. No.	*Particulars/Material*	*Specification*	*Quantity (Nos.)*
1.	Die. Plate	200 × 50 × 35 h mm	2Nos
2.	Die support plate	250 × 75 × 20 hmm	2 Nos.
3.	Needle support plate	150 × 50 × 10 hmm	2 Nos.
4.	Spikes (Needles)	1ϕ mm, 2ϕ mm, 3ϕ mm × 70h	36 Nos.
5.	Spring	(60*h* × 2*t*) OD 2ϕ × ID (16ϕ) mm	4 Nos.
6.	Die support spindle	8ϕ × 255 L mm.	2 Nos.
7.	Spike adjust alien bolt	5ϕmm.	4 Nos.
8.	Machining drilling, sizing and cutting work	–	One job.
9.	Crome plating	–	One job.

D. Practical Application of Pricking Machine

The manual operated pricking machine comprised of three separate dies with two cavities. Each unit

was having eighteen needles. The diameters of needles were, 1, 2 and 3 mm, for three separate dies. For single stroke nine holes from upper side and nine holes from lower side total eighteen holes, were created on single fruit. Pricking frequency was two strokes. For fruits in coupled cavity two strokes could create 18 × 2 = 36 holes on the fruit. Two strokes for pricking could cover entire surface area of the aonla.

The data on the effect of needle diameter on range and average percent surface area pricked is given in Table 3. The data shows that percent surface area pricked increased with the increase in the diameter of needle. For 1 mm needle diameter percent surface area pricked ranged between 1.57 to 2.39 and the average percent surface area pricked was found to be 1.92. For 2 mm needle diameter, percent surface area pricked ranged between 6.28 to 9.54 and average percent surface area was found to be 7.20. For 3 mm needle diameter, percent surface area pricked ranged between 14.05 to 21.48 and average percent surface area pricked was 17.17.

Three different needle diameters in three different dies could achieve three different depth of penetration for pricking, thus exposing area of different dimensions on fruit for syruping during the candy preparation. Moreover, the capacity of the pricking was also different for different needle diameter. The data on the effect of pricking method and needle diameter on capacity is shown in Table 2. The capacity of the machine changed with respect to the diameter of the needle. The data shows that the capacity of the machine decreased with increase in the needle diameter. The maximum capacity (10 kg/hr) was found in case of 1 mm needle whereas minimum capacity (5.8 kg/hr) was found in case of 3 mm needle.

No special skills were required to operate the pricking machine. Except for cleaning the cavities on the machine and needles after pricking operation was over, no special maintenance was required. Due to simple prototype of the machine the risk of the casualties were nil, moreover handling of the fruit was also very less hence maintaining the hygienic condition of the fruit. The design and development of aonla pricking machine after studying the engineering properties of aonla fruit are well in corroboration with the finding of Jino Chacko *et.al.* (2003), who had developed and tested a low cost manual operated aonla pricking machine.

CONCLUSION

It could be concluded from the studies of engineering properties of aonla fruit that, a prototype of aonla pricking machine consisting of supporting frame a pricking stand with handle and aonla pricking die unit could be designed and developed. The overall dimensions of machine were 300 × 300 × 1200 mm.

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