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Assessment of Engineering Properties of Aonla Stone and Seeds

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A B S T R A C T

In the present article an attempt was made to determine some engineering properties of aonla stones and seeds. Stones and seeds were extracted manually from fresh and fully mature aonla fruits. Physical, gravimetric, frictional and mechanical properties of aonla stones, seeds and seed shell were assessed. Moisture content of aonla stone and seed was found to be 51.36 and 8.63 % (wb) respectively. Size of aonla stone and seed was recorded 14.98 and 4.07 mm respectively. Percent sphericity of aonla stone and seed was found as 90.22 and 48.59 respectively. Volume and surface area of aonla stone 17.21 cm^3 and 3221.9 mm^2 respectively. Weight of aonla stone was obtained 3.31 g and thousand seed weight of seeds was 17.21g. Aspect ratio of aonla stone and seed was 88.80 and 48.59 % respectively. Bulk density of aonla stone, seed and seed shell was 0.310, 0.461 and 0.277 g/cc. Similarly true density was 0.729, 0.666 and 0.752 g/cc. Porosity of aonla stone, seed and seed shell was 57.82, 30.75 and 63.08 % respectively. Coefficient of friction of aonla stone, seed and seed shell on mild steel surface was 0.63, 0.63 and 0.66 respectively. Similarly it was recorded as 0.60, 0.62 and 0.752 for stainless steel and 0.56, 0.53 and 0.63 for glass surface respectively. Rupture force of aonla stone was noted as 496 N.

Introduction

India is second largest producer of fruits and vegetables in the world and is leader in various fruits and vegetables area and production. Due to perishable nature of horticultural produce their value addition is the prime necessity to preserve them for long time at the time of glut and to make them available in off season. Their processing needs advanced mechanization and new processing methodology to be developed for ease of harvesting, handling, processing and storage and to reduce the human drudgery. Design of advanced machines and processes requires knowledge of engineering properties of these materials. India ranks first in the area under production and productivity of aonla or Indian gooseberry (*Emblica officinalis* Gaertn). It belongs to genus Emblica of the

family Euphorbiaceae and order Euphorbiales (Wali *et al.,* 2015). It is well known Indian fruit for its medicinal and therapeutic properties from the ancient time in India (Kore *et al.,* 2013). Aonla fruit is perishable and thus needs to be processed after few days of harvesting or else immediate marketing of raw fruits is required. Raw aonla fruit is not much acceptable by consumers because of its high acidic nature and its astringent taste (Priya and Khatkar, 2013). But the aonla products like candy, supari, pickle, preserve, triphala and chavaprash are very famous and have huge demand in the market because of their health benefits (Kore *et al.,* 2013). Aonla seed extracts also showed higher antioxidant activity and both seed and seed coat have good amount of major and micro minerals. Seed powder has very good amount of P, K, Mn, and Co. Fatty acid profile of seed and seed coat showed that the major portion of fatty acid is unsaturated in nature especially rich in ω-3 fatty acid. Seed coat is a good source of antioxidants and may be used for value addition of products alone or in combination with seed. Seeds being very good source of protein, minerals, ω-3, ω-6 fatty acids can be used to enrich foods. Combined utilization of aonla seed and seed coat with better hydration and water retention properties and higher P, Cr, Co, Fe, Mn and ω-3 and ω-6 fatty acids levels than fruit powder will be more fruitful (Mishra and Mahanta, 2014). Following research was conducted to determine the physical, textural and frictional properties of aonla stone and seed which can be used for design of machinery and methods for aonla processing, its transportation and storage.

Materials and Methods

For this study fresh mature aonla fruits were procured from farms of College of Dairy and Food Science Technology, MPUAT Udaipur in the first week of December. To obtain the aonla stone pulp of aonla fruits was extracted by manually with the help of knife. Stones were then dried in tray drier at temperature 50 °C to obtain the seeds. As the whole stones dried they broke along the ridges with a crackling sound and then brown seeds were separated from the covers of stone manually. Plate (1), (2) and (3) shows the picture of dried aonla stones, aonla seeds and aonla seed shell respectively. Fresh aonla stone, dried aonla stone, aonla seeds and seed covers were studied for their physical, gravimetric, frictional and mechanical properties.

Moisture content

The moisture content of aonla stone and seed was determined by using standard Association of official analytical chemist (1984) method. The experiment was replicated thrice for each sample. Equation (1) was used for calculation of moisture content.

$$\text{moisture content (\% wb)} = \frac{W_1 - W_2}{W_1} X \ 100 \qquad (1)$$

Where,

W_1 and W_2 are initial and final weight of sample (g)

Physical properties of aonla stone and seed

Size and sphericity of aonla stone and seed

Physical dimensions are needful for deciding the machine parameters. Three linear dimensions viz. length (L), width (W), thickness (T) in mm, of aonla stone and seeds were measured by using Vernier caliper (PRECISE 0-300mm Digital Caliper) with 0.01 mm least count.

The geometric mean diameter or size, S of the stone and seed was calculated by using Equation (2), (Mohsenin, 1986).

$$S = (L \ x \ W \ x \ T)^{1/3} \qquad \dots (2)$$

Sphericity is the ratio of the geometric mean diameter to the major diameter. Percent sphericity of the aonla stone and seeds was estimated by using Equation (3) recommended by Mohsenin, (1986).

$$\text{Sphericity } (\phi) = \frac{(L \times W \times T)^{1/3}}{L} \times 100 \quad \ldots (3)$$

Where,
S is the size of aonla stone/ seed (mm),
L, W, and T are the length, width and thickness of stone/seed, mm, respectively.

Aspect Ratio (Ra)

It is the term used to express the shape of material. The aspect ratio is the ratio between the sizes in different directions i.e. Width to Length. The aspect ratio (Ra) of aonla stone and seed was obtained by using Equation (4), (Owolarafe *et al.,*2007).

$$\text{Aspect ratio, Ra } (\%) = \frac{W}{L} \times 100 \quad \ldots (4)$$

Where,

Ra = Aspect ratio (%)
L = Length of stone/seed (mm)
W = Width of stone/seed (mm)

Gravimetric properties of aonla stone and seed

Stone weight

Aonla stones, stones were removed manually from the fully mature fruits and weighed for the investigation.

An electronic precision balance (Sartorius AG Germany, max 3200 g with accuracy 0.01 g) was used to record the weight. The average weight of 50 samples was recorded as stone weight.

Thousand seed weight

Thousand seed weight was determined by weighing 100 seeds in an electronic precision balance (Sartorius AG Germany, max 3200 g with accuracy 0.01 g) and then multiplying by 10 to get the mass of 1,000 seeds (Malik and Saini, 2016).

Volume and surface area of aonla stone

Volume of aonla stone was calculated by considering the geometry of the object similar to the geometrical shape. Knowing the values of length, width and thickness, the volume and surface area of the aonla stone were calculated by considering the geometry as to be oblate spheroid by using Equations (5 and 6) respectively (Mohsenin, 1986).

$$V = \frac{4}{3} (\pi a^2 b)$$
$$S = 2 \pi a^2 + \pi \frac{b^2}{e} \ln \frac{(1+e)}{(1-e)}$$

Where,
a and b = Major and minor semi axis of the ellipse of rotation (mm)
V = Volume of aonla stone (cc),
S = Surface area of aonla stone (mm^2) and
e = Eccentricity, calculated as Equation (7)

$$e = \left[1 - \left(\frac{b}{a}\right)^2 \right]^{1/2} \quad \ldots (7)$$

Bulk density (ρ_b)

Bulk density is the ratio of the weight of a sample to its total volume. Bulk density of aonla stone, seed and seed shell was determined by using the following Equation (8) (Mohsenin 1986).

$$\rho_b = \frac{W}{V} \quad \ldots (8)$$

Where,
ρ_b = Bulk density (g/cc),
W = Weight of stone/seed/seed shell (g)
V = Volume of measuring cylinder (cc).

True density (ρ_t)

True density of aonla stone, seed and seed shell was also determined by toluene displacement method using the equation (9). The observations were replicated thrice.

$$\rho_t = \frac{W}{V} \qquad \dots (9)$$

Where,
ρ_t = True density, (g/cc)
W = Weight of stone/seed/seed shell, (g)
V = Volume of liquid displaced, (cc).

Porosity (P)

Porosity was calculated by using bulk and true densities. Equation (10) was used for calculation of porosity of aonla stone, seed and seed shell.

$$\text{Porosity(P)} = (1 - \frac{\rho_b}{\rho_t}) \text{ X } 100 \qquad \dots (10)$$

Where,
P = Porosity, (%)
ρ_b = Bulk density (g/cc)
ρ_t = True density (g/cc)

Frictional properties of aonla stone, seed and seed shell

Coefficient of friction of aonla stone, seed and seed shell

Coefficient of static friction is the ratio of frictional force to the normal force. Static coefficient of friction of aonla stone, seed and seed shell was determined by using the method given by Kaleemullah and Kailappan

(2003). An experimental setup was consisting of frictionless pulley fitted on a frame, loading pan, test surfaces, and bottomless and topless box was used. The box attached by string parallel to the surface of the material and pass over the frictionless pulley with pan hanging from it. For the determination of coefficient of friction of aonla stone, seed and seed shell of known weight was taken in the test box; then it was tied to the string attached to loading pan. The pan was loaded with weights until sample began to slide on the surface. Weight in the pan was recorded, and the coefficient of friction was calculated by using Equation (11). Coefficient of friction of all the samples was also determined by changing the test surface using as mild steel, stainless steel and glass. The experiments were replicated 5 times.

$$\mu = F/N_f \qquad \dots (11)$$

Where,
μ = Coefficient of friction
F = Frictional force, g
N_f = Normal force, g

Rupture force of aonla stone

Rupture force of dried aonla stone was measured using Stable micro system TA-HD plus textural analyzer (Texture Technologies Corp., UK). 75 mm cylinder probe was used for a compression test. Probe was attached to probe carrier. The test was conducted at a test speed of 0.5 mm/s and at load cell of 5kg. The load required for breaking of dried aonla stone was recorded. Average of 10 sample data was considers as rupture force expressed in N. The testing parameters of texture analyzer were as following (Li *et al.,* 2016). Plate (3) shows the experimental setup of aonla stone compression test.

Pre test speed   :   1 mm/s
Test speed   :   2 mm/s

Post test speed : 2 mm/s
Distance : 5 mm
Trigger auto type : 50 g
Probe Type : 75 mm cylinder probe (p/75)
Load cell : 5 kg

Results and Discussion

Moisture content

Moisture content of aonla stone and seed was found in the range of 46.89 to 55.15 and 8.12 to 8.93 % (wb) respectively. Mean of stone and seed moisture content was 51.36 and 8.63 % (wb) respectively. Data of moisture content with standard deviation is presented in Table 1.

Physical properties of aonla stone and seed

Size and sphericity of aonla stone

Physical dimensions of stone and seeds were measured to obtain the size and sphericity of it. Three linear dimensions of aonla stone and seed were measured and reported as mean value as 16.61, 14.74, 13.75 mm and 6.81, 3.30, 3.01 mm respectively. Size and percent sphericity of aonla stone and seed were obtained as 14.98 mm, 90.22 and 4.07 mm, 59.84 respectively. Mean and standard deviation of all the mentioned parameters are presented in Table 1.

Aspect ratio (Ra)

Aspect ratio of aonla stone and seed was determined and reported as mean value 88.80 and 48.59 % respectively (Table 2). High aspect ratio of stone indicates its rolling and sliding ability on flat surface. Aspect ratio value close to sphericity indicates that it might undergo rolling and sliding action on flat surface.

Gravimetric properties of aonla fruits, stone and seed

Stone weight and thousand seed weight

Stone weight was found to be in the range of 2.08 to 3.29 g while thousand seed weight ranged between 22.20 g to 23.40 g with their average values as 3.29 g and 22.84 g respectively (Table 2).

Volume and surface area of aonla stone

Volume and surface area of aonla stone was found to vary in the range from 9.86 to 21.24 cm^3 and 2227.85 to 3708.52 mm^2 with average values of 17.21cm^3 and 3221.94 mm^2 respectively (Table 2).

Bulk density (ρ_b)

Average bulk density of aonla stone, seed and seed shell variegated between 0.294 to 0.320 g/cc, 0.459 to 0.464 g/cc and 0.250 to 0.311 g/cc with average values as 0.307, 0.461, 0.277 g/cc respectively (Table 3).

Higher value of bulk density was recorded for aonla seed compare to aonla stone and seed shell.

True density (ρ_t)

True density of aonla stone, seed and seed shell was found to vary from 0.726 to 0.772 g/cc, 0.655 to 0.677 g/cc and 0.737 to 0.778 g/cc and average was noted as 0.729, 0.673, 0.752 g/cc respectively (Table 3).

Porosity (P)

Porosity of aonla stone, seed and seed shell ranged from 57.35 to 60.26 %, 29.4 to 31.88 and 58.09 to 67.89 % and its average was found as 57.823, 30.756 and 63.089 % respectively (Table 3).

Frictional properties of aonla stone and seed

Coefficient of friction of aonla fruit, stone, seed and seed shell

The mean values of coefficient of friction of aonla stone, seed and seed shell on mild steel surface were found as 0.63, 0.63 and 0.66 respectively while the values for stainless steel were 0.60, 0.62 and 0.62 respectively

and for glass were 0.56, 0.53, and 0.63 respectively. Data revealed that mild steel exerts more friction to stone, seeds and seed shell compare to stainless steel and glass. Aonla seed shell and stone has more values of coefficient on all the surfaces; it may be due to its rough and sticky surface texture. Data recorded for coefficient of friction of aonla stone, seed and seed shell are presented in Table 4.

Table.1 Moisture content and physical properties of aonla stone and seed

Property	Moisture content	Length	Width	Thickness	Size	Sphericity
	%(Wb)	(mm)	(mm)	(mm)	(mm)	(%)
Aonla stone	51.36± 1.34	16.61 ± 1.07	14.74 ±1.24	13.75 ±1.04	14.98 ± 0.90	90.22 ± 2.67
Aonla seed	8.63 ± 0.44	6.81 ± 0.34	3.30 ± 0.20	3.01 ± 0.23	4.07 ± 0.17	9.84 ± 2.03

Table.2 Weight, volume and surface area of aonla stone and seed

Property	Weight	1000 seed mass	Volume	Surface area	Aspect ratio
	g	g	(cm^3)	(mm^2)	(%)
Aonla stone	3.31 ± 0.43	-	17.21 ± 3.10	3221.9 ± 400.4	88.80 ± 0.06
Aonla seed	-	22.84 ± 0.36	-	-	48.59 ± 3.51

Table.3 Density and porosity of aonla stone, seed and seed shell

Property	Bulk density	True density	Porosity
	g/cc	g/cc	%
Aonla stone	0.310±0.013	0.729 ±0.04	57.823 ± 2.24
Aonla seed	0.461 ± 0.002	0.666 ± 0.010	30.756 ± 1.433
Aonla seed shell	0.277 ± 0.03	0.752 ± 0.02	63.089 ± 4.896

Table.4 Coefficient of friction (μ) of aonla stone, seed and seed shell on various surfaces

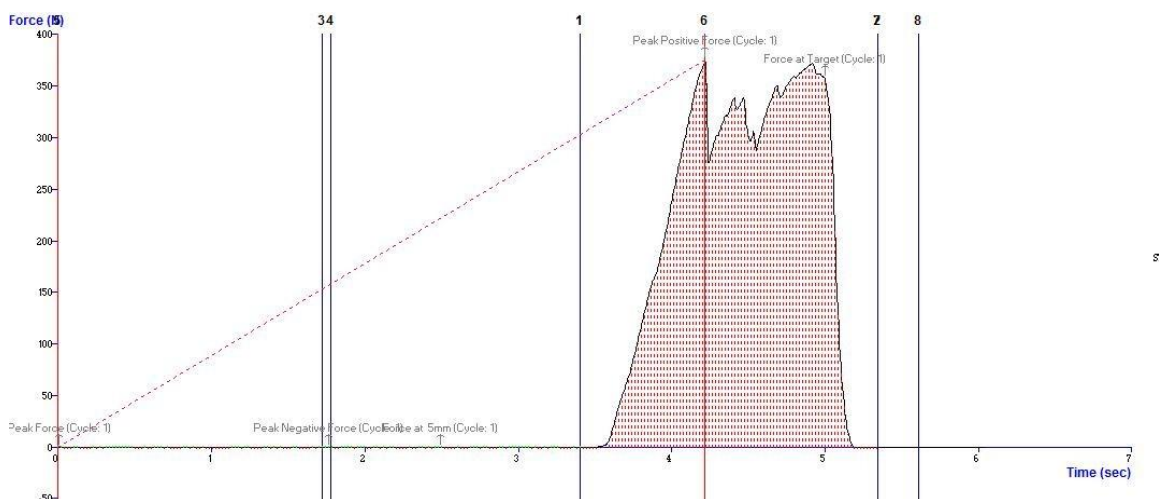| Property	Mild steel	Stainless steel	Glass
Aonla stone	0.63 ± 001	0.60 ± 0.02	0.56 ± 0.02
Aonla seed	0.63 ± 0.01	0.62 ±0.01	0.53 ± 0.01
Aonla seed shell	0.66 ± 0.01	0.62 ± 0.02	0.63 ± 0.02

Plate.1,2&3 Dried aonla stones, aonla seeds & seeds shell

Plate 4 Experimental set up for testing of rupture force of aonla stone

Fig.1 Aonla stone rupture force test sample

Rupture force of aonla stone

The rupture force of aonla stone is needed to estimate the force required for decortication of aonla stones to extract the seeds. Figure 1 is presented as sample of software generated graph of force required to rupture the aonla stones expressed in N. Rupture force of aonla stones was obtained in the range of 309 to 700 N. Mean value of aonla stone rupture force was 496 N.

In conclusion, aonla is having high productivity and processing potential due to its multiple health benefits. Seeds of aonla are also rich in antioxidant properties. Knowledge of engineering properties of aonla stone and seeds is helpful in development of technology related to aonla stone and seeds. Physical properties of aonla stone and seed are helpful for design of machineries for aonla stone decortication, and seed processing. Size and shape of stones and seeds can be used for designs of screens and hoppers. Gravimetric properties of aonla stone's and seed's are needed for designing of storage and transport facility of it. Knowledge of frictional properties of aonla stones and seeds helped for design of conveyors and hoppers. Rupture force is needed for estimation of force required for decortication of aonla stones. Results obtained in this investigation will be helpful in design of aonla stone decortication and seed processing assembly.

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