

Engineering and physiochemical properties of jamun (*Syzygium cuminii* L.)

ABSTRACT

Jamun (*Syzygium cuminii* L.) is a subtropical fruit comes under the myrtaceae family from Indian subcontinent. Jamun is a seasonal fruit so that processing and preservation is important to make the availability of the products from jamun. For the handling and processing of fruits, engineering as well as physiochemical properties are important. The study was conducted by focusing the basic properties of jamun during handling and processing. The engineering properties of jamun fruit such as physical, mechanical and frictional properties were studied. The physiochemical properties of jamun juice such as pH, TSS, acidity, total anthocyanin content, vitamin C were measured. The physical properties of jamun fruit such as length, width, thickness, sphericity, bulk density, porosity values were found to be 22.22 mm, 21.93 mm, 20.99mm, 0.947, 0.67, 32.48%. Jamun contains 80 percentage of pulp and nearly 20 percentage of seed. The firmness of the fruit was measured as 1.09 N and co efficient of friction of the fruit also calculated for different materials such as wood, stainless steel, cardboard and glass. The physiochemical properties like moisture, pH, TSS, acidity, specific gravity, total phenolic content, antioxidant activity, total anthocyanin content and vitamin c were found to be 85.33 % (Wb), 3.12, 13.14%, 0.81, 0.9, 256.76 mg/100ml, 86%, 1281 mg/100ml and 16 mg/100ml respectively. These properties can be useful for the understanding of jamun fruit structure and composition.

Keywords: Engineering properties, Jamun fruit, Jamun juice, Physiochemical properties

1. INTRODUCTION

Jamun (*Syzygium cuminii*) is an under-utilized fruit tree from Indian subcontinent. It belongs to the family of myrtaceae. Jambul, black palm, java palm, and Indian blackberry are the common names of jamun. The promising values of phytochemicals, minerals and vitamins gives a great therapeutic value for jamun. Hypoglycaemic, anti-inflammatory, antimicrobial, antioxidant, antidiarrhoeal, analgesic, astringency and gastro-protective are the proven pharmacological properties of jamun on animal system. The demonstrated studies of jamun for diabetes gave positive results (Jagetia, 2024; Kaur, 2024²).

The world's second-largest producer of jamun is India. India contributes 15.4% of the world's estimated 13.5 million tonnes of jamun output (Anonymous, 2005). Maharashtra is India's top producer of jamun, with Uttar Pradesh, Tamil Nadu, Gujarat, Assam, and other states following closely after. This

fruit is not cultivated in any regular cultivars. "Konkan bhadoli" is well-known among the several varieties (Patil *et al.* 2011). From Tamil Nadu in the south to the Indo-Gangetic plains in the north, jamun is grown extensively throughout India's largest regions. There is no information on its total acreage in India.

Jamun can grow in the saline area also. It provides a good source of diet in the food security (Rasheed *et al.* 2024). Anthocyanin is the bioactive compound which is rich in jamun (Tavares *et al.* 2016). The processed food like jam, jelly, chips, squash, wine, vinegar, beverages and pickles are made by utilizing the jamun fruit (Lago-Vanzela *et al.* 2011). Incorporating jamun fruit, juice and seed, several products were made.

Jamun is a rich nutritious fruit but it is a seasonal one. In order to make the availability of jamun through the year, processing and preservation are important (George *et al.* 2023). For making good process technique, method and equipment understanding of the raw material is very important. Fruits' physical characteristics are crucial for machinery design and food processing. It is important in post-harvest handling such as sorting, grading, packaging, storage and transportation (Athmaselvi *et al.* 2014). The biochemical properties are used to make a new product (Sood *et al.* 2018).

The objective of the study contains the engineering properties of jamun fruit and physiochemical properties of fruit and juice for developing the data for machinery design and product formulation.

2. MATERIAL AND METHODS

2.1 Sample collection

Jamun fruits were procured from local market of Malappuram of Kerala. The sample preparation takes place as following the flowchart:

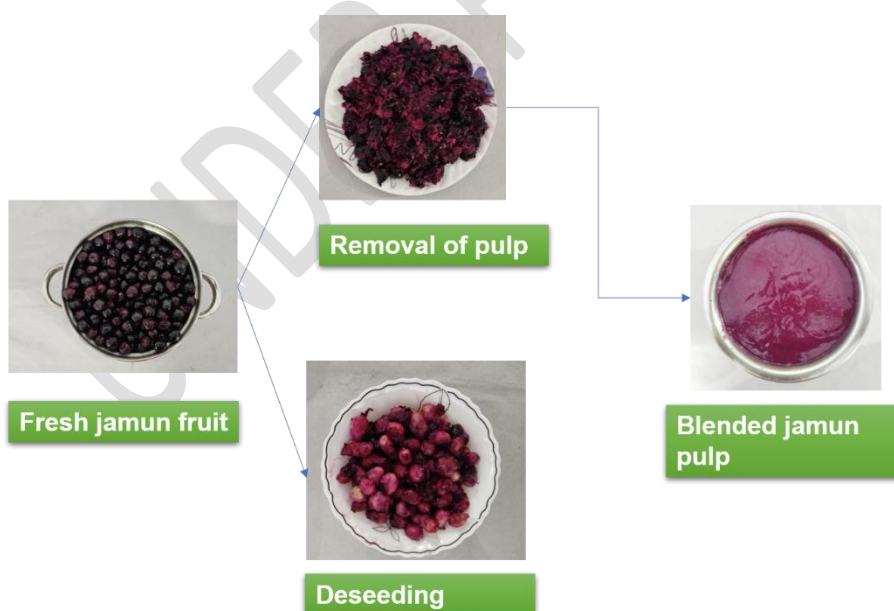


Fig.1. Sample preparation of jamun

2.2 Engineering properties

Engineering properties of biological materials classified into physical properties, mechanical properties, frictional properties, physiochemical properties and nutritional properties etc. (Rahman & McCarthy, 1999)

2.2.1 Physical properties

Physical properties of agriculture materials include shape, size, density, color, volume, surface area, porosity etc. physical properties are important in the area of equipment design and handling of particular products.

2.2.1.1 weight

Fruit weight was measured by an electronic balance with the accuracy 0.01 gram.

2.2.1.2 Axial dimensions

The axial dimensions are length, width and thickness. These dimensions of the fruits were measured by vernier caliper with least count of 0.02 mm.

2.2.1.3 Shape index (SI)

The shape index of the fruit was calculated by the following formula (Mohsenin, 1980):

$$SI = \frac{W+T}{2L} \dots (1)$$

W- width (mm)

T- thickness (mm)

L- length (mm)

2.2.1.4 Geometric mean diameter (Dg)

Geometric mean diameter was calculated by using the following formula (Mohsenin, 1980):

$$Dg = (L * W * T)^{\frac{1}{3}} \dots (2)$$

L - largest intercept

W - largest intercept perpendicular to l

T - largest intercept perpendicular each other

2.2.1.5 Arithmetic mean diameter (AMD)

The formula for calculation of AMD is:

$$Da = \frac{(L*W*T)}{3} \dots (3)$$

2.2.1.6 Aspect ratio (AR)

The formula for calculation of AR IS ((Dash *et al.* 2008):

$$AR = \left(\frac{W}{L}\right) \times 100 \quad \dots (4)$$

2.2.1.7 Elongation ratio

The formula for elongation ratio follows:

$$ER = \frac{T}{W} \quad \dots (5)$$

2.2.1.8 Sphericity

Sphericity is normally used to express the shape and size of the material. It is calculated using the following formula (Sahay & Singh, 1996):

$$\emptyset = \frac{(L \cdot W \cdot T)^{\frac{1}{3}}}{L} \quad \dots (6)$$

2.2.1.9 Surface area

The fruit surface area was measured by the following formula (Mohsenin, 1980):

$$S = \pi * Dg^2 \quad \dots (7)$$

2.2.1.10 Fruit volume

Platform scale method was used for measuring the volume (Sahay & Singh, 1996):

2.2.1.11 Density

Density of any material can be expressed as ratio weight of the material to volume of the material.

2.2.1.11.1 Bulk density

A 100 ml cylindrical glass container was filled entirely with jamun fruits in order to calculate the bulk density. Without crushing the fruits, the surplus jamun fruits were removed by repeatedly tapping the container. Using an electronic balance, weight was measured. The formula for bulk density follows (Işikli & Yilmaz, 2014).

$$\text{Bulk density (g/ cm}^3\text{)} = \frac{\text{Bulk mass (g)}}{\text{Total volume (cm}^3\text{)}} \quad \dots (8)$$

2.2.1.11.2 True density

True density was determined using the toluene (C₇H₈) displacement method (Mohsenin, 1980). The formula for true density is

$$\text{True density (g/ cm}^3\text{)} = \frac{\text{Mass of the individual fruit (g)}}{\text{Volume of individual fruit (cm}^3\text{)}} \quad \dots (9)$$

2.2.1.11.3 Density ratio

Using the bulk density and true density measurements, the fruits' density ratio was determined (Işikli & Yılmaz, 2014).

$$D_r(\%) = \left(\frac{\rho_t}{\rho_b}\right) \times 100 \dots (10)$$

ρ_t = true density

ρ_b = bulk density

2.2.1.12 Porosity

Porosity was calculated by using the values of bulk density and true density. The formula for porosity given by (Mohsenin, 1980):

$$\epsilon = \left(\frac{\rho_t - \rho_b}{\rho_t}\right) \times 100 \dots (11)$$

2.2.1.13 Color

The color was determined by colorimeter. It was expressed as L, a, b value.

2.2.1.14 Yield calculation

2.2.1.14.1 Pulp content

The term "pulp content" describes the fruit's edible component. After the seeds were removed from the fruits, it was measured using the formula below.

$$\text{Pulp content (\%)} = \frac{\text{weight of the pulp (g)}}{\text{weight of the fruit (g)}} \times 100 \dots (12)$$

2.2.1.14.2 Juice content

The fruit's juice content is determined by how much juice it can yield. The juice content was ascertained by separating the pulp and removing the seeds. A blender was used to blend the pulp, and a muslin cloth was used to extract the juice (Zeng *et al.* 2019).

$$\text{Juice content (\%)} = \frac{\text{weight of the juice (ml)}}{\text{weight of the fruit (g)}} \times 10 \dots (13)$$

2.2.1.14.3 Seed content

The inedible portion of the fruit which was separated to make pulp was taken for the calculation

$$\text{Seed content (\%)} = \frac{\text{weight of the seed (g)}}{\text{weight of the fruit (g)}} \times 100 \dots (14)$$

2.2.2 Mechanical property

Using an electronic penetrometer, the firmness of the fruit was tested (Jantra *et al.* 2018). The meter's sharp edge was positioned on the fruit's surface. To create a rupture on the fruit's surface, it was gradually compressed. It was noted how much force was needed to cause a rupture.

2.2.3 Frictional property

The frictional properties are important for designing of conveyer and moving parts in processing machineries. The coefficient of friction of fruits were determined by the following formula (Sahay & Singh, 1996):

$$\text{Coefficient of friction } (\mu) = \frac{F}{W} \dots (15)$$

F – frictional force required

W – weight of the fruits

2.3 Physiochemical properties

The chemical properties like moisture content, pH, TSS, titratable acidity and nutritional content were determined for pulp and juice.

2.3.1 Moisture content

Moisture content was determined using the method given by (AOAC, 2005). For the determination of moisture, the grinded pulp was taken. 10g of both samples was taken in a petri dish. The initial weight was noted. It placed in a hot air oven at the temperature of 105°C for 3 hrs. Weight of the samples were checked at frequent interval till the constant weight reached. The moisture content was calculated by the following formula:

$$\text{Moisture content (Wet basis \%)} = \frac{w_i - w_f}{w_f} \times 100 \dots (16)$$

w_i – initial moisture

w_f – final moisture

2.3.2 pH

The pH of the fruit sample was determined using a digital pH meter (AOAC, 1980). One gram of fruit pulp, juice, and peel were diluted to 10ml with water respectively. The pH was analysed with buffer (pH 4.7). Triplicate was taken from each sample.

2.3.3 Acidity

Acidity was determined by titrating sample with 0.1 N alkali (NaOH). One ml of fruit pulp, juice, and one gram of seed were diluted to 10 ml with water respectively and approximately 0.1 ml of phenolphthalein was added. It was titrated against 0.1 N NaOH solution until the pink colour appears. Three replications per each sample were taken. Results were expressed in terms of acid as gram of citric acid per gram (AOAC, 1980).

$$\text{Percentage acidity of pulp} = \frac{\text{ml of 0.1 N NaOH} \times 0.0064}{\text{volume of the sample} \times 100} \dots (17)$$

2.3.4 Total soluble solids

Samples were prepared by diluting one gram of pulp, juice, and peel in 20ml. Total soluble solids were measured at 20°C with a digital refractometer (Atago/RX-5000) and the results were expressed as °Brix (AOAC, 2005).

2.3.5 Specific gravity

Specific gravity refers to the density difference of the substance. The formula for specific gravity follows:

$$\text{Specific gravity of juice} = \frac{\text{density of juice}}{\text{density of water}} \dots (18)$$

2.3.6 Bioactive compounds

2.3.6.1 Total phenolic content

The concentration of total phenols in the extracted samples were determined by using Folin-Ciocalteu Reagent (FCR). To an aliquot of 0.2ml of sample extracts, 2.5 ml of 1:1 FCR reagent was added and left for 5 mins. To that 2ml of unsaturated sodium carbonate solution (7.5% w/v) was added and incubated for 2 hrs at room temperature. Using a spectrophotometer, the absorbance was measured at 760 nm. The amount of total phenolics was determined and reported as mg GAE/100g FW. Calibration curve was made by using gallic acid (Wang *et al.* 2011).

2.3.6.2 Total anthocyanin content

0.5 mL of extract was combined with 10 mL of two buffers: 0.025 M potassium chloride (pH 1.0) and 0.4 M sodium acetate (pH 4.5) and allowed to sit at room temperature for 15 minutes prior to taking absorbance measurements at wavelength of 520 and 700nm (Nguyen & Nguyen, 2018).

$$\text{Total anthocyanin content (mg/100 mL)} = \frac{A \times MW \times DF \times 1000}{\epsilon \times l} \dots (19)$$

where:

$$A = (A_{520\text{nm}} - A_{700\text{nm}})_{\text{pH 1.0}} - (A_{520\text{nm}} - A_{700\text{nm}})_{\text{pH 4.5}}$$

MW (molecular weight) = 449.2 g/mol for cyanidin-3-glucoside

DF = dilution factor established in D

$$l = 1 \text{ cm}$$

ϵ = 26,900 molar extinction coefficients, in L/mol cm, for cyanidin-3-glucoside

2.3.6.3 Antioxidant Capacity (DPPH)

The antioxidant capacity was measured for juice. It was measured using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay. 1 mL of the sample extract was mixed with 3 mL of 0.1 mM methanolic DPPH solution then it was vortexed and placed at dark for 30 min at room temperature. The absorbance reading was 517 nm. UV-Visible spectrophotometer was used to measure the absorbance reading (Nguyen & Nguyen, 2018). Triplicate reading was taken for the determination. It was calculated as follows:

$$\text{DPPH scavenging effect (\%)} = \left(1 - \frac{A}{A_0}\right) * 100 \quad \dots (20)$$

where

A₀ - control solution absorbance

A - DPPH solution absorbance

2.3.6.4 Ascorbic acid

Ascorbic acid present in fresh fruits can be calculated either volumetric method or colorimetric method. Volumetric method was adopted to estimate vitamin C content present in jamun fruit juice. 200 ml of dye solution was prepared in distilled water using 42 mg of sodium bicarbonate and 52 mg of 2,6-dichloro indophenols. The dye is reduced to a colourless leucobase by ascorbic acid. The titrating medium, 4% oxalic acid, aids in identifying the titration's end point by giving it a pale pink hue. In an acidic media, the dye has the colour of pink. Stock standard solution was prepared by dissolving 100 mg of ascorbic acid in 100 ml of 4% oxalic acid in a standard flask (concentration 1 mg/ml). The working standard solution was obtained by diluting 10 ml stock solution to 100 ml with 4% oxalic acid (concentration 100 µg/ml) (Joy *et al.* 2015). Sample was prepared by 4% oxalic acid and titrated against the dye.

$$\text{Ascorbic acid mg/100g} = \frac{0.5}{V_1} \times \frac{V_2}{5} \times \frac{100}{V_s} \times 100 \quad \dots (21)$$

V₁- titration value of blank

V₂ – titration value of sample

V_s – weight of the sample

3. Results and discussion

The minimum and maximum weight of the fruit was measured to be 2.03g and 15.36g, respectively. From the weight values it was noted that jamun having uneven weight distribution. From the results it was noted that the fruit having more value of length compared to width and thickness. The fruit has a shape like oblong shape. The minimum and maximum length, width and thickness was measured as 14.93mm,14.95mm,14.12mm and 29.11mm,28.94mm,28.72mm respectively. The geometric mean diameter, arithmetic mean diameter, square mean diameter and sphericity were measured by using the axial dimension values. The geometric mean diameter having the minimum value of 14.27mm and maximum value of 27.93mm. Sphericity is an important fruit parameter in

physical properties. The minimum and maximum value of sphericity were measured as 0.863 and 1.0, respectively. Surface area was measured based on the formula in the materials and method section. The maximum area was measured as 2455.7mm^2 and minimum value found to be 639.6mm^2 , respectively. Volume of the fruit was measured using platform scale method. It is employed to determine the volume of materials with irregular shapes. The minimum and maximum volume was found to be 2.03mm^3 and 15.06mm^3 , respectively.

For measuring the bulk density and true density the fruits were selected randomly. By measuring the weight and volume, bulk density was found. The minimum and maximum values found to be 0.56g/cm^3 and 0.69g/cm^3 respectively. The mass and bulk density were used to calculate the density ratio. The porosity was measured as the formula mentioned in section 2. The minimum and maximum values were found to be 30.31 and 33.52. The different percentage of fruit composition was measured. The maximum pulp percentage was noted as 82.62 and minimum value was 74.56. The seed percentage having the minimum and maximum values of 12.78 and 19.05 respectively. The maximum juice yield was found to be 50 percentage. Firmness was calculated as mechanical property. It was measured based on the rupture caused by the penetrometer. The value of firmness was noted as 1.09 N respectively. The frictional property like coefficient of friction was measured for different materials viz., wood, stainless steel, cardboard and glass. Among the various material glass had maximum value of 1.98 respectively.

The moisture content of the fruit was determined as per standard procedure. It was determined on wet basis. The physicochemical properties and bioactive compounds of jamun juice such as pH, TSS, acidity, specific gravity, total phenolic content (TPC), total anthocyanin (TAC), antioxidant activity (DPPH), vitamin C and colour were determined as per standard procedure. The pH changed from 3.12 to 3.29. Total soluble solids changed from 10 to 13 respectively. Acidity of the juice changed from 0.81 to 1.71 respectively. From the table 2 it was found that jamun juice was rich in bioactive compounds like anthocyanin. The amount of anthocyanin in jamun juice was found to be 1824 mg/100ml and the TPC and antioxidant values were found to be 256.76 mg/100 ml and 86% respectively. Anthocyanin is the main compound for the fruit colour. Vitamin C content was in the range of 16 to 18 mg/100ml, respectively. The colour values of juice such as L^* , a^* and b^* values were measured as 17.43, 25.57 and 8.57, respectively.

Table 1. Physical properties of jamun fruit

Properties	values
Weight (g)	6.679±0.92
Axial dimensions	
L(mm)	22.22±3.65
W(mm)	21.93±3.90
T(mm)	20.99±3.78
Shape index	0.96±0.05
Geometric mean diameter (mm)	21.04±3.55
Arithmetic mean diameter (mm)	21.72±3.70
Aspect ratio	0.98±0.06

Elongation ratio	0.95±0.04
Sphericity	0.947±0.03
Surface area (mm^2)	1427±487
Volume (mm^3)	7.28 ± 4.1
Bulk density (g/cm^3)	0.67±0.01
True density (g/cm^3)	1±0.002
Density ratio	1.48±0.04
Porosity (%)	32.48±1.41
Colour (Pulp)	
L*	13.13±0.75
a*	3.833±0.35
b*	-3.6±0.36
Pulp content (%)	79.20±2.1
Juice content (%)	50.20±5.1
Seed content (%)	17.23±1.7

Table 2. Mechanical property of jamun fruit

Property	Value
Firmness (N)	1.09±0.56

Table 3. Frictional property of jamun fruit

Materials	Co efficient of friction (μ)
Stainless steel	1.25
Plywood	1.28
Cardboard	1.56
Glass	1.98

Table 4. Physiochemical properties of jamun juice

Properties	Juice
Moisture content (%)	85.33
pH	3.12±0.01
TSS (%)	13.14±0.2
Acidity	0.81±0.07
Specific gravity	0.9±0.0
Total phenolic content (mg/100ml)	256.76±0.52
Total anthocyanin content (mg/100 ml)	1284.14±1.66
Antioxidant activity (% DPPH)	86±0.04
Vitamin C (mg/100 ml)	16±1.25
Colour	
L*	17.43±0.65
a*	25.57±4.07
b*	8.57±2.24

* Moisture content on wet basis

4. CONCLUSION

The objective of the study was to know the different engineering and physiochemical properties of jamun fruit and juice. The physical properties like weight, dimensions, sphericity, volume, mechanical property and frictional properties are useful for the machinery development. The biochemical properties of fruit and juice will give the understanding of the nutritional benefits for further food formulation and product development using this fruit.

REFERENCES

1. Jagetia, G. C. (2024). Bioactive Phytoconstituents and Medicinal Properties of Jamun (*Syzygium cumini*). *Journal of Exploratory Research in Pharmacology*
2. Kaur D, Yousuf B., & Qadri OS. (2024). *Syzygium cumini* anthocyanins: recent advances in biological activities, extraction, stability, characterisation and utilisation in food systems. *Food Production, Processing and Nutrition*.6(1). doi:10.1186/s43014-023-00177-6
3. Anonymous. (2005). Jamun production trends in India and World. Market updates fruits,
4. Patil, S. S., Thorat, R. M., & Rajasekaran, P. (2011). *Utilization of Jamun Fruit (Syzygium cumini) for Production of Red Wine*. www.sospublication.co.in
5. Rasheed, H. U., Shoukat, U., Arshad, U., Afzal, S., Khan, M. S., Aleem, S., Fatima, S., Noman, M., Hasan, R. W., & Arshad, M. A. (2024). Adaptation and Agricultural Significance of *Syzygium cumini* L. in Saline Environments: A Global Perspective on Jamun Cultivation and Salt Stress Resilience. *Haya: The Saudi Journal of Life Science*, 9(05),172–187.
6. Tavares, I. M. de C., Lago-Vanzela, E. S., Rebello, L. P. G., Ramos, A. M., Gómez-Alonso, S., García-Romero, E., Da-Silva, R., & Hermosín-Gutiérrez, I. (2016). Comprehensive study of the phenolic composition of the edible parts of jambolan fruit (*Syzygium cumini* (L.) Skeels). *Food Res Int*,82, 1–13
7. Lago-Vanzela, Ellen Silva, Ginaldo Vieira dos Santos, Fernanda Arcaro de Lima, Eleni Gomes, & Roberto da Silva. (2011). Physical-chemical, caloric and sensory characterization of light jambolan (*Syzygium cumini* Lamarck) jelly. *Food Science and Technology*, 31, 666-673.
8. George, S., Thomas, A., Kumar, M.V.P., Kamdod, A.S., Rajput, A. & Abdullah, S. (2023). Impact of processing parameters on the quality attributes of spray-dried powders: a review. *European Food Research and Technology*, 249(2),241-257.
9. Athmaselvi, K.A., Jenney, P., Pavithra, C., & Roy, I. (2014). Physical and biochemical properties of selected tropical fruits. *International Agrophysics*, 28(3).
10. Sood, M., Julie Bandral, I. D., Manmeet Kaur, I., Correspondence Monika Sood, I., Bandral, J. D., & Kaur, M. (2018). Development and quality evaluation of jamun seed powder supplemented noodles. *Journal of Pharmacognosy and Phytochemistry*, 7(3).
11. Rahman M. S. & McCarthy O. J. (1999): A classification of food properties, *International Journal of Food Properties*, 2:2, 93-99.
12. Mohsenin, N.N. (1980). Physical properties of plant and animal materials. Gordon and Breach Science Publishers, New York.

13. Dash, A., Pradhan, R., Das, L., & Naik, S. (2008). Some physical properties of simarouba fruit and kernel. *International Agrophysics*.
14. Sahay, K.M., & Singh, K.K. (1996). *Unit operations of agricultural processing*, Vikas publishing house
15. Işıklı ND & Yılmaz I. (2014). Some physical properties of sun-dried Berberis fruit (*Berberis crataegina*). *Journal of Food Science and Technology*. 51(1),104-10. doi: 10.1007/s13197-011-0469-y.
16. Zeng, D., Xiao, G., Xu, Y., Zou, B., Wu, J. & Yu, Y., (2019). Protein and polyphenols involved in sediment formation in cloudy litchi juice. *Food Science and Biotechnology*, 28(4),945-953.
17. Jantra, C., Slaughter, D.C., Roach, J. & Pathaveerat, S. (2018). Development of a handheld precision penetrometer system for fruit firmness measurement. *Postharvest Biology and Technology*, 144,1-8.
18. AOAC. (2005). *Official Methods of Analysis*. Association of Official Analytical Chemists. Washington, DC.
19. AOAC. (1980). *Official Methods of Analysis* (13th edition). Washington, DC; Association of Official Analytical Chemists, 31,521
20. Wang, Zhenbin, Pan, Zhongli, Ma, Haile, Atungulu, & Griffiths. (2011). Extract of Phenolics From Pomegranate Peels. *The Open Food Science Journal*,5,17-25.
21. Nguyen CL, & Nguyen HVH. (2018). Ultrasonic effects on the quality of mulberry juice. *Beverages*,4(3). doi:10.3390/beverages4030056
22. Joy, P. P., Surya, S., & Aswathy, C. (2015). *Laboratory manual of biochemistry*. Pineapple research station, Kerala Agricultural University, Vazhakkulam,91-133.