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PHYSICO-CHEMICAL AND ENGINEERING PROPERTIES OF PINEAPPLE (*Ananas comosus*)

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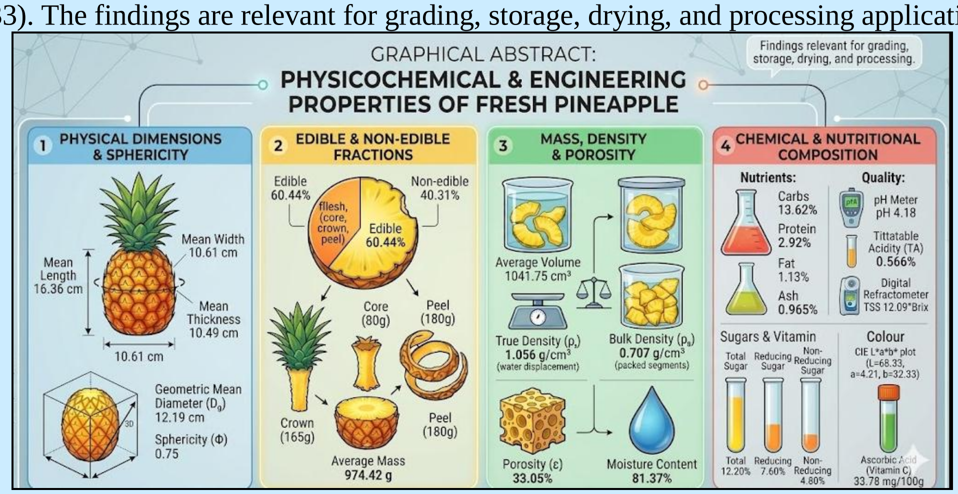
ABSTRACT

The aim of this paper is to discuss the physicochemical and engineering properties of fresh pineapple, noting that 60.44% of the fruit is edible and 40.31% is non-edible including core, crown & peel. The mean length, width and thickness are 16.36 cm, 10.61 cm and 10.49 cm, respectively, with a geometric mean diameter of 12.19 cm and a sphericity of 0.75. The average masses are 974.42 g and 1041.75 cm^3 for the average weight and volume respectively. The physical properties are bulk density (0.707 g/cm^3), true density (1.056 g/cm^3), porosity (33.05%) and high moisture content (81.37% wb). Nutrient composition includes carbohydrates (13.62%), Protein (0.54%), fat (0.21%), and ash (0.965%). The pH is 4.18, the titratable acidity is 0.566% and the total soluble solids 12.09°Brix.The sugar content is total sugar-12.20%, reducing sugar-7.60% and non-reducing sugar- 4.80% and ascorbic acid is present at 33.78 mg/100g. The colour characteristics suggest a bright yellow colour (L= 68.33; a= 4.21; b=32.33). The findings are relevant for grading, storage, drying, and processing applications.



***Keywords* :** Pineapple; physico-chemical properties; engineering properties; dehydration; post-harvest processing.

Introduction

Pineapple (*Ananas comosus*) is a tropical plant whose fruit is one of the most significant crops grown globally, due to its special taste, nutrition and economic value (FAO, 2023). It is widely used as a raw material in the food processing industry in fresh, processed and dried forms (Bartholomew *et al*., 2003; FAO, 2020). Pineapples are rich in vitamins, minerals, dietary fibre, and bioactive compounds like bromelain which are responsible for their health benefits and rising demand in the market (Ketnawa *et al*., 2012; Hossain *et al*., 2015).

India is one of the leading producers of pineapples in the world, falling among the top producing nations in the world (FAO, 2023). The National Horticulture Board reported that its production was in the range of 1.2 million tonnes (NHB, 2015). The nation's annual production of pineapples ranges between 1.7–1.9 million tonnes, which represents around 6-8% of the total production in the world, representing a steady growth over time (FAO, 2023). Pineapple is widely grown in India, mainly in states like Assam, Tripura, Meghalaya, West bengal, Kerala, Karnataka and konkan region in Maharashtra.

Understanding the physico-chemical properties of pineapple is essential for determining its quality, shelf life, and suitability for various processing operations. These properties include moisture content, pH, total soluble solids (TSS), acidity, and sugar composition, which directly influence the taste, texture, and preservation of the fruit. Additionally, these parameters are critical in designing processing techniques such as drying, juice extraction, and storage. Engineering properties of pineapple, including size, shape, density, porosity, and thermal characteristics, play a crucial role in the design and optimization of equipment used in handling, processing, packaging, and transportation. Knowledge of these properties is particularly important in developing efficient drying systems, grading machines, and packaging solutions.

Pineapple is an important commercial fruit; however, its physio-chemical and engineering properties vary depending on factors such as variety, stage of maturity and processing conditions. These variations influence its handling, processing and storage behaviour. Therefore, the present study was carried out to investigate the physio-chemical and engineering properties of pineapple for improving processing efficiency, product development and post-harvest management.

Hence present study was conducted to determine the physical dimensions of fresh pineapple, including length, width and thickness along with related geometric properties & Bulk density, true density and porosity. In addition, important chemical properties such as moisture content, total soluble solid and acidity were also evaluated. The information generated from this study will be helpful in design and optimization of drying and dehydration equipment, thereby improving processing efficiency and minimizing post-harvest losses.

Materials and Methods

Location of the experiment

The experiment was performed at the NAIP Laboratory of the Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, at Dapoli, Dist. Ratnagiri district, Maharashtra, India.

Procurement of raw materials

For this investigation, a bulk sample of pineapple fruits (*Ananas comosus*) were procured from AICRP WAKAWALI, DBSKKV Dapoli. The fruits were chosen based on their uniformity in size, maturity, and lack of physical damage and microbial spoilage. The selected fruits were weighted individually using a digital balance record the average fruit weight.

Sample Preparation

Fresh pineapple fruits were washed thoroughly to remove dirt and impurities. The peel and crown were removed manually, and the fruit was cut to separate the core and obtain the edible pulp. The fruit fractions, including pulp, peel, crown, and core, were separated and weighed individually, and their percentage composition was calculated based on total fruit weight.

Physical properties

The physical properties of pineapple fruit determined were size, shape, bulk density, true density, porosity, and surface area. The standard methods were adopted for estimating these engineering parameters which are described below.

Dimensions properties of pineapple

The three pineapple principal dimensions namely length (L), Width (w), and Thickness (T) were measured as shown in fig 1 for each pineapple fruit by using thread and ruler with accuracy (1mm). A total of 20 pineapple samples were randomly selected to find their physical dimensions. Length (L), width (W), and thickness (T) of each sample were found, and averages were calculated.

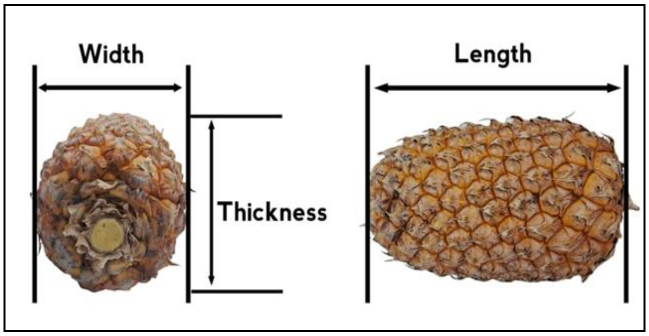


Fig. 1: Characteristics dimension

Geometric mean diameter (Dg)& Arithmetic Mean daimeter (Da):

Dg and Da of 20 fruits were determined using the dimensions of length (L), width (W) and thickness (T) in the following equation (1) & (2) given by (Mohsenin, 1986 & Zainal Bidin *et al*., 2020).

$$GMD = \sqrt[3]{LWT} \quad \text{.... (1)}$$

$$AMD = \frac{L+W+T}{3} \quad \text{.... (2)}$$

Sphericity:

Sphericity (S) is defined as the ratio of the surface area of a sphere having the same volume as the fruit to the surface area of the fruit (Dhineshkumar and Siddharth, 2015). The sphericity of each pineapple fruit was determined by using the equation (4) given by Birania *et al*. (2022).

$$S = (L+W+T)^{1/3} / L \quad \text{.... (3)}$$

Where, L is the length, w is width, T is a Thickness in mm

Surface area

Surface area (S) of pineapple was calculated based on the geometric mean diameter (GMD) using the following equations (Panda *et al*., 2015, Gosavi *et al*., 2023).

$$S = \pi\,(GMD)^2 \quad \text{.... (4)}$$

Determination of weight

Twenty samples of whole pineapple fruits were weighed individually by using the analytical balance with an accuracy 0.01g. The weight was measured in grams (g) as given by Shamsudin *et al*., (2023).

Determination of Aspect ratio

The aspect ratio (Ra) was obtained using the following relationship Equation (5) as recommended by Azman *et al*. (2020) and Birania *et al*. (2022).

$$Ra = (W)/ L \quad \text{.... (5)}$$

Volume

Fruit volume was determined by water displacement method described by Mohsenin (1986). The container with a volume of 10 litres was filled with 8 litres of water and the initial volume was recorded. The displaced water when the fruit was placed in the container is recorded as the volume of the sample (Abdul Halim, 2021).

$$\text{Volume (ml)} = \text{Displaced Water (ml)} \quad \text{.... (6)}$$

Bulk density

This is the mass of a group of individual particles divided by the space occupied by the entire mass, including the air space. It was determined using a standard container (beaker) of known weight and volume. The container was filled with the sample without compaction, and the content weighed. The bulk density was calculated as the ratio of the mass of pineapple to the volume of fruit occupied by the container. The bulk density determines by using the following formula as adopted by Dhineshkumar and Siddharth (2015) for orange:

$$\text{Bulk density} = \frac{\text{Mass (kg)}}{\text{Volume}} \quad \text{.... (7)}$$

True density

This is the ratio of the mass of the sample to its pure volume. For pineapple fruit, true density was determined by the water displacement method given by (Dhineshkumar and Siddharth (2015).

$$\text{True density} = \frac{\text{Mass of indivual fruit(kg)}}{\text{Volume of indivual fruit (ml)}} \quad \text{.... (8)}$$

Porosity

Calculated by using formula,

$$\acute{\varepsilon} = \frac{\rho t - \rho b}{\rho t} \times 100 \quad \text{.... (9)}$$

Where, ($\acute{\varepsilon}$) was the Porosity, ρt was the true density and ρb was the bulk density.

Water activity

The water activity of fresh, Pineapple fruit was measured by water activity analyzer (*aw*-HP23) (Make: rotronics; Model: water activity). Before measuring the water activity of pineapple fruit samples, the instrument was tested for its accuracy by measuring the water activity of the distilled water.

Proximate Analysis of Pineapple

Moisture Content

The initial moisture content of pineapple samples was determined using a hot air oven method at 105 °C until constant weight was obtained, as per AOAC

(2010). About 5 g of sample was taken in a pre-weighed moisture box. Moisture content was calculated on wet basis (WB) and dry basis (DB) using standard equations.

Protein Content

Protein content was determined by the Kjeldahl method (AOAC, 2012). The sample was digested using concentrated H_2SO_4 and catalyst, followed by distillation and titration. Nitrogen content was calculated and multiplied by a factor of 6.25 to obtain protein percentage.

Fat Content

Fat content was estimated using Soxhlet extraction method (AOAC, 2012) with petroleum ether as solvent. The extracted fat was determined gravimetrically and expressed as percentage of sample weight.

Ash Content

Ash content was determined by incinerating the sample in a muffle furnace at 550 °C until a constant weight was obtained, following AOAC (2012) method. The ash percentage was calculated based on residue weight.

Total Carbohydrate Content

Total carbohydrate content was calculated by difference method (AOAC, 2012) by subtracting moisture, protein, fat, and ash content from 100.

Chemical Properties of Pineapple

Total Soluble Solids (TSS)

TSS was measured using a digital refractometer (Atago, Japan) after calibration with distilled water, and expressed in °Brix (AOAC, 2012).

pH

The pH of pineapple juice was measured using a digital pH meter after calibration with standard buffer solutions of pH 4.0 and 7.0 (AOAC, 2012).

Acidity

Titratable acidity was determined by titration with 0.1 N NaOH using phenolphthalein as indicator, as described by Ranganna (1986), and expressed as percentage.

Ascorbic Acid

Ascorbic acid content was estimated using 2,6-dichlorophenol indophenol dye titration method (Ranganna, 1986) and expressed as mg/100 g of sample.

Reducing Sugars

Reducing sugars were determined by Lane and Eynon method with suitable clarification and titration against Fehling's solution, as described by Ranganna (1991).

Total Sugars

Total sugars were estimated after acid hydrolysis (inversion) followed by titration with Fehling's solution, as per Ranganna (1991), and expressed as percentage.

Colour

The colour of L, a , b Value of fresh pineapple slices was determined by using Hunter lab colourimeter.

Results and Discussion

Physical Parameters of Pineapple Fruits

The distribution of different fruit components revealed that pineapple consists of a considerable proportion of non-edible portions. The peel accounted for 27.34% of the total fruit weight, followed by crown (8.39%) and core (4.58%), resulting in a total waste fraction of 40.31%. The edible portion constituted 60.44% of the fruit weight which is consistent with findings reported by Ketnawa *et al*. (2012) & Manasa *et al*., (2025). This indicates that although pineapple is a commercially valuable fruit, a significant fraction remains underutilized, highlighting the potential for by-product valorization in food processing industries.

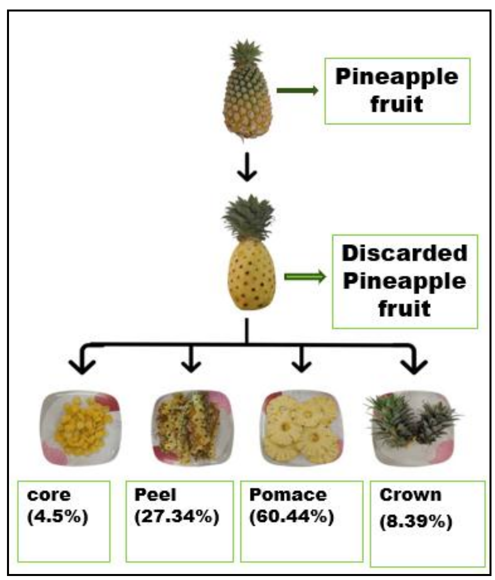


Fig. 2 : Physical properties of pineapple fruit

Dimensional Characteristics of Pineapple fruit

The average length, width, and thickness of pineapple pieces were 16.36 ± 2.36 cm, 10.61 ± 0.71 cm, and 10.49 ± 1.01 cm, respectively. Similar dimensional characterization of pineapple has been reported by Shamsudin *et al*.(2023), who evaluated the physical properties such as length, width, and thickness of pineapple fruit for engineering and processing applications. The lower variation in width indicates better uniformity, while slight variations in length and thickness may be due to cutting and natural fruit structure. These dimensional differences are important for processing operations requiring size uniformity.

Table 1: Selected physical and dimensional properties of pineapple

Sr. No.	Property	Symbol	Unit	Mean ± SD
1	Length	L	cm	16.36 ± 2.36
2	Width	W	cm	10.61 ± 0.71
3	Thickness	T	cm	10.49 ± 1.01
4	Arithmetic Mean Diameter	AMD	cm	12.49 ± 1.20
5	Geometric Mean Diameter	GMD	cm	12.19 ± 1.11
6	Sphericity	φ	–	0.75 ± 0.08
7	Aspect Ratio	AR	–	0.66 ± 0.10
8	Volume	V	cm^3	1041.75 ± 284.48
9	Weight	Wt	g	974.42 ± 192.65

(Values are expressed as mean ± standard deviation of 20 observations)

Arithmetic Mean Diameter (AMD)& Geometric Mean Diameter (GMD)

The arithmetic mean diameter and geometric mean diameter of pineapple were found to be 12.49 ± 1.20 cm and 12.19 ± 1.11 cm, respectively. The small difference between these values indicates minor irregularity in fruit shape. These results are in close agreement with findings reported by Bhore *et al*. 2017 and other studies on tropical fruits, highlighting natural variation in shape and their relevance in equipment design. Based on the geometric mean diameter (12.19 ± 1.11 cm), the surface area of the pineapple fruit was calculated to be approximately 466.7 cm^2, assuming a spherical shape Similar result of pineapple has been reported by Shamsudin *et al*.(2023).

Sphericity (φ)

The sphericity was calculated as 0.75 ± 0.08, indicating that the fruit are moderately spherical but slightly elongated. These results are in close agreement with the findings reported by Bhore *et al*.(2017), who reported a value of 0.77, which is comparable to the value obtained in the present study.

Aspect Ratio (AR)

The aspect ratio was observed as 0.66 ± 0.10, suggesting that the fruit are not perfectly spherical and exhibit elongation. These results are in close agreement with the findings reported by Shamsudin *et al*.(2023), who reported a value of 0.77, which is comparable to the value obtained in the present study.

Volume (mm^3)

The volume was recorded as 1041.75 ± 284.48 mm^3, with a relatively high standard deviation indicating variability in sample size. Such variations are commonly attributed to differences in fruit maturity and size. A comparable trend has been reported by Shamsuddin *et al*., 2023 who observed a volume of 120.7 cm^3.

Weight (g)

The average weight of the pineapple fruit was 974.42 ± 192.65 g. A similar trend has been reported by Shamsuddin *et al*.(2025) and Siti Rashima *et al*. (2019). The observed variation in weight may be attributed to differences in fruit size, cultivar, and growing conditions.

Bulk density, true density & porosity of fruit pieces

Further analysis of engineering properties indicated that bulk density (0.707 g/cm^3) was lower than true density (1.056 g/cm^3), confirming the presence of internal pores and void spaces within the fruit structure. The porosity was calculated as 33.05%, suggesting moderate air space within the fruit matrix. The bulk density and true density were recorded as 190 kg/m^3 and 940 kg/m^3, respectively for whole pineapple fruit without crown. Based on these values, the porosity was calculated to be 79.8%, indicating a high proportion of void spaces within the fruit structure These results are in close agreement with the findings reported by Bhore *et al*.(2017).

Water Activity

The measured water activity (0.95) was high, indicating the availability of free water for microbial growth and explaining the highly perishable nature of fresh pineapple. Similar high water activity values (0.90–0.99) have been reported for pineapple products by Rattanathanalerk *et al*. (2013) supporting pineapple juice.

Proximate Composition of Fresh Pineapple

The proximate composition of fresh pineapple indicates that moisture is the predominant component, recorded at 81.37 ± 2.62% (wb), reflecting the highly perishable nature of the fruit. On a dry basis, the moisture content was 445.53 ± 74.50%, confirming the dominance of water in the fruit matrix.

Among the solid constituents, carbohydrates were found to be the major component (16.9%), contributing significantly to the energy value and sweetness of the fruit. Protein (0.54 ± 0.09%) and fat (0.21 ± 0.02%)

were present in relatively low amounts, indicating that pineapple is not a significant source of these macronutrients.

Table 2: Proximate composition of Fresh Pineapple (Mean ± SD)

Sr. No.	Property (Unit)	Mean ± SD
1	Moisture Content (wb) %	81.37 ± 2.62
2	Moisture Content (db) %	445.53 ± 74.50
3	Ash Content (%)	0.965 ± 0.035
7	Fat Content (%)	0.21 ± 0.02
8	Protein Content (%)	0.54 ± 0.09
9	Carbohydrates (%)	16.9 ± 2.7%

The ash content (0.965 ± 0.035%) represents the mineral fraction of the fruit, present in small quantities. Overall, the proximate composition highlights that pineapple is a carbohydrate-rich, high-moisture fruit with low fat and moderate protein content, which is consistent with findings reported by (Bartholomew *et al*., 2003; Food and Agriculture Organization, 2013).

Chemical properties of pineapple

The chemical quality parameters of fresh pineapple were evaluated to assess its compositional and nutritional characteristics. The results obtained for pH, acidity, total soluble solids, sugars, and ascorbic acid are presented in Table 4.3.

Table 3: Chemical Properties of Fresh Pineapple (Mean ± SD)

Sr. No.	Property (Unit)	Mean ± SD
4	pH	4.18 ± 0.15
5	Acidity (%)	0.566 ± 0.049
6	Total Soluble Solids (TSS) (°Brix)	12.09 ± 1.16
7	Total sugar	12.20
8	Reducing Sugar	7.60
9	Non reducing sugar	4.80
10	Ascorbic Acid (mg/100 g)	33.78 ± 2.69

pH

The pH of fresh pineapple was found to be 4.18 ± 0.15, indicating its acidic nature. This level of acidity is typical for tropical fruits and plays an important role in flavor as well as microbial stability. Similar pH values ranging from 3.5 to 4.5 have been reported for ripe pineapple, confirming the present findings Mansa *et al*., (2025).

Acidity (%)

The titratable acidity of the pineapple was found to be 0.566 ± 0.049%, which gives the fruit its familiar sweet–tart taste. This value fits well within the typical range of 0.5–0.8% reported for ripe pineapples, suggesting that the sample was at a suitable stage of maturity. Acidity, together with sugar levels, plays an important role in shaping the overall flavor and consumer preference. Similar results have been observed in other varieties, with values of 0.53% reported for MD-2 and 0.54% for New Phuket varieties by Lu *et al*.,(2014).

Total Soluble Solids (TSS)

The total soluble solids content was found to be 12.09 ± 1.16°Brix, indicating the presence of sugars and other soluble constituents. This value falls within the commonly reported range of 10-15°Brix for pineapple, suggesting good fruit maturity and quality .These findings are consistent with earlier work by Lu *et al*.,(2014) who reported an average TSS value of 10.6°Brix across 26 pineapple Varity.

Total Sugar (%), Reducing Sugar (%) & non-reducing sugar

The total sugar content was 12.20%, aligning well with the TSS values and confirming that sugars make up the major portion of soluble solids in pineapple. Among these, reducing sugars accounted for 7.60%, indicating the predominance of glucose and fructose, which contribute directly to sweetness and are easily metabolized. Non-reducing sugars were recorded at 4.80%, mainly representing sucrose similar finding reported by Hossain *et al.* (2015).

Ascorbic Acid (mg/100 g)

The ascorbic acid content was found to be 33.78 ± 2.69 mg/100 g, indicating that pineapple is a good source of vitamin C. Ascorbic acid contributes to antioxidant properties and nutritional quality. The result was closed agreement with Lu *et al*. (2014) for MD-2 Varity of pineapple.

Colour

The colour L, a, b value of fresh pineapple slices was found to be color values were L = 68.33, a = 4.21, and b* = 32.33, indicating a bright appearance with slight red tones and a strong yellow color, typical of semi-ripe pineapple.

Conclusion

The study showed that fresh pineapple has high moisture (81.37%) and moderate sugars (12.20%), making it sweet but highly perishable. About 40.31% of the fruit is waste, indicating good potential for by-product utilization. The fruit exhibited moderate variability in size and structure, with porosity (33.05%) and density differences supporting its suitability for processing like drying. Overall, pineapple has good nutritional quality with balanced acidity (pH 4.18) and vitamin C content, making it suitable for both fresh consumption and value-added products.

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