Characterisation of Physico-Mechanical Properties and Colour of *Physalis Angulata*

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Abstract: This work was conducted to characterise the physical and mechanical properties *of Physalis angulata.* At a moisture content of 76.50 ± 1.10% wb, the study showed that the average polar, equatorial and geometric diameters were 13.49 ± 0.69 mm, 12.92±0.76 mm, 13.10±0.66 mm. The surface area, mass and volume were 540.19±54.55 mm^2, 1.39 ± 0.20 gr and 2.63 ± 0.47 cm^3 respectively. The particle and bulk densities were 0.53 ± 0.04 gr/cm^3 and 0.42± 0.005 gr/cm^3. The sphericity, aspect ratio and porosity ranged from, 97.17 ± 3.51 %, 95.84 ± 5.18%, and 20.26 ± 6.63% respectively. The fruits were spherical, and the colour was pale yellow with the value of CIE l*a*b* and CIE l*c*h* of (37.80 ± 0.010, 1.85 ± 0.023, 10.79 ± 0.006), and (37.80 ± 0.010, 10.95 ± 0.007, 0.002 ± 0.002) respectively. The average hardness, gumminess, adhesiveness, chewiness, cohesiveness , resilience and springiness ranged from 625.01± 101.97 gf, 346.74±64.28 gf, -2.27± 0.60 gf/sec, 27.41±5.79 gf/sec, 0.57± 0.13, 0.32 ± 0.12 and 0.08 ± 0.008 respectively. The mean angle of repose on stainless steel, aluminium, acrylic and plywood ranged from 7.97± 3.200, 9.23±3.730, 8.77±3.740 and 7.47 ± 2.910 respectively.

1 INTRODUCTION

The identity of *Physalis angulata* L. as a distinct species is now well-established (Nicolson *et al*., 1998; Reddy *et al*., 1999) although there is known to be several synonyms. Two of the more commonly quoted are *Physalis minima* and *Physalis lanceifolia*, but neither is in current use. The preferred common name of *Physalis angulata* is cutleaf ground cherry, wild tomato, camapu, winter cherry and morrel berry. In Indonesia, Physalis angulata has known as Ciplukan. In Indonesia, the name of Ciplukan has varied depending on the location, such as Ceplukan (Jawa), Cecendet (Sunda), Yor-yoran (Madura), Lapinonat (Seram), Angket, Kepok-kepokan, Keceplokan (Bali), Dedes (Sasak) and Leletokan (Minahasa) (Mardisiswoyo, 1965).

Physalis angulata is native to tropical America and has been distributed pantropically to various regions in America, Pacific, Australia, and Asia, including Indonesia (Reddy *et al*., 1999). In Indonesia, *Physalis angulata* is an invasive weed of crops. These plants have not cultivated and grown naturally in the bushes near the settlements to the edges of the forest and still allowed to grow wild naturally. The fruits favoured by producers and consumers due to their sweetness and high nutraceutical value (Nicolas *et al*., 2014; Bart-Plange, 2003). Although Physalis angulata used for consumption as fresh products, along with the development technology, now a day Physalis angulata fruits have begun to processed into syrup, sauce and marmalades. In the processing of any fruit into a different product, physical and mechanical properties are indispensable.

The physical and mechanical properties of various agricultural products have been studied by other researchers, such as, cocoa bean (Nicolas *et al*., 2014; Bart-Plange, 2003; Lam *et al*., 2016), Bambara groundnut (Adejumo, 2005), Kumquat (Jaliliantabar *et al*., 2013), Russian olive fruit (Zare, 2012), Date fruit (Keramat *et al*., 2008), Sesame seed (Tunde, 2004), Almond (Loghavi, 2011), sunflower (Gupta, 1998), wheat (Tabatabaeefar, 2003), soybean (Manuwa, 2004; Deshpande, 1993; Davies, 2009), Jatropha curcas (Karaj *et al*., 2008), and sugar beet seed (Dursun, 2007). The physical and mechanical properties of the agricultural crop

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are helpful in providing physical and mechanical properties of *Physalis angulata*.

There are some researcher done studies on the characteristics of *Physalis angulata* fruits. The fruit of *Physalis angulata* is round and has a diameter of about 6 - 8 mm (Reddy, 1999). The other studies showed that the diameter of the fruits ranged from 10-18 mm (Gönen, 2000; Pier, 2011), 15 -20 mm (Mahalakshmi, 2014), 8-14 mm (South Australia, 2012) and 12 mm (US-Departement of Agriculture, 2014). Regarding the previously published papers, the physical and mechanical properties of *Physalis angulata* have not studied completely yet. Therefore this study aimed to measure the physical and mechanical properties to provide the database on *Physalis angulata*.

2 MATERIALS AND METHODS

The *Physalis angulata* samples were taken from subdistrict of Pagaden ($6^0$30'24" S, $107^0$48'74"E, 55 MAMSL) Subang district, province of west java. Physical properties measured in this study consisted of polar diameter, equatorial diameter, mass, volume, moisture content, geometric diameter, surface area, particle density, bulk density, porosity, aspect ratio, and sphericity. The mechanical properties consisted of hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, resilience and angle of repose. The measurements of physical properties and angle of repose, hardness, and fracturability, and colour were conducted on 50, 11 and ten random samples respectively, with the moisture content of 76.50 ± 1.10% wb. The moisture content was measured based on the AOAC procedure (AOAC, 1995).

Instruments used for measuring the sample consisted of drying oven , digital vernier caliper with an accuracy 0.01 mm, an electronic balance with an accuracy 0.01 gram, an analytical balance with an accuracy 0.01 mg, an apparatus to determine angle of repose , a texture analyser , a beaker glass , a graduated cylinder and colorimeter NH310. The statistical package was used to determine the average value, correlation coefficient and linear regression of the in-between relationship of physical and mechanical properties.

2.1 Measurement of Physical Properties

The major of physical properties determined, consisted of polar diameter, equatorial diameter, mass, and volume. Figure 1 showed the position of polar and equatorial diameters measurements.

Figure 1: A position of the polar and equatorial diameter of *Physalis angulata.*

The minor of physical properties consisted of geometric diameter, surface area, particle density, bulk density, porosity, aspect ratio, and sphericity were found by the following relationship (Mohsenin, 1986; Sacilik, 2003; Tunde, 2004; Aluntas *et al.*, 2005; Loghavi, 2011; Zare, 2012; Sessiz *et al.*, 2013; Kaveri, 2015).

$$D_{gm} = \sqrt[3]{D_p \times D_e^2} \quad \text{mm}$$
$$A_s = 3.14(D_{gm})^2 \quad \text{cm}^2$$
$$\rho_p = \frac{M}{V} \ \text{gr/cm}^3$$
$$\rho_b = \frac{M_{v250}}{V_{250}} \ \text{gr/cm}^3$$
$$\varepsilon\ (\%) = \frac{(\rho_p - \rho_b)}{\rho_p} \times 100\ \%$$
$$\psi = 100 \times \frac{D_{gm}}{D_p}$$
$$R_a = \frac{D_e}{D_p} \times 100\ \%$$

Where :

D_p	:	Polar diameter, mm	D_{gm}	:	Geometric diameter, mm
D_e	:	Equatorial diameter, mm	A_s	:	Surface area, mm^2
M	:	Mass, gr	D_{gm}	:	Geometric diameter, mm
V	:	Volume, ml	ε	:	Porosity, %
ρ_p	:	Particle density, gr/ml	ψ	:	Sphericity, %
ρ_b	:	Bulk density, gr/ml	R_a	:	Aspect ratio, %

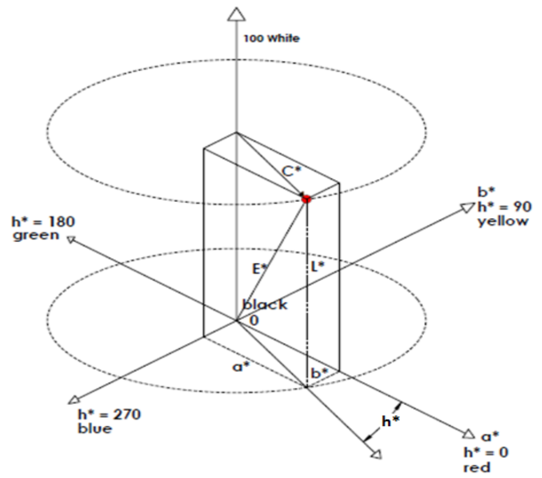

Figure 2: The CIE L*a*b* and L*C*h* geometric coordinates systems.

2.2 Measurement of Mechanical Properties

The mechanical properties measured included texture profile and angle of repose. Texture profile consisted of hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience. The angle of repose was measured on four types of materials, i.e., stainless steel 1 mm, aluminium 1 mm, acrylic 3 mm and plywood 18 mm.

2.3 Measurement of Colours

The analysis methods used were CIE (Commission Internationale de L'Eclairage) L* a* b* and CIE L* c* h* coordinates. The value of L*, a* and b* obtained were used to determine the chroma, hue angle and total colour difference between all three coordinates by using equation as follows (Ruiz *et al*., 2012). Figure 2 showed the geometric colour coordinates of the two colour models.

Chroma, $c^* = \sqrt{(a^*)^2 + (b^*)^2}$

Hue angle, $h^* = \tan^{-1}\left(\frac{b^*}{a^*}\right)$

$\Delta E^*_{A\text{-}B} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$

3 RESULTS AND DISCCUSSION

3.1 Physical Properties

Table 1 showed the values of, minimum, maximum, mean and standard deviation of Polar diameter, equatorial diameter, geometric diameter surface area, particle density, bulk density, sphericity, aspect ratio and porosity of *Physalis angulata* fruits.

Table 1 showed the values of, minimum, maximum, mean and standard deviation of Polar diameter, equatorial diameter, geometric diameter surface area, particle density, bulk density, sphericity, aspect ratio and porosity of *Physalis angulata* fruits. Results of the measurement showed that the dimension of the *Physalis angulata* fruits was following results from other studies (Gönen, 2000; Pier, 2012; South Australia, 2012; US-Departement of Agriculture, 2014), but relatively bigger that of a previous study (Reddy *et al*., 1999) and smaller than that of research (Mahalakshmi, 2014). Based on the chart developed in the previously published paper (Paul, 1965), the result of the study found that the shape of *Physalis angulata* fruit was spherical. Figure 3 showed the coordinates of the *Physalis angulata* shape.

Table 1: Descriptive statistics of the physical properties of *Physalis angulata* fruits.

Properties	Minimum	Maximum	Mean	Std. Deviation
D_p (mm)	12.02	14.90	13.49	0.69
D_e (mm)	10.90	14.39	12.92	0.76
M (gr)	1.00	1.80	1.39	0.20
V (ml)	1.80	4.00	2.63	0.47
D_{gm} (mm)	11.58	14.45	13.10	0.66
A_s (mm^2)	420.85	655.62	540.19	54.55
ρ_p (gr/ml)	0.45	0.64	0.53	0.04
ρ_b (gr/ml)	0.42	0.43	0.42	0.00
Ψ (%)	88.65	105.15	97.18	3.51
R_a (%)	83.46	107.82	95.84	5.19
ε (%)	4.34	34.30	20.26	6.63

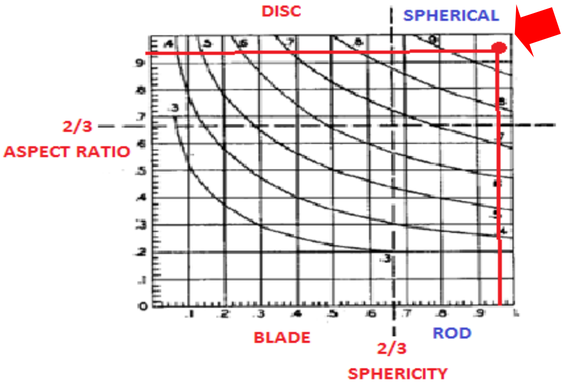

Figure 3: The chart of shape coordinates of *Physalis angulata* fruits.

Regarding the in-between relationship of the physical properties, results of regression analysis showed that equatorial diameter, geometrical diameter, and surface area were dependent on mass. The polar diameter and porosity were dependent on volume and particle density respectively. The equation of those relationships was as follows:

$D_e = 3.208\ M + 8.456$ R = 0.883 SEE = 0.4222

$D_{gm} = 3.050\ M + 8.860$ R = 0.905 SEE = 0.2838

$A_s = 252.687\ M + 188.958$ R = 0.909 SEE = 23.0163

$D_p = 1.133\ V + 10.515$ R = 0.776 SEE= 0.4408

$\varepsilon = 102.057\ \rho_p + 35.406$ R = 0.982 SEE= 0.8598

3.2 Mechanical Properties

Table 2 showed the minimum, maximum, mean and standard deviation values of the texture profile of samples. Figure 4 showed the typical texture profile graph of *Physalis angulata* fruits.

The value of gumminess was determined from the multiplication of hardness and cohesiveness values. The negative work between the two cycles showed the amount of adhesiveness. Due to the small number, figure 4 could not be able to show the adhesiveness. The value of chewiness was obtained from the multiplication of hardness, cohesiveness and springiness values. The amount of Cohesiveness was determined from the area of work during the second compression (A1 or A5) divided by the area of work during the first compression (A2 or A4). The value of resilience had been measured on the withdrawal of the first penetration before the waiting period was started, in figure 4 that value was pointed out as the ratio of A4 and A3. Results of the study showed that *Physalis angulata* were similar to tofu 25%, hotdog 50% and Jello 50% (Bourne, 2002).

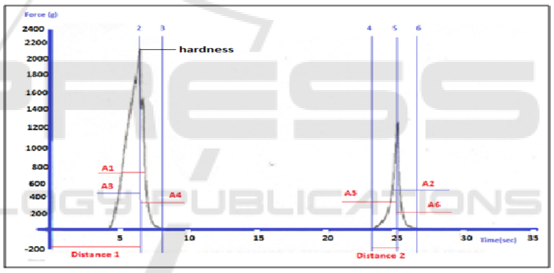

Figure 4: Typical texture profile of *Physalis angulata* samples.

Table 2: Descriptive statistics of the texture profile of *Physalis angulata* fruits.

Texture Profile	Minimum	Maximum	Mean	Std. Deviation
Hardness, H	467.32	769.51	625.0120	101.9654
Gumminess, G	272.09	517.81	346.7401	64.2784
Adhesiveness, A	-3.33	-1.46	-2.2687	0.5953
Chewiness, C_h	18.43	38.18	27.4129	5.7940
Cohesiveness, C_o	0.47	0.91	0.5654	0.1297
Resilience, R	0.23	0.63	0.3238	0.1158
Sprigines, S	0.07	0.09	0.0788	0.0081

Table 3: Statistics description of an angle of repose on various surface materials.

	Minimum	Maximum	Mean	Std. Deviation
Stainless steel, α_{ss}	6.04	20.81	7.9704	3.19972
Aluminium, α_{al}	6.04	20.81	9.2276	3.73443
Acrylic, α_{acry}	6.04	17.62	8.7690	3.73675
Plywood, α_{plyw}	6.04	17.62	7.4648	2.90841

Results of the correlation analysis showed that springiness was dependent on hardness. Chewiness depended more on gumminess than on springiness, and resilience depended more on cohesiveness than on gumminess. The equation of the relationship between springiness and hardness, and gumminess, and between resilience and cohesiveness were as follows:

$S = 6.683E\text{-}5\ H + 0.037$ R= 0.713 SEE = 0.0046

$R = 0.938\ C_o - 0.159$ R= 0.998 SEE = 0.0057

$C_h = 0.079\ G - 0.109$ R= 0.881 SEE = 2.8945

Table 3 showed the minimum, maximum, mean and standard deviation values of the angle of repose on four different surfaces. Results of the measurement showed that the smallest repose angle occurred on the surface of the plywood and the greatest occurred on the aluminium.

Results of paired t-test analysis indicated that there was a significant difference between the angle of repose of stainless steel and aluminium, stainless steel and acrylic, stainless steel and plywood, aluminium and acrylic and between acrylic and plywood ($p > 0.05$). Otherwise, there was not any significant difference in the angle of repose on between aluminium and plywood ($p<0.05$).

Results of statistical analysis using stepwise multiple regression showed that there was a relationship between the angle of repose and the physical properties. The angle of repose on stainless steel had a tangential relationship with sphericity, aspect ratio and particle density. The angle of repose on aluminium had a tangential relationship with sphericity, aspect ratio, mass and equatorial diameter. The angle of repose on acrylic had a tangential relationship with polar diameter, sphericity, equatorial diameter and particle density. The angle of repose on plywood had a tangential relationship with sphericity and aspect ratio. The regression equations of all those relationships were presented as follows,

Table 4 showed the minimum, maximum, mean and standard deviation values of coordinates of CIE l*a*b* and CIE l*c*h*. Results of the colour analysis showed that the *Physalis angulata* fruits tended to have a pale yellow colour. This colour of the *Physalis angulata* fruit was following that of previous researches (Mahalakshmi, 2014; Bastos, 2006).

$$\alpha_{ss} = (1.816\ \psi - 1.239\ R_a - 0.217\ Dp) \tan \alpha_{ss} - 0.259$$
R=1.000 SEE= 0.0623

$$A_{al} = (1.750\ \psi - 1.151\ R_a + 2.387\ M - 0.625\ D_e) \tan \alpha_{al}$$
R=1.000 SEE=0.0607

$$\alpha_{acry} = (2.786\ D_p + 0.574\ \psi - 2.897\ D_e - 1.541\ \rho_p) \tan \alpha_{acry}$$
R=1.000 SEE=0.0445

$$\alpha_{plyw} = 1.693\ \psi - 1.139\ R_a) \tan \alpha_{plyw} + 0.184$$
R=1.000 SEE=0.0275

Table 4: Descriptive Statistics of colours.

	Minimum	Maximum	Mean	Std. Deviation
E*	39.34	39.36	39.3493	0.010
l*	37.79	37.81	37.7960	0.010
a*	1.83	1.87	1.8527	0.023
b*	10.78	10.79	10.7880	0.006
c*	10.94	10.95	10.9460	0.007
h*	0.00	0.00	0.0017	0.002

4 CONCLUSION

The results of this work found that the analysed *Physalis angulata,* physically had an average polar diameter, equatorial diameter, geometric diameter and surface area ranged from 13.49 ± 0.69, 12.92±0.76, 13.10±0.66 mm and 540.19±54.55 mm^2 respectively. These biometric characteristics were relatively similar to those characteristics reported in the literature for the same product. The average mass and volume ranged from 1.39 ± 0.20 gr and 2.63 ± 0.47 cm^3 respectively. The average particle and bulk density ranged from 0.53 ± 0.04 and 0.42± 0.005 gr/cm^3 respectively. The average sphericity, aspect ratio and porosity ranged from 97.17 ± 3.51, 95.84 ± 5.18 and 20.26 ± 6.63 %. On the relationship within the physical measures, results of regression analysis indicated that equatorial diameter, geometrical diameter, and surface area were dependent on mass. The polar diameter and porosity were dependent on volume and particle density respectively In term of the in-between relationship of mechanical properties; springiness was dependent on hardness. Chewiness depended on springiness, and resilience was dependent on cohesiveness.

Regarding the angle of repose, the highest angle of repose occurred on the surface of aluminium; otherwise, the lowest of that happened on the surface of the plywood. The angle of repose on the stainless steel surface tangentially was dependent on aspect ratio and polar diameter. The angle of repose on aluminium surface tangentially was dependent aspect ratio, mass and equatorial diameter, the angle of repose of acrylic surface was tangentially dependent on polar diameter, sphericity, equatorial diameter and particle density and angle of repose of plywood were tangentially dependent on sphericity and aspect ratio. There were significant differences of the angle of repose between stainless steel and all of aluminium, acrylic and plywood, between aluminium and acrylic and between acrylic and plywood; otherwise, there was not any significant difference between aluminium and plywood. Regarding the colour, the *Physalis angulata* fruits tended to have pale yellow colour, with the L*a*b*c*h* coordinates of 37.80 ± 0.0101, 85 ± 0.023, 10.79 ± 0.006, c* = 10.95 ± 0.007, and h*=0.02 ± 0.002 respectively.

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