A Comparative Study between Wild and Cultivated Varieties of Adlay Grains for Some Engineering Properties

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Abstract: This study was carried out to complement the database of wild and cultivated Adlay grain varieties and to identify the similarities and differences between them. Results of the analyses determined that regarding the polar diameter (D_p), thickness (T), and coefficient of contact surface (C_{cs}), there were not any significant differences between wild and cultivated varieties ($p>0.05$); Otherwise there were significant differences on the properties of equatorial diameter (D_e), geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), frontal surface area (A_{fs}), transverse area A_t), sphericity (ø), shape index I_s), mass (M), volume (V), particle density (ρ_p), bulk density (ρ_b), and porosity (ε) ($p<0.05$). In term of shape, the wild variety tended to be widened, while the cultivated variety tended to be lengthwise. Based on hardness and stickiness, the wild type was harder and stickier than the cultivated ones. The emptying angle of repose, filling angle of repose and the static friction of cultivated variety was relatively higher than that of the wild type. The mean total colour difference between the wild and cultivated variety was 6.952 ± 0.011.

1 INTRODUCTION

Adlay (*Coix lacryma-jobi* L.) is a broad-leaved, branched grass, a grain-bearing tropical plant of the family Poaceae. It is indigenous to China but also cultivated widely in many other Asian countries such as Philippine, Burma, Sri Lanka and Thailand (Bender, 1999). According to the previously published paper (LIPI, 1986), in Indonesia, there are four varieties of Adlay, namely *Agrotis, Ma-yuen, Palustris* and *Aquatic* which is then categorised into wild and cultivated types. The grain size of the wild type usually is about 1 cm in diameter with the form of roundish, whereas that of the cultivated variety usually exceeds 2 cm in diameter with the shape of spheroidal (Arora, 1977). The wild type (*Coix lacryma-jobi var. lacryma-jobi*) has a hard shell, stony, unbreakable by hand, shining and has various colours and is often used as ornamental beads for making rosaries necklaces, and other objects, Whereas the cultivated types, have a soft shell, breakable, coarse, not shining, bold and is used as folk medicine and foodstuffs (Arora, 1977; J.A Duke, 1985).

As medicine Adlay grains are often used as an antipyretic anodyne, anti-inflammatory, antiseptic, antispasmodic, hypotensive, hypoglycemic, sedative and vermifuge, antirheumatic, diuretic, pectoral, refrigerant and tonic (J.A.Duke, 1985; Chopra, 1986). The tea from the boiled seeds is used as part of a treatment to cure warts (Brooklyn Botanical Garden, 1986) and is also used in the treatment of lung abscess, lobar pneumonia, appendicitis, rheumatoid arthritis, diarrhoea, oedema and painful urination (H.Yeung, 1985).

As a stuffed food Adlay grains offer many opportunities for utilisation in diversified product such as for soups, porridge, drinks and pastries (Waraluck, 2007), it was reported that per 100 g, Adlay grains contain about 380 calories, 11.2 g H2O, 15.4 protein, 6.2 g fat, 65.3 g total carbohydrate, 0.8 g fibre, 1.9 gram ash, 25 mg Ca, 435 mg P, 5.0 mg Fe, 0.28 mg thiamine, 0.19 mg riboflavin, 4.3 mg niacin and 0 mg ascorbic acid (Kumar *et.all,* 2014).

Machine and equipment designing, handling, harvesting, processing and storing of grains, requires physical and mechanical properties. The properties of various grains have been determined by other researchers, such as finger millet (Ramashia *et.all*,

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2018), Kumquat fruits (Jaliliantabar *et. all*, 2013)], Coffee fruits (Dario *et. all*, 2012), Russian olive fruits (Dario *et.all*, 2012), tiger nut (Abano, 2011), Almonds (Loghavi *et. all,* 2011), finger millet (Swami, 2010), paddy grains (Zareiforoush, 2009), Jatropha curcas (Shkelqim, 2008), Date fruit (Keramat, 2008), and Sesame Seeds (Akintunde, 2004), cocoa beans (Plange and Baryeh, 2003), cumin seeds (Singh, 1996), and karinga seeds Suthar and Das, 1996). Concerning the Adlay grain, there is still lacking information about the physical, mechanical and colour properties; therefore the study aimed to characterise the physical, mechanical and colour properties to complement the database of two Adlay grain varieties.

2 MATERIALS AND METHODS

The study was taken place in Research Center for Appropriate Technology, Indonesian Institute of Sciences, Subang- West Java. The wild type of Adlay grains samples was taken from Cigadung village (Latitude 6⁰33'27" S, Longitude 107⁰45'45" E, and elevation 87 MAMSL), Subang subdistrict, Subang district, West Java province; and the cultivated type of Adlay grains samples were taken from Sukajadi village (Latitude 6⁰59'26" S, Longitude 108⁰06'32"E) , Wado subdistrict, Sumedang district, West Java province. The measurement of engineering properties included physical, mechanical and the colour was conducted at a moisture content of 10.74 % (wb) for wild type and 10.93 % for the cultivated variety of Adlay grains. The instrument used to measure the physical properties comprised of digital vernier calliper, digital balance, analytical balance, and baker glass. The apparatus used to measure the mechanical properties was the TA- XT plus Texture Analyser Stable Micro System and apparatus for measuring friction, emptying and filling angle of repose. The colour was observed using colourimeter NH 310. The collected data were statistically analysed to assess the minimum, maximum, means, standard deviation and means were compared using paired sample t-test.

2.1 Measurement of Physical Properties

The measurement of physical properties covered polar diameter (D_p), equatorial diameter (D_e), thickness (T), geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), frontal surface area (A_{fc}), transverse area (A_t), coefficient of contact surface (C_{cs}), shape index (I_s), sphericity (ø), mass (M), volume (V), particle density (ρ_p), bulk density (ρ_b), and porosity (ε). Population number of each type of the sample was 30, except for bulk density the measurement was performed for ten samples. Figure 1 showed the measurement position of polar and equatorial diameter and thickness of Adlay grains.

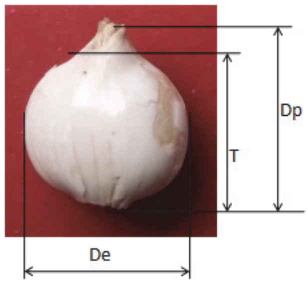

Figure 1: Position of Polar diameter, equatorial diameter and thickness of Adlay grains.

Knowledge of physical characteristics which composed of sphericity, shape index, polar diameter, equatorial diameter, surface area, porosity and colour are essential parameters in designing of the specific machine and analysing the behaviour of the product in the handling of materials. The frontal and transverse area is used to determine the coefficient of contact surface which is an important parameter to evaluate the contact surface between the Adlay grain and the other surfaces such as milling machine surfaces (El Gendy, *et .all,* 2011) The grain of Adlay is considered as an oval if the value of the shape index is more than 1.50 and as a spherical if that less than 1.50 (El Gendy, *et .all,* 2011; Bahnasawy *et. all*, 2004 ; Kaveri, 2015)

Density is required in a separation process such as hulling, quality evaluation, and also in the determination of thermal diffusivity in heat transfer problems (Zareiforoush, 2009). The geometric mean diameter, arithmetic mean diameter, frontal surface area, transverse area, cross-sectional area, shape index, sphericity, porosity, volume, particle density and bulk density were derived by using the following equations given by Mohsenin (Ramashia *et.all*, 2018) and had been used by other researchers (El Gendy, *et. all,* 2011; Bahnasawy *et. all*, 2004 ; Kaveri, 2015; Mohsenin *et.all,* 1986; Ismail *et. all,* 2014; Marioti *et. all,* 2006).

$$D_{gm} = \sqrt[3]{(D_e D_p T)} \qquad \emptyset = \frac{\sqrt[3]{D_e D_p T}}{D_e}$$

$$D_{am} = \frac{(D_e + D_p + T)}{3} \qquad \varepsilon = (\frac{(\rho_p - \rho_b)}{\rho_p}) \times 100\,\%$$

$$A_{fs} = \frac{\pi}{4}(D_e D_p) \qquad V = \frac{1}{4}[\frac{\pi}{6} D_p(D_e + t)^2]$$

$$A_t = \frac{\pi}{4} T D_e \qquad \rho_p = \frac{M}{v}$$

$$C_{cs} = \frac{A_{fs} - A_t}{A_{fs}} \times 100 \qquad \rho_b = \frac{M_{v500}}{V_{500}}$$

$$I_s = \frac{D_e}{\sqrt[2]{D_p T}}$$

2.2 Measurement of Mechanical Properties

The properties of mechanical measured consisted of hardness, stickiness, emptying angle of repose, filling angle of repose and friction. The number of each samples type was 5 for hardness and stickiness, 10 for filling angle of repose, emptying angle of repose and static friction, and 3 for colour analyses. The hardness and stickiness were measured using TA- XT plus Texture Analyser Stable Micro System. The hardness is an essential parameter in designing milling machine (Jesukristina *et. all*, 2015).

The angle of repose is an essential parameter in predicting flow characteristics, for inventorying grain and designing bins and grain handling systems (Zareiforoush, 2009; Bhadra,,2016; Tarighi, 2011; Hamzah, 2018). There are to types of the angle of repose, i.e. emptying and filling. The emptying angle of repose was measured using an electrically inclined plane supported by the sensor; Figure 2 showed the apparatus for measuring the emptying angle of repose. The emptying angle of repose and static friction coefficients were determined to four surfaces, i.e., stainless steel, aluminium, acrylic and plywood. The static friction (μ) was calculated by using the following equation (Zareiforoush, 2009; Plange, *et.all*, 2003; Singh, 1996)

$$\mu = \tan \theta_e$$

The filling angle of repose was determined by using a PVC of 100 mm diameter and 100 mm height. The PVC cylinder was placed on four types of surfaces, i.e. stainless steel, aluminium, acrylic and plywood; the filled PVC was raised until it formed the cone and the mean diameter (D) and height of pile (H) were recorded to calculate the filling angle of repose. The following formula was employed to determine the filling angle of repose (Zareiforoush, 2009, Tarighi, 2011; Hamzah, 2018).

$$\theta_f = \tan^{-1} \; [\frac{2H}{D}]$$

Where:
θe: Emptying angle of repose
θf: Emptying angle of repose
H: Height of cone
D: Diameter of the cone
μs: Static Friction

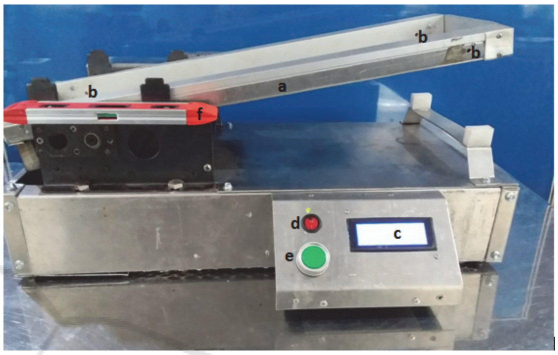

Figure 2: The angle of repose measuring instrument. (a: Adjustable Plane, b: Sensor 4 units; c: Display; d: ON/OFF Button; e: Start button, f: Water level).

2.3 Colour

The colour of wild and cultivated Adlay grains samples was determined using a colourimeter NH 310. The analysis methods used were CIE (Commission Internationale de L'Eclairage) L* a* b* and CIE L* c* h* coordinates (Ruiz *et.all*, 2012) The value of L*, a* b* and L* c* h*obtained was used to determine the total colour difference between each group of samples; the measurements were performed on three-grain samples which randomly taken from each type of Adlay grains samples. The entire colour difference was calculated using the following equation (Ruiz *et.all*, 2012; Pathare *et.all,* 2013)

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

The colour of the sample principally can be described using three specific qualities of visual sensation, i.e. tonality, luminosity, and chromatism. Tonality (h*) is the characteristics of the colour, i.e. red, yellow, green, and blue. The clarity is the attribute of the visual sensation according to the appearance of the sample whether less or more luminous. The chromatism (c*) is the level of colour related to a lower or higher intensity of the colour. Coordinate L* represents the clarity, in which L=0 is black, and L*= 100 is colourless. Coordinate a* represents the shade of red and green, in which a*> 0 indicates red colour and a*< 0 indicates green colour. Coordinate b* represents the tone of blue and yellow, in which b*> 0 shows the intensity of yellow and b*< 0 means the hue of blue. The total colour difference (ΔE*) is the difference between the two colours of the samples

3 RESULTS AND DISCCUSSION

Table 1 showed the minimum, maximum, average and standard deviation of wild and cultivated varieties of Adlay grains. The polar diameter of wild and cultivated varieties ranged from 9.40 ± 0.35 mm and 9.42 ± 1.67 mm respectively and the equatorial diameter of those ranged from 8.32 ± 0.30 and 7.02 ± 0.38 mm respectively; it meant that the shape of wild Adlay variety tended to be widened, whereas that of cultivated ones tended to be lengthwise. The density of wild type was more significant than that of cultivated ones; these results were found to be in close agreement with the past researchers (Jesukristina *et. all,* 2015; Gruben and Partohardjono, 1996; Agripina *et.all.* 2018). The porosity associated inversely with the sphericity; the higher the sphericity, the smaller the porosity.

In term of polar diameter (D_p), thickness (T), and coefficient of contact surface (C_{cs}), table 2 showed that results of paired sample t-test analysis determined that there were not any significant differences between wild and cultivated varieties ($p>0.05$); Otherwise there were significant differences on the properties of equatorial diameter (D_e), geometric mean diameter (D_{gm}), arithmetic mean diameter (D_{am}), frontal surface area (A_{fs}), transverse area At), sphericity (ø), shape index I_s), mass (M), volume (V), particle density (**ρ_p**), bulk density (**ρ_b**), and porosity (**ε**) ($p<0.05$).

Table 2 showed the hardness and stickiness of wild and cultivated varieties of Adlay grain. Results of measurement indicated that the hardness of wild type was relatively stronger than that of cultivated ones, as well as for stickiness. The average hardness of wild variety was about eight times compared to that of cultivated ones; it meant that the wild type was stony, in the other hand the cultivated variety was breakable. This result was found under that of the earlier researchers (Jesukristina, 2015); Grubben and Partohardjono, 1996).

Table 1: Physical properties of wild and cultivated varieties of Adlay grain.

Physical Properties	WILD				CULTIVATED			
	Minimum	Maximum	Mean	Std. Deviation	Minimum	Maximum	Mean	Std. Deviation
D_p	8.71	10.14	9.40	0.35	7.51	17.30	9.42	1.67
D_e	7.59	8.85	8.32	0.30	6.12	7.88	7.02	0.38
T	6.05	8.71	10.14	0.41	6.02	8.38	7.18	0.53
D_{gm}	7.76	7.59	8.85	0.25	6.81	8.97	7.77	0.48
D_{am}	7.82	8.83	8.32	0.25	6.87	10.08	7.87	0.61
A_{fs}	54.93	68.48	61.41	3.37	39.39	94.11	51.95	9.73
A_t	38.85	55.37	47.34	3.75	30.30	48.68	39.60	4.19
C_{cs}	12.06	35.84	22.87	5.09	12.25	65.20	22.35	9.40
ø	0.82	0.95	0.88	0.03	1.01	1.29	1.11	0.06
I_s	0.81	0.97	0.89	0.04	0.40	0.90	0.76	0.09
M	0.24	0.38	0.33	0.04	0.08	0.12	0.10	0.01
V	0.26	0.37	0.32	0.03	0.17	0.38	0.25	0.05
ρ_p	0.86	1.23	1.03	0.10	0.30	0.58	0.42	0.08
ρ_b	0.53	0.61	0.58	0.02	0.20	0.31	0.29	0.03
ε	33.70	49.79	42.21	5.99	19.60	46.74	33.82	9.06

Table 2: Physical properties comparison between wild and cultivated of Adlay grains.

Pairs	Paired Differences					t	df	Sig (2-tailed)
	Mean	Standard		95% Confidence Interval of the Difference				
		Deviation	Error Mean	Lower	Upper			
D_{pw}- D_{pc}	-0.02	1.66	0.30	-0.64	0.60	-0.08	29.00	0.94
D_{ew}- D_{ec}	1.31	0.41	0.07	1.15	1.46	17.44	29.00	0.00
t_w- t_c	0.06	0.72	0.13	-0.21	0.33	0.46	29.00	0.65
D_{gmw}- D_{gmc}	0.50	0.49	0.09	0.31	0.68	5.59	29.00	0.00
D_{amw}- D_{amc}	0.45	0.60	0.11	0.22	0.67	4.11	29.00	0.00
A_{sw}- A_{sc}	24.41	24.04	4.39	15.43	33.39	5.56	29.00	0.00
A_{fsw}- A_{fsc}	9.47	9.26	1.69	6.01	12.92	5.60	29.00	0.00
A_{tw}-A_{tc}	7.75	5.55	1.01	5.67	9.82	7.64	29.00	0.00
C_{scw}-C_{scc}	0.52	11.38	2.08	-3.73	4.77	0.25	29.00	0.80
$ø_w$- $ø_c$	-0.23	0.07	0.01	-0.25	-0.20	-17.85	29.00	0.00
I_{sw}- I_{sc}	0.13	0.10	0.02	0.09	0.17	6.76	29.00	0.00
M_w- M_c	0.23	0.04	0.01	0.21	0.24	33.84	29.00	0.00
V_w- V_c	0.07	0.05	0.01	0.05	0.09	7.75	29.00	0.00
ρ_{pw}- ρ_{pc}	0.62	0.13	0.02	0.57	0.67	25.87	29.00	0.00
ρ_{bw} - ρ_{bc}	0.29	0.04	0.01	0.27	0.32	23.37	9.00	0.00
ε_w- ε_c	0.08	0.11	0.04	0.00	0.16	2.32	9.00	0.05

Table 3: Hardness and stickiness of wild and cultivated varieties of Adlay grain.

	WILD				CULTIVATED			
TA-Profile	**Minimum**	**Maximum**	**Mean**	Std. Deviation	Minimum	Maximum	Mean	Std. Deviation
Hardness	28466.73	40546.65	35584.70	4966.19	3544.07	5049.88	4426.05	614.97
Stickiness	-5.40	-3.64	-4.5300	0.63	-1.29	-0.94	-1.15	0.13

Table 4: Hardness and stickiness comparison between wild and cultivated varieties of Adlay grain.

Pairs	Paired Differences					t	df	Sig (2-tailed)
	Mean	Standard		95% Confidence Interval of the Difference				
		Deviation	Error Mean	Lower	Upper			
H_w-H_{cul}	31158.65	4594.85	2054.88	25453.38	36863.91	15.16	4.00	0.00
S_w-S_{cul}	-3.38	0.75	0.34	-4.31	-2.44	-10.03	4.00	0.00

Results of paired sample t-test analysis which could be seen in table 4, determined that there were significant differences of hardness and stickiness between wild and cultivated varieties ($p<0.05$).

Table 5 showed the emptying angle of repose on a different type of surfaces. The highest angle of repose occurred on the surface of plywood; otherwise, the smallest of that happened on the aluminium surface.

Results of paired sample t-test analysis, which could be seen in table 6, showed that there were not any significant differences of emptying angle of repose on aluminium and acrylic surfaces of wild and cultivated varieties ($p>0.05$); otherwise, there was

Table 5: The emptying angle of repose of wild and cultivated varieties of Adlay grains on a different type of surfaces.

	WILD				CULTIVATED			
	Minimum	Maximum	Mean	Std. Deviation	Minimum	Maximum	Mean	Std. Deviation
θ_{eSS}	28,10	34,02	31,56	1,94	29,60	35,52	33,06	1,94
θ_{eAL}	28,10	38,28	31,42	2,84	28,89	37,18	34,12	2,77
θ_{eACRY}	29,28	36,86	32,62	1,99	29,13	39,31	33,96	2,84
θ_{ePLYWD}	32,13	39,23	35,80	2,26	35,52	50,91	41,17	4,01

Table 6: The emptying angle of repose comparisons between wild and cultivated of Adlay grains on the surface of aluminium, acrylic and plywood.

Paired Differences								
Pairs	Mean	Standard		95% Confidence Interval of the Difference		t	df	Sig (2-tailed)
		Deviation	Error Mean	Lower	Upper			
θ_{eALW} - θ_{eALCUL}	-2.70	4.35	1.37	-5.82	0.41	-1.97	9.00	0.08
θ_{eACRYW} - $\theta_{Eacryw\ CUL}$	-1.33	3.56	1.13	-3.88	1.22	-1.18	9.00	0.27
$\theta_{ePLYWDW}$ - $\theta_{ePLYWD\ CUL}$	-5.37	4.00	1.26	-8.23	-2.51	-4.25	9.00	0.00

Table 7: The emptying angle of repose comparisons between wild and cultivated of Adlay grains on the surface of stainless steel.

	Chi-Square	df	Asymp. Sig.
$\theta_{eSS\ W}$ - $\theta_{eSS\ CUL}$	0.800	8	0.999

Table 8: Filling angle of repose of wild and cultivated varieties of Adlay grains on a different type of surfaces.

	WILD				CULTIVATED			
	Minimum	Maximum	Mean	Std. Deviation	Minimum	Maximum	Mean	Std. Deviation
θ_{fSS}	68.29	73.38	70.88	1.52	73.06	77.83	75.75	1.37
θ_{fAL}	65.51	72.80	70.53	2.35	74.22	78.83	76.40	1.56
θ_{fACRY}	70.76	74.76	73.06	1.35	75.30	79.41	76.90	1.43
θ_{fPLYWD}	68.50	73.55	71.79	1.63	75.77	79.00	77.71	0.89

a considerable difference of that on the surface of plywood ($p<0.05$).

Results of Chi-square analysis of emptying angle of repose on the stainless steel surface for wild and cultivated varieties as could be seen in table 7, did not show any significant difference ($p>0.05$).

Table 8 showed that the highest a filling angle of repose occurred on the surface of plywood; otherwise, the smallest of that happened on the surface stainless steel.

The result of paired sample t-test as shown in Table 9 indicated that there were significant differences

Table 9: Filling angle of repose comparisons between wild and cultivated of Adlay grains.

Pairs	Paired Differences					t	df	Sig (2-tailed)
	Mean	Standard		95% Confidence Interval of the Difference				
		Deviation	Error Mean	Lower	Upper			
$\theta_{fSS\ W} - \theta_{fSS\ CUL}$	-5.87	2.89	0.91	-7.94	-3.80	-6.43	9.00	0.00
$\theta_{fal\ W} - \theta_{fal\ CUL}$	-4.87	2.23	0.71	-6.46	-3.27	-6.90	9.00	0.00
$\theta_{facry\ W} - \theta_{facry\ CUL}$	-5.92	1.16	0.37	-6.75	-5.09	-16.14	9.00	0.00
$\theta_{fplywd\ W} - \theta_{fplywd\ CUL}$	-3.84	1.80	0.57	-5.13	-2.55	-6.72	9.00	0.00

Table 10: The friction of wild and cultivated varieties of Adlay grains on a different type of surfaces.

	WILD				CULTIVATED			
	Minimum	Maximum	Mean	Std. Deviation	Minimum	Maximum	Mean	Std. Deviation
μ_{SS}	0.53	0.68	0.62	0.05	0.57	0.71	0.66	0.05
μ_{AL}	0.53	0.79	0.61	0.07	0.55	0.76	0.69	0.07
μ_{ACRY}	0.56	0.75	0.64	0.05	0.56	0.82	0.66	0.08
μ_{PLYW}	0.63	0.82	0.72	0.06	0.71	0.91	0.83	0.05

Table 11: Friction comparisons between wild and cultivated of Adlay grains.

Pairs	Paired Differences					t	df	Sig (2-tailed)
	Mean	Standard		95% Confidence Interval of the Difference				
		Deviation	Error Mean	Lower	Upper			
$\mu_{SSW} - \mu_{SS\ CUL}$	-0.04	0.03	0.01	-0.06	-0.02	-4.00	9.00	0.00
$\mu_{ALW} - \mu_{AL\ CUL}$	-0.07	0.11	0.04	-0.15	0.01	-2.02	9.00	0.07
$\mu_{ACRYW} - \mu_{ACRY\ CUL}$	-0.02	0.10	0.03	-0.09	0.05	-0.72	9.00	0.49
$\mu_{PLYWW} - \mu_{PLYW\ CUL}$	-0.11	0.07	0.02	-0.16	-0.06	-4.83	9.00	0.00

between one surface and the others ($p<0.05$).

Comparisons between emptying and filling angle of repose on different surfaces, it was found that the filling angle of repose had a higher value than the emptying angle of repose.

Table 10 showed the static friction of wild and cultivated varieties of Adlay grains. As it was presented in the table, the highest static friction occurred in the surface of plywood, for both wild and cultivated varieties; Otherwise, the lowest of that happened in aluminium surface for wild type, and on the acrylic surface for cultivated ones.

Result of paired sample t-test as shown in table 11 pointed out that there were significant differences between wild and cultivated varieties in static friction on the surfaces of stainless steel and plywood ($p<0.05$), on the other hand, there were not any significant differences of that on the surfaces of aluminium and acrylic ($p>0.05$).

Table 12: Colour of Wild and Cultivated Varieties of Adlay Grains.

	WILD				CULTIVATED			
								
	Minimum	Maximum	Mean	Std. Deviation	Minimum	Maximum	Mean	Std. Deviation
L*	39.769	39.777	39.773	0.004	41.950	41.953	41.951	0.002
a*	0.015	0.041	0.030	0.013	3.024	3.055	3.037	0.016
b*	0.866	0.894	0.881	0.014	6.749	6.769	6.758	0.010
c*	0.867	0.895	0.882	0.014	7.399	7.414	7.409	0.009
h*	0.000	0.001	0.000	0.000	0.001	0.002	0.001	0.001
ΔE*	**6.952 ± 0.011**							

Visually a wild Adlay was shiny and had a various colour, i.e. grey, yellow-brownish, purplish and blackish, while the cultivated one was not shiny and had a uniform colour of white-brownish. These findings were relatively under that of the previous study (Grubben and Partohardjono, 1996). The geometrical CIE L*a*b*c*h* coordinates of wild and cultivated Adlay grains were (39.773±0.004; 0.030±0.013; 0.881±0.014; 0.882±0.014; 0.000±0.000) and (41.951±0.002; 3.037±0.016; 6.758±0.010; 7.409±0.009; 0.001±0.001) respectively. Results of the calculation determined that the total colour difference between wild and cultivated variety (ΔE*w-cul) was 6.952±0.011.

4 CONCLUSION

Results of the study found that the polar diameter, equatorial diameter and thickness of wild Adlay grain varieties were 9.40 ± 0.35 mm, 8.32 ± 0.30 mm and 7.24 ± 0.41 mm respectively, and those for cultivated variety were 9.42 ± 1.67 mm, 7.02 ± 0.38 mm, and 7.18 ± 0.53 mm respectively.

There was not any significant difference in the polar diameter, thickness and coefficient of contact surface between wild and cultivated varieties of Adlay grains; otherwise there were significant differences in equatorial diameter, geometric mean diameter, arithmetic mean diameter, frontal surface area, transverse area, sphericity, shape index, mass, volume, particle density, bulk density and porosity. The shape of wild Adlay tended to be widened, whereas that of cultivated ones tended tobe lengthwise. The particle density, bulk density and porosity of wild Adlay were bigger than that of cultivated ones. The particle density, bulk density and porosity of wild Adlay were 1.03 ± 0.10 gr/cm3, 0.58 ± 0.022 gr/cm3, and 42.21 ± 5.99 % respectively, and those of cultivated ones were 0.42 ± 0.08 gr/cm3, 0.29 ± 0.03 gr/cm3, and 33.82 ± 9.06 % respectively.

Concerning the texture profile, the wild Adlay grain was harder and stickier than the cultivated ones. The hardness and stickiness for wild Adlay grain were 35 584.70 ± 4 966.19 g-force and -4.53 ± 0.63 g-forces respectively and those for cultivated ones were 4 426.05 ± 614 ± 614.97 g-force and -1.15 ± 0.13 g-force respectively. The emptying angle of repose, filling angle of repose and static friction of wild Adlay grain was smaller than that of cultivated ones.

The geometrical CIE L*a*b*c*h* coordinates of wild and cultivated Adlay grains were (39.773±0.004; 0.030±0.013; 0.881±0.014; 0.882±0.014; 0.000±0.000) and (41.951±0.002; 3.037±0.016; 6.758±0.010; 7.409±0.009; 0.001±0.001) respectively, and the total colour different of them was 6.952±0.011.

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