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# Influence of Moisture Content to the Physical Properties of Unhusk Rice Grain

Renny Eka Putri#, Santosa#, Muhammad Makky#

#*Department of Agricultural Engineering, Faculty Agricultural Technology,*
*University Andalas, West Sumatera, Indonesia*
*Email: renny.ekaputri@yahoo.co.id*

***Abstract*— Determination physical properties of rice grain are important for design of harvesting, conveying and processing equipment. Size, sphericity, bulk density, a hundred grain seed mass, angle of repose and angle of friction against different surfaces were evaluated for five varieties of unhusk rice grain (Junjungan, Mundam, SokanPulau, Simaung and Bakwan) as a function of moisture content in the range of 9 to 25 (w.b.%). The objective of this study is to determine the influance of moisture content on the physical properties of local varieties of grain and rice from West Sumatra, Indonesia. Among the varieties, Junjungan had the highest values for geometric mean diameter, sphericity and thousand seed mass at all moisture levels. Geometric Mean Diameter (GMD) and sphericity increased significantly from 3.11 to 3.76 and 0.37 to 0.42 variety in a moisture content range of 9 to 25% w.b. Maximum values of bulk density and a thousand grain mass were obtained for Sokan Pulau (0.55-0.63g/cm3) and for Bakwan (29.99- 35.21 g). The angle of repose and angle of friction ranges for Mundam increased from 27.36 to 38.75˚and 27.33 to 37˚, respectively as increasing moisture content levels.**

***Keywords*— physical properties; moisture content; rice grain varieties**

## I. INTRODUCTION

The water content in food ingredients influences the quality and shelf life of the food. Therefore, the determination of moisture content of food is significant for the processing and distribution got the right treatment. Quality of grain is a set of physical properties of the individual (quality components) which make up the grain. Grain with high quality will produce high-quality rice as well. Grain moisture content affects the grain milling process due to if the moisture content is high, or more than 14%, the rice will feel soft or mushy so that during the milling process will cause the rice is broken. Another vital quality factor is the shape, size, weight, and uniformity of grain seeds. Dimensions rice is determining rice grading and demand in the international market. Besides, the dimensions of rice will determine dryers and processing equipment that is needed so that the dimensions of rice are also an essential factor in the assembly of new varieties.

Several studies conducted to find the effect of moisture content to the physical properties of any types of grain other than rice; barley seeds [1], saffron flower [15], Alfalfa Grain [17], canola seeds [26] and faba bean [3]. Some parameters of the physical nature of this research are the size of the grain, sphericity, bulk density and angle of friction. Then, a study of the physical properties of paddy of Hashemi varieties conducted from Iran [35]. Therefore, it is essential to study the physical properties of grain and rice from local varieties of West Sumatra, Indonesia. The objective of this study aims to determine the effect of moisture content on the physical properties of local varieties of rice grain from West Sumatra, Indonesia.

## II. MATERIALS AND METHODS

Unhusk rice grain was obtained from several areas in West Sumatra Indonesia, namely Junjungan (J), Mundam (M), Sokan Pulau (SP), Simaung (S) and Bakwan (B). To determine the effect of moisture content against physical properties, the grains were set in five levels deferent moisture content with a range of 9 to 25% in wet basis. The initial moisture content of the samples was determined by using grain moisture meter. The G-7 Delmhorst Grain Moisture Meter has moisture content range from 9 to 30%. It has built-in correction factors for various grains such as barley, coffee, corn, flax, hay, oats, rapeseed, rough rice, sorghum, soybeans, wheat, and rye. The grain meter has built-in temperature correction over the range of 0 to 37$^{o}$C.

To vary the moisture content of the rice grain was used two methods, namely by soaking method and drying method. The drying processes for this research were done from 0 to 10 minutes inside the moisture analyzer. The different times drying process is used to get a variation of moisture content until 10%. Another process, the soaking method was done in 0 until 24 hours to increase moisture content until 25% [26].

The three linear dimensions of the seeds, namely length (L), width (W) and thickness (T) were carefully measured using micrometer gauge with an accuracy of 0.01 mm. The geometric mean diameter (GMD) and sphericity ratio were computed using the following equations:

$$GMD = (L*W*T)^{1/3} \quad (1)$$

$$Sphericity = GMD / L \quad (2)$$

Sphericity was useful to know the shape of the grains that are aimed at the grinding process and determine the quality of grain. Sphericity is the ratio between Geometric Mean Diameter (GMD) with Length seed. Bulk density affects the process of transportation of materials, and the value of bulk density is different for every grain. The following equation can determine bulk density values:

$$\rho = m / v \quad (3)$$

For 1000 grain seed mass can be determined by quantifies 1000 grain seeds were then weighed using a digital scale. The angle formed between the grain and rice to the plane of the surface and forms a cone and the angle formed is called angle of repose. The angle of repose for each variety of grain and rice varies depending on the smoothness of the surface. The angle of repose of the seeds could be determined by pouring the seeds on to a flat surface, and one sloping side of the pile of seeds was measured using a protractor. Based on the slope of the resulting stacks can then be measured slope or the called angle of repose.

The angle of friction refers to a flat surface. Board or the iron plate slowly tilted until the grain moves down. The angle of friction is very important for the construction of storage facilities and storage tub for the removal of material with an elevator. The angle of friction of grain is done by using two surfaces, namely plywood, and aluminum. The angle of friction determined by placing the seeds on the surface of the material a second runway and the runway then tilted slowly and by the time the seeds begin to slide then that is when the tilt angle measurement of the wood. The angle of repose is the angle formed between the slope of the pile of grain or rice, to the plane.

For each treatment, 100 rice grains were randomly selected to measure seed size, sphericity, bulk density and for seed mass, the angle of repose and angle of friction tested in five replications. Statistical analysis was reformed on the experimental data obtained using SPSS 17.0 (Statistical Product and Service Solution). An analysis of variance (ANOVA) was used to study the effect of moisture content and physical properties of the grain (GMD, sphericity, 1000 grain seed mass, bulk density, the angle of repose and angle of friction). Also, Duncan's Multiple Range Test was conducted to compare the means of the treatments.

## III. Results and Discussion

Table 2 shows the Physical properties of unhusk rice grain at different moisture contents in the range of 10 to 25 (w.b. %). Significant differences were observed among measured parameters with an increase in moisture content. Increase in moisture content caused an increase in GMD, sphericity, bulk density, 1000 seed mass, the angle of repose and angle of friction.

*1)* The Geometric Mean Diameter (GMD) of different variety of unhusks rice grain shows in Fig. 1. The GMD value is very essential for harvesting, separation, sizing, and sorting equipment. GMD of all variety of unhusk rice grain increase with increasing moisture content. GMD value of Mundam, Sokan Pulau, Junjungan, Simauang and Bakwan varieties are an increase from 3.025 to 3.74 mm, 2.98 to 3.744 mm, 3.109 to 3.757 mm, 3.474 to 4.012 mm and 3.528 to 4.345mm with increasing moisture content from 9 to 25%, respectively. The relationship between length, width, thickness, unit mass and moisture content of rice grain is presented in Table 1. Analysis of data shows significant differences among geometric mean diameter with an increase in moisture content. This observation has also been observed for barley seed [1], for sorghum seed [24], caper seed [13], flaxseed [11] and okra seeds [8].

TABLE I
THE RELATIONSHIP BETWEEN GMD AND MOISTURE CONTENT FOR FIVE VARIETIES OF RICE GRAIN

| Variety | Equation | $R^2$ |
|---|---|---|
| Mundam | $GMD_M = 0.048x + 2.496$ | 0.970 |
| Junjungan | $GMD_J = 0.041x + 2.735$ | 0.996 |
| Sokan Pulau | $GMD_{SP} = 0.063x + 2.206$ | 0.937 |
| Simaung | $GMD_S = 0.043x + 3.005$ | 0.940 |
| Bakwan | $GMD_B = 0.058x + 3.092$ | 0.794 |

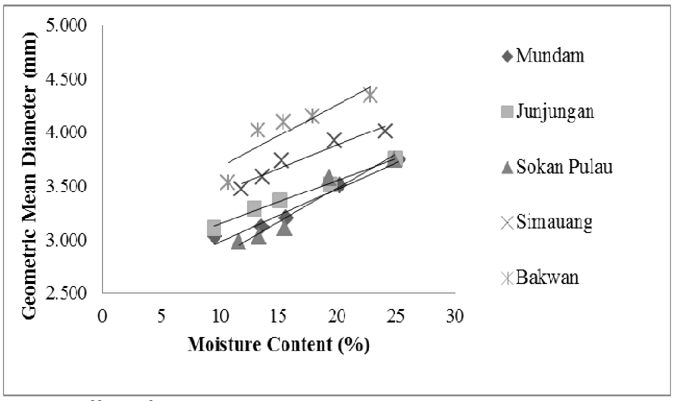


Fig. 1 Effect of varying moisture content on *Geometric Mean Diameter* (GMD) of rice grain

TABLE II
DUNCAN'S MULTIPLE RANGE TESTS ON MEAN PHYSICAL PROPERTIES OF UNHUSK RICE GRAINS AT DIFFERENT MOISTURE CONTENT LEVELS

| Variety | Observation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Moisture Content (%) | GMD (mm) | Sphericity | Bulk Density ($gcm^3$) | 1000 Seed Mass (g) | The angle of repose (º) | Angle of friction | |
| | | | | | | | Plywood (º) | Aluminum (º) |
| Mundam | 10 | $3.03^{a}$ | $0.37^{a}$ | $0.53^{a}$ | $21.98^{a}$ | $21.63^{a}$ | $27.33^{a}$ | $23.00^{a}$ |
| | 13 | $3.12^{ab}$ | $0.37^{a}$ | $0.54^{b}$ | $24.45^{b}$ | $23.99^{b}$ | $29.33^{b}$ | $24.33^{b}$ |
| | 15 | $3.20^{b}$ | $0.38^{a}$ | $0.56^{c}$ | $25.67^{c}$ | $27.72^{c}$ | $31.00^{c}$ | $26.00^{c}$ |
| | 20 | $3.2^{b}$ | $0.38^{a}$ | $0.58^{d}$ | $27.15^{d}$ | $31.96^{d}$ | $33.667^{d}$ | $27.00^{c}$ |
| | 25 | $3.50^{c}$ | $0.41^{b}$ | $0.63^{e}$ | $29.04^{e}$ | $36.89^{e}$ | $37.00^{e}$ | $29.00^{d}$ |
| Junjungan | 10 | $3.12^{a}$ | $0.38^{a}$ | $0.45^{a}$ | $22.38^{a}$ | $27.35^{a}$ | $32.33^{a}$ | $19.33^{a}$ |
| | 13 | $3.30^{b}$ | $0.40^{b}$ | $0.51^{b}$ | $22.52^{b}$ | $30.30^{b}$ | $35.67^{b}$ | $29.00^{b}$ |
| | 15 | $3.37^{b}$ | $0.40^{b}$ | $0.56^{c}$ | $27.57^{c}$ | $32.94^{c}$ | $37.67^{c}$ | $30.00^{b}$ |
| | 20 | $3.52^{c}$ | $0.42^{c}$ | $0.61^{d}$ | $30.54^{d}$ | $36.43^{d}$ | $40.00^{d}$ | $33.67^{c}$ |
| | 25 | $3.76^{d}$ | $0.43^{d}$ | $0.66^{e}$ | $32.43^{e}$ | $38.77^{e}$ | $42.33^{e}$ | $36.67^{d}$ |
| Sokan Pulau | 10 | $2.98^{a}$ | $0.37^{a}$ | $0.35^{a}$ | $22.46^{a}$ | $28.14^{a}$ | $32.00^{a}$ | $22.00^{a}$ |
| | 13 | $3.03^{ab}$ | $0.37^{a}$ | $0.57^{b}$ | $23.77^{b}$ | $29.86^{ab}$ | $34.33^{b}$ | $26.67^{b}$ |
| | 15 | $3.11^{b}$ | $0.37^{a}$ | $0.59^{c}$ | $24.87^{c}$ | $31.17^{b}$ | $36.00^{c}$ | $28.00^{c}$ |
| | 20 | $3.57^{c}$ | $0.41^{b}$ | $0.60^{d}$ | $27.32^{d}$ | $34.56^{c}$ | $37.67^{d}$ | $31.67^{d}$ |
| | 25 | $3.74^{d}$ | $0.42^{c}$ | $0.63^{e}$ | $29.44^{e}$ | $36.98^{d}$ | $40.33^{e}$ | $33.67^{e}$ |
| Simauang | 10 | $3.49^{a}$ | $0.35^{a}$ | $0.48^{a}$ | $25.52^{a}$ | $26.15^{a}$ | $28.33^{a}$ | $24.67^{a}$ |
| | 13 | $3.57^{b}$ | $0.37^{b}$ | $0.51^{b}$ | $26.62^{b}$ | $28.83^{ab}$ | $31.00^{b}$ | $27.33^{b}$ |
| | 15 | $3.74^{c}$ | $0.38^{b}$ | $0.55^{c}$ | $27.55^{c}$ | $31.98^{bc}$ | $38.00^{c}$ | $31.00^{c}$ |
| | 20 | $3.92^{d}$ | $0.39^{c}$ | $0.58^{d}$ | $28.27^{d}$ | $34.70^{cd}$ | $41.00^{d}$ | $32.67^{d}$ |
| | 25 | $4.01^{e}$ | $0.40^{c}$ | $0.66^{e}$ | $29.07^{e}$ | $36.49^{d}$ | $44.67^{e}$ | $36.00^{e}$ |
| Bakwan | 10 | $3.53^{a}$ | $0.37^{a}$ | $0.56^{a}$ | $29.99^{a}$ | $26.40^{a}$ | $33.33^{a}$ | $24.00^{a}$ |
| | 13 | $4.02^{b}$ | $0.40^{b}$ | $0.57^{b}$ | $31.43^{b}$ | $28.59^{b}$ | $35.00^{b}$ | $25.67^{b}$ |
| | 15 | $4.10^{c}$ | $0.40^{bc}$ | $0.61^{c}$ | $33.11^{c}$ | $30.94^{c}$ | $36.67^{c}$ | $28.00^{c}$ |
| | 20 | $4.15^{d}$ | $0.41^{cd}$ | $0.61^{c}$ | $35.40^{d}$ | $34.67^{d}$ | $38.33^{d}$ | $29.33^{d}$ |
| | 25 | $4.34^{e}$ | $0.41^{d}$ | $0.63^{d}$ | $38.21^{e}$ | $37.89^{e}$ | $40.00^{e}$ | $32.00^{e}$ |

*) Duncan grouping showing different letters indicates that the mean voltage reading of the four treatments is significantly different at 5% significant level or 0.05 probability level.

*2) Sphericity:* Shape of grain can be determined by determining the value Sphericity. Sphericity (Φ) is the ratio of geometric mean diameter (GMD) with a length of seeds. Fig. 2 show the value sphericity of all variety of unhusk rice grain increase with increasing moisture content. Sphericity value of Mundam, Sokan Pulau, Junjungan, Simauang and Bakwan varieties are an increase from 0.369 to 0.442, 0.37 to 0.421, 0.379 to 0.431, 0.352 to 0.401 and 0.372 to 0.413 with increasing moisture content from 9 to 25%, respectively. The relationship between sphericity and moisture content of rice grain is presented in Table 3. It has been proved for paddy Hashemi varieties as shown, the sphericity of the paddy grain increased significantly (*P* <0.01) from 34.53 to 35.46% as the moisture content increased from 8 to 24% (d.b.) [34

*3)* ], raw and parboiled paddy [27

*4)* ], fenugreek seeds [2], popcorn kernels [20] and pea seed [33].

TABLE III
THE EQUATION OF SPHERICITY FOR EVERY VARIETY

| Variety | Equation | $R^2$ |
|---|---|---|
| Mundam | $\Phi M = 0.0_{0}3x + 0.325$ | 0.926 |
| Junjungan | $\Phi_J = 0.003x + 0.350$ | 0.974 |
| Sokan Pulau | $\Phi SP = 0._{00}4x + 0.314$ | 0.921 |
| Simaung | $\Phi S = 0.0_{0}3x + 0.317$ | 0.905 |
| Bakwan | $\Phi_B = 0.002x + 0.354$ | 0.682 |

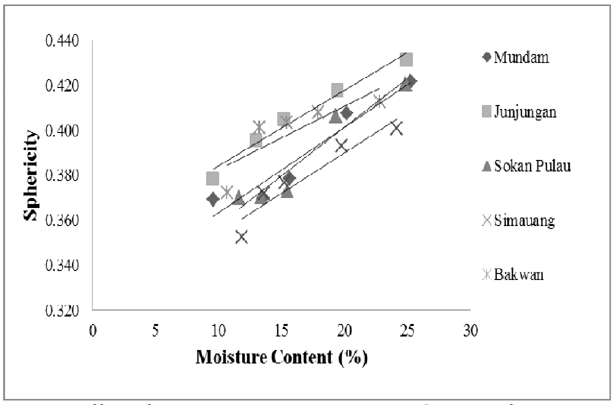


Fig. 2 Effect of varying moisture content on Sphericity of rice grain

*5) Bulk Density:* Bulk density is obtained by determining the weight of unhusk rice grain loaded into the tube. The effect of bulk density with different moisture content can be seen in Fig. 3. The bulk density of all variety of unhusks rice grain increase with increasing moisture content. Bulk density value of Mundam, Sokan Pulau, Junjungan, Simauang and Bakwan varieties are increase from 0.53 to 0.627 g/cm$^3$, 0.553 to 0.632 g/cm$^3$, 0.452 to 0.655 g/cm$^3$, 0.475 to 0.583 g/cm$^3$ and 0.56 to 0.63 g/cm$^3$ with increasing moisture content from 9 to 25%, respectively. The relationship between bulk density and moisture content of rice grain is presented in Table 4. Paddy Hashemi varieties results showed that the bulk density increases linearly 381.77 to 428.5 kg / m$^3$ with an increase in moisture content of 8 to 24% [35], dried pomegranate seeds have reported similar increasing trend in bulk density [21], chickpea seed [22], rapeseed [8] and safflower [7].

TABLE IV
THE RELATIONSHIP BETWEEN BULK DENSITY AND MOISTURE CONTENT

| Variety | Equation | $R^2$ |
|---|---|---|
| Mundam | $\rho_M = 0.013x + 0.328$ | 0.939 |
| Junjungan | $\rho_J = 0.006x + 0.463$ | 0.975 |
| Sokan Pulau | $\rho_{SP} = 0.013x + 0.328$ | 0.939 |
| Simaung | $\rho_S = 0.013x + 0.323$ | 0.971 |
| Bakwan | $\rho_B = 0.005x + 0.502$ | 0.916 |

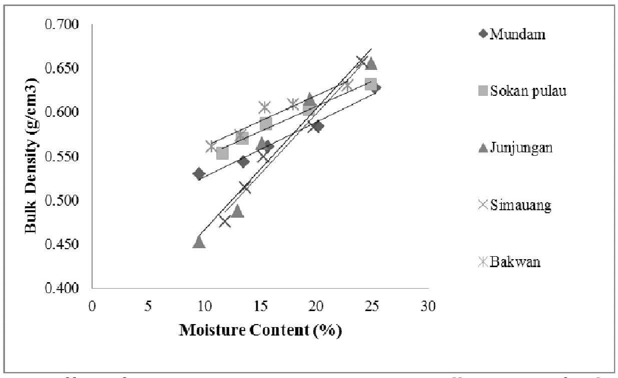


Fig. 3 Effect of variation on moisture content on Bulk Density of unhusk rice grain

*6) 1000 Seed Mass:* Thousand ($M_{1000}$) seed mass is obtained by calculating 1000 unhusk rice grain seed is then weighed with digital scales. Value of mass thousand seeds of all variety of unhusks rice grain increase with increasing moisture content. Mass thousand seeds value of Mundam, Sokan Pulau, Junjungan, Simauang and Bakwan varieties are an increase from 21.983 to 29.035 to 29.435 g, 22.376 to 32.43 g, 25.517 to 29.066 g and 29.993 to 35.21 g with increasing moisture content from 9 to 25%, respectively (Fig. 4). The relationship between the mass thousand seeds and moisture content of rice grain is presented in Table 5. Trends similar increase has been reported sunflower seed [29], moisture content increased from 4% - 22% w.b., thousand unhusk rice grain weight increased considerably from 80.3 to 96.8 g, observed a linear increase for the thousand unhusk rice grain weight of faba bean from 1140.15 to 1332.67 g when the moisture content increased from 9.89% to 25.08% d.b [3], jatropha seed [16], Bambara groundnut [6] and barbunia beans [10].

TABLE V
THE RELATIONSHIP BETWEEN 1000 SEED MASS AND MOISTURE CONTENT

| Variety | Equation | $R^2$ |
|---|---|---|
| Mundam | $M_{1000M} = 0.435x + 18.31$ | 0.976 |
| Junjungan | $M_{1000J} = 0.654x + 16.95$ | 0.959 |
| Sokan Pulau | $M_{1000SP} = 0.528x + 16.62$ | 0.985 |
| Simaung | $M_{1000S} = 0.265x + 22.9$ | 0.906 |
| Bakwan | $M_{1000B} = 0.698x + 22.42$ | 0.992 |

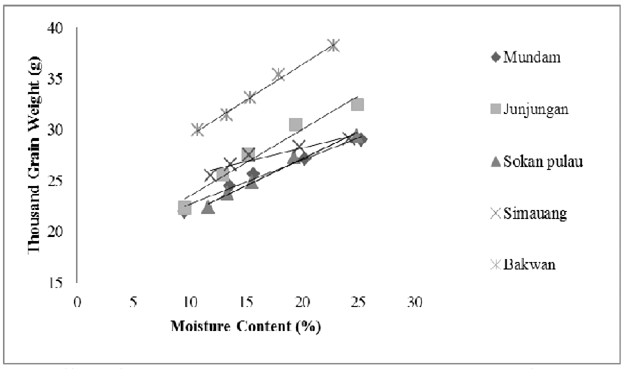


Fig. 4 Effect of varying moisture content on 1000 seed mass of unhusk rice grain seed

*7) Angle of Repose:* Angle of repose (θ) is the angles formed between the materials to the plane of the surface and form a cone. Value angle of repose unhusks rice grain can be seen in Fig. 5. Table 6 show angle of repose of all variety of unhusk rice grain increase with increasing moisture content. The angle of repose value of Mundam, Sokan Pulau, Junjungan, Simauang and Bakwan varieties are increasing from 21.63˚to 36.876˚, 28.135˚ to 36.944˚, 27.361˚ to 38.755˚, 25.78˚ to 35.94˚ and 26,402˚ to 37,887˚ with increasing moisture content from 9 to 25%, respectively. The relationship between the angle of repose and moisture content of rice grain is presented in Table 3. This is because increases in moisture absorption leads to create a larger surface layer of moisture surrounding the particles, holding the aggregate of grains together by producing higher surface tension. The results were comparable to those reported for wheat [30], green gram [25], canola and sunflower meal pellets [32], areca nut kernels [19], okra [28] and faba grains [2].

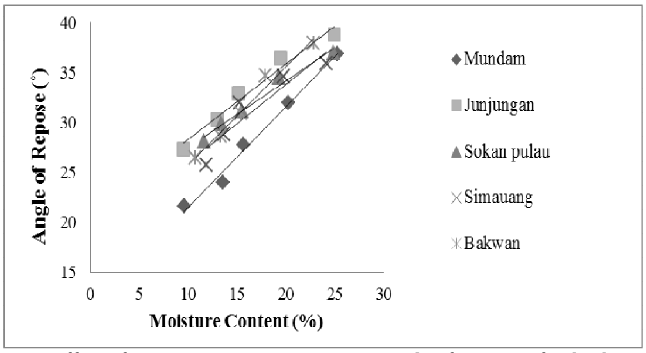

Fig. 5 Effect of varying moisture content on Angle of Repose of unhusk rice grain

TABLE VI
THE EQUATION OF ANGLE OF REPOSE FOR EVERY VARIETY

| No | Variety | Equation | $R^2$ |
|---|---|---|---|
| 1 | Mundam | $\theta_M$ = 1.005x + 11.50 | 0.988 |
| 2 | Junjungan | $\theta_J$ = 0.754x + 20.76 | 0.968 |
| 3 | Sokan Pulau | $\theta_{SP}$ = 0.670x + 20.77 | 0.978 |
| 4 | Simaung | $\theta_S$ = 0.785x + 18.12 | 0.880 |
| 5 | Bakwan | $\theta_B$ = 0.984x + 15.90 | 0.981 |

*8) The angle of Friction:* Angle of friction (μ) is the angle formed by the unhusk rice grain during the unhusk rice grain slide. The medium used is plywood and aluminum. This is to compare the magnitude of the angle of various varieties of unhusk rice grain with a moisture content varies. Plywood and aluminum have a different surface, where the plywood surface is rougher than the aluminum. The angle of friction of unhusk rice grain can be seen in Figs. 6 and 7. Angle of friction value of Mundam, Sokan Pulau, Junjungan, Simauang and Bakwan varieties are increasing from 27.333 to 37˚, to 40.333˚, 32.333˚to 42.333˚, 28.333˚ to 44666˚ and 33.333 to 40˚ and 23 to 29˚, 22 to 33.666˚, 19.333 to 36.666˚, 24.666 to 36˚, 24 to 29.333˚ with increasing moisture content from 9 to 25%, respectively. Similar trends have been reported in the case of gram [14] and Jatropha seed [16], respectively. Variation existed between plywood and galvanized iron for pulse grains [4], the low static coefficient of friction values on plywood for soybean as compared to results obtained for maize and locus bean seeds [31], pumpkin seeds [18], lentil seeds [9] and hazelnuts [5].

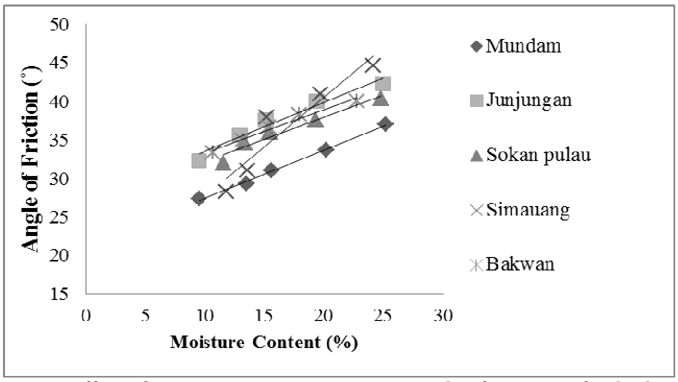

Fig. 6 Effect of varying moisture content on Angle of Friction of unhusk rice grain with Plywood

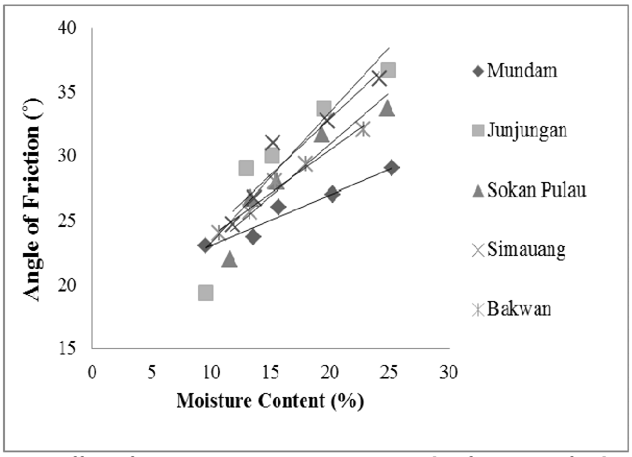

Fig. 7 Effect of varying moisture content on *Angle of Friction* of unhusk rice grain with Aluminium

## IV. CONCLUSIONS

Based on the results of the research and conducted in this study can be summarized as follows: there are effects of from the variety of rice grains which tested on the physical properties, Junjungan had the highest values for geometric mean diameter, sphericity and thousand seed mass at all moisture levels. Geometric Mean Diameter (GMD) and sphericity increased significantly from 3.11 to 3.76 and 0.37 to 0.42 variety in a moisture content range of 9 to 25% w.b. Maximum values of bulk density and a thousand grain mass were obtained for Sokan Pulau (0.55-0.63g/cm$^3$) and Bakwan (29.99- 35.21 g). The angle of repose and angle of friction ranges for Mundam increased from 27.36 to 38.75˚and 27.33 to 37˚, respectively as increasing moisture content levels. This information is vital in the designing of machines for rice grain processing.

## NOMENCLATURE

| | | |
|---|---|---|
| L | length | mm |
| W | width | mm |
| T | thickness | mm |
| GMD | geometric mean diameter | |
| $\Phi$ | sphericity | |
| ρ | bulk density | kg / cm$^3$ |
| M | mass of seed | kg |
| v | the volume of the tube | cm$^3$ |
| θ | angle of repose | |
| μ | angle of friction | |


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