Effect of Moisture Content on Some Physical and Mechanical Properties of ‘Genjah Arum’ Local Rice (Oryza sativa L) Variety in Banyuwangi

To cite this article: Sandra et al 2020 IOP Conf. Ser.: Earth Environ. Sci. 515 012020

View the article online for updates and enhancements.
Effect of Moisture Content on Some Physical and Mechanical Properties of ‘Genjah Arum’ Local Rice (Oryza sativa L) Variety in Banyuwangi

Sandra¹, R E Putri², G Djowowasito¹, and S N Wijaya¹

¹ Department of Agricultural Engineering, Faculty of Agricultural Technology, Brawijaya University, Malang, Indonesia
² Department of Agricultural Engineering, University of Andalas, Kampus Unand Limau Manis - Padang, Indonesia

Corresponding author’s email address: sandra.msutan@ub.ac.id

Abstract. Designing post-harvest rice equipment and machinery requires data on its physical and mechanical properties. Physical and mechanical properties were examined in the local variety rice ‘Genjah Arum’ with a moisture content of 12.80%, 15.90% and 20.50% (wet basis). The physical properties measured are axial diameter and average diameter, where the higher the moisture contents the diameter increases. Sphericity, volume, and surface area, will increase if the moisture content is higher. If the moisture content rises, the average thousand grain weight will increase. There is an increase in true density and bulk density with increasing moisture content. Porosity decreases with the addition of paddy moisture content. Mechanical properties at moisture content of 12.80%, 15.90% and 20.50% are 9.12 kgf, 7.162 kgf and 6.196 kgf. The static angle of friction is measured on glass, plywood and stainless steel, the highest friction angle measurement results found on plywood.

Keywords: Moisture Content, Physical and Mechanical Properties, Rice, Banyuwangi

1. Introduction

Rice is a staple food for most countries, especially in Asian countries such as China, Korea, Japan, Malaysia, Thailand, India, Vietnam and Indonesia. More than half of the world's population is 3.5 billion people (90% are Asians) [1] [2].

Rice is a source of calories for the human body, especially for carbohydrate and protein intake. In addition, these foods can not only provide calories, they can also provide nutritional fiber, minerals and vitamins. The current level of food consumption is quite high. This is proven by the many processed products that can be used as high-value products.

Rice production in 2014 was 741.8 million tons and it was predicted that in 2015 it would be 749.1 million tons. The largest rice producing country is China producing 206.5 million tons of rice or 27.8% of total world rice production. While the second country is India with a total rice production of 153.9 million tons, India is also the largest rice exporting country in the world with 11.5 million tons. Indonesia is the third largest rice producer in the world with a total of 75.6 million tons [1]

The moisture content of rice has a high influence on processing, storage and distribution. Engineering physical properties has a major influence on the behavior of agricultural crops when undergoing various postharvest handling and processes [33] These properties are needed to design
appropriate equipment and systems for planting, harvesting and post-harvest operations such as cleaning, and storage for agricultural crops [34]. Weight, diameter, surface area, bulk density, thickness, length and width are some of the engineering properties required and are needed in the design and optimal performance of the wheat threshing unit [33].

Grain properties influence the characteristics of each stage of material processing significantly [3]. Research on physical, mechanical and thermal properties has been carried out on several agricultural products including physical properties of fenell seeds [4], Moringa Oleifera Seed [5], Jatropha curcas [6], almond nut and kernel [7], Soybean Grains [8]. The physical properties of some rice varieties have also been studied by several researchers of Basmati Varieties of Paddy [9] as well as two rice varieties in Iraq [10], rice (rough and milled) region of Kashmir (India) [11], and other rice varieties [12], [13], [35], Sunflower Seeds [14], and oilbean seed [24]. Research on physical properties were also carried out on other agricultural products including soybean and cowpea [25], [34], Banana Fruit [26], [27], tomato fruit [28], orange fruit [29] [30], and apple [31] [32].

The purpose of this study was to determine the physical properties of local rice varieties planted by farmers in Banyuwangi, East Java Province, Indonesia.

2. Methods
The rice used in this study was local rice varieties Genjah Arum which was planted by farmers in Banyuwangi, East Java Province, Indonesia. The seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature, broken seeds from a 3 kg sample for each grain variety and randomly selected for the measurement of dimensions, weight, and projected area. Drying is done by sunlight.

The moisture content of rice is conditioned using ASAE standards (2003). The amount of water added to rice (Q) is carried out using the eq:

\[ Q = \frac{A(b-a)}{100-b} \]

Rice samples that will be arranged for water content are packaged separately and put in a refrigerator at 5 ° C for 7 days. Before observing the sample, the sample is left in the open room for approximately 1 hour.

2.1. Physical Properties
The moisture content of each of the samples was determined on a wet basis using the Grain Moisture Meter. Paddy grains were randomly selected from each cultivar and their principal dimensions length (L), width (W) and thickness (T) were measured using vernier caliper.

![Figure 1. The lines represent the rice L, length; W, width; T, thickness](image)

2.1.1 Equivalent Diameter
After obtaining the dimension value, a calculation is performed to determine the equivalent diameter. In addition, calculations are also carried out to determine the average diameter of arithmetic and the average diameter of the geometry with equations 1 to 3, namely (Ciro, 1997):

\[ Da = \frac{L+W+T}{3} \]

\[ Dg = (LWT)^{1/3} \]
The sphericity ($\phi$) defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain was calculated as [4]:

$$\phi = \frac{(LWT)^{1/3}}{L}$$  \hspace{1cm} (4)

where $L$ is the grain length, $W$ the grain width and $T$ is the grain thickness. Whereas Geometric Mean Diameter (GMD). Grains can be said to be round if Sphericity is 1.

$$GMD = L \times W \times T$$  \hspace{1cm} (5)

The equivalent diameter ($D_p$) in mm considering a prolate spheroid shape for a paddy grain, was calculated using [6]:

$$D_p = \left[4L \left(\frac{W+L}{2}\right)^2\right]^{1/3}$$  \hspace{1cm} (6)

Grain volume ($V$) was calculated using [7]:

$$V = 0.25 \left[\frac{\pi}{6} L (W + T)^2\right]$$  \hspace{1cm} (7)

Grain surface area ($S$) was calculated using [8]:

$$S = \frac{\pi BL^2}{2L - B}$$  \hspace{1cm} (8)

where:

$$B = \sqrt{WT}$$  \hspace{1cm} (9)

The bulk density is the ratio of the mass sample of rices to its total volume. It was determined by filling a 500 ml container with rices from a height of 150 mm, striking off the top level without the rices being compacted in any way and then the content was weighed (Sobukola, et al. 2013)

2.1.2 Roundness

The roundness calculation method can be obtained by equation 10 [3], namely:

$$\psi = \frac{D_p}{L}$$  \hspace{1cm} (10)

2.1.3 Volume ($V$) and Surface Area ($S$)

The volume and surface area of the material can be calculated using 11 to 13 [15]:

$$V = \frac{\pi^2 L^2}{6(2L - B)}$$  \hspace{1cm} (11)

$$S = \frac{\pi BL^2}{2L - B}$$  \hspace{1cm} (12)

Where:

$$B = (WT)^{0.5}$$  \hspace{1cm} (13)

2.1.4 A mass of 1000 seeds

Early maturing rice arum grouped per 1000 seeds in each treatment of water content. The mass of early arum grain is then weighed using analytical scales. The mass data of 1000 seeds of early maturing rice will be used as a database reference data.

2.1.5 Bulk Density, True Density and porosity

The formula used in the calculation of bulk density can be seen in equation 14:
The formula used for the calculation of true density can be seen in Equations 15 and 16 below [3]:

\[
\rho_t = \frac{a}{V_{sg}}
\]

Porosity is a function of the bulk density and true density above. Porosity can be calculated by equation 17 [17] [18] [19]:

\[
P = 1 - \frac{\rho_b}{\rho_t} \times 100\%
\]

2.1.6 Compressive strength test
The Mechanical Properties Test is performed by analyzing the compressive strength carried out with a penetrometer with a diameter of a 3.5 mm probe by pressing the early arum grain until cracks or splits occur.

2.1.7 Angle of friction is the angle formed when the seeds begin to slide on the friction surface
Friction surfaces to be used are plywood boards and iron plates. How to determine the glide angle is to put the seeds on one side of the plywood or iron plate and then on the other side put a bow. The side of the seed is placed gently raised until the seed begins to slide (figure 2). When the first seed begins to slide, it is noted as the angle of friction.

3. Results and Discussions

3.1 Dimensions
Axial dimension data has a role in determining the size in the planning of agricultural product processing machines [3] and the axial dimension value of early maturing arum rice is strongly influenced by rice moisture content, where the higher the moisture content, the higher the axial dimension value (table1, 2). The same thing happened with fennel seeds [4], Moringa Oleifera Seed [5], Jatropha curcas [6], coriander seeds [16] also in paddy basmati rice varieties [9] rice varieties in Iraq [10], rice varieties in India [11]

<table>
<thead>
<tr>
<th>No</th>
<th>Moisture content (%) (b.b.)</th>
<th>length (mm)</th>
<th>width (mm)</th>
<th>thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>Min.</td>
<td>average</td>
<td>Max.</td>
</tr>
<tr>
<td>1</td>
<td>12,80</td>
<td>9,54</td>
<td>6,88</td>
<td>8,15</td>
</tr>
<tr>
<td>2</td>
<td>15,90</td>
<td>9,66</td>
<td>7,04</td>
<td>8,22</td>
</tr>
<tr>
<td>3</td>
<td>20,50</td>
<td>9,64</td>
<td>6,95</td>
<td>8,24</td>
</tr>
</tbody>
</table>
Tabel 2. Diameter in various moisture content conditions

<table>
<thead>
<tr>
<th>Moisture content, % (b.b.)</th>
<th>Average Diameter (mm)</th>
<th>Aritmatik (Da)</th>
<th>Geometric mean diameter (Dg)</th>
<th>Kuadrat (Dk)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.80</td>
<td>4.57</td>
<td>3.90</td>
<td>4.19</td>
<td></td>
</tr>
<tr>
<td>15.90</td>
<td>4.62</td>
<td>3.95</td>
<td>4.24</td>
<td></td>
</tr>
<tr>
<td>20.50</td>
<td>4.66</td>
<td>4.00</td>
<td>4.28</td>
<td></td>
</tr>
</tbody>
</table>

From table two it can also be seen that the geometric diameter is also directly proportional to the moisture content, this is due to the higher moisture content in rice, causing an increase in the dimensions of length, width and thickness.

Table 3. Relationship of moisture content with the dimensions of rice

<table>
<thead>
<tr>
<th>Dimensi</th>
<th>Equation</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>$y = 0.0109 , MC + 8.0235$</td>
<td>0.893</td>
</tr>
<tr>
<td>Width</td>
<td>$y = 0.0127MCx + 3.2795$</td>
<td>0.988</td>
</tr>
<tr>
<td>Thickness</td>
<td>$y = 0.0101MC + 1.9965$</td>
<td>0.895</td>
</tr>
<tr>
<td>Aritmatik</td>
<td>$y = 0.0112MC + 4.4332$</td>
<td>0.961</td>
</tr>
</tbody>
</table>

3.2 Roundness, volume and surface area

The physical properties of roundness, volume and surface area are used in the design of agricultural processing equipment and machines, among others in designing product packaging.

Table 4. Roundness, Volume, Surface area under various moisture content conditions

<table>
<thead>
<tr>
<th>Moisture content, % (b.b.)</th>
<th>Roundness</th>
<th>Volume (mm³)</th>
<th>Surface area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.80</td>
<td>0.507</td>
<td>65,655</td>
<td>31,857</td>
</tr>
<tr>
<td>15.90</td>
<td>0.509</td>
<td>66,870</td>
<td>32,729</td>
</tr>
<tr>
<td>20.50</td>
<td>0.513</td>
<td>67,337</td>
<td>33,279</td>
</tr>
</tbody>
</table>

The higher the moisture content, the higher the roundness is also due to the more moisture content of the rice, the width and thickness dimensions also increase, causing rice to become more rounded. Likewise, the volume and surface area are also the same condition where moisture content gives a significant effect on increasing both. Increased roundness values were also emphasized in the study of sweet corn [20] showing a similar pattern, as well as research in barbunia beans [21] and in kenaf seeds [22], spinach seeds, bambara beans, and millet seeds [23].

3.3 1000 seed mass

Observation of 1000 seed mass was carried out on some grain water content

![Figure 3. Relationship of water content to a mass of 1000 seeds](image)

In figure 3 it appears that the seed mass increases with increasing water content, this is due to the increase in the value of water content so that the grain mass of the seed becomes increased for the
same number of seeds. Sweet corn research [20] shows a similar pattern, as well as barbunia beans [21].

3.4 Bulk density, true density and porosity
Rice density increases with increasing water content but porosity decreases with increasing water content. This is due to the high water content, the volume of rice will increase so that the volume value increases where the bulk density is inversely proportional to the volume while porosity will be higher if the bulk density is higher. The results of the density and porosity of rice are shown in table 4.

Table 5. Density and Porosity in various water content conditions

<table>
<thead>
<tr>
<th>Water content, % (b.b.)</th>
<th>Bulk density (g/cm$^3$)</th>
<th>True density (g/cm$^3$)</th>
<th>Porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.80</td>
<td>0.53</td>
<td>0.86</td>
<td>38.4</td>
</tr>
<tr>
<td>15.90</td>
<td>0.54</td>
<td>0.87</td>
<td>38.0</td>
</tr>
<tr>
<td>20.50</td>
<td>0.55</td>
<td>0.88</td>
<td>37.5</td>
</tr>
</tbody>
</table>

The results of this study are the same as the results in Alikazemi rice varieties and Hazemi varieties [37]. This phenomenon is also found in research [38] for cotton seeds.

3.5 Compressive strength
The compressive strength value of early rice arum decreases frequently with increasing water content. The compressive strength value of the water content of 12.80% is around 9124 kgf, in the water content of 15.90% it has fallen to 7162 kgf, and has decreased again in the water content of 20.50% to 6196 kgf.

![Figure 4](image)

From figure 4 shows that the greater the water content of early arum grain will the smaller the compressive strength value (opposite), with the relationship in the equation $y = -0.3672x + 13.516$ and $R^2 0.909$ this is due to the higher water content, the rice will be softer because of component comparisons solids with water are getting bigger.

3.6 Angle of friction
The angle of friction testing used three test boards namely glass boards, plywood boards, and stainless steel boards. Friction angle data can be seen in Table 6.

Table 6. Table of friction angle values

<table>
<thead>
<tr>
<th>No.</th>
<th>Surface plate</th>
<th>Angle of friction (°)/coefficient static friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Glass</td>
<td>30.00/0.58</td>
</tr>
<tr>
<td>2</td>
<td>Plywood board</td>
<td>38.22/0.794</td>
</tr>
<tr>
<td>3</td>
<td>Stainless steel</td>
<td>20.21/0.369</td>
</tr>
</tbody>
</table>
From table 6 it can be seen that the higher the water content, the angle of friction and coefficient of static friction for all slides is greater. The largest to smallest angle of friction and coefficient of static friction occurs consecutively on plywood, glass and stainless steel slides. Research conducted by [39] for pine nuts shows that the highest coefficient of friction obtained on plywood boards is 0.251 - 0.292, followed by galvanized iron boards of 0.241 - 0.271, and the smallest is shown on stainless steel boards of 0.218 - 0.247. In cowpea and soybeans [25] the static friction stainless steel coefficient is higher than wood and glass, whereas paddy [36] has the same result.

4. Conclusions
The physical properties of genjah arum rice for the moisture content range of 12.80% - 20.50% (b.b.) are as follows, major dimensions are 8,203 mm, minor dimensions are 2,163, and intermediate dimensions are 3,541. The average diameter of arithmetic is 4.62 mm, geometry is 3.95 mm, and quadratic is 4.24 mm. The average roundness is 0.510. The average volume is 67,615 mm³, and the average surface area is 32,604 mm². The average mass of 1000 seeds is 25,518 gr. Bulk density 0.539 kgf. Static friction of glass surface 30,89°, plywood surface 39,23°, and stainless steel surface 20,53°.

Nomenclature

<table>
<thead>
<tr>
<th>Q</th>
<th>Mass of water to be added, in Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Initial mass of sample in Kg</td>
</tr>
<tr>
<td>a</td>
<td>Initial MC of sample in % d.b.</td>
</tr>
<tr>
<td>b</td>
<td>Final (desired) MC of sample % d.b.</td>
</tr>
<tr>
<td>L</td>
<td>Length, mm</td>
</tr>
<tr>
<td>W</td>
<td>Width, mm</td>
</tr>
<tr>
<td>T</td>
<td>Thickness, mm</td>
</tr>
<tr>
<td>Dₐ</td>
<td>Geometric average diameter, mm</td>
</tr>
<tr>
<td>Dₐ</td>
<td>Arithmetic average diameter, mm</td>
</tr>
<tr>
<td>GMD</td>
<td>Geometri Mean Diameter (mm)</td>
</tr>
<tr>
<td>V</td>
<td>Volume, mm³</td>
</tr>
<tr>
<td>S</td>
<td>Surface area,cm²</td>
</tr>
<tr>
<td>ρₐ</td>
<td>Bulk density, kg m⁻³</td>
</tr>
<tr>
<td>ρₐ</td>
<td>Bulk density (kg/cm³)</td>
</tr>
<tr>
<td>ρₐ</td>
<td>true density (kg/cm³)</td>
</tr>
<tr>
<td>ρₐ</td>
<td>true density (kg/cm³)</td>
</tr>
<tr>
<td>ρₐ</td>
<td>water density (kg/cm³)</td>
</tr>
<tr>
<td>ρₐ</td>
<td>water density (kg/cm³)</td>
</tr>
<tr>
<td>P</td>
<td>Porosity (%)</td>
</tr>
<tr>
<td>ϕ</td>
<td>Angle of internal friction, degrees</td>
</tr>
</tbody>
</table>

References


[16] (Coskun dan Karababa, 2007).===> satria


