AGROINTEK

JURNAL TEKNOLOGI INDUSTRI PERTANIAN

AGROINTEK: Jurnal Teknologi Industri Pertanian

KATA PENGANTAR

Salam,

Dengan mengucap syukur kepada Allah Tuhan Yang Maha Esa, kami terbitkan Agrointek edisi September 2021. Di tengah pandemi yang berkepanjangan ini, ilmuwan Indonesia masih tetap berkarya. Pada edisi kali ini 32 artikel hasil penelitian, yang terdiri dari 11 artikel dari bidang pengolahan pangan dan nutrisi, sistem manajemen, rantai pasok, dan pengendalian kualitas; 3 artikel tentang rekayasa pangan, dan 2 artikel tentang manajemen limbah. Para penulis berasal dari berbagai institusi pendidikan dan penelitian di Indonesia.
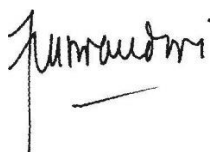
Kami mengucapkan terima kasih kepada para penulis dan penelaah yang telah bekerja keras untuk menyiapkan manuskrip hingga final. Kami juga berterimakasih kepada ibu dan bapak yang memberi kritik dan masukan berharga bagi Agrointek.

Untuk menyiapkan peringkat jurnal Agrointek di masa depan, kami mengharap kontribusi para peneliti untuk mengirimkan manuskrip dalam bahasa Inggris. Semoga kita akan mampu menerbitkan sendiri karya-karya unggul para ilmuwan Indonesia.

Selamat berkarya.

Salam hormat

Prof. Umi Purwandari

A REVIEW ON THE ENGINEERING PROPERTIES OF SOYBEAN TO SUPPORT THE TOFU AGRO-INDUSTRIAL MACHINERY DEVELOPMENT AND IMPORTANT HIGHLIGHTS

Agustami Sitorus[1], Devianti[2], Ramayanty Bulan[2*]

¹Research Center for Appropriate Technology, Indonesian Institut of Sciences (LIPI), Indonesia
²Department of Agricultural Engineering, Syiah Kuala University, Indonesia

ABSTRACT

Studies of soybean engineering properties have not been widely highlighted and reviewed. This makes researchers of soybean processing machines still have to search through experimentation or read deeply through scientific papers before applying it. Therefore, the aim of this paper was to highlights and reviews studies related to the measurement and modeling of soybean engineering properties. The methodology utilized in this research is an in-depth literature review on the engineering properties of soybeans that are available online. The keywords used in the search process are "physical properties", "mechanical properties", "soybean grains," and "moisture-dependent". Results show that ten scientific papers are strictly related to the measurement of soybean engineering properties. In general, all research papers investigated the engineering properties of soybean in the moisture content ranges from 6.7% (d.b.) to 49.7% (d.b.). The widely studied physical properties are diameter, surface area, roundness, the weight of 1000 soybeans, bulk density, and true density associated with moisture content. Mechanical parameters investigated include friction coefficient, angle of repose, terminal velocity, angle of internal friction, rupture force, and rupture energy. The effect of soaking and blanching on changes in the soybean engineering properties (physical, mechanical, thermal, optical, and aerodynamic) has not been done in-depth, even though these properties are essential for the processing of tofu. Besides that, most of the soybean processing agro-industry requires soybean engineering properties to be able to design their machines more precisely. One of the agro-industries that need data engineering properties of soybean with these treatments is the tofu processing industry.

INTRODUCTION

The engineering properties of an agricultural material are closely related to the accuracy in designing machinery and equipment for handling it from farm to table. It cannot be separated from soybean, which is an agricultural product in the form of grain, which is very massive in its technological development from pre-harvest technology to post-harvest handling. Especially the post-harvest soybean handling technology is needed because the derivative products from soybean are very diverse.

The diversity of these derivative products makes supporting equipment technology more varied. This variation makes parameter measurements of the engineering properties of soybean very different and needed. On the one hand, soybean processing technology is closely related to the processing method and the material used. On the other hand, the soybean's engineering properties are highly dependent on the processing method and the material used. Therefore, several studies have deepened the engineering properties of soybean individually according to the needs of the machine designed.

The study of the physical and mechanical properties of soybean has been conducted from 1985 to 2012 with various varieties and intended uses. Unfortunately, there are no studies that review the results of these studies to be more easily used for various purposes in handling machinery and equipment for soybean. Since there is still limitation of knowledge in the scientific literature about the properties of soybeans, it is impossible to build precise soybean processing machines, especially in Indonesia. The only one in the last ten years and not too focused is the result of a study by Manuwa (2011) that can summarize the physical properties of soybeans for best post-harvest options. This is based on the results of research and collaboration in recent years. But after that, research into engineering properties is still ongoing, and it is essential to summarize it again. Therefore, in this paper, we highlight related to the measurement of soybean engineering properties and their application in the past few decades.

METHOD

The methodology utilized in this research is an in-depth literature review on the engineering properties of soybeans that are available online. The keywords used in the search process are "physical properties", "mechanical properties", "soybean grains," and "moisture-dependent". These keywords are entered in one of the reputable global paper indexing search engines. It is intended that the paper obtained is a paper that has the best qualifications.

This review paper begins with the background, which describes research problems related to data collection on the physical properties of soybean. Furthermore, it provides some case studies of recent research involving soybeans. There are at least nine in-depth descriptions of the papers which were published from 1993 to 2012. From that, the critical findings of the paper are highlighted to collect information related to the engineering properties of soybeans that can be used to support the design of machines that handle soybeans.

A discussion in the form of a general comment was given from the published research results. This is related to how the availability of these data can be used to support machine design, especially in the tofu industry. In addition, soybean characteristics needed in processing it into tofu were also mapped to provide an overview of the needs for these characteristics in the industry.

Finally, close with a discussion of future recommendations related to the availability of this data. This is related to what data must be collected from engineering properties of soybeans to provide complete data for the future design of machinery for the tofu industry. A summary of this paper is presented in the basic conclusion at the end.

SOME CASES OF RESEARCH ON SOYBEAN RECENTLY

Description from Deshpande et al., (1993)

Deshpande et al., (1993) conducted a study of soybeans' physical properties, depending on their moisture content. The soybean variety measured was JS-7244 cultivar. The measured range of soybean moisture content was 8.7% (d.b.) to 25% (d.b.). There are 6 levels of moisture content in that range and (8.70%, 10.4%, 14.6%, 16.4%, 21.8%, 25.0%) ten replications of each moisture content level.

According to this research, its physical properties need to be known to design equipment

for handling, aeration, storing, and processing soybean. Soybeans are stored at room temperature (303±5 K) with a moisture content of 8.5±0.5%, for variations in moisture content, which are being conducted by re-wetting the dried soybeans. Moisture content measurements were carried out with a sample weight of 15g at an oven temperature of 376 K for 72 hours. The sample is stored in polyethylene bags at a temperature of 278 K. Shortly before testing. A sample will be opened so that the sample temperature is the same as the room temperature. The geometric mean diameter is calculated using Equation 1. Sphericity is computed using Equation 3. Surface areas are calculated using Equation 3. Porosity is calculated using Equation 4.

$$D_P = (LWT)^{1/3} \qquad (1) \qquad s = \pi D_P^2 \qquad (2)$$

$$\phi = \frac{(LWT)^{1/3}}{L} \qquad (3) \qquad \varepsilon = \frac{\rho_b - \rho_t}{\rho_t} \qquad (4)$$

In general, Deshpande et al., (1993) reported that dimensions, geometric mean diameter, sphericity, surface area, volume of grain, thousand grain mass of soybean increased linearly with increased moisture content. Kernel density, bulk density, and porosity of soybean are increased linearly with increased moisture content. However, the results of this study highlight that all physical parameters may have differences for different soybean varieties.

Description from Polat et al., (2006)

Polat et al., (2006) measured some physical by adding aerodynamic properties of soybeans to four levels of moisture content. Moisture content is 6.7%, 9.6%, 12.1%, and 15.3% (d.b.). Polat et al., (2006) state that physical and aerodynamic properties are important to design processing equipment and facilities for sorting, separation, transportation, processing, and storing. The types of soybean varieties sampled were not specified describe in this study. However, Polat et al., (2006) stated that soybean varieties. *Glycine max* is an important annual plant in Turkey.

The physical properties of soybeans measured are length, width, thickness, 1000 seed mass, geometric mean diameter, arithmetic mean diameter, sphericity, porosity, true, and bulk density. Aerodynamic properties parameters that are part of the mechanical properties measured in this study are terminal velocity. Another parameter is the coefficient of static friction on

three surfaces, namely glass, galvanized iron, and plywood.

Determination of moisture content from soybean samples using the thermal gravimetric method (103±2°C)—a variation of samples at four levels of soybean conditioning by adding water and sealing in separate polyethylene bags. To uniform soybean samples, samples were kept at 5°C in a refrigerator for 15 days. Before soybean samples are measured, soybeans will be removed from the refrigerator and warm up to room temperature.

Geometric mean diameter, sphericity, and porosity are calculated using Equation 1, Equation 3, and Equation 4, respectively. The arithmetic means the diameter is calculated using Equation 5. The coefficient of the static friction parameter is calculated using Equation 6. Terminal velocity parameters are measured using an air column with a 75 mm diameter, 1 m long glass tube. Air flowed upwards in the tube, and the air velocity at which the soybean was suspended was recorded by an anemometer (0.1 m/s sensitivity).

$$A_{md} = \frac{L+W+T}{3} \qquad (5) \qquad \mu_1 = \frac{T_m}{W_r \cdot q} \qquad (6)$$

In general, Polat et al., (2006) reported that length, width, thickness, 1000 seed mass, arithmetic mean diameter, geometric mean diameter, sphericity, true density, terminal velocity, and static coefficient of friction (on glass, galvanized iron, plywood) of soybean increased linearly with increasing moisture content. Bulk density and porosity of soybean decreased linearly with increased moisture content.

Description from Sirisomboon et al., (2007)

Sirisomboon et al., (2007) measured the physical properties of green soybean with pod related to the criteria for developing sorting tools. The type of green soybean variety measured was Glycine max variety AGS 292. According to Sirisomboon et al., (2007), the physical properties of green vegetable soybean are needed to design and develop appropriate machines. However, the information on these properties has not been available. However, this research does not explain the moisture content of the green soybean tested.

The physical properties include size, pod weight, projected area, apparent density, and bulk density. However, one of the parameters measured

in this study is mechanical properties, namely seed firmness. Size (width, length, and thickness) measure by caliper and pod weight by an electronic balance of 0.01 g sensitivity. Fifty pods for each group with six replicates were measured. The firmness of green soybean measure using a penetrometer (maximum force 1 kgf).

Apparent density is calculated using Equation 7. Pod volume is computed using Equation 9. Bulk density is calculated using Equation 8.

$$D_A = \frac{W_P}{V_P} \qquad (7) \qquad \rho_b = \left(\frac{W_P}{V_c}\right) \times 100\% \qquad (8)$$

$$V_P = \frac{W_{PW}}{D_W} \qquad (9)$$

This study's results related to soybean seeds are the seed firmness parameter. The amount of seed firmness of soybean seeds is in the range of 1.20 ± 0.29 kg/cm^2 to 1.43 ± 0.25 kg/cm^2.

Description from Isik (2007)

Isik (2007) measured some engineering properties of soybean grains. The measured range of soybean moisture content is from 10.62% - 27.06% (d.b.). The types of varieties measured in this study were not explicitly explained and only mentioned soybeans in Turkey.

Physical properties parameters observed include length, width, thickness, arithmetic, and geometric mean diameter, sphericity, 1000 grain mass, true density, porosity, bulk density. Mechanical properties observed in the study were terminal velocity, static coefficient of friction on some surfaces (rubber, aluminum, stainless steel, galvanized iron, glass, medium-density fiberboard).

The initial moisture content of soybean was determined by a digital moisture meter (0.01%). The treatment of the range of moisture content of soybeans measured was carried out by adding distillate water to the soybean again. The amount of water added to obtain the desired soybean moisture content is calculated using Equation 10. The following sample is packaged using polyethylene bags and stored in a refrigerator at 5°C for one week. Samples will be removed from the refrigerator and wait for the temperature to stabilize near ambient temperature for two hours before the sample is tested. This study's arithmetic means diameter, geometric mean diameter, and

sphericity are calculated using Equation 5, Equation 1, and Equation 3, which refer to Mohsenin (1970). The surface area in mm^2 of soybean is computed using Equation 2. Projected areas are determined by taking photos of soybean grains using digital cameras. After that, the photo is analyzed using the Global Lab Image 2-streamline program. Bulk density is measured by filling a container of 500 mL with grain from a height of 150 mm at a constant rate and then weighing the content. True density was determined using the toluene (C_7H_8) displacement method. Porosity is calculated using Equation 4.

$$Q = \frac{W_i \left(M_f - M_i\right)}{100 - M_f} \qquad (10)$$

Terminal velocity is measured using a cylindrical air column. The air velocity was recorded using a digital anemometer with a count of 0.1 m/s. The static coefficient of friction on some surfaces is measured using an adjustable tilting plate. The measurement results will be obtained angle of tilt, which can then calculate the static coefficient of friction using Equation 11. Soybean shelling resistance is determined by forces applied to one axial dimension (thickness). The force measurement uses a penetrometer.

In general, Isik (2007) reported that length, width, thickness, 1000 seed mass, arithmetic mean diameter, geometric mean diameter, the projected area of soybean increased linearly with increased moisture content. Surface area, sphericity, true density, porosity, the terminal velocity of soybean increased polynomial with increased moisture content. Bulk density and shelling resistance of soybean decreased polynomial with increased moisture content. The static coefficient of friction (rubber, stainless steel, aluminum, glass, MDF, galvanized iron) of soybean increased logarithmically with increased moisture content.

$$\mu_2 = \tan(\alpha) \qquad (11)$$

Description from Kibar et al., (2008)

Kibar et al., (2008) measured the physical and mechanical properties of soybean in the moisture content range from 8% to 15% (d.b.). According to Kibar et al., (2008), the measurement of physical and mechanical properties of soybean tends to be used in designing storage structures and storage equipment. The types of soybean varieties measured were not explained in detail. The identity of the type of

soybean measured was obtained from the Unity of the black sea agriculture cooperation in Turkey.

Physical properties parameters observed include length, width, thickness, geometric average diameter, sphericity, the volume of grain, surface area, bulk density, true density, and porosity. The parameters of mechanical properties measured are the angle of internal friction and static coefficient of friction (galvanized steel, wood, concrete).

The treatment process to get moisture content is the re-wetting method on dried soybean grains. The amount of water added to get the soybean moisture content as expected is referred to in Equation 10.

The geometric mean diameter in this study also uses Equation 1. But for sphericity and surface area in this study using Equation 12 and Equation 14, which is different from the equations used by previous studies (Equation 3 and Equation 2). The volume of grain was analyzed by theoretical methods using Equation 16. Bulk density is determined by using a 1000 ml volume container with a height of 108 mm. Then the container is filled with soybean to a height of 58 mm to settle. After that, the container and soybean are weighed, and the bulk density is calculated using Equation 8. True density is analyzed utilizing the toluene (C_7H_8) displacement method.

Furthermore, true density can be calculated using Equation 15. The angle of internal friction of soybean is determined using the direct shear method. The static coefficient of friction used in this study is to apply several normal loads on a surface. Then the load is pulled at the front 2.4 cm/s. The tensile force needed to start to move the normal load is measured using a dynamometer. Furthermore, the static coefficient of friction can be calculated using Equation 17.

$$\phi_2 = \left[\frac{B(2L-B)}{L^2} \right]^{1/3} \quad (12) \qquad B = (WT)^{1/2} \quad (13)$$

$$S_2 = \frac{\pi B L^2}{2L-B} \quad (14) \qquad \rho_t = \frac{m_s + m_w}{V_s + V_w} \quad (15)$$

$$V_t = \frac{\pi B L^2}{6(2L-B)} \quad (16) \qquad \mu_3 = \frac{F_s}{W_n} \quad (17)$$

In general, Kibar et al., (2008) report that length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity,

the volume of grain, surface area, angle of internal friction, static coefficient of friction (galvanized steel, wood, concrete) of soybean increased linearly with increased moisture content. Porosity, bulk density, and true density of soybean are linearly drawn with increased moisture content.

Description from Davies et al., (2009)

Davies et al., (2009) measured the physical properties of soybeans used for parameters for the design of processing equipment, transportation, sorting, and separating. The measured range of soybean moisture content is from 9.5% to 49.7% (d.b.). The varieties described are only from the local market in Yenegoa, Nigeria.

Physical property parameters measured include length, width, thickness, 1000 grains mass, bulk density, true density, porosity, sphericity. The parameters of mechanical properties measured are the static angle of repose and the static coefficient of friction (glass, plywood).

Re-wetting dry soybeans achieve a variety of soybean moisture content. Soybean moisture content was measured using a standard (ASAE, 2006). The filling or static angle of repose is determined using a topless cylinder of 0.15 m and 0.25 m height. After that, the soybean-filled cylinder is shed on a 0.35 m diameter circular plate until the soybean is formed a cone. The height of the cone is measured, and the angle of repose is calculated using Equation 18.

$$\theta = \tan^{-1}\left(\frac{2H}{D} \right) \quad (18)$$

In general, Davies et al., (2009) report that length, width, thickness, arithmetic mean diameter, geometric mean diameter, surface area, angle of repose, 1000 seed mass, and static coefficient of friction (glass, plywood) of soybean increased linearly with increased moisture content. Bulk density, true density, porosity, and sphericity of soybean are decreased linearly with increased moisture content.

Description from Tavakoli et al., (2009)

Tavakoli et al., (2009) measured several physical properties and mechanical behavior under the compression load of soybean grains (*Glycine max* L). The range of moisture content measured was from 6.92% to 21.19% (d.b.). This study does not explicitly report the usefulness of measuring some engineering properties. Tavakoli

et al., (2009) only explain the general usability of each of the parameters of some of the engineering properties.

Physical properties parameters that measure among them are length, width, thickness, arithmetic, and geometric mean diameter, sphericity, surface area, 1000 grains mass, bulk density, true density, and porosity. Mechanical properties measured are the angle of repose, static coefficient of friction, rupture force, and rupture energy.

To reach the moisture content range of soybeans, a wetting method was carried out on soybeans that had an initial moisture content of 6.92% (d.b.) using Equation 10. The initial moisture content of soybeans was determined by oven drying at 103±1°C for 72 hours (ASAE, 2006). Sphericity, surface area, porosity, arithmetic, and geometric mean diameter are calculated using Equation 3, Equation 2, Equation 4, Equation 5, and Equation 1.

Mechanical properties in the form of the angle of repose are determined by measuring the angle formed when the material will stand when piled. The angle of repose is determined using the apparatus for measuring the emptying angle of repose. The apparatus consists of a plywood box of 140×160×35 mm, fixed plates, and adjustable plates. The box will be filled with soybeans, and then the adjustable plate is inclined gradually, allowing grains to follow and assume a natural slope. Mechanical properties in the form of the coefficient of friction are calculated using Equation 11. Other soybean mechanical properties such as rupture force are measured using a tension/compression testing machine. It's equipped with a 500 kg compression load cell and integrator. The rupture point is a point on the force deformation curve at which the loaded specimen shows a visible or invisible failure in the form of breaks or cracks. This point is detected by a continuous decrease of the load in the force-deformation diagram. While the rupture point was detected, the loading was stopped. These tests were carried out at a 5 mm/min loading rate for all moisture levels (ASAE, 2006a). Rapture energy is calculated based on the rupture force measured using the UTM with Equation 19.

$$Ea = \frac{F_r D_r}{2} \qquad (19)$$

In general, Tavakoli et al., (2009) reported that length, width, thickness, arithmetic, and geometric mean diameter, 1000 grains mass, surface area, porosity, angle of repose, static coefficient of friction (plywood, glass, and galvanized iron sheet), of soybean increased linearly with increasing moisture content. Rupture force of soybean decreased polynomial with increased moisture content, whereas rupture of soybean energy increased polynomially with increased moisture content. Bulk density, true density, sphericity of soybean decreased linearly with increased moisture content.

Description from Sirisomboon et al., (2007)

Shirkole et al., (2011) measured the physical properties of soybean in two varieties (*Glycine max* L. cv. TAMS-38 and *Glycine max* L. cv. JS-335). The measured moisture content range of soybean was 7.30% to 30.80% (d.b.) for TAMS-38 and 7.35% to 30.70% (d.b.) for JS-335. This type of soybean has a composition of 40% protein and 20% oil. This parameter is important to measure for modernized technology of harvesting and threshing required the knowledge of physical and mechanical properties. Shirkole et al., (2011) also regret that the physical properties of the soybean area are still scary until now.

Physical property parameters measured include geometric mean diameter, sphericity, bulk density, true density, porosity, and 1000 grain mass. Mechanical properties measured are the angle of repose, static coefficient of friction (stainless steel, aluminum, galvanized iron, mild steel, plywood, rubber), and terminal velocity.

The re-wetting method is done on soybeans, which have an initial moisture content of 7.30% (d.b.). The moisture content of the grain is determined using the method from ASAE (2006). The angle of repose is determined by the angle of repose apparatus. Terminal velocity is measured using an air column with a blower as a source of air velocity. Airspeed is measured using an anemometer having at least a count of 0.1 m/s.

In general, Shirkole et al., (2011) reported that geometric mean diameter, 1000 grains mass, angle of repose, static coefficient of friction (stainless steel, aluminum, galvanized iron, mild steel, plywood, rubber), the terminal velocity of soybean increased linearly with increased moisture content. Bulk density, true density, porosity, sphericity of soybean decreased linearly with increasing moisture content.

Description from Wandkar et al., (2012)

Wandkar et al., (2012) measured the physical properties of soybean at different moisture levels. This property is essential for Wandkar et al., (2012) to design equipment and structures for handling, transportation, processing, storage, and quality assessment of soybean. The range of moisture content from soybean measured was 7.37% to 15.80% (d.b.). The type of soybeans measured was obtained from a local farmer and did not specifically explain the variety.

Physical property parameters are length, width, thick, geometric mean diameter, sphericity, 1000 grains mass, bulk density, true density, and porosity. The parameters of mechanical properties measured are the angle of repose and the static coefficient of friction on glass and wood. The method used to achieve the soybean's moisture content range is by re-wetting the soybean, which has an initial moisture content of 7.37% (d.b.). The moisture content of the grain is determined using the ASAE (2006). Geometric mean diameter, sphericity, porosity, angle of repose, static coefficient of friction are calculated using Equation 1, Equation 3, Equation 4, Equation 18, and Equation 11, respectively.

In general, Wandkar et al., (2012) reported that length, width, thickness, geometric mean diameter, 1000 grains mass, sphericity, porosity, angle of repose, static coefficient of friction (glass, wood) increased linearly with increased moisture content. Bulk density and true density of soybean decreased linearly with increased moisture content.

HIGHLIGHT OF RESEARCH
Soybean Physical Properties

The dominant physical properties measured are related to length, width, thickness, mass, and volume. These physical properties will be used to analyze other related physical properties such as sphericity, mean diameter geometry, mean diameter arithmetic, bulk density, kernel density, porosity, surface area, and true density.

The physical properties of soybean length, width, thickness was carried out by seven studies of seven paper papers related to their engineering properties (Figure 1). The moisture content spectrum of the seven studies was in the range of 6.7% (d.b.) conducted by Polat et al., (2006) up to 49.7% (d.b.) conducted by Davies et al., (2009) on various soybean varieties. In general, physical

properties' length and thickness increase for all research results with increasing moisture content. But for the width parameter, the results of Tavakoli et al., (2009) show this is inversely proportional to most other research results. This is thought to be related to the variety of soybean varieties.

The main physical properties of soybean above can be further analyzed related to the physical properties of derivatives in the form of sphericity, geometric mean diameter, arithmetic mean diameter, surface area presented in Figure 2. The moisture content spectrum analyzed is from 6.7% by Polat et al., (2006) up to 49.7% by Davies et al., (2009) on various varieties. The sphericity and geometric mean diameter were analyzed by all papers related to the soybean engineering nature. In general, the sphericity of soybean has a decreasing characteristic if most of the content is rising, and the geometric mean diameter has a characteristic that increases with increasing moisture content. However, it is different from the results of Isik (2007), which found that sphericity increases positively with its moisture content. This is presumed by the soybean varieties used mainly related to the main properties of length, width, and thickness. The arithmetic means diameter and surface area were analyzed respectively by five and four papers from the nine papers reviewed. In general, arithmetic means diameter and surface area increase with a high moisture content of soybean.
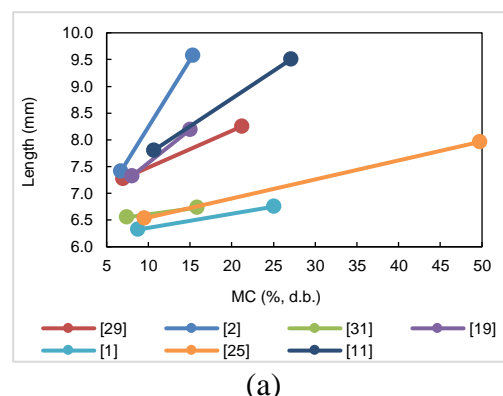

(a)

Figure 1 Length properties of soybean

The volume of grain and thousand-grain mass was carried out in each of two studies, eight studies from nine reviewed papers (Figure 3). The moisture content spectrum of the volume of grain analyzed was from 8.0% by Kibar et al., (2008) to 25% by Deshpande et al., (1993) on various types of varieties. The thousand-grain mass analyzed the

moisture content spectrum from 6.7% by Polat et al., (2006) up to 49.7% by Davies et al., (2009) on various varieties. In general, the soybean volume of grain and thousand-grain mass increases with a high moisture content of soybean.
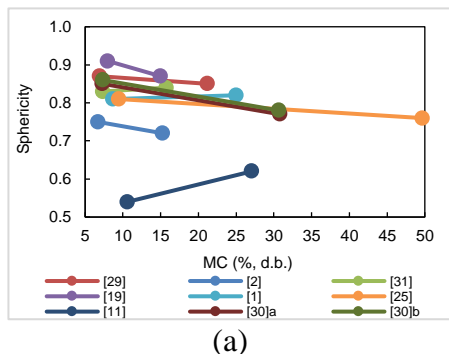

(a)

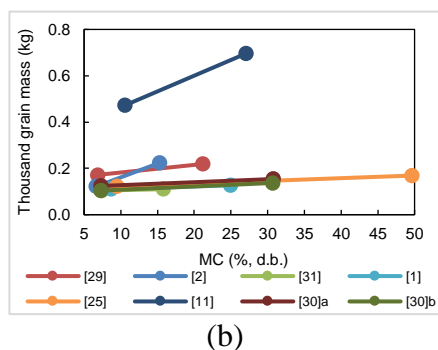Figure 2 Sphericity properties of soybean

(b)

Figure 3 One thousand grain mass properties

The parameters of bulk density, kernel density, true density was carried out by nine studies, one study, and four studies of the nine research papers reviewed, respectively. The moisture content spectrum of the volume of soybean analyzed was from 6.7% by Polat et al., (2006) up to 49.7% by Davies et al., (2009) on various varieties of bulk and true density. Meanwhile, kernel density was only studied in the range of 8.7% to 25% moisture content by Deshpande et al., (1993). In general, the physical parameters of bulk density, kernel density, and true density have a trend of decreases with increased moisture content. However, the research results by Isik (2007) and Polat et al., (2006) showed that the trend of the results was different from other studies on the true density parameter. This is thought to be due to differences in the types of soybean varieties measured by each researcher.

Porosity parameters were carried out by all studies of the reviewed paper (Figure 4). The moisture content spectrum of the volume of grain analyzed was from 6.7% by Polat et al., (2006) up

to 49.7% by Davies et al., (2009) on various types of varieties for bulk density and true density. The porosity of soybean tends to decrease with increasing moisture content. However, Isik (2007) showed a trend of different results from the results of other studies. This is thought to be due to differences in the types of soybean varieties measured by each researcher.
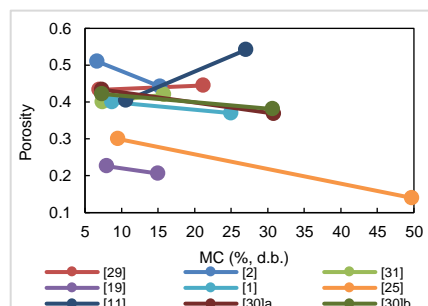

Figure 4 Physical properties of porosity

Soybean Mechanical Properties

The most commonly measured mechanical properties are related to the angle of repose, terminal velocity, angle of internal friction, rupture force, and rupture energy. The angle of repose was reviewed by five researchers from nine papers reviewed in the 6.92% moisture content range by Tavakoli et al., (2009) up to 49.7% by Davies et al., (2009). Terminal velocity was reviewed by four researchers from nine papers reviewed in the 6.7% moisture content range by Polat et al., (2006) up to 30.8% by Shirkole et al., (2011). The angle of internal friction was reviewed by four researchers from nine papers reviewed in the range of 8.0% to 15.0% moisture content by Kibar et al., (2008). Each force and rupture energy was reviewed by one researcher from nine papers reviewed in the moisture content range of 6.92% to 21.19% by Tavakoli et al., (2009). In general, the angle of repose, terminal velocity, angle of internal friction, and rupture energy have an increased tendency with a high moisture content of soybean for all reported research results. At the same time, the rupture force decreased with increased moisture content.

The static coefficient of friction (SCoF) for various materials has been investigated. The materials most frequently tested to determine the static coefficient of friction are glass, galvanized iron, plywood, rubber, stainless steel, aluminum, wood, mild steel, galvanized steel, medium-density fiberboard, and concrete. ScoF on glass material was investigated in the range of 6.7%

moisture content by Polat et al., (2006) up to 49.7% by Davies et al., (2009). SCoF on galvanized iron material was investigated in the range of 6.7% moisture content by Polat et al., (2006) up to 30.8% by Shirkole et al., (2011). SCoF on plywood material was investigated in the 6.7% moisture content range by Polat et al., (2006) up to 49.7% by Davies et al., (2009). SCoF on rubber material was investigated in the range of moisture content of 7.3% to 30.8% by Shirkole et al., (2011). ScoF in stainless steel material was investigated in the range of moisture content of 7.3% to 30.8% by Shirkole et al., (2011). SCoF on aluminum material was investigated in the range of moisture content of 7.3% to 30.8% by Shirkole et al., (2011). SCoF in wood material was investigated in the 7.37% to 15.8% moisture content range by Wandkar et al., (2012). SCoF in mild steel material was investigated in the range of moisture content of 7.3% to 30.8% by Shirkole et al., (2011). SCoF on galvanized steel material was investigated in the range of 8.0% to 15.0% moisture content by Kibar et al., (2008). SCoF on galvanized steel material was investigated in the range of 10.62% to 27.06% moisture content by Isik (2007). SCoF in concrete material was investigated in the range of 8.0% to 15.0% moisture content by Kibar et al., (2008).

GENERAL COMMENTS

Soybean grinding machines are made into tofu products, and soybean seeds have undergone a soaking process. This has an impact on the changing physical and mechanical properties. Therefore, exploration of the post-soaking and blanching engineering properties is essential to conduct.

It can be seen that the center of the book from all studies measuring the physical properties of soybean is connected with Mohsenin (1970). In general, the book written by Mohsenin (1970) has classified the technical parameters of an agricultural product as restated in Figure 5. This can be a reference for researchers in the engineering properties of agricultural materials in providing the naming of the set of parameters measured to avoid confusion.

In general, the range of measurements of physical and mechanical properties of soybean conducted by Kibar et al., (2008) was investigated by Deshpande et al., (1993) with a moisture content range of 8.7% to 25% (d.b.), Polat et al., (2006) with a moisture content range of 6.7% to

15.3% (d.b.), Isik (2007) with a moisture content range of 10.62% to 27.06% (d.b.). Some researchers acknowledge that research measuring some of the engineering properties of soybeans related to their moisture content was investigated by several researchers a few years ago. However, supplementing it with other varieties is essential, as was conducted by Isik (2007) with typical soybeans from Turkey.

A critical comment in the research on the soybean engineering properties is focused on how the researchers apply the method in the variation of moisture content. In all of these studies, it is known that treating moisture content, which is a dependent property of soybean, is conducted by re-wetting dried soybeans. It can be understood that it is difficult to obtain the desired moisture content as a treatment variation. However, it is an essential note in this paper. It is better if the soybean moisture content is in its natural treatment to get closer to the value of the engineering properties in actual conditions.
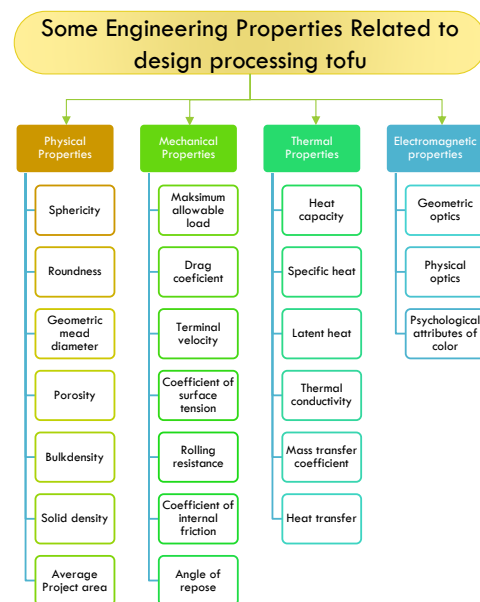
Figure 5 Soybean characteristics needed in processing it into tofu

FUTURE RECOMMENDATIONS

It is better to determine the moisture content of the soybeans measured naturally. This is because the use of soybean engineering properties, in reality, is in the condition of natural moisture content. Although it has not been determined yet that the re-wetting method for dried soybean will make a difference with the engineering properties of soybean.

The in-depth investigation showed that some engineering characteristics of soybean had not been studied in-depth on some parameters caused by the processing, especially in the processing of tofu. Previous studies only characterized soybeans' engineering properties from moisture content 6.7% (d.b.) to 49.7% (d.b.). Therefore, measurements with a broader range of moisture content and heat treatment of soybeans are still wide open for further investigation. Engineering characteristics that have been identified for the tofu processing are presented in full in Figure 5.

CONCLUSION

Highlights related to the measurement of soybean engineering properties have been summarized and described in this paper. A number of these studies can conclude that the engineering properties of soybean have been measured by the main categories of physical and mechanical properties. Physical properties that are quite often known are length, width, thickness, mass, volume, sphericity, the geometry of mean diameter, arithmetic mean diameter, bulk density, kernel density, porosity, surface area, and true density. Mechanical properties that are often analyzed are the angle of repose, terminal velocity, angle of internal friction, rupture force, and rupture energy. Moisture content spectrum measurement of physical and mechanical properties ranges from 6.70% to 49.7%. Last but not least, the effect of soaking and blanching treatment on soybean's physical properties is essential to be explored again. It is essential to know in the future to help researchers and engineers be more precise in designing soybean processing machinery and equipment into its derivative products.

SYMBOL

D_p	Geometric mean diameter (mm)	L	Length (mm)
W	Width (mm)	T	Thickness (mm)
ϕ	Sphericity	s	Surface area (cm^2)
ε	Porosity	ρ_b	Bulk density of grain (kg/m^3)
ρ_t	True density of grain (kg/m^3)	A_{md}	Arithmetic mean diameter (mm)
μ_1	Coefficient of friction	T_m	Torque (N.mm)
q	Length of torque arm (mm)	W_r	Weight of soybean on the rotating surface (N)
D_A	Apparent density (g/cm^3)	W_P	Soybean weight (g)

V_P	Soybean volume (cm^3)	W_{PW}	Soybean weight in water (g)
D_W	Water density (g/cm^3)	V_C	Container volume (cm^3)
Q	Mass of water to add (kg)	W_i	Initial mass of sample (kg)
M_f	Final moisture content of sample (%, d.b.)	M_i	Initial moisture content of sample (%, d.b.)
μ_2	Static coefficient of friction	α	Angle of tilt (°)
ϕ_2	Sphericity method Kibar et al., (2008)	S_2	Surface area metode Kibar et al., (2008) (cm^2)
V_l	Volume grain (cm^3)	m_s	Weight of liquid (kg)
m_w	Weight of dry sample (kg)	V_s	Volume of liquid (m^3)
V_w	Volume of sample (m^3)	μ_3	static coefficient of friction
F_s	Strength of friction (N)	W_n	Normal strength (N)
θ	Angle of repose (°)	H	Height of the cone (m)
D	Diameter of cone (m)	Ea	Repture energy (mJ)
F_r	Rupture force (N)	D_r	deformation at rupture point (mm)

REFERENCES

ASAE, A. 2006. S352. 2: Moisture measurement—unground grain and seeds. American Society of Agricultural and Biological Engineers, Michigan.

Davies, R., El-Okene, A. 2009. Moisture-dependent physical properties of soybeans. Int. Agrophysics, 23(3), 299-303.

Deshpande, S., Bal, S., Ojha, T. 1993. Physical properties of soybean. Journal of Agricultural Engineering Research, 56(2), 89-98.

Isik, E. 2007. Some engineering properties of soybean grains. American Journal of Food Technology, 2(3), 115-125.

Kibar, H., Ozturk, T. 2008. Physical and mechanical properties of soybean. International Agrophysics, 22(3), 239-244.

Manuwa, S. I. 2011. Properties of Soybean for Best Postharvest Options. Soybean: Physiology and Biochemistry, 51.

Mohsenin, N. N. 1970. Physical properties of plant and animal materials. Vol. 1. Structure, physical characterisitics and mechanical properties. 1.

Polat, R., Atay, U., Saglam, C. 2006. Some physical and aerodynamic properties of soybean. Journal of Agronomy, 5(1), 74-78.

Shirkole, S., Kenghe, R., Nimkar, P. 2011. Moisture dependent physical properties of soybean. International Journal of Engineering Science and Technology, 3(5), 3807-3815.

Sirisomboon, P., Pornchaloempong, P., Romphophak, T. 2007. Physical properties of green soybean: criteria for sorting. Journal of food engineering, 79(1), 18-22.

Tavakoli, H., Rajabipour, A., Mohtasebi, S. S. 2009. Moisture-dependent some engineering properties of soybean grains. Agricultural Engineering International: CIGR Journal.

Wandkar, S. V., Ukey, P. D., Pawar, D. A. 2012. Determination of physical properties of soybean at different moisture levels. Agricultural Engineering International: CIGR Journal, 14(2), 138-142.

<div align="center">**AUTHOR GUIDELINES**</div>

Term and Condition

1. Types of paper are original research or review paper that relevant to our Focus and Scope and never or in the process of being published in any national or international journal
2. Paper is written in good Indonesian or English
3. Paper must be submitted to http://journal.trunojoyo.ac.id/agrointek/index and journal template could be download here.
4. Paper should not exceed 15 printed pages (1.5 spaces) including figure(s) and table(s)

Article Structure

1. Please ensure that the e-mail address is given, up to date and available for communication by the corresponding author
2. Article structure for original research contains
   Title, The purpose of a title is to grab the attention of your readers and help them decide if your work is relevant to them. Title should be concise no more than 15 words. Indicate clearly the difference of your work with previous studies.
   Abstract, The abstract is a condensed version of an article, and contains important points of introduction, methods, results, and conclusions. It should reflect clearly the content of the article. There is no reference permitted in the abstract, and abbreviation preferably be avoided. Should abbreviation is used, it has to be defined in its first appearance in the abstract.
   Keywords, Keywords should contain minimum of 3 and maximum of 6 words, separated by semicolon. Keywords should be able to aid searching for the article.
   Introduction, Introduction should include sufficient background, goals of the work, and statement on the unique contribution of the article in the field. Following questions should be addressed in the introduction: Why the topic is new and important? What has been done previously? How result of the research contribute to new understanding to the field? The introduction should be concise, no more than one or two pages, and written in present tense.
   Material and methods, "This section mentions in detail material and methods used to solve the problem, or prove or disprove the hypothesis. It may contain all the terminology and the notations used, and develop the equations used for reaching a solution. It should allow a reader to replicate the work"
   Result and discussion, "This section shows the facts collected from the work to show new solution to the problem. Tables and figures should be clear and concise to illustrate the findings. Discussion explains significance of the results."
   Conclusions, "Conclusion expresses summary of findings, and provides answer to the goals of the work. Conclusion should not repeat the discussion."

References, We suggest authors to use citation manager such as Mendeley to comply with Ecology style. References are at least 10 sources. Ratio of primary and secondary sources (definition of primary and secondary sources) should be minimum 80:20.

Journals

Adam, M., Corbeels, M., Leffelaar, P.A., Van Keulen, H., Wery, J., Ewert, F., 2012. Building crop models within different crop modelling frameworks. Agric. Syst. 113, 57–63. doi:10.1016/j.agsy.2012.07.010

Arifin, M.Z., Probowati, B.D., Hastuti, S., 2015. Applications of Queuing Theory in the Tobacco Supply. Agric. Sci. Procedia 3, 255–261.doi:10.1016/j.aaspro.2015.01.049

Books

Agrios, G., 2005. Plant Pathology, 5th ed. Academic Press, London.