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# The Effect of Heat Treatment on Specific Gravity and Organoleptic Properties of Jack Bean (*Canavalia ensiformis*) Milk

## *Pengaruh Perlakuan Panas terhadap Berat Jenis dan Sifat Organoleptik Susu Kacang Koro (Canavalia ensiformis)*

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**Abstract**

Most of the dairy products sold in the market in Indonesia are animal milk but those products cannot be consumed by people with lactose intolerance and allergies. Plant-based milk is an alternative substitute for animal milk, and the most widely known is soy milk, but the production of soybeans in Indonesia is low. Jack beans (*Canavalia ensiformis*) are an alternative raw material substitute for plant-based milk. Meanwhile, the protein content of jack beans is similar to soybeans, but it is not popular as a food ingredient. This study aims to obtain the acceptable combination factors in processing jack bean milk. A full factorial design experiment was conducted to analyze the effect of temperature and heating duration on the specific gravity of jack bean milk and its organoleptic properties such as color, aroma, taste, and texture. The results showed that the temperature and heating time influenced the specific gravity and organoleptic properties of jack bean milk. In addition, the best combination of factors and levels is at a heating temperature of 100 °C for 20 minutes, which results in the specific gravity of jack bean milk, which is 1.0758.
**Keywords:** design of experiments, jack beans, plant-based milk

***Abstrak***

*Sebagian besar produk susu yang dijual di pasaran di Indonesia adalah susu hewani, tetapi produk tersebut tidak dapat dikonsumsi oleh penderita intoleransi laktosa dan alergi. Susu nabati dapat menjadi alternatif pengganti susu hewani. Susu nabati yang paling dikenal adalah susu kedelai, tetapi produksi kedelai di Indonesia masih rendah. Kacang koro pedang (Canavalia ensiformis) dapat menjadi alternatif pengganti dalam pembuatan susu nabati. Kacang koro pedang belum dikenal sebagai bahan makanan meskipun kandungan protein dalam kacang koro pedang mirip dengan kacang kedelai. Tujuan penelitian ini adalah untuk menemukan kombinasi faktor dalam mengolah kacang koro pedang yang dapat diterima masyarakat. Percobaan faktorial dalam rancangan acak lengkap dilakukan untuk melihat pengaruh suhu dan lama waktu pemanasan terhadap berat jenis dan karakteristik organoleptik susu koro pedang, seperti warna, aroma, rasa, dan tekstur. Hasil penelitian menunjukkan bahwa suhu dan lama waktu pemanasan mempengaruhi berat jenis dan karakteristik organoleptik susu koro pedang. Kombinasi faktor dan level terbaik diperoleh pada pemanasan dengan suhu 100 °C selama 20 menit yang menghasilkan berat jenis 1,0758.*
***Kata kunci**: kacang koro, rancangan percobaan, susu nabati*

## INTRODUCTION

Milk is not only a "drink" but a "liquid food", because of its complete nutritional content. World organizations such as the Food and Agriculture Organization (FAO) and government agencies in various countries consistently campaign for the habit of drinking milk to increase people's nutritional intake. Furthermore, the Indonesian government is actively encouraging consumption through the determination of June 1st as the national milk day called “Hari Susu Nusantara” (HSN). Milk is an excellent source of energy, amino acids, fatty acids, vitamins, inorganic elements, and fluids in sufficient quantities that is beneficial for health and promotes growth.

The domestic dairy market is still dominated by animal milk and 85% supply is from cows. Animal milk can be used as a supplement for human

nutritional needs even though there is some controversy related to consumption. The determination as healthy food raises pros and cons due to differences in social, cultural, belief, and even scientific perspectives (DuPui, 2002). In addition, the demand for animal milk shows a decreasing trend due to health problems associated with the consumption (Tamuno & Monday, 2019), and in Indonesia, it has only been consumed by indigenous people since the 19th century. Social, cultural, and public trust factors have caused the consumption of milk and its derivatives products as food intake differs from regions and countries in the world (Gerosa & Skoet, 2012). In agricultural countries, such as China, the consumption of milk only contributes about 12 kilocalories in daily intake. Meanwhile, in Ireland, a country with a strong herding tradition, the people's consumption contributes up to 436 kilocalories per day.

The habit of drinking milk was introduced since Dutch colonialism and continues until today. Based on statistical data, domestic fresh milk production has not been able to meet the national milk demand. The total consumption of fresh cow's milk was recorded at 1,261,502 tons in 2017, while the production was only 928,108 tons (Badan Pusat Statistik, 2018). These conditions require this country to import milk (Astuti & Sudarman, 2012), and the high price with the shortage of production causes the need for alternative substitutes for animal milk. The popular alternative is plant-based or vegetable milk, which is a vegan beverage consumed as alternatives. Currently, plant-based milk is widely consumed by people with allergies and lactose intolerance to animal milk. Moreover, the price of vegetable protein sources is cheaper than animal protein sources, and it is a fine source to fulfill the demand for protein in developing countries (Chima et al., 2013). The infamous vegetable milk is derived from soybean extract. Soy milk is used as a substitute for cow milk because it has almost the same protein quality. However, Indonesia is also unable to meet its soybean demand from domestic production, it is therefore imported to fulfill 65% of domestic demand (Ningrum et al., 2018). The statistics results showed that soybean production from 2010 to 2015 has declined in succession (Badan Pusat Statistik, 2021). Hasan et al. (2015) predicted that Indonesia will expand 70% of the soybean production area every year for 20 years and increase land productivity by 125% to be self-sufficient in soybeans.

There is one type of beans in Indonesia potentially used as an ingredient for vegetable milk, called jack bean (*Canavalia ensiformis*). The plant is usually planted by farmers in the islands of Java and Sumatra during crop rotation to increase soil fertility. Therefore, the jack bean plant can improve the quality of soil to optimize crop productivity (Fageria et al., 2013). The plant is also easy to grow in various types of soil with average productivity of 7 tons/ha and a potential yield of 12 tons/ha. It can be harvested up to four times in one year (Nuddin et al., 2019).

Jack bean contains 27.4% protein, which is higher than the content in peanuts that is only 23.1%, and is close to the protein content of soybeans. Nimenibo–Uadia (2017) stated that the protein content in jack beans can reduce cholesterol levels in the blood, especially when applied as a treatment in the hypercholesterolemic diet. Furthermore, it is also suggested as an additive in baby food, protein supplements for breakfast cereals, and instant snacks. The concentrate is useful in the protein fortification of bread and other baked products (Ugwuona & Suwaba, 2013). A further study conducted by Harvian et al. (2019) showed that jack bean proteins can be food precursors to release antioxidants. Therefore, it is feasible to cultivate this plant as a source of vegetable protein.

The cultivation of jack beans to support Indonesia's food security program is still not sufficient. Until today, it has not been popularly used as a food ingredient for humans because of the hydrogen cyanide (HCN) contents (Okomoda et al., 2016). Improper processing of jack beans can potentially cause poisoning when consumed, and heat treatment is an effective procedure to detoxify jack beans from HCN (Arpah et al., 2015). Several previous studies have been conducted to show the potential use of this plant as a food ingredient. Astuti et al. (2012) conducted a study on the effect of fermentation on the levels of HCN contained in jack bean sauce. Furthermore, Gilang et al. (2013) examined the effect of pretreatment in the manufacture of jack bean flour on its chemical and physical characteristics. The plant has been used as the main ingredient for some food products such as jack bean tempeh (Ma'rifat & Asngad, 2014), jack bean butter (Suyanto, 2014), shortcake biscuit (Ugwuona et al., 2019), and jack bean flour for making breakfast cereal (Agustia et al., 2019).

Some studies have been focused on jack bean milk production. Susanti et al. (2013) considered

the factor of soaking duration to eliminate the HCN content in jack bean milk. Naufalina & Nuryanto (2014) found that jack bean milk can reduce the level of low-density lipoprotein (LDL) cholesterol which is the cause of coronary heart disease. However, very little is known about the taste of jack bean milk that is acceptable by potential consumers. According to Wanich et al. (2018) taste is a subjective factor that influences the acceptance of food choices. It is also known that heat treatment of milk will affect the organoleptic quality of food products (Ritota et al., 2017). A recent review on dairy processing conducted by Carrillo-Lopez et al. (2021) stated that physicochemical parameters such as color and texture can affect consumer preference. Therefore, an experiment was designed to determine the effect of heating temperature and duration on specific gravity and organoleptic quality (color, aroma, taste, and texture) of jack bean milk.

## METHODS

Table 1 shows the factors and levels defined in the experimental design. The maximum duration of heating time was set to 30 minutes, which is based on a previous study conducted by Okomoda et al. (2016), which showed that after being heated to 30 minutes the protein content in jack bean was decreased. Each treatment combination in the experimental design was repeated twice. All experiments were conducted in the laboratory of the Industrial Engineering Department, Widya Mandala Surabaya Catholic University. The normality test was performed as the prerequisite for performing the analysis of variance (ANOVA) to check a normally distributed population. The test was conducted using the Anderson-Darling approach, and the experimental results were then examined using Analysis of Variance (ANOVA). The Minitab 18 software was employed for conducting these statistical analyses.

**Table 1.** Factors and factor levels in the experiment

| Factors | Factor Levels | | |
|---|---|---|---|
| Heating Temperature ($X_1$) | 60 °C | 80 °C | 100 °C |
| Heating duration ($X_2$) | 10 minutes | 20 minutes | 30 minutes |

**Jack Bean Milk Production**

The sample of jack bean (*Canavalia ensiformis*) used came from the city of Yogyakarta, and the tools used for the milk production are a measuring cup, digital scale, pot, thermometer, stirring rod, blender, and filter cloth. There are several steps in making the jack bean milk. Firstly, the beans are sorted and soaked in water for three days, and the water should be changed every 12 hours to remove the HCN content. In addition, the jack beans are ground using a food processor for five minutes, and during this process, warm bottled mineral water with a temperature of 80 °C is added. The ratio of beans and water should be a 1:3 ratio. The addition of water is intended to facilitate the grinding process and eliminate unpleasant odors.

The next step is filtering the jack bean using a cotton cloth to separate the solids (dregs) and the liquid, which is then referred to as jack bean milk. The jack bean milk is then heated following the temperature and duration specified in Table 1. This process uses a double boiler heating technique, where two containers are needed. One large container is filled with water while the other is floated on the water. Jack bean milk with a temperature of 20-25 °C is poured into the small container when the water reaches the predetermined temperature level. The temperature of the water as a conductor of heat should be kept constant until the specified heating duration is fulfilled.

**Specific Gravity Measurement**

The specific gravity is measured with a pycnometer bottle, and the tools used in testing are a 0.01-gram precision scale, pycnometer bottle, tissue, and thermometer. Initially, the pycnometer bottle is cleaned and then dried to remove all water droplets. The mass of the empty pycnometer bottle (m') and the mass of the pycnometer bottle filled with a liquid sample (m) were weighed. During the measurement, the sample temperature was maintained at 27.5 °C following SNI 3141.1:2011 (Badan Standardisasi Nasional, 2011). The following is the equation used to calculate the specific gravity of jack bean milk:

$$\rho = \frac{m\prime - m}{v} \quad (1)$$

where,
m' = the mass of empty pycnometer bottle (gram)
m = the mass of pycnometer bottle + sample (gram)
v = volume of pycnometer (milliliter)

**The Organoleptic Test**

The organoleptic test evaluates the quality of a food product through the sense organs. In this study, the test was conducted based on the organoleptic testing instructions stipulated by the National Standardization Agency for Indonesia (Badan Standardisasi Nasional, 2006). The assessment of the test included quality characteristics, which are color, aroma, taste, and texture. A scoring test was conducted involving 35 non-standard panelists (untrained). The panelists of this test had general preferences of being willing to take the test, good health, not color blind, and not allergic to the stated product. Furthermore, they were asked to try samples and assess the taste characteristics of nine samples provided with the same container in terms of size, shape, and quantity. Each container contains a 16-milliliter sample coded to avoid presumption toward the quality to be tested. Panelists were asked to drink water to neutralize their sense of taste after trying one sample before moving on to try the next. They were given an assessment sheet with response scales: 1, 3, 5, 7, and 9 for each sample, and the responses can be 1=strongly dislike, 3=dislike, 5=neither like nor dislike, 7=like, or 9=strongly like.

## RESULTS AND DISCUSSION

**Specific Gravity**

The effect of treatment against changes in specific gravity is summarized in Table 2. The highest average specific gravity was obtained when the combination of the heating temperature is 100 °C and the duration is 30 minutes. This treatment results in the specific gravity of jack bean milk of 1.0812, and it is consistent with Fox et al. (2015) statement that specific gravity will increase when the water which acts as a solvent evaporates, causing the volume of milk to decrease and making the milk thicker. A study conducted by ul Haq et al. (2013) also showed that there was a significant effect of heat treatment on milk's specific gravity. In all treatments, the specific gravity of jack bean milk is above that of fresh milk stipulated by the National Standardization Agency for fresh cow's milk SNI 3141.1:2011 (Badan Standardisasi Nasional, 2011), which is a minimum of 1.0280. The specific gravity of milk depends on the protein and fat content. The water content is higher than normal when the specific gravity of milk depends on the protein.

**Table 2.** The effect of treatment on the specific gravity of jack bean milk

| Heating Temperature | Heating Duration | | |
|---|---|---|---|
| | 10 Minutes | 20 Minutes | 30 Minutes |
| 60 °C | 1.0452 | 1.0468 | 1.0560 |
| | 1.0448 | 1.0484 | 1.0520 |
| 80 °C | 1.0468 | 1.0564 | 1.0624 |
| | 1.0436 | 1.0480 | 1.0600 |
| 100 °C | 1.0680 | 1.0756 | 1.0816 |
| | 1.0696 | 1.0760 | 1.0808 |

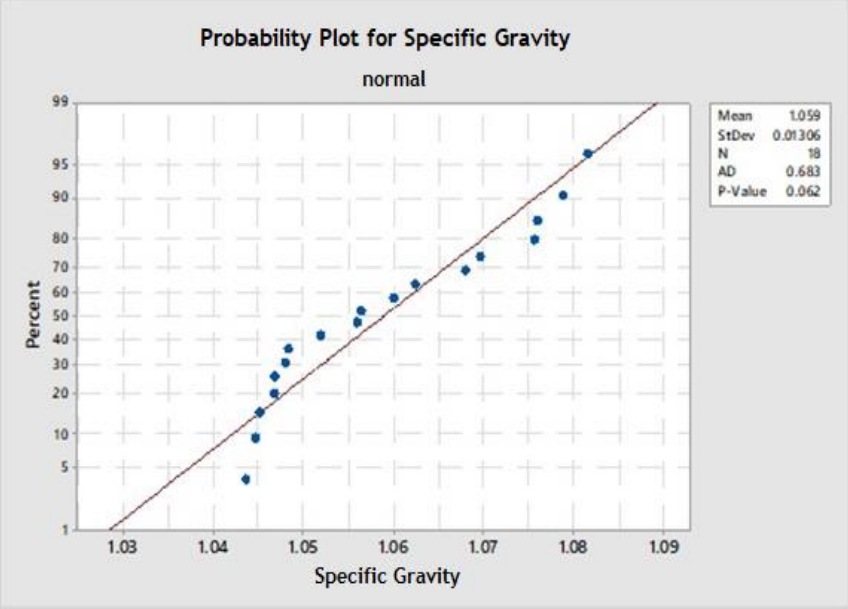


**Figure 1.** The Normality Test of the Specific Gravity Data of Jack Bean Milk

The normality test was performed to analyze the result, where $H_0$ was obtained from a normally distributed population and the $H_1$ was not obtained from a normally distributed population. Figure 1 showed that the p-value of the normality test is 0.062, which is greater than $\alpha = 0.05$, therefore, $H_0$ fails to be rejected. This concludes that the specific gravity data of jack bean milk is normally distributed. Furthermore, the ANOVA test was conducted to determine the effect of temperature and heating duration on the specific gravity of jack bean milk. The P-value of heating temperature and duration is smaller than the value of $\alpha = 0.05$. Therefore, the temperature and heating duration have a significant effect on the specific gravity of jack bean milk. However, the interaction results in a P-value greater than $\alpha = 0.05$. This denotes that the interaction of these two factors does not have a significant effect on the specific gravity of jack bean milk.

**Organoleptic Test**

Color

The results of the organoleptic test showed that the average preference score of jack bean milk concerning color ranged from 4.60 to 7.14, and it lies in the category of 'neutral' to 'like'. Figure 2 showed the average preferences score for the color of each treatment. Meanwhile, the code aa: bb on the x-axis of the bar chart showed the combination of the temperature factor level (aa) and heating duration (bb). For example, code 60:10 indicates the heating temperature of 60 °C with a duration of 10 minutes. This test is important because the color of jack beans milk cannot be as white as that of the animal due to its lower fat content. Temperature and duration of heating are proven to affect the color of animal and vegetable milk (Amador-Espejo et al., 2014; Kumar et al., 2021). The higher the temperature and the longer the duration of the heating will cause the color of milk to turn yellowish to brown. In addition, milk with a dark yellow to brownish color is less desirable (Liepa et al., 2017). Figure 2 showed that the highest average preference score for color is at the combination of heating temperature of 80 °C with a duration of 10 minutes. This combination produces jack beans milk with an attractive white to yellowish color. Consumers tend to choose jack bean milk with this color, and the darker the color, the lesser the customer preferences.

Aroma

Good quality milk should have very little odor (Molina et al., 2009), and the organoleptic test for the quality of aroma showed that the average preference score of jack bean milk is around 2.83 to 6.97 in the range of category 'dislike' to 'somewhat like'. Figure 3 showed the average preference score for aroma in each treatment. The combination of factors that showed the highest preference score for aroma is at the heating temperature of 80 °C and duration of 30 minutes. The experiment results showed that the jack beans milk will have raw and grainy aromas at low heating temperatures and duration. Meanwhile, at high temperatures, it will have an overcooked aroma, and the combination eliminates the raw aroma but does not spring an overcooked aroma. Therefore, it is preferable by respondents.

Taste

A previous study conducted by ul Haq et al. (2014) proved that heat treatments affected milk's taste**.** Increased heating temperature and duration will produce jack beans milk with cooked off-flavor (Amador-Espejo et al., 2014). Meanwhile, when the temperature is too low with a short heating duration, the milk will have an undesirable bitter and unclean taste. The organoleptic test concerning the taste of jack bean milk showed that the average preference score ranged from 3.06 to 6.94 in the category of 'dislike' to 'somewhat like'. Figure 4 showed the average preference score for the taste in each treatment, and the highest preference value for taste is at the combination of a heating temperature of 100 °C with a duration of 10 minutes. This combination removes bitterness and unclean tastes but does not create a distinct "cooked" flavor, therefore, a minimal undesirable aftertaste for respondents is left.

Texture

Withers et al. (2013) categorized dairy beverage texture into three-condition: thickness, mouth-coating, and mouth-drying. The results of the organoleptic test for the jack bean milk texture showed that the average preference score ranged from 3.89 to 7.11 is in the category of the 'dislike' to 'like' range. Figure 5 showed the average preference score for texture in each treatment. Meanwhile, the combination of the factor level that showed the highest preference score for texture is at a heating temperature of 100 °C with a duration

of 20 minutes. The study reported that high heating temperature and duration will increase the thickness texture of jack beans milk, and this will lead to an increasingly creamy texture. Respondents preferred jack beans milk with creamy texture but does not leave an undesirable aftertaste like residual mouth-coating.

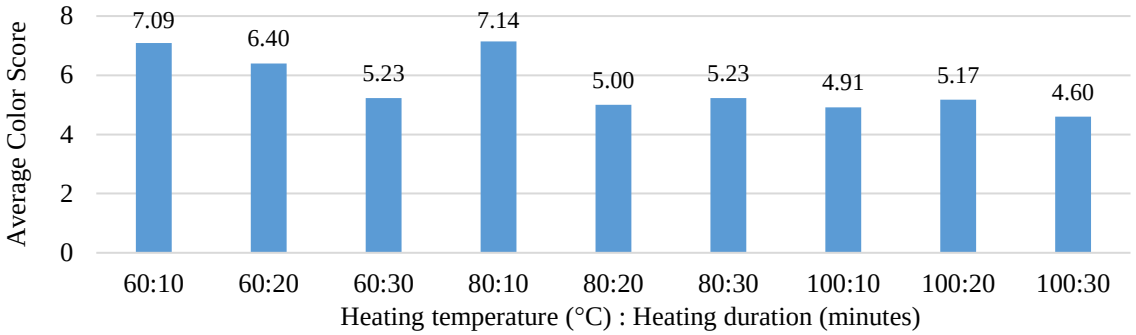


**Figure 2.** The Average Preference Score for Color in Each Treatment

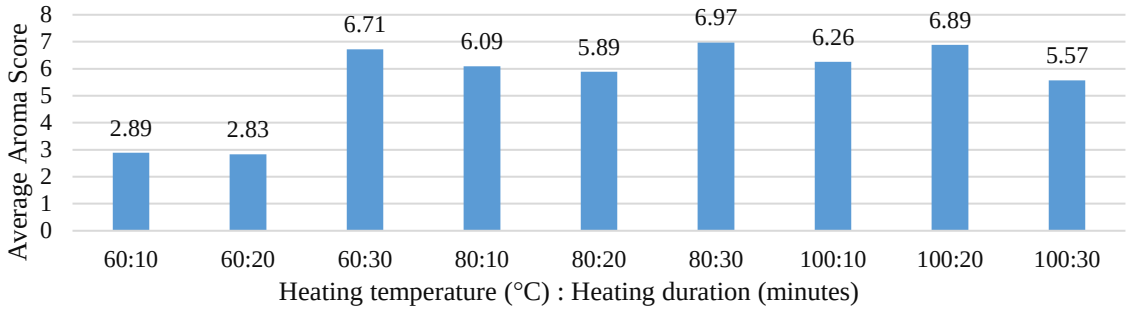


**Figure 3.** The Average Preference Score for Aroma in Each Treatment

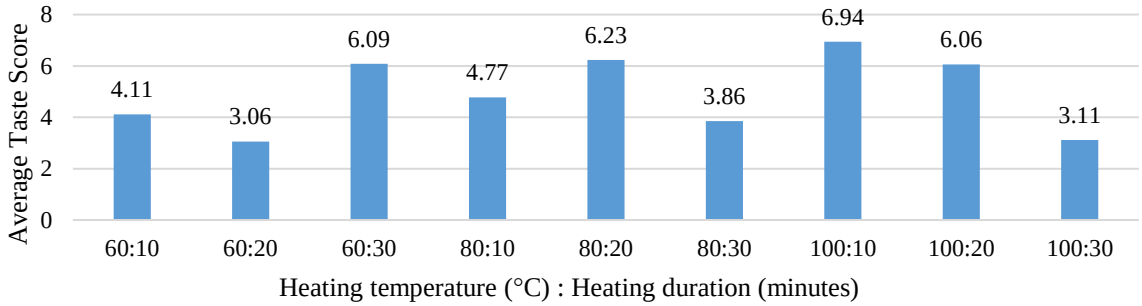


**Figure 4.** The Average Preference Score for Taste in Each Treatment

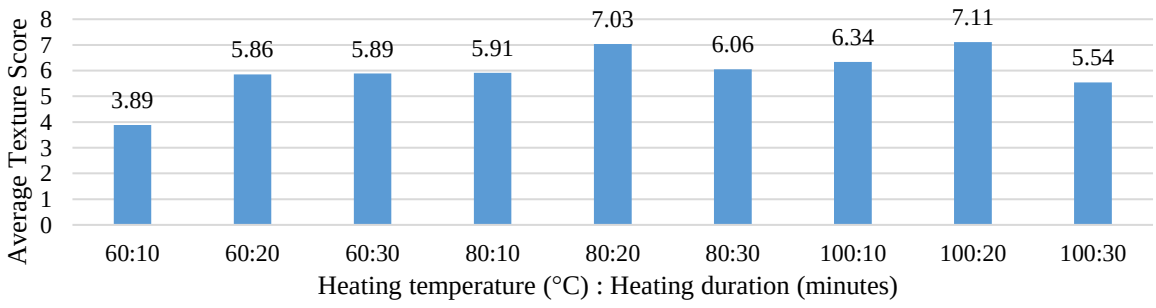


**Figure 5.** The Average Preference Score for Texture in Each Treatment

The Results of ANOVA Test on Organoleptic Test

The ANOVA test was performed on the organoleptic results to analyze the effect of treatment on the organoleptic quality of jack bean milk. All F-statistic value of the organoleptic quality was greater than the F-distribution with $\alpha = 0.05$. Therefore, there is an effect of temperature and heating duration on the preference score of color, aroma, taste, and texture of jack bean milk.

Best Treatment Analysis

The best treatment analysis was performed to consider the panelists' acceptance following the preference score of color, taste, aroma, and texture on the specific gravity of jack bean milk represented by each treatment. Furthermore, a radar chart was employed to determine the best treatment and was created by using the spreadsheet software Microsoft Excel. The selection was conducted by comparing the area formed from the four organoleptic characteristics against the specific gravity of jack bean milk. The best treatment was determined by evaluating the largest area in the radar chart and examining the feature point towards the edges. Figure 6 showed the radar chart for each treatment.

The radar chart is a result summary of the organoleptic test that measured four dimensions of the sensory quality of jack beans milk: color, aroma, taste, and texture. The wider the area on the chart indicates increased the respondent's preferences. Therefore, a single decision related to the best heating temperature and duration for producing jack beans milk can be made following the largest area of the radar chart. The calculation of the area for each average specific gravity is shown in Table 3, which showed that the best factor combination is at a heating temperature of 100 °C with a duration of 20 minutes, and a specific gravity of 1.0758. The average scores for color, aroma, taste, and texture preferences were 5.17, 6.89, 6.06, and 7.11, respectively.

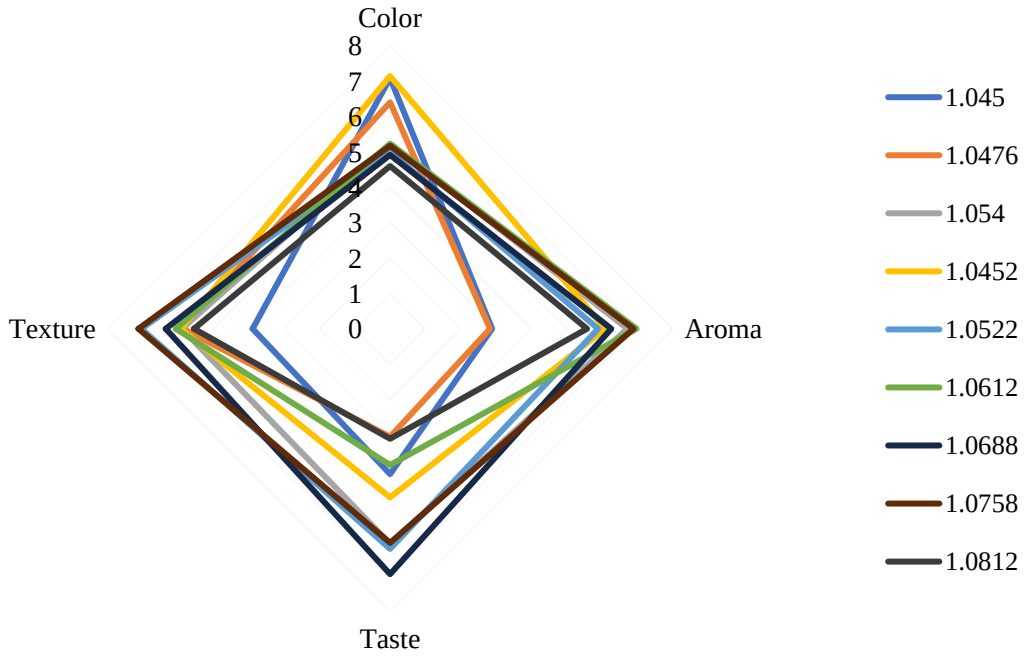


**Figure 6.** Results of overall organoleptic test against the Specific Gravity of Jack Bean Milk

**Table 3.** The calculation of the radar chart area for each average specific gravity

| Heating Temperature (°C) | Heating Duration (Minutes) | Specific Gravity | Area | Rank |
|---|---|---|---|---|
| 100 | 20 | 1.0758 | 78.600 | 1 |
| 100 | 10 | 1.0688 | 74.700 | 2 |
| 80 | 20 | 1.0522 | 72.504 | 3 |
| 80 | 10 | 1.0452 | 71.486 | 4 |
| 60 | 30 | 1.0540 | 71.280 | 5 |
| 80 | 30 | 1.0612 | 59.187 | 6 |
| 100 | 30 | 1.0812 | 42.869 | 7 |
| 60 | 20 | 1.0476 | 41.071 | 8 |
| 60 | 10 | 1.0450 | 37.920 | 9 |

## CONCLUSIONS

It can be concluded that the heating temperature and time affect the specific gravity and organoleptic quality (color, aroma, taste, and texture) of jack bean milk. This study showed that the specific gravity of jack bean milk for all treatments met the standard in SNI for fresh milk which should be higher than 1.0280. In addition, the best factor combination of treatment is at the heating temperature of 100 °C with a duration of 20 minutes, and this combination produces jack bean milk with a specific gravity of 1.0758. The result of the organoleptic test with this combination from the highest to the lowest is texture 7.11, aroma 6.89, taste 6.06; and color 5.17 through a fixed composition of ingredients. Further studies should consider the composition of the ingredients as factors and levels at the time of making jack beans milk in the experimental design. The use of trained panelists is also recommended to facilitate the implementation and increase the validity of organoleptic test results. Finally, the implication is in the statistical approaches used to determine the optimal point in the manufacture of jack beans milk such as Response Surface Methodology (RSM).

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