

Evaluasi Suhu dan Kondisi Penyimpanan Tepung Singkong (*Manihot esculenta*) Ditinjau dari Parameter Fisikokimia: Studi Kasus di PT. Lombok Gandaria, Karanganyar

[Evaluation of Temperature and Storage Conditions of Onggok flour (*Manihot esculenta*) Viewed from Physicochemical Parameters]

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ABSTRACT

Onggok flour is a flour obtained by grinding dried and sieved cassava tubers until it becomes coarse granules in certain sizes. Storage will greatly affect the characteristics of the material as well as its shelf-life. This study aimed to determine the value of physicochemical parameters of onggok flour at storage temperatures of 30°C and 50°C. In addition, this research also aimed to evaluate the physical condition of the existing warehouse in the company. The study was conducted by storing onggok flour at two different temperatures for five weeks. In assessing the best storage temperature, the main characteristics will be assessed as a reflection of the quality of onggok flour quality, defined into 6 parameters based on Indonesian National Standard and the industry's internal standard, such as moisture content, pH, colour, degree of acidity, and viscosity at 50°C and 90°C. The physicochemical parameter values of onggok flour obtained at 31°C and 55°C were 9.37% and 8.88% for moisture content, 3 ml and 3.07 ml NaOH for acidity degree, 82.26 and 82.46 for colour (lightness), 0.31 and 0.33 for viscosity at 50°C, 0.26 and 0.28 for viscosity at 90°C, and 5.22 and 5.27 for pH, respectively. 5 of the 6 parameters showed a better characteristic at 55°C, so the more appropriate temperature for onggok flour storage is 55°C. The suggested improvements includes adding more vents, roof plasterboard, wooden pallets, and temperature control devices, reduction of sack piles, periodic floor cleaning and the increase in the number and type of pest control instruments.

Keywords: onggok flour, temperature, storage, warehouse

ABSTRAK

Tepung singkong adalah tepung yang diperoleh dengan cara menggiling umbi singkong yang telah dikeringkan dan diayak hingga menjadi butiran kasar dengan ukuran tertentu. Penyimpanan akan sangat mempengaruhi karakteristik bahan serta daya simpannya. Penelitian ini bertujuan untuk mengetahui nilai parameter fisikokimia tepung ubi kayu pada suhu penyimpanan 30°C dan 50°C. Selain itu, penelitian ini juga bertujuan untuk mengevaluasi kondisi fisik gudang yang ada di perusahaan. Penelitian dilakukan dengan menyimpan tepung singkong dalam 2 suhu berbeda selama 5 minggu. Dalam menilai suhu penyimpanan terbaik, karakteristik utama yang akan dinilai sebagai cerminan kualitas mutu tepung singkong dibagi menjadi 6 parameter berdasarkan Standar Nasional Indonesia dan standar internal perusahaan yaitu kadar air, pH, warna, derajat keasaman, dan viskositas pada suhu penyimpanan 50°C dan 90°C. Nilai parameter fisikokimia tepung singkong yang diperoleh pada suhu 31°C dan 55°C adalah 9,37% dan 8,88% untuk kadar air, 3 ml dan 3,07 ml NaOH untuk derajat keasaman, 82,26 dan 82,46 untuk warna (kecerahan), 0,31 dan 0,33 untuk viskositas pada suhu 50°C, 0,26 dan 0,28 untuk viskositas pada suhu 90°C, dan 5,22 dan 5,27 untuk pH. 5 dari 6 parameter menunjukkan karakteristik yang lebih baik pada suhu 55°C, sehingga suhu yang lebih tepat untuk penyimpanan tepung singkong adalah 55°C. Perbaikan yang disarankan antara lain penambahan ventilasi, eternit atap, palet kayu, dan alat pengatur suhu, pengurangan tumpukan karung, pembersihan lantai secara berkala, serta penambahan jumlah dan jenis alat pengendali hama.

Kata kunci: tepung singkong, suhu, penyimpanan, gudang

Introduction

PT Lombok Gandaria is a company that produces soy sauce, chilli sauce, tomato sauce and table vinegar located in Surakarta, Central Java, Indonesia. The production of chili and tomato sauce product at PT. Lombok Gandaria uses onggok flour as a filler to increase the viscosity of the sauce. Wet cassava has been proven to be good when used in the sauce production process at PT. Lombok Gandaria, this material can increase the viscosity of the sauce and give certain sensory characteristics to the sauce products produced. PT Lombok Gandaria uses a type of onggok flour that is a by-product of extraction in the processing of tapioca flour; it has a dark beige or creamy brown colour with a rough texture (Widayanti et al., 2024). Onggok flour has a higher percentage of crude protein, moisture content, and crude fibre than ordinary onggok flour which are 2.89%, 20.31%, and 14.73%, while for onggok flour are 1.1%, 9.1%, and 4%. However, onggok flour has a higher fat percentage and ash content of 0.5% and 1.5% compared to the flour used with a fat percentage of 0.38% and ash content of 1.21%. According to Hidayat et al. (2020), the quality of onggok flour is determined by several factors, such as the white colour, low water content, does not contain much fibre, and has high adhesion. Its high carbohydrate content and mild flavour make onggok flour a great material for condiment products.

Storage of food or agricultural products is an integral part of food industry. Proper storage conditions are influenced by the type of food that will be stored (Lancelot et al., 2021). Flour is stored commercially in, and for use within a few weeks, flour can be packed in 14% air humidity, but air humidity higher than 13% will cause mould growth. Awol et al. (2024) has recommended that for long term storage, flour can be stored in a closed atmosphere, noting that with increasing storage temperature, the quality of flour can be decreased as the ash content increases. According to Lancelot et al. (2021), the optimum temperature for storage of dried food products is 40°F but good storage can still be done in temperatures of 60°F and below, with the best air humidity below 60%.

A warehouse consists of a floor, walls, roof, and one or more doors, as well as other components such as ventilation, windows, lighting, and so on. The floor must be able to withstand the weight of the products to be arranged on it, and it must also be impermeable to stagnant water. The walls of the warehouse should be made of bricks that are 15-20 cm thick and should be flat on both sides; painted white, on the inside to facilitate insect pest detection, and on the outside to help keep the warehouse as cool as possible. The roofing material can be made of galbani iron or aluminium sheets; the triangular ends of the roof should be overhung by about 0.7-1 metre and the plasterboard part by at least 1 metre, this ensures that rainwater can drain well into the walls. Based on South Carolina Department of Agriculture (2021), open vents are necessary to allow air renewal and reduce the temperature in the shed, as well as to allow light in, provided they are installed at the top of the shed and fitted with trellises.

Improper storage conditions can accelerate quality deterioration, thereby reducing the physicochemical stability and overall product acceptability of onggok flour and the product where its applied in. However, there is still limited information regarding the effect of warehouse storage temperatures on the physicochemical quality of onggok flour, and the current warehouse conditions have not been fully evaluated against applicable standards, making it important to investigate both aspects in this study. Determination of storage conditions is done by considering temperature as a

dependent variable. The temperatures chosen were 30°C to represent warehouse temperature when the machine is turned off and 50°C when the machine is turned on. The samples were measured for six parameters: moisture content, acidity, colour, viscosity at 50°C dan 90°C, according to company's internal quality procedure that reflects their production process, and pH. Evaluation of storage temperature based on these parameters will also be carried out based on SNI 01-2997-1996 as a quality standard. In addition, this research also aimed to evaluate the physical condition of the existing warehouse in the company. Components of storage conditions visually evaluated include stacking, pallet use, ventilation, lighting, flooring, pest control, and availability of air temperature and humidity control devices.

Materials and Methods

Materials and equipments

Onggok flour was obtained from a partner supplier, PT Lombok Gandaria, which was then weighed as many as 24 plastics each containing 100 grams of onggok flour and labelled according to the temperature code and storage period. Major equipment used during the research included an incubator (Mettler IN55, Germany), moisture balance (Ohaus MB45, USA), colour reader (Minolta CR-400, Japan), pH meter (Mettler Toledo SevenCompact, Switzerland), and viscometer (Brookfield DV2T, USA). Other common glassware and laboratory utensils were also used. The main reagents included NaOH, PP indicator, filter paper, plastic wrap, regular plastic, and 96% ethanol.

Experimental design

The independent variable that is the control factor in the study is temperature, namely normal warehouse temperature (30°C) and extreme temperature (50°C), these two temperatures were chosen to compare changes in flour characteristics that appear when stored in a onggok flour storage warehouse in normal air conditions and when the production machine is turned on which causes an increase in air temperature in the warehouse. Samples will be tested once per week during 5 weeks of storage duration with 3 repetitions for each parameters.

Research methodology

In assessing the best storage temperature, in the storage period of 5 weeks, once in a week, the main characteristics will be assessed as a reflection of the quality of onggok flour quality, defined into 6 parameters based on Indonesian National Standard (SNI 01-2997-1996) and the industry's internal standard, such as moisture content, pH, colour, degree of acidity, and viscosity at 50°C and 90°C. Moisture content testing was carried out using a Moisture Balance tool with 2 grams of samples. pH testing was carried out using a pH meter with a onggok flour sample of 0.5 grams then dissolved in 100 ml of distilled water. Colour testing was done with a colour reader. Testing the degree of acidity is done by leaving a 96% ethanol solution containing 10 grams of sample for 24 hours, then filtered and titrated using 0.1N NaOH; the final result is obtained from the calculation with a predetermined formula. Viscosity testing is done by dissolving 4 grams of sample in 200 ml of distilled water, then the sample that has been heated to 90°C is measured with a viscometer, the same was done to measure viscosity at 50°C. The data processing was carried out using the Independent T-Test method for homogeneous and normally distributed data and Mann-Whitney for non-homogeneous data or data with abnormal distribution. In addition, observations is made at the factory warehouse where the flour is stored, and is compared with applicable warehouse standards according to several standards and previous studies, including Institutional Food Service Systems Guideline

from Ministry of Health of the Republic of Indonesia (Bakri et al., 2018), Regulation of the Minister of Industry of the Republic of Indonesia No. 75/M-IND/PER/7/2010 about Good Manufacturing Practices (2010), and other standards.

Data Analysis

After all results were tested for normality and homogeneity, the data were then tested with repeated measures ANOVA to see the main effect of the between-subjects variable (temperature), the main effect of the within-subjects variable (week), and the interaction between the two.

Results and Discussion

Evaluation of Storage Condition

The flour warehouse at PT. Lombok Gandaria, has an area of 120 m² with a length of 20 m and a width of 6 m. This warehouse is located inside the main factory building, next to the sauce cooking machine, opposite the soybean steaming machine. Inside this warehouse, not only onggok flour is stored, but also other flours such as modified starch flour along with a sorting machine for removing foreign objects from the flour. In this warehouse, the flour is stored for approximately 1 to 3 months before being transferred to a temporary warehouse for 3 to 5 days and finally entering the processing stage. The concrete floor is used, as seen in **Figure 1**, is deemed generally suitable for a flour warehouse because it is durable, able to withstand heavy loads, and are relatively easy to maintain (Layrensus and Sutapa, 2020).



Figure 1. Flour warehouse of PT. Lombok Gandaria

The temperature and RH control devices used in the warehouse are still simple, using conventional thermometers. Temperature inside the warehouse is around 31°C with a relative humidity of approximately 80%. The temperature is higher than the normal temperature, which ranges from 27-28°C, but the relative humidity is normal. Ahmad (2015) stated that the ideal temperature for storing flour in a warehouse is generally between 10 and 20 °C, with humidity below 60% and away from direct light, to help prevent moisture buildup and subsequent issues like mold or lumping.

This flour warehouse has five vents that are quite small, measuring approximately 1×1 metre, as shown in **Figure 2**. The number of vents is considered insufficient because, according to Regulation of the Minister of Industry of the Republic of Indonesia No. 75/M-IND/PER/7/2010 about Good

Manufacturing Practices (2010), the area of fixed ventilation openings (vents that cannot be opened or closed) must be at least 15% of the floor area of the room, meaning the required ventilation area is at least 18 m². The ventilation openings are fitted with filters to prevent insects from entering. The filters used are 10-mesh or 2 mm copper filters. Copper is used as material for filter to reduce the likelihood of rust formation and because copper is more durable than other materials.



Figure 2. Ventilation

The sacks used to store flour are 50 kg capacity plastic sacks without lamination, which are sealed with manual stitching. Sacks are stacked in a straight line, as shown in **Figure 3**, with each stack consisting of a maximum of 5 sacks. In these stacks, it is common to find sacks at the bottom layer with their seams coming undone, resulting in a significant amount of flour being spilled out. The stacks of sacks are placed on a wooden pallet spaced away from the wall to prevent water seepage, which typically originates from the roof and flows down the wall. The sacks are stacked on a wooden pallet lined with plastic; however, the wooden pallets used are mostly rotten and infested with termites or small mould, as shown in **Figure 4** above. Swedish Institute for Wood Technology Research stated on their report (2002), that while wooden pallets are common in many industries, including flour warehousing, their use in flour storage requires careful consideration of hygiene and potential contamination risks. Wooden pallets, being porous, can absorb moisture and harbor bacteria, potentially contaminating the flour if not properly managed. However, with some mitigation steps, such as regular cleaning, sanitization and inspections, selecting high-quality and durable wood, proper storage in clean, dry conditions away from moisture and pests can further enhance food safety when using wooden pallets. Unfortunately, however, the company does not seem to have implemented these measures properly.



Figure 3. Flour sacks



Figure 4. Woodeen pallet

Figure 5 shows asbestos roofing with water stains, indicating that the warehouse still has poor water resistance, considering that the product stored inside is flour, which is highly susceptible to water. These water stains can contribute to the dampness of the warehouse, especially given the already high temperature inside the warehouse. Curado et al (2024) stated that asbestos fibers, if released, can contaminate fine powder like onggok flour and pose serious health risks to those consuming it, making it unsafe. Flour is highly susceptible to moisture (Hidayat et al., 2020), and according to Sanitation Performance Standards Compliance Guide released by published by the Food and Drug Administration of the United States of America (FDA USA; 1999), a leaky roof will cause it to clump, spoil, and potentially become contaminated. Proper flour storage requires a cool, dry, and dark place, ideally in airtight containers to prevent moisture and pests from compromising its quality. Additionally, there is one pest control instrument: a rat trap (**Figure 5**). Although installing filters on the ventilation system is also considered a pest control measure, this is deemed insufficient because during observations, pests other than flying insects and rodents were found. Based on the same regulatory standards mentioned before, this certainly require further treatment to prevent fatal impacts on the flour products stored in the warehouse (Rossos et al., 2025).



Figure 5. Leaky asbestos roof (left), Pest control instrument (right)

Evaluation of Storage Temperature

The physicochemical parameter testing to evaluate storage temperature included 3 physical parameters and 2 chemical parameters. The physical parameters were colour and viscosity, while the chemical parameters were water content, pH and acidity.

a) Moisture content

According to Lancelot et al. (2021), moisture content is one of the physical properties of a material that indicates the amount of water contained within it. A simple concept regarding the moisture content of food materials states that food materials consist of dry matter plus a certain amount of water. This also applies to dry products such as flour, which is why moisture content is an important parameter that significantly influences the quality of the flour itself, especially since food storage is an integral part of processing.

The results of the mixed ANOVA analysis showed that there were no significant differences in moisture content based on the drying temperature treatment as a whole (main effect of temperature, $p > 0.05$) or based on the observation period of five weeks (main effect of time, $p > 0.05$). Moisture content at 30°C, fluctuated unpredictably from the first week to the fifth week. Samples at normal temperature experienced irregular fluctuations, as shown in **Figure 6**. This was due to the humid storage conditions and uncontrolled temperature. In contrast to that, Despite statistically not significant, samples at 50°C showed a decreasing trend from the first week onwards. This is because the controlled incubator temperature causes water in the flour to evaporate, resulting in a decrease in moisture content. Interestingly, a significant interaction between temperature and time (interaction effect, $p < 0.05$) was found, indicating that the effect of temperature on water content differed in each week of observation. The quality standard for onggok flour moisture content according to SNI 01-2997-1996 on onggok flour is less than 12%. This standard is already met by the onggok flour used as a sauce ingredient, as the average moisture content measured during testing was 9.34% at room temperature and 8.88% at incubator temperature.

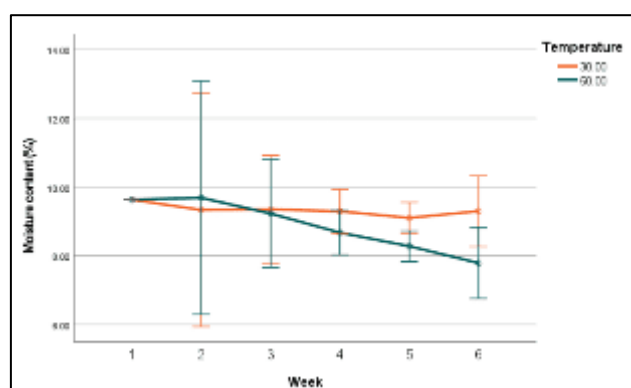


Figure 6. Moisture content (%) over 6 weeks at two storage temperatures. Error bars represent 95% CI. Significant interaction between temperature and week was found ($p < 0.05$), although the main effects were not significant

b) pH

pH is the acidity level of a solution, expressed on a scale of 0 to 14 (Rahman and Rahman, 2020). pH of food affects its ability to destroy bacteria through heating; if the pH is low, less heat is required than for food with a higher pH.

The data in **Figure 7** indicates that although the main effects of week and drying temperature on pH were not statistically significant ($p=0.103$ and $p=0.841$, respectively), a significant interaction between week and temperature was observed ($p=0.001$), indicating that the effect of storage temperature on pH is not consistent between week, even though neither factor alone had a significant effect. This interaction is evident in the contrasting trends between the two temperature groups shown in the graph. At 30°C , pH initially declined sharply at week 2 before gradually rising, while at 50°C , pH showed a slight increase at week 2 and then gradually declined. Despite these fluctuations, both groups exhibited relatively stable pH values from week 4 onward. This suggests that drying temperature did not directly influence the overall acidity level of the product, but it did modulate how pH evolved over time during storage, due to several reasons. Firstly, it may be influenced by differences in water activity and diffusion of soluble compounds (Singh et al., 2014), where lower drying temperatures might allow more acidic compounds to migrate during storage. Additionally, according to Volatile loss and buffering effects differ with temperature where elevated temperatures may facilitate the volatilization of acidic compounds and modify the buffering capacity (Mennah-Govela and Bornhorst, 2021). Finally, enzymatic and non-enzymatic reactions post-drying like protein breakdown could generate or consume acidic/basic compounds, contributing to the divergent pH trends (Silva et al., 2020).

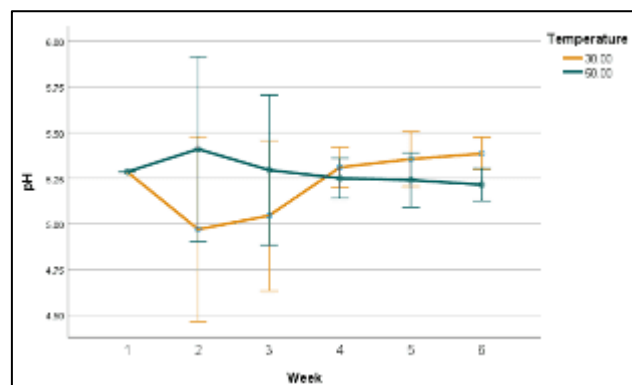


Figure 7. pH over 6 weeks at two storage temperatures. Error bars represent 95% CI. No significant main effects of week ($p = 0.103$) or temperature ($p = 0.841$) were observed, but a significant interaction between week and temperature was found ($p = 0.001$)

c) Titratable Acidity

Although at first glance it appears to be the same as acidity or pH, titratable acidity (TA) has a striking difference from pH in that its value is inversely proportional to pH (Sadler and Murphy, 2020). The relationship between pH and TA is generally inverse, where higher TA values are typically associated with lower pH levels. While pH measures the concentration of free hydrogen ions (H^+) in

a solution, reflecting the intensity of acidity, TA quantifies the total amount of titratable acids, including both ionized and non-ionized forms.

While no significant main effect of drying temperature on titratable acidity ($p > 0.05$), a significant main effect of time ($p < 0.05$) was observed (see **Figure 8**), suggesting that titratable acidity changed significantly over the six-week storage period regardless of temperature. More importantly, a significant interaction effect between temperature and time ($p < 0.05$) was found, indicating that the pattern of TA changes over time differed depending on the drying temperature. This suggests that the dynamics of TA development throughout storage were temperature-dependent, as visualized in the interaction plot in **Figure 8**. Visually, samples stored at 30°C appeared to exhibit a declining trend in titratable acidity over the 6-week storage period, while those stored at 50°C showed a gradual increase, particularly between Week 2 and Week 5. This contrasting pattern is consistent with the significant interaction effect observed, suggesting a temperature-dependent trajectory of TA development during storage. This contrasting pattern can be explained through finding by Sadras et al. (2013), stating that at 30°C, the decrease in TA over time may be linked to the slow degradation or neutralization of residual organic acids or acid-forming compounds present in the flour. In contrast, at 50°C, the observed increase in TA suggests that higher temperatures may accelerate thermal reactions involving residual carbohydrates or organic matter, possibly leading to the formation of acidic degradation products (El Hosry et al., 2025).

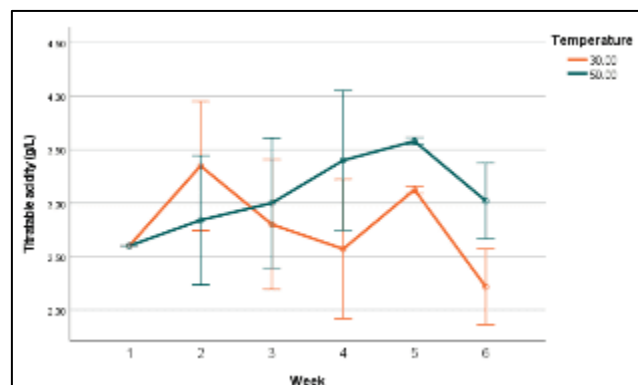


Figure 8. Titratable acidity (g/L) over 6 weeks at two storage temperatures. Error bars represent 95% CI. A significant effect of time ($p < 0.05$) and a significant temperature–time interaction ($p < 0.05$) were observed, while drying temperature alone had no significant effect ($p > 0.05$)

d) Viscosity

According to Lie-Piang et al. (2021), for certain food products, viscosity is not only important as an indicator of the content of certain substances, but also used as an indicator of damage, deviation, or deterioration in the quality of some food products. Viscosity is influenced by several factors, including temperature, the concentration and molecular weight of dissolved substances, pressure, and the presence of suspended particles. Among these, temperature and solubility of the dissolved components are generally considered the most critical in determining a solution's viscosity. As temperature rises, viscosity typically decreases due to the increased molecular motion, which reduces internal resistance. However, if the dissolved particles exhibit high solubility, they tend to integrate more readily into the solution, which may mitigate the temperature-induced reduction in viscosity.

Viscosity measurements conducted at two different dispersion temperatures, 50°C and 90°C, revealed varying patterns of change across storage time as seen in **Figure 9**. At both 50°C and 90°C, no significant main effect of drying temperature on viscosity was observed, indicating that the thermal treatment applied during the drying process did not substantially alter the flour's physicochemical properties responsible for viscosity. However, a significant main effect of storage time and its interaction with drying temperature was observed at 50°C ($p < 0.05$), suggesting that viscosity changes were influenced by how the flour's components responded over time in conjunction with prior drying conditions. In contrast, at 90°C, storage time alone had a significant impact on viscosity ($p < 0.05$), while the interaction effect was not significant ($p > 0.05$), implying that any influence of drying temperature became negligible at higher rehydration temperatures. The overall trend in viscosity across both temperatures showed a similar gradual decrease over the storage period, likely due to mild structural degradation of starch or protein components, such as limited depolymerization or reduced water-binding capacity (Singh et al., 2014). During storage, especially under fluctuating environmental conditions, hydrolytic and oxidative reactions may occur, leading to the breakdown of these macromolecules into smaller fragments, which results in a lower resistance to flow or lower viscosity.

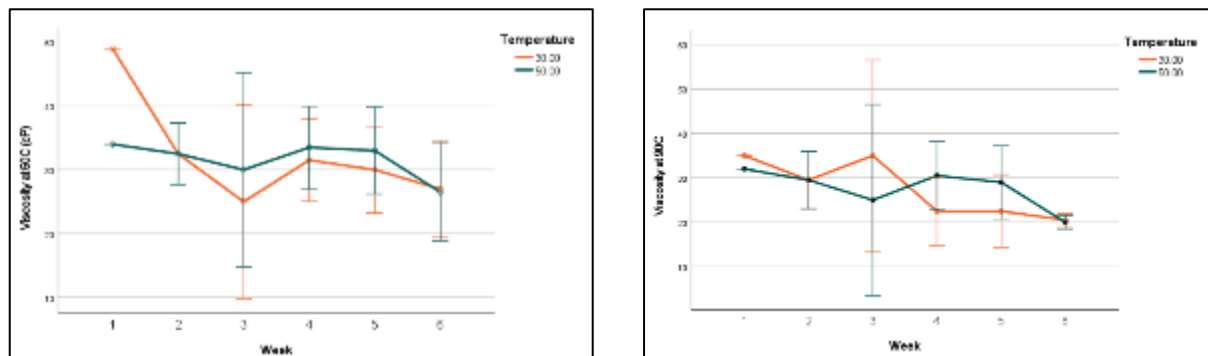


Figure 9. Viscosity at 500C (left) and 900C (right) over 6 weeks at two storage temperatures. Error bars represent 95% CI. At 50°C, no significant main effect of drying temperature observed, while a significant main effect of storage time interaction between both on viscosity was observed ($p < 0.05$). At 90°C, storage time had a significant effect on viscosity ($p < 0.05$), while the main effect of drying temperature and the interaction between both were not significant ($p > 0.05$).

e) Color (lightness)

Colour can provide clues about chemical and physical changes in food. Together with smell, taste and texture, colour plays an important role in food acceptance (Kardas et al., 2024).

Statistically significant main effect of storage time (week) has been observed on the lightness value ($p = 0.044$), however, there was no significant main effect of temperature ($p = 0.526$), nor was there a significant interaction effect between temperature and storage time ($p = 0.566$). These results suggest that the change in lightness over time occurred regardless of the storage temperature, and that temperature did not significantly influence the overall lightness or modify the pattern of change across weeks. As seen in **Figure 10**, both temperature groups experienced a dip in lightness around week 3, followed by a recovery toward the initial values by week 6. Since onggok flour has relatively low protein and sugar content, the extent of browning is limited and may be influenced by oxidative

changes or moisture redistribution during storage (Hidayat et al., 2020). The gradual return of lightness values to baseline may indicate stabilization of the flour's surface color as volatile compounds dissipated or as moisture content equilibrated, leading to a more uniform visual appearance over time.

Conclusion

This study concluded that onggok flour stored at 50 °C showed better physicochemical stability in five of six parameters compared to 30 °C, indicating that 50 °C is the more suitable storage temperature for maintaining flour quality. In addition, the warehouse evaluation revealed several aspects that need improvement, including ventilation, roofing material, wooden pallets, temperature control equipment, sack pile management, floor hygiene, and pest control instruments.

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