Kinetics of Porang (*Amorphophallus oncophyllus*) Chips during Storage at Various Temperatures

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ABSTRACT

Porang chips are dried food products that easily absorb moisture from storage environment. This highlights the need for storing porang chips under appropriate environmental conditions to maintain quality by controlling temperatures and humidity of storage area. Therefore, this study aimed to assess quality characteristics of porang chips by analyzing the rate of change using the kinetics model and determining storage period at various temperatures. Porang chips were stored at a relative humidity (RH) of approximately 70% and temperatures of 15 °C, 20 °C, 25°C, and 30 °C for 90 days. The parameters measured were moisture content, hardness, density, color, glucomannan, and ash content. The rate of quality change in hardness and density of chips was analyzed using the kinetics model that was validated through the Arrhenius equation. After the validation test confirmed its accuracy, storage period was determined based on the hardness parameter. The measurement of porang chips parameters was analyzed using ANOVA with Duncan's post hoc test to assess the effect of storage temperatures. The results showed that storage temperatures affected hardness and density parameters but did not affect the color, glucomannan, and ash content. The kinetics analysis of changes in hardness and density of porang chips followed a zero-order reaction, showing that higher storage temperatures produced larger rate constant values. Validation using the Arrhenius equation yielded the following equations for density Y = -5154.5 + 9.1773 and hardness Y = -2152.4 + 2.3371. The determination of shelf life for porang chips based on the hardness parameter resulted in values of 386, 345, 312, and 271 days at storage temperatures of 15 °C, 20 °C, 25 °C, and 30 °C, respectively.

Keywords: Kinetics; porang chips; shelf life; storage temperature

INTRODUCTION

Porang (*Amorphophallus oncophyllus*) is among the plants in high demand across various countries, particularly in Indonesia (Haerunnisa et al., 2023). One form of processed porang tubers is chips which are dried, sliced products subjected to several processes, such as cleaning, slicing, and drying with a moisture content of <12%. These chips are widely used in various industries such as food, chemicals, and health (Nofrida et al., 2021; Suharto et al., 2018) due to the high glucomannan content of approximately 65% dry basis (Sari et al., 2019). In the food sector, glucomannan has high water absorption capacity and is a dietary fiber that provides a gel and thick effect, making it useful as a thickener, binder, preservative substitute, and fat substitute (Handayani et al., 2020). Processing porang tubers into chips is one of the efforts to extend shelf life and facilitate the use of raw materials for both food and non-food industries (Yuniwati et al., 2021). According to (Sari et al., 2019), porang chips currently have great potential to be developed as raw materials for export

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to several countries such as Taiwan, Japan, Korea, and China that require porang products as industrial raw materials.

Quality of porang chips is essential to consider during storage period and distribution process for export, particularly the moisture content parameters that affect the hardness and are sensitive to microbial development as well as fungal growth (Herawati, 2008). Therefore, long storage is feared to affect quality standards, emphasizing the need for appropriate storage conditions. One effort that can be made to maintain quality is to control environmental parameters in storage area (Arnanto & Darnawi, 2020). There is a need to predict shelf life of porang chips to maintain their quality appropriate to the provisions of the Indonesian National Standard 7939:2020. Several key factors, such as storage temperature and relative humidity, must be considered to preserve product quality throughout the storage period (Ramdan et al., 2022).

Changes in quality parameter of chips during storage can be analyzed using the kinetic model. Storage temperatures are one of the factors that greatly influences the rate of quality change in chips. This is because higher storage temperatures correlate with a faster reaction rate. Several methods are commonly used in analyzing shelf life of a product, such as Accelerated Shelf Life Testing (ASLT) by storing porang chips outside normal conditions to accelerate quality decline. The kinetic model is used to determine the rate constant for the decline in quality of the measured porang chips.

This study is based on previous reports, focusing on determining shelf life of chips using the ASLT method. Wijanartii et al (2019) explored shelf life of pegagan chips products with PE and Aluminum foil packaging using the ASLT method. The results showed that the moisture content parameter had an important effect on quality of chips. This suggested that the packaging of pegagan chips with PE and aluminum foil could maintain quality and produce a fairly long shelf life of 2.7 and 4.6 months. Therefore, this study aimed to examine changes in quality of porang chips during storage period by analyzing the rate of quality change and determining storage period using various temperatures.

METHODS

Materials

The main material was chips dried with the help of an oven at an initial moisture content of <12% and a thickness of 3 – 4 mm, which was obtained from PT Sanindo Porang West Java Indonesia with porang species *Amorphophallus oncophyllus*. Meanwhile, the supporting materials included polyethylene plastic with a thickness of 0.075 mm as packaging and saturated salt NaCl 70%. The equipment used was an analytical scale O'Haus Pioneer brand PX223 (United States) with an accuracy level of 0.0001, analitycal scales O'Haus with an accuracy scale of 0.01 with model NV221 (United States), an oven with spesification SANYO Drying Oven brand with model MOV-112 P (Japan), thermohygro as a measuring tool for temperature and air humudity (RH), a container box as an airtight storage space with the capacity 35 L, a heater as a room temperatures conditioner, color meter model TES 135A (Taiwan), Force Gauge Lutron brand with model FG-20KG (Taiwan), and hotplate stirrer Advantec brand type SRS710HA (Japan).

Conditioning Storage Temperatures and RH

Temperatures used in this study were 15 °C, 20 °C, 25°C, and 30 °C with relative humidity (RH) of 70%. Proper storage conditions were crucial to maintaining quality and safety of porang chips. Therefore, a range of low to high temperatures was recommended to determine the right conditions during storage with an RH of no more than 70% (Julianti and Mimi, 2007). Various temperatures were used to determine the differences and effects on porang chips during storage. The 15 °C treatment was conducted in a cold storage chamber. For the 20 °C and 25 °C conditions, container boxes containing the packaged porang chips were placed in an air-conditioned room. Meanwhile, at storage temperature of 30°C, the container box was placed in a room regulated by a heater. The conditioning of RH 70% used supersaturated salt NaCl as much as 359 g dissolved in distilled water to a volume of 1.75 L.

Preparation of Porang Chips Samples

Approximately 40 g of porang chips were packed in polyethylene plastic measuring 14 cm x 15 cm with a thickness of 0.075 mm and stored in a tightly closed container box according to the set storage temperature. Moisture content, density, hardness, and color were measured every 5 days, while the glucomannan and ash content of porang chips were measured every 15 days.

Collection of Porang Chips Quality Data during Storage

The moisture content of porang chips was calculated based on the thermogravimetric method (drying) referring to (SNI 0891:1992). The density was measured using the waxing method because porang chips were porous objects that could absorb a lot of moisture and caused measurement errors when not coated with wax. A sample of 2−3 g was dipped into wax and weighed to determine the weight of the sample and wax. Furthermore, it was put into water in a measuring cylinder to determine the increase in volume (Rahardjo et al., 1997). The hardness of porang chips was determined using a force gauge by placing the sample directly under the probe until it broke. The measurement results were observed in the numbers shown on the show of the tool in Kgf units (Mubarok et al., 2020). Color measurement uses a colormeter by analyzing the L*, a*, b* value (Engelen, 2018). The glucomannan content of chips was analyzed using the extraction method (Ifmalinda et al., 2024). The ash content was determined by weighing a sample of 1−2 g, while the ashing process was carried out using a Furnace until the sample became ash. Furthermore, it was reweighed and recorded as the ash content result (Sundari et al., 2015).

Shelf Life Analysis

Shelflife analysis was carried out using the kinetic model through the selection of order 0 or 1 shown by the largest coefficient of determination value. The process was conducted by knowing the rate of quality change in hardness and density parameters using the kinetic model that applied orders 0 and 1 (Renate et al., 2014), as shown in Equations 1 and 2.

$$A_t = A_0 - k.\, t \quad (1)$$

$$\text{In } A_t = A_0 - k.\, t \quad (2)$$

The constant value obtained from the selected order was validated using the Arrhenius equation by plotting the k value at various storage temperatures to determine the Ea (Activation Energy) value. The effect of storage temperature on the reaction rate is written in Equation 3.

$$\text{In } k = \text{In } k_0 \,.\, {}^{E_A}/_{R.\,T} \quad (3)$$

After obtaining the constant value of porang chips at each temperature, the calculation of shelf life based on orders 0 and 1 at each storage temperature was performed using Equations 4 and 5.

$$\text{ts} = \frac{N_0 - N_t}{k} \quad (4)$$

$$\text{ts} = \frac{in(N_0 - N_t)}{k} \quad (5)$$

Where A_t=Parameter value of porang chips after storage, A_0=Initial parameter value of porang chips, k= reaction rate constant at storage temperature T, and ts = storage period (days).

Statistical Analysis

This study used the ANOVA statistical test with the assistance of the IBM SPSS Statistic 25 application where the treatment was storage temperature conditions of chips, namely 15 °C, 20 °C, 25 °C, and 30 °C. When there was a significant effect on quality parameter of chips, the study was continued with Duncan's further test to determine the difference between storage temperatures.

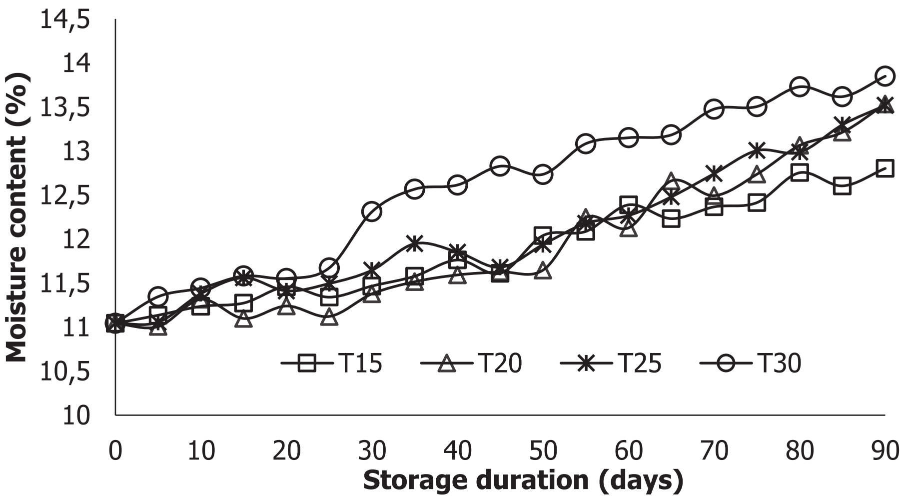


Figure 1. Changes in the moisture content of porang chips at various storage temperatures

RESULTS AND DISCUSSION

Characteristics of Porang Chips

Moisture content

The moisture in porang chips is capable of affecting their shelf life because the high moisture content in a product can be used as a place for the growth and development of microbes. The observation results of the moisture content are shown in Figure 1.

The observation results in Figure 1 show that there was increase in moisture content for 3 months of storage, especially at storage temperature of 30 °C. The hygroscopic nature of porang chips experiences an adsorption process of water vapor from storage environment. The increase in the moisture content of chips during storage is influenced by the permeability of the packaging at certain temperatures and RH conditions. The smaller the permeability value of a package, the lower the ability of water vapor to pass through the packaging, and vice versa. High storage temperatures cause the pores in the packaging to expand, leading to greater moisture absorption from the environment to the product passing through the packaging. Similarly, (Razak et al., 2018) stated that storage temperature has a significant effect on the increase in the moisture content of a product during storage. The product absorbs more water vapor from the environment at higher storage temperatures. The statistical test shows that storage temperature has a significant effect on moisture content during storage

Hardness

The hardness of porang chips needs to be evaluated as an important parameter in determining quality classification. Changes in the hardness are determined with the help of a Force Gauge tool. The hardness observation results during 90 days of storage are shown in Figure 2.

The observation results in Figure 1 show that the hardness value of porang chips at each temperature increases until the end of storage. The increase in value is closely related to the moisture content in the material. The higher moisture content in porang chips creates harder conditions, making it difficult to break. According to Kondo (2023), hardness is one of the properties used to determine the amount of pressure needed to change the shape of a product component. The increase in the hardness value causes a decrease in quality indicated by lower crispness. Hardness increases with increasing temperature in storage room. The higher storage temperature, the greater the increase in hardness, causing the process of water vapor entering storage air through the packaging to chips which is easier. Based on the statistical test, storage temperature has a significant effect on changes in the hardness value of porang chips during storage period (p>0.05). This is because the hardness value is closely related to the increase in the moisture content. Therefore, the higher moisture content of porang chips correlates with hardness value. According to (Amanda et al., 2019), the higher storage temperature can enlarge the pores of the packaging which causes a high permeability value.

Density

Density measurement is carried out to determine the effect of storage temperature on the density value of porang chips during storage. (Rusmono and Zein, 2021) explained that density measurement was an important

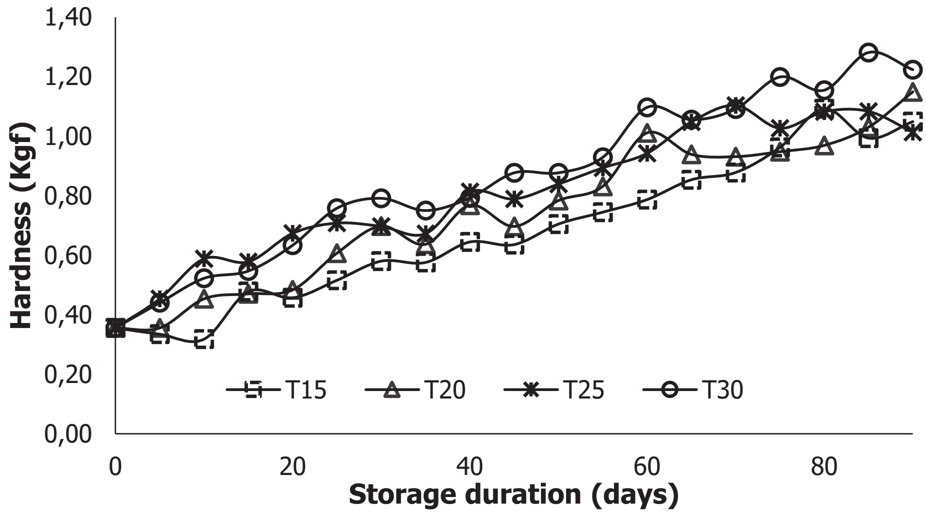


Figure 2. Changes in the hardness of porang chips at various storage temperatures

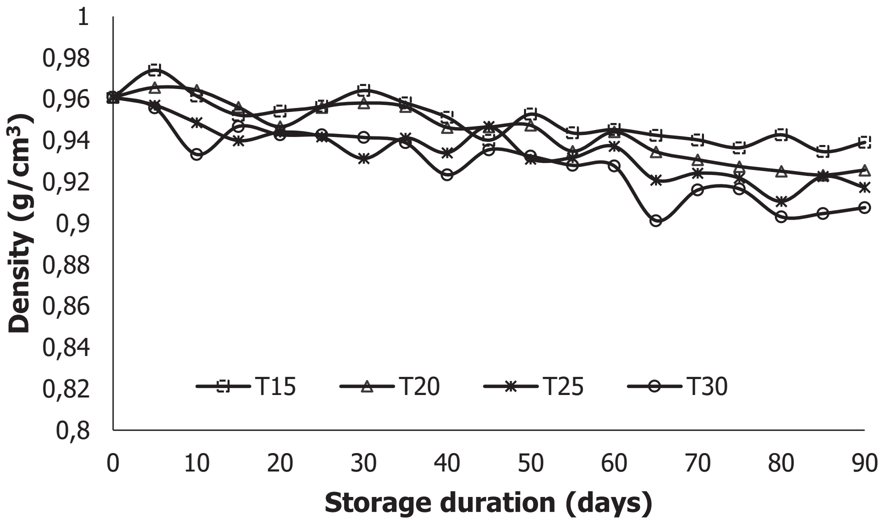


Figure 3. Changes in the density of porang chips at various storage temperatures

physical property of materials for planning the volume of processing equipment and storage warehouses. In this study, density measurement was performed using the waxing method to avoid the moisture absorption process which could cause measurement errors. The observation results for the density of porang chips during storage are shown in Figure 3.

The observation results in Figure 3 show a decrease in chips density along with the length of storage. The density value decreases the most at 30 °C storage. This is related to the moisture content observed, where denser porang chips have lower density. Similar results were shown by Pakhpahan et al (2017) using raw cracker samples with the same initial moisture content producing different density values, where high storage temperatures produced lower density values. This shows an effect of moisture content in the material on changes in the density value. The absorption of moisture in the material can reduce the density of starch polymers, thereby decreasing the density value. Furthermore, a statistical test is carried out to determine the effect of storage temperature and the difference in hardness value produced at each storage temperature. The results show that storage temperature affects the density value as indicated by a significance value of p>0.05. This is supported by (Forsido et al., 2021) with baby food samples where the density value decreased with increasing storage temperature.

Color

Color is one of the important parameters in a food product that is used as a reference in determining

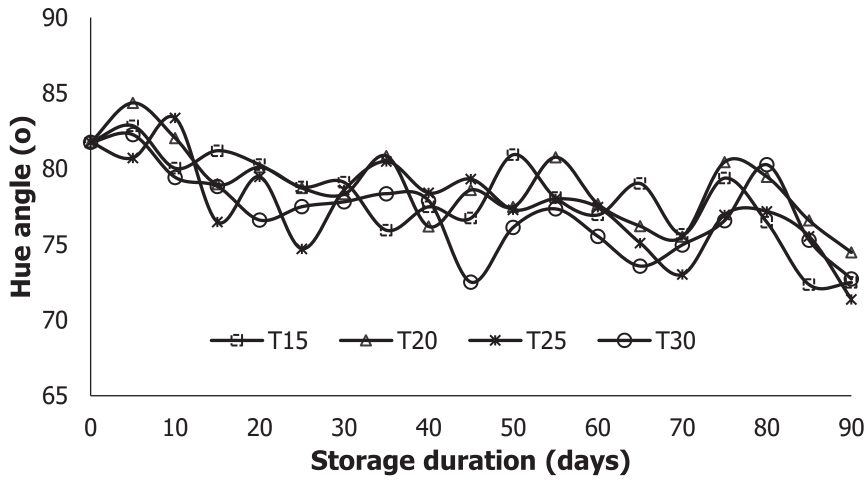


Figure 3. Changes in the color of porang chips at various storage temperatures

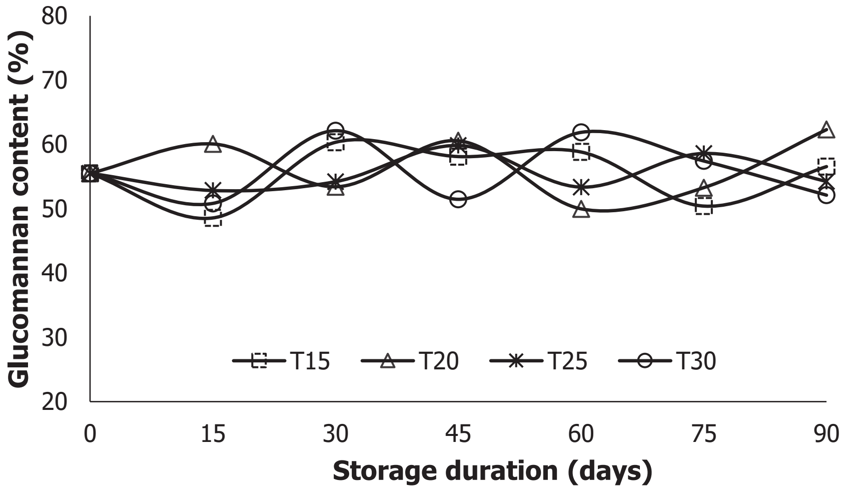


Figure 4. Changes in the glucomannan content of porang chips at various storage temperatures

quality. Therefore, this parameter is expected to be a reference for consumers in purchasing the product (Saragih & Sulaiman, 2019). The color test is performed with a colormeter by analyzing the L* a* b* results using hue angle to determine the color characteristics of porang chips shown in Figure 3.

Figure 3 shows that the results of changes in color at each storage temperature tend to fluctuate, but there is no significant difference from each temperature. This is due to the initial storage condition of porang chips, which have uneven color. Therefore, when data collection, there is a different value from the previous sample, making the data inhomogeneous. Long-term storage of the product causes a decrease in the color of the product due to an oxidation reaction. According to (Paravisini & Peterson, 2018), along with the length of storage, the dark reaction will occur due to an oxidation reaction, inducing non-enzymatic browning which can reduce quality. This is shown by the statistical test where storage temperature does not have a significant effect on changes in the color of porang chips ($p>0.05$).

Glucomannan content

Determination of glucomannan content in porang chips is carried out using the extraction method with ethanol. According to Sari et al., (2019), glucomannan has the highest content in porang at 15 – 64%. The observation results of glucomannan content during 90 days of storage are shown in Figure 4.

The initial glucomannan content is 55.51% and ranges from 50.1% to 63.47% during storage as shown in Figure 4. This is appropriate to quality standard for porang chips SNI 7939:2020 where the glucomannan content is ≥ 35%, 20-<35%, and 15-<20% in quality I, II, and III, respectively. Based on the classification according to SNI, the glucomannan content value falls into quality I. The observation results of the glucomannan content in porang chips fluctuate in all temperature treatments for 90 days of storage. Therefore, storage temperature treatment does not affect the increase or decrease in porang chips. This is in line with (Wardani et al., 2021), where the glucomannan value is only influenced by pretreatment factors such as the drying process, harvest age, and quality of porang tubers. The high and low glucomannan content is caused by several factors, such as the possibility of contaminant mixing during the flour dissolution process when chips are ground. During the solution filtration process, many small particles that might have escaped when weighed before and after the drying process are not counted as glucomannan content and the age of porang plant is uneven. Furthermore, the statistical test shows that storage temperature does not significantly affect changes in the glucomannan content during storage period ($p>0.05$) of 0.811. Since there is no significant effect on glucomannan content, Duncan's further test is not conducted.

Ash content

The determination of ash content in porang chips aims to determine the minerals contained. According to (Afify et al., 2017), the ash content in a product shows the total minerals, comprising the summation of inorganic components in the form of calcium (Ca), potassium (K), and sodium (Na). The ash content test is carried out to determine the effect of storage temperature on the ash content value during storage period, with the results shown in Figure 5.

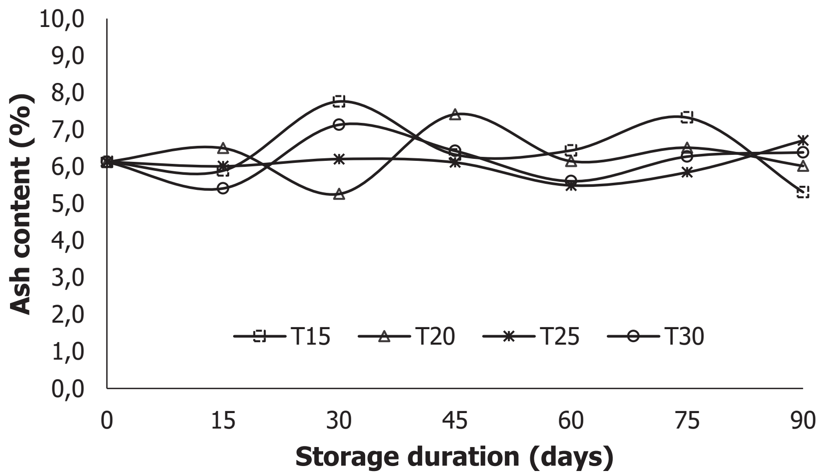


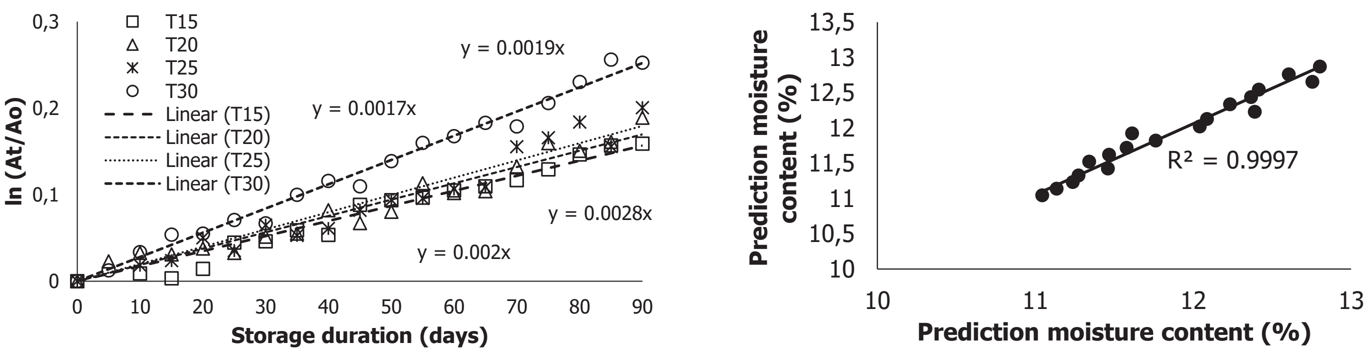
Figure 5. Changes in the ash content of porang chips at various storage temperatures

Based on the observation results in Figure 5, the ash content value of porang chips fluctuates at each temperature during 90 days of storage. The initial value is 6.125% and ranges from 5.01% to 7.69 I during storage. The values obtained are slightly higher than the provisions of SNI 7939-2020, which specifies quality I, II, and III to be ≤ 4%, 4-5%, and 5-6.5%, respectively. The observation results show that storage temperature treatment does not affect the ash content value. This is due to differences in initial treatment during the drying process. The ash content results which tend to fluctuate in all treatment conditions are attributed to the effect of material factors and drying in different initial conditions. This is supported by the statistical test results that show no significant effect of storage temperatures regarding changes in the ash content of porang chips with a significance level of >0.05, namely 0.11.

Kinetic Analysis

Changes in moisture content based on the kinetic

The rate of change in the moisture content of porang chips during storage can be observed based on the order kinetic analysis. Data on changes in moisture content used in the kinetic analysis are measurements obtained from day 0 to the end of storage (day 90). In this context, the change in moisture content during storage will experience a state of equilibrium hence the resulting graph is curved and the kinetic used is order 1 (Figure 6.a). For curves that are difficult to distinguish in terms of graph shape, the coefficient of determination value can be identified by selecting the largest to determine the reaction order used. Furthermore, to determine the accuracy of the equation used, a graph of the relationship between



(a) (b)

Figure 6. (a) Kinetic of changes in moisture content follows order 1, (b) Relationship between predicted and observed moisture content

Table 1. Constant value of changes in the moisture content of porang chips during storage

Storage temperature (°C)	k value
15	0.0017
20	0.0019
25	0.002
30	0.0028

observed and predicted moisture content is made in Figure 6 (b).

The predicted moisture content value of porang chips determined by the kinetic equation is approximately close to the observed value. The graph of the relationship between observed and predicted moisture content in Figure 6 (b) shows a coefficient of determination (R^2) value of 0.9997. This shows that the order selected is correct and can be used properly. From the kinetic analysis results based on moisture content with order 0, the detailed constant value of changes at each storage temperature is shown in Table 1.

Storage temperature has a significant effect on moisture content. This is because higher storage temperature correlates with a faster rate of change

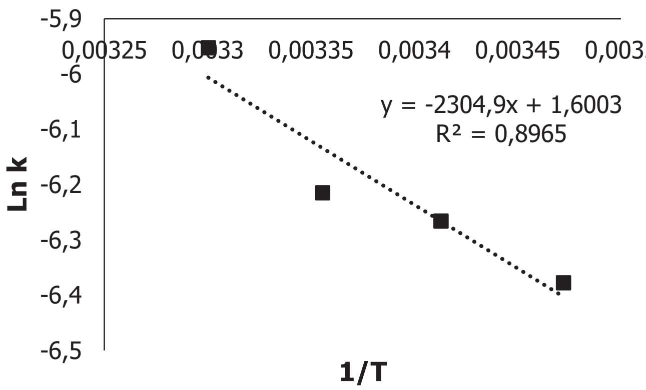


Figure 7. Relationship between Ln k vs 1/T

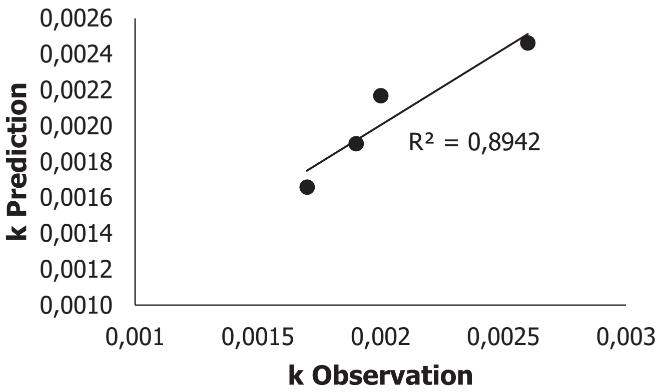


Figure 8. Observation k value vs prediction k value

in moisture content, as shown by the k value. Besides kinetic analysis, Arrhenius modeling also needs to be carried out as a validation test by determining the observed constant for changes in the density of porang chips. In Arrhenius, the Ea (activation energy) and A (collision frequency) values are determined. From these values, the predicted constant for the moisture content can be determined, by initially making a graph of the relationship between lnk vs 1/T, as shown in Figure 7.

The predicted and observed constants obtained have similarities. As presented in Table 2, the largest predicted k value obtained at storage temperature of 30°C is 0.0025 and the lowest is 0.0017 at 15 °C.

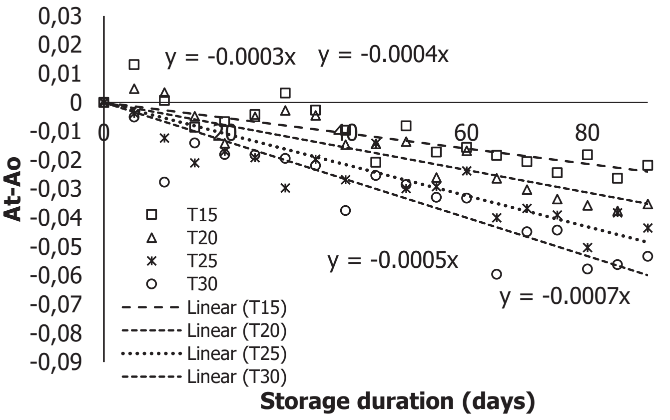
The graph of the relationship between observed and predicted constants (k) in Figure 8 shows a coefficient of determination (R^2) value of 0.8942. This shows that the values of observed and predicted constant have a fairly high level of similarity.

Density change based on the kinetic

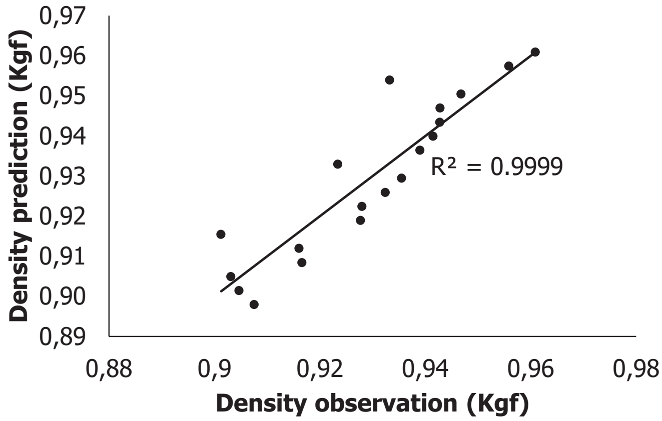
Kinetic analysis was conducted to determine the reaction rate constant of quality changes (k) during storage period (Afify et al., 2017). The order selected for the density parameter is 0 because the coefficient of determination obtained has the largest value or R^2 approaching 1, as shown in Figure 6 (a). Therefore,

Table 2. Ea, A, and constant values predicted for the moisture content of porang chips

Storage Temperature (°C)	Ea (kJ/mol)	A	k
15	19162.9	4.95452	0.0017
20			0.0019
25			0.0022
30			0.0025



(a)



(b)

Figure 6. (a) The kinetic of density change follows order 0 (b) predicted density vs observed density relationship

Table 3. Constant value of density changes of porang chips during storage period

Storage temperature (°C)	K Value
15	0.0003
20	0.0004
25	0.0005
30	0.0007

the predicted density is determined from the previously obtained constant value using Equation 1. A graph of the relationship between the observed and predicted density values is made, as shown in Figure 6 (b).

The observed and predicted density values in Figure (6.b) are approximately close to 1, which is 0.9999. This shows that the predicted density change is appropriate to the observed density. The density change constant at each storage temperature obtained from order 0 graph is shown in Table 3.

The largest density change constant occurred in porang chips stored at 30 °C compared to other storage temperatures, which was 0.0007. The higher

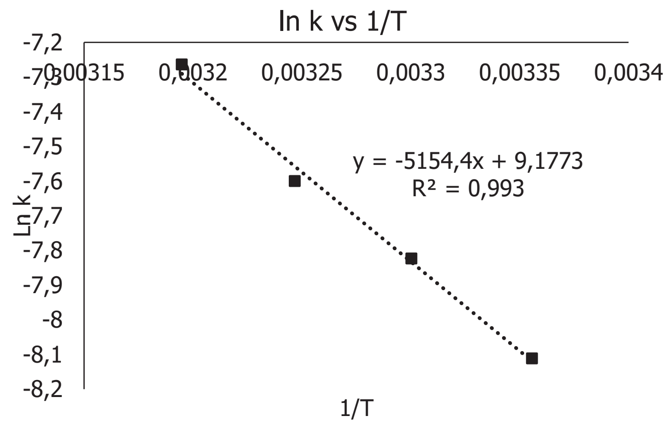


Figure 7. Arrhenius analysis of Ln k vs 1/T on the density of porang chips

the reaction rate constant value shows a greater density change process. In addition to analyzing kinetic, Arrhenius modeling also needs to be carried out as validation tests by determining the observation constant for changes in the density. In Arrhenius, the Ea value (activation energy) and the A value (collision frequency) are determined. From these values the predicted density

Table 4. Values of Ea, A, and prediction constants on porang chips density

Storage temperature (°C)	Ea (kJ/mol)	A	k
15	5154.4	9674.995	0.0003
20			0.0004
25			0.0005
30			0.0007

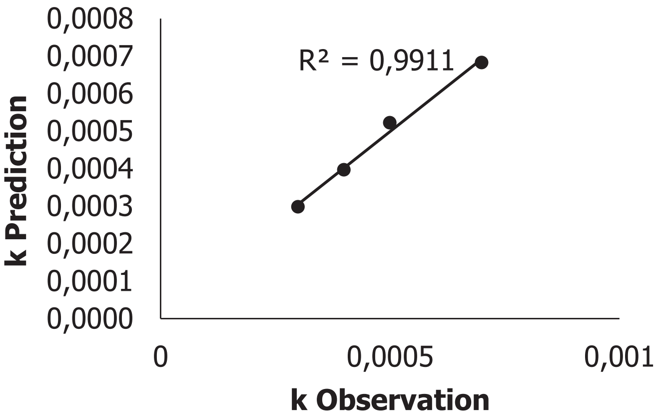


Figure 8. Relationship between k observation vs k prediction

constant of porang chips can be determined (Table 4), where a graph of the relationship between lnk vs 1/T is made, as shown in Figure 7.

The activation energy obtained is 5154.4 cal/mol, where Ea is the minimum energy used to produce quality change reaction (Barus, 2017). The largest predicted k value obtained (Table 4) is shown at storage temperature of 30 °C of 0.0007 and the lowest value of 0.003 is achieved at 15 °C. The predicted k value obtained was compared with the observed k during storage to determine the accuracy.

The relationship between observed and predicted k in Figure 8 produces a coefficient of determination value that is close to 1, namely 0.9911. This shows that the level of similarity of the two factors is approximately close. Therefore, the Arrhenius modeling used for changes in the density of porang chips can be properly performed.

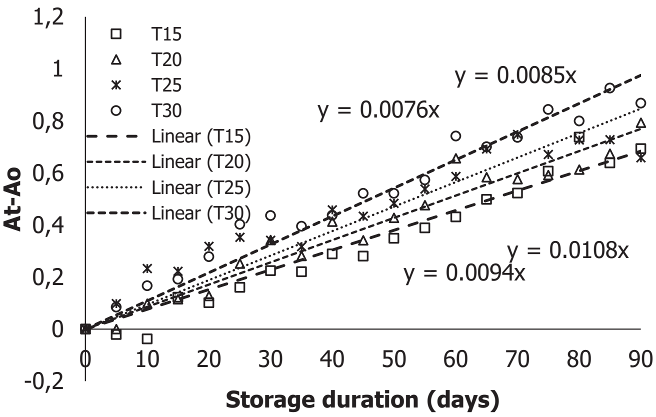
Table 5. Constant value of changes in the hardness of porang chips during storage period

Storage temperature (°C)	K Value
15	0.0076
20	0.0085
25	0.0094
30	0.0108

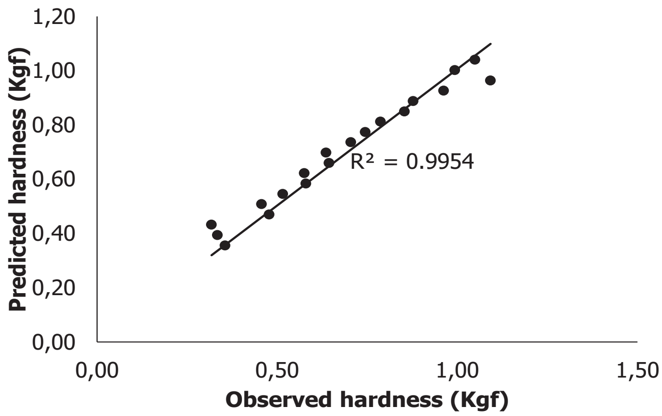
Change in hardness based on the kinetic

The rate of change in the hardness value of porang chips during storage was analyzed using order kinetic. The change data used in this analysis were the measurements from day 0 to 90 of storage. The analysis was used to determine the constant change in porang chips per five days of storage by plotting a graph between At - A0 as the y-axis and storage period (t) as the x-axis for the order 0. ln (A_t / A_0) used as the y-axis against storage period (t) as the x-axis for the order. In the hardness parameter, order 0 was selected because the largest determination coefficient was produced, as shown in Figure 9 (a). To determine the accuracy of the equation used a graph of the relationship between observation and predicted hardness was made in Figure 9 (b).

The predicted hardness value of porang chips determined by the kinetic equation is approximately close to the observation value. The graph of the relationship between observed and predicted hardness in Figure 9 (b) shows a coefficient of determination (R^2) value of 0.9954. This shows that the selection of the



(a)



(b)

Figure 9. (a) The kinetic of hardness change follows zero order, (b) Relationship between predicted and observed hardness

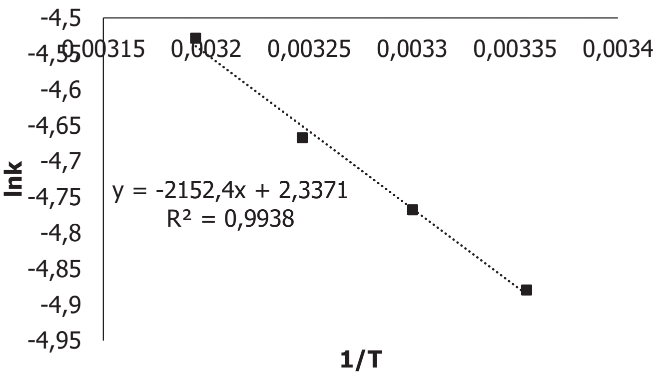


Figure 10. Arrhenius analysis of Ln k vs 1/T on the hardness of porang chips

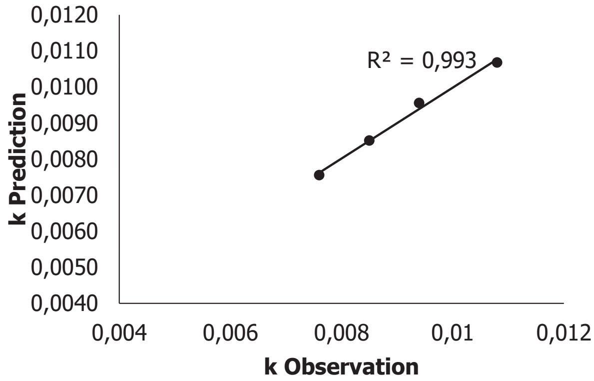


Figure 11. Relationship between k observation vs k prediction

Table 6. Ea, A, and constant values predicted for the hardness of porang chips

Storage temperature (°C)	Ea (kJ/mol)	A	k
15	17895	10.351	0.0076
20			0.0085
25			0.0096
30			0.0107

Table 7. Shelf life of porang chips based on hardness value

Storage temperature	Storage duration (days)
	Critical chips hardness limit (Kgf) = 1.0423
15	386
20	345
25	312
30	271

order used is correct and can be applied appropriately. From the results of the kinetic analysis based on order 0 hardness, the detailed constant changes at each storage temperature are shown in Table 5.

The kinetic of hardness changes in porang chips in Table 5 were carried out using order 0. The k value of observations in storage variations had a significantly large difference during 90 days of storage. Similar to observed k, the largest prediction constant occurred at storage temperature of 30 °C compared to others. The constants that had been obtained were subjected to a validation test to determine the prediction using the Arrhenius equation model by creating a graph of the relationship between lnk and 1/T, as shown in Figure 10.

In Table 6, there are differences in each storage temperature, where the largest constant of 0.0107 occurs at temperature of 30 °C and lowest value of 0.0076 at 15 °C. Furthermore, a graph of the relationship between the observed and predicted k is made and shown in Figure 11 to determine the level of similarity.

The relationship graph between observed and predicted k shows a determination coefficient value (R^2) of 0.993 or close to 1, suggesting a high level of similarity. This shows that the Arrhenius equation can model changes in the hardness of porang chips properly. Therefore, shelf life calculation is carried out using the critical hardness limit of 1.0423 Kgf with Equation (4), as shown in Table 7.

Table 7 shows that higher temperature correlates with shorter shelf life of porang chips. This is because high temperatures can enlarge the pores of the packaging, thereby facilitating the process of water vapor entering the air into the material. Robetson (2010) stated that during storage process, there would be a process of water vapor absorption in the product. This would lead to a decrease in quality, as showed by the product becoming damp or reducing crispiness. Similarly, (Khatiri et al., 2015) stated that higher storage temperature correlated with shorter shelf life. The same condition was also found in the study of palm sugar (Kurniawan et al., 2018) and pineapple (Ali et al., 2022).

Shelf Life Application Based on the Arrhenius Equation

Determining shelf life of porang chips is important to evaluate the consumption limits of a food product by considering its critical parameters. Quality parameters that can be determined are the hardness of chips, susceptible to change during storage. The hardness of a product is closely related to the moisture content contained in the material. Therefore, there is a need to calculate storage period as a reference for the product safety limit and provide good quality assurance. The constant rate of change in predicted hardness and shelf life can be determined using Arrhenius modeling values in Table 5 according to the predetermined temperature range. By using the Ea and A values (Table 6), the predicted k value and shelf life of porang chips are obtained based on the moisture content shown in Table 8.

Table 8. Prediction of shelf life of porang chips at various storage temperatures

Temperature (°C)	k (Pred)	Shelf life of porang chips based on hardness (days)
20	0.0067	439
21	0.0068	428
22	0.0070	418
23	0.0072	407
24	0.0074	398
25	0.0076	388
26	0.0077	379
27	0.0079	370
28	0.0081	361
29	0.0083	353
30	0.0085	344

From the results of the Arrhenius analysis, higher storage temperature caused greater the rate of change constant, leading to a shorter shelf life of chips. The lower shelf life was caused by the increasing moisture content at high storage temperatures. Moreover, the permeability value of the packaging would be greater when stored at high temperatures, making it easier for water vapor to enter porang chips.

CONCLUSION

In conclusion, this study showed that storage temperatures affected the hardness and density parameters. However, there was no significant effect on color parameters, glucomannan content, and ash content of porang chips. The rate of change in moisture content followed order 1, while hardness and density were based on order 0. The results of determining storage period of porang chips based on the hardness parameter showed that at storage temperatures of 15 °C, 20 °C, 25 °C, and 30 °C shelf life was 386, 345, 312, and 271 days, respectively.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this research.

REFERENCES

Afify, A. S., Abdalla, A. A., Elsayed, A., Gamuhay, B., Abu-Khadra, A. S., Hassan, M., Ataalla, M., & Mohamed, A. (2017). Survey on the moisture and ash contents in agricultural commodities in al-rass governorate. *Journal of Agricultural Sciences, 48*(6), 55–62. https://doi.org/10.21608/ajas.1999.5752

Ali, M. M., Hashim, N., Abd Aziz, S., & Lasekan, O. (2022). Shelf life prediction and kinetics of quality changes in pineapple (ananas comosus) varieties at different storage temperatures. *Horticulturae, 8*(11). https://doi.org/10.3390/horticulturae8110992

Amanda, V., Sulaiman, I., & Yunita, D. (2019). Variety of packaging and estimated shelf life of acehnese traditional food (Pliek U). *IOP Conference Series: Materials Science and Engineering*, *536*(1). https://doi.org/10.1088/1757-899X/536/1/012121

Arnanto, D., & Darnawi, D. (2020). Studi pengaruh media penyimpanan benih terhadap viabilitas dan vigoritas tanaman koro pedang (Canavalia Ensiformis). *Jurnal*

Pertanian Agros, 22(2). http://dx.doi.org/10.37159/jpa.v22i2.1127

Engelen, A. (2018). Analisis kekerasan, kadar air, warna dan sifat sensori pada pembuatan keripik daun kelor. *Jounal of Agritech Science, 2*(1). https://doi.org/10.30869/jasc.v2i1.173

Fadhila, D. N., & Rostika. F. (2025). Pengembangan produk kerupuk dengan penambahan limbah cangkakang udang dan daun kelor (Moringa oleifera). *Jurnal Sains dan Teknologi Pangan, 10*(2). https://doi.org/10.63071/gr6s1q42

Forsido, S. F., Welelaw, E., Belachew, T., & Hensel, O. (2021). Effects of storage temperature and packaging material on physico-chemical, microbial, and sensory properties and shelf life of extruded composite baby food flour. *Heliyon, 7*(4). https://doi.org/10.1016/j.heliyon.2021.e06821

Haerunnisa, Fitri. H., & Ricky F. (2023). Potential analysis and mapping of porang plants in international export markets. *jurnal manajemen bisnis, akuntansi dan* keuangan, *2*(1),13-26. https://doi.org/10.55927/jambak.v2i1.4209

Handayani, T., Aziz, Y. S., & Herlinasari, D. (2020). Pembuatan dan uji mutu tepung umbi porang di Kecamatan Ngrayun*. Jurnal MEDFARM: Farmasi dan Kesehatan, 9*(1). https://doi.org/10.48191/medfarm.v9i1.27

Herawati, H. (2008). Penentuan umur simpan produk pangan*. Jurnal Litbang Pertanian, 27*(4). http://dx.doi.org/10.21082/jp3.v37n1.2018.p17-25

Ifmalinda, Krisna, G., & Dinah, C. (2024). Pengaruh suhu pengeringan pada alat pengering tipe rak terhadap mutu tepung porang*. Jurnal Rona Teknik Pertanian, 17*(1). http://dx.doi.org/10.17969/rtp.v17i1.30336

Julianti E. & Mimi, N. (2007). *Teknologi pengemasan.* Sumatera Utara: USU.

Khathir, R., & Apriesti, P. M. (2015). Shelf life estimation of sweet corn based on its total soluble solid by using arrhenius model. *Agritech, 35* (2). https://doi.org/10.22146/agritech.13831

Kurniawan, H., Bintoro, N., & W.K., J. N. (2018). Pendugaan umur simpan gula semut dalam kemasan dengan pendekatan arrhenius (shelflife prediction of palm sugar on packaging using arrhenius equation). *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem*, *6*(1), 93–99. https://doi.org/10.29303/jrpb.v6i1.68

Mubarok. A.Z., & Solisa.V.J. (2020). Karakteristik fisik cookies pada berbagai rasio terigu dengan tepung umbi dahlia dan penambahan margarin*.* J*urnal Teknologi dan Industri Hasil Pertanian, 25*(2). https://doi.org/10.23960/jtihp.v25i2.90-97

Nofrida, R., Abas, Z., & Novia, R. (2021). Pelatihan cara pengolahan pangan yang baik dan pengolahan chip umbi porang di Desa Gondang Kabupaten Lombok Utara*.* J*urnal AbdiMas TPB, 3*(1), 80–84. http://dx.doi.org/10.29303/amtpb.v3i1.71

Pakpahan, N., Kusnandar, F., & Syamsir, E. (2017). Perilaku isoterm sorpsi air dan perubahan fisik kerupuk tapioka pada suhu penyimpanan yang berbeda. *Jurnal Teknologi & Industri Pangan*, *28*(2). https://doi.org/10.6066/jtip.2017.28.2.91

Paravisini, L., & Peterson, D. G. (2018). Role of reactive carbonyl species in non-enzymatic browning of apple juice during storage. *Food Chemistry*, *245*, 1010–1017. https://doi.org/10.1016/j.foodchem.2017.11.071

Rahardjo. B., B. Suratmo., & R. Kushendarti. (1997). Pengukuran volume benda padat berbagai bentuk dengan berdasarkan volume desakan pada bahan curah. *Agritech, 17*(4),13–17. https://doi.org/10.22146/agritech.19339

Ramdan, E. P., Kanny, P. I., Pribadi, E. M., & Budiman, B. (2022). Peranan suhu dan kelembaban selama penyimpanan benih kedelai terhadap daya kecambah dan infeksi patogen tular benih. *Jurnal Agrotek Tropika, 10*(3), 389. https://doi.org/10.23960/jat.v10i3.5136

Razak. N. A., Hamid. N. A., &Abdul. R. S. (2018) Effect of storage temperature on moisture content of encapsulated orthosiphon stamineus spray-dried powder*. AIP Conference Proceedings 2030* (1). http://dx.doi.org/10.1063/1.5066835

Renate, D., Pratama, F., Yuliati, K., & Priyanto, G. (2014). Model kinetika degradasi capsaicin cabai merah giling pada berbagai krenateondisi suhu penyimpanan. Agritech, *34*(3). https://doi.org/10.22146/agritech.9462

Robertson, G. L. (Ed.). (2009). *Food packaging and shelf life: a practical guide*. CRC Press. https://doi.org/10.1201/9781420078459

Saragih, M. R. A., & Sulaiman, I. (2019). Pengaruh kemasan plastik polietilen dan polipropilen terhadap umur simpan abon ikan tongkol (katsuwonus pelamis) dengan menggunakan model arrhenius (effect of polyethylene and polypropylene plastics packaging on the shelf life of tuna fish. *Jurnal Ilmiah Mahasiswa Pertanian Unsyiah, 4*(2), 317–328. http://dx.doi.org/10.17969/jimfp.v4i2.7475

Sari, P. P., Andhika, C. P., & Admiral, E. (2019). Pemberdayaan masyarakat Jembul dengan teknologi tepat guna pengolahan chips porang dalam meningkatkan daya saing. *International Journal of Community Service Learning, 3*(4), 244–251. https://doi.org/10.23887/ijcsl.v3i4.15723

Suharto, Suryanto, Sarana, & Teguh B. S. (2018). Rancangan bangun mesin pencuci umbi porang untuk meningkatkan kinerja pengolahan porang. *Jurnal Teknologi Terapan,* *4*(2). https://jurnal.polindra.ac.id/index.php/jtt/article/view/148

Sundari, D., Almasyhuri, A., & Lamid, A. (2015). Pengaruh proses pemasakan terhadap komposisi zat gizi bahan pangan sumber protein. *Media Litbangkes, 25*(4), 235–242. http://dx.doi.org/10.22435/mpk.v25i4.4590.235-242

Utami, W., Suroto, D., Setyabudi, F., Davinia, A., & Ratri, D. (2025). Effects of mixed yeast fermentation on volatile compounds composition of arabica coffee beans. *agriTECH, 45*(2), 127–138. http://dx.doi.org/10.22146/agritech.87365

Wardani, N. E., Subaidah, W. A., & Muliasari, H. (2021). Ekstraksi dan penetapan kadar glukomanan dari umbi porang (amorphophallus muelleri blume) menggunakan metode DNS. *Jurnal Sains dan Kesehatan, 3*(3), 383–391. https://doi.org/10.25026/jsk.v3i3.574

Wijanarti. S, Galih. A., & Imam. S. (2019). Shelf life determination of pegagan (Centella asiatica) chips using accelerated shelflife testing (ASLT) method. *Jurnal Agroindustrial, 6*(1), 396–404. https://doi.org/10.22146/aij.v6i1.53957

Yuniwati, I., Trianasari, E., & Aldy, B. I. (2021). Program pelatihan pembuatan chip porang berkualitas pada petani umbi porang desa kembiritan. Seminar Nasional Terapan Riset Inovatif (SENTRINOV) Ke-7 ISAS Publishing. https://proceeding.isas.or.id/index.php/sentrinov/article/view/1085