ISOTHERM CURVE MODEL OF PURPLE SWEET POTATO FLOUR (*IPOMOEA BATATAS L*)

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DEPARTMENT OF AGRICULTURAL TECHNOLOGY

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DEPARTMENT OF AGRICULTURAL TECHNOLOGY
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LEMBAR PENGESAHAN

MODEL KURVA ISOTERM TEPUNG UBI JALAR UNGU

(*IPOMOEA BATATAS L*)

Disusun dan diajukan oleh

AMPERIANI
G041 18 1017

Telah dipertahankan dihadapan Panitia Ujian yang dibentuk dalam rangka Penyelesaian Studi Program Sarjana Program Studi Teknik Pertanian Fakultas Pertanian Universitas Hasanuddin pada tanggal 17 Oktober 2022 dan dinyatakan telah memenuhi syarat kelulusan

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Menyatakan dengan ini bahwa skripsi dengan judul Model Kurva Isoternis Tepung Ubi Jalar Ungu (*Ipomoea batatas L*) adalah karya saya sendiri dan tidak melanggar hak cipta pihak lain. Apabila dikemudian hari skripsi karya saya ini membuktikan bahwa sebagian atau keseluruhannya adalah hasil karya orang lain yang saya pergunakan dengan cara melanggar hak cipta pihak lain, maka saya bersedia menerima sanksi.

Makassar, 17 Oktober 2022

Yang Menyatakan,

Amperiani

ABSTRACT

AMPERIANI (G041181017). *Curve Model of Isoterm Sweet Purple Potato Flour (Ipomoea batatas L)*: JUNAEDI MUHIDONG dan IQBAL.

Purple sweet potato is a tuber plant that has many benefits. Utilization that can be done to extend the shelf life of purple sweet potato is by doing the flouring process. To produce purple sweet potato flour with quality during storage. So it is necessary to use an isotherm that functions in a food drying system to determine the equilibrium moisture content. The purpose of this study was to determine the isothermic curve model used to estimate the equilibrium moisture content in relation to the Rh of storage. This method is to store samples of purple sweet potato flour in a desiccator with an Rh interval of 10-80%. Storage is carried out until the sample reaches a state of equilibrium. Parameters of water content and determination of the best model based on the highest R^2. The results showed that the moisture content of a material was influenced by temperature and storage Rh. To determine the best model, it shows that the model that has the highest R^2 value is the Oswin model. The value obtained at a temperature of 30 is 0.953282689 and at a temperature of 40 is 0.955045191. The model with the highest R^2 value indicates that the model is the best and appropriate model that can be used to describe the best water absorption in purple sweet potato flour.

Keywords: *Purple sweet potato, flour,,r and model isoterm.*

BIOGRAPHY

Amperiani, born in Bulukumba, Kel. Bonto Minasa, Kec. Bulukumpa, Kab. Bulukumba, on June 12, 2000, is the child of Mr. Muh. Arfah and Mrs. Musrawati. Born into a humble and down-to-earth family, the author began their education at SDN 280 Bonto Minasa from 2006 to 2012. They continued their junior high school education at SMP Negeri 5 Bulukumba from 2012 to 2015 and then pursued their high school education at SMA Negeri 2 Bulukumba from 2015 to 2018.

Afterward, the author pursued higher education at Hasanuddin University in 2018 and enrolled as a student in the Agricultural Engineering program, the Department of Agricultural Technology, Faculty of Agriculture, with the support of the BIDIKMISI educational scholarship from the government. In addition to their academic pursuits, the author is an active member of the Agricultural Technology Student Association (HIMATEPA UNHAS). They also participated in the Soybean Cultivation Development Program (P3BK) in the Jeneponto Regency, organized by the Ministry of Food Security in collaboration with the Faculty of Agriculture at Hasanuddin University

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1. INTRODUCTION

1.1 Background

The production of root crops, especially in Indonesia, is increasing. Plants that have many benefits for the body, these plants can be used as raw materials for the food industry. There are many types of root crops, one of which is the sweet potato plant. Sweet potato plants are vines that can grow in all weather, both in mountainous and coastal areas. In addition to the tubers that can be utilized, sweet potato leaves can be processed into delicious vegetables. There are many common sweet potato varieties and purple sweet potato (Ipomoea batatas L) is one of them. The characteristic of this sweet potato is its purple color, making it very easy to recognize. Purple sweet potatoes contain carbohydrates, vitamins, fiber, anthocyanins, and other substances the human body needs.

Purple sweet potato is a food raw material and can be processed into food. Examples of food products include traditional cakes, baby food, sweet potato chips, flour, and other food ingredients. However, the processing of purple sweet potato is still very limited. Storage is still done simply. For example, purple sweet potatoes stored indoors can allow microorganisms to multiply and cause damage. Based on references from previous research (Kusmiah et al., 2015) said that a product stored in a place that has high humidity will affect the growth of microorganisms more quickly. To overcome these problems and extend the shelf life of purple sweet potatoes, flour processing can be done.

To produce purple sweet potato flour with good quality during the storage period. It is necessary to use isotherms that function in food drying systems to determine their equilibrium moisture content. Especially in predicting the estimation of food equilibrium moisture content. Based on references from previous research (Setiaboama et al., 2020) stated that isotherms can be used to determine the shelf life of a food ingredient which can be known from the water activity and equilibrium water content contained in a food ingredient.

Based on the description above, the purpose of this research is to determine the water sorption isotherm curve of purple sweet potato flour and predict it using various mathematical models.

1.2 Objectives and Uses

The objective of this research is to determine the isotherm curve model used to predict the equilibrium moisture content about the relative humidity (RH) of the storage environment for purple sweet potato flour. The utility of this research is to serve as a reference for modeling purple sweet potatoes and provide information for the production of purple sweet potato flour.

2. LITERATURE REVIEW

2.1 Purple Sweet Potato

In addition to staple foods like rice, wheat, and legumes, one of the food crops that has many uses for the body and is popular among many communities is tuberous plants. Furthermore, tuberous plants grow easily in both tropical and subtropical regions. Some examples of tuberous plants include potatoes, cassava, radishes, and sweet potatoes, all of which have many nutrients and benefits in their tubers.

One such tuberous plant commonly found and easily grown everywhere is the sweet potato. The production of sweet potatoes is widely used as a food source, and it can also be used as animal feed and as a raw material for various industries. Sweet potatoes are rich in complete nutrition. There are also various colors of sweet potatoes, including white, yellow, light purple, and purple. The different colors of sweet potato flesh indicate their unique nutritional characteristics and bioactive components (Rosidah, 2014).

Figure 2-1. Purple Sweet Potato
Source: (Fatimatuzahro et al., 2019).

The classification of purple sweet potatoes (Ipomoea batatas L) according to Arniati, 2019:

Kingdom	: Plantae
Sub Kingdom	: Tracheobionta
Super Division	: Spermatophyta
Division	: Magnoliophyta
Class	: Magnoliopsida
Subclass	: Asteridae

Order	: Solanes
Family	: Convolvulaceae
Genus	: Ipomoea
Species	: Ipomoea batatas (L) Lamk.

The community's need to fulfill its food requirements can be met by utilizing these tuberous plants. One of the sweet potatoes that most people highly favor is the purple sweet potato. Purple sweet potatoes have a distinctive color and are easily recognizable, containing a wealth of nutrients that are highly beneficial to the body. Generally, purple sweet potatoes are sold and can be consumed directly. However, if purple sweet potatoes are stored at room temperature for too long, they can rot, causing harm. Damage to the fruit can occur due to delayed storage, storage that is too long or too short, and uneven storage, leading to a decrease in the quality and overall quality of the product (Arniati, 2019).

2.2 Content of Purple Sweet Potato

The distinctive color of purple sweet potatoes is due to the presence of a natural compound called anthocyanin. Purple sweet potatoes have a higher content of anthocyanin compared to other sweet potatoes. The presence of anthocyanin contributes to the reddish color. Anthocyanin compounds play a role in preventing aging, reducing the risk of cancer, and treating conditions like gout, diabetes, and other degenerative diseases. The advantage of having anthocyanin compounds in purple sweet potatoes makes them a highly attractive food source. Given that people prioritize a healthy lifestyle, they should pay attention to the physical quality of this food source. The unique color of purple sweet potatoes is particularly appealing to consumers for culinary purposes. Additionally, sweet potato leaves can be used as a traditional remedy for conditions such as boils or itching (Husna et al., 2013).

To maintain the distinctive color of purple sweet potatoes, proper processing is necessary to preserve the anthocyanin compounds for an extended period. Anthocyanin is a pigment that lowers blood cholesterol levels. However, the anthocyanin content in purple sweet potatoes is influenced by pH, temperature, light, oxygen, and metal ions. Furthermore, processing purple sweet potatoes by methods such as frying or boiling with oil can reduce other nutritional elements like ascorbate, anthocyanin, and beta-carotene contained in the sweet potatoes (Wahyuni et al., 2018).

2.3 Purple Sweet Potato Flour

Purple sweet potatoes, which can be used as a food source, can also be processed into flour and utilized in various other industries. The processing of purple sweet potatoes into flour can be done manually or by using a flour milling machine. Manual processing involves thinly slicing and grinding the sweet potatoes before drying them to obtain the characteristic color of purple sweet potatoes. The purpose of milling is to extend the shelf life of purple sweet potatoes while preserving the compounds found in purple sweet potatoes. This makes them practical for further food processing (Arniati, 2019).

Processing purple sweet potatoes into flour is one of the alternatives that can have a significant impact on the food industry and reduce the community's dependence on imported flour products. Additionally, purple sweet potato flour has many health benefits due to the sugar content in purple sweet potatoes, which reduces the need for additional sugar during processing. In other countries, the economic value of purple sweet potato flour products is higher than wheat flour. This has a significant impact on farmers who cultivate purple sweet potatoes (Santosa et al., 2016).

When the processing of purple sweet potatoes into flour is done correctly, it results in the highest quality flour. If the process follows the Indonesian national standards, the quality of the flour matches the color of the raw material. However, if not handled properly, the quality of the flour produced can be dark or brown. Storage is also a crucial factor that significantly affects the final product. High humidity in storage areas can lead to the absorption of moisture by the material, making it susceptible to mold growth (Kusmiah et al., 2015).

Nevertheless, the most critical stage in processing flour is storage because it greatly influences the quality of the final product. Flour production in small and medium-sized enterprises nowadays may not always meet the Indonesian National Standard (SNI), as it may not achieve safe moisture levels during storage to prevent microbial growth, and the packaging and storage conditions may not be suitable.

To ensure physicochemical quality, proper handling, safe storage humidity, suitable packaging, and appropriate storage conditions are necessary to extend the shelf life of the flour (Wibisono et al., 2019)

Table 2-1. Quality Requirements for Purple Sweet Potato Flour (SNI 01-3751-2000)

No.	Chemical Component	Unit	Content ± sd
1.	Water	%	10,92 ± 0,09
2.	Protein	%	6,44 ± 0,27
3.	Fat	%	0,61 ± 0,06
4.	Ash	%	2,58 ± 0,01
5.	Carbohydrates	%	90,37 ± 0,00
6.	Strach	%	74,54 ± 0,32
7.	Amylose	%	24,79 ± 0,94
8.	Reducing Sugar	%	3,15 ± 0,30
9.	Crude Fiber	%	2,40 ± 0,35

Source: SNI 01-3751 (2000)

Kadar air tepung ubi jalar ungu cukup rendah (10,92%), hal ini menandakan bahwa kondisi tepung cukup kering sehingga kualitasnya baik. Kadar air tepung ubi jalar ungu memenuhi syarat mutu tepung yang ditetapkan SNI 01-3751- 2000 dan SNI 01-2997-1992 untuk tepung terigu dan tepung singkong sebesar berturut-turut 14,5 dan 12% (Nindyarani dkk., 2011).

2.4 Isoterm Model

The shelf life determines the quality of a food ingredient, especially in flour, which is characterized by taste and odor that are still acceptable to consumers. A food ingredient can last long if processing and storage are done correctly. Appropriate storage conditions can be determined from sorption isotherms and proper food product packaging design. Sorption isotherms can be used as an essential parameter in studying the storage behavior of a substance. Sorption isotherms can be used to determine the shelf life of a food ingredient, which can be determined from water activity and equilibrium moisture content in a food ingredient (Soleimanifard and Naser, 2018).

In determining the isotherm curve, data on sample weight until reaching a constant state is needed. A sample can be considered constant when there is no evaporation process occurring on the surface of the substance or when there is no weight loss in the sample (Musdalifah, 2012).

The water sorption isotherm can be represented as an isotherm curve by connecting the water activity and equilibrium moisture content of food products under certain storage conditions at specific relative humidity and temperature values (Rukmawati et al., 2017)

2.4.1 Water Activity

The spoilage of food ingredients is generally a microbiological, chemical, and enzymatic process or a combination of these processes. All three of these processes require water, and it is known that only free water can facilitate these processes.

The moisture content in agricultural materials will affect their resistance to microbial attack and is usually expressed as "water activity" (Aw), which refers to the amount of free water in a substance that can be used by microbes for their growth. To extend the shelf life of a substance, some of the moisture content is removed to reach a specific moisture content (Winarno, 1984).

Microbes can only grow within a certain range of water activity; therefore, to prevent microbial growth, the water activity of a substance must be controlled. Food materials with water activity below 0.70 are generally considered good and resistant to spoilage during storage (Sri Setijahartini, 1980).

Water activity plays a crucial role in storage. The water activity value can be calculated using one of the two formulas below:

$$\mathrm{Aw} = \frac{\mathrm{P}}{\mathrm{P0}} = \frac{\mathrm{E.R.H}}{100} \quad (1)$$

Where,

Aw = Water Activity.

P = Vapor Pressure of Water from the Food Material.

P_0 = Saturated Vapor Pressure at the Same temperature.

E.R.H = Equilibrium Relative Humidity.

Using Raoult’s law,

$$\mathrm{Aw} = \frac{\mathrm{Mw}}{(\mathrm{Mw}+\mathrm{Ms})} \quad (2)$$

Where,

Mw = Number of Moleses water

Ms = Number of Moles Solute

From the first formula, water activity can be directly determined by measuring the equilibrium relative humidity using various types of hygrometers or by determining the dew point and subsequently finding the equilibrium relative humidity using a psychrometric chart. Additionally, it can be calculated by measuring the vapor pressure of water from the food material monometrically. The use of Raoult's law for determining water activity is particularly suitable, especially in formulations for producing food ingredients (Adnan, 1980).

When agricultural products are placed in the open air, their moisture content will reach equilibrium with the surrounding air's humidity (equilibrium moisture content). Each relative humidity can produce a specific equilibrium moisture content. Thus, a curve can be created that connects the relative humidity and equilibrium moisture content.

The value of water activity (Aw) is equal to the relative humidity divided by 100. Therefore, a curve connecting a specific relative humidity with the equilibrium moisture content essentially also represents the relationship between the moisture content and water activity. This curve is called the Moisture Sorption Isotherm (Moisture Sorption Isotherm) (Taib et al., 1988).

The water sorption isotherm of food materials covers the adsorption and desorption processes of water molecules at a constant temperature. The adsorption process involves the mobility of water molecules from a free state to a bound state within the substance. On the other hand, the desorption process involves the mobility of water molecules from a bound state to a free state (Taib et al., 1988).

2.4.2 Equilibrium Moisture Content and Humidity

Wet substances in a drying apparatus will experience evaporation over their entire surface. At some point, this evaporation will stop because the number of water molecules not absorbed from the substance is equal to the number of water molecules absorbed by the surface of the wet substance. This condition is called the equilibrium between evaporation and condensation. The moisture content of the substance in this equilibrium state is called the equilibrium moisture content (Equilibrium Moisture Content). This equilibrium occurs at a specific temperature and is determined by a specific relative humidity as well.

The equilibrium moisture content of a substance can be defined as the minimum moisture content that can be dried under constant drying conditions or at a constant temperature and relative humidity. The equilibrium moisture content can also be defined as a state where there is no longer an exchange of water vapor between the substance and the air, and the product no longer undergoes changes or additions in weight. The moisture content in food ingredients affects their resistance to microbial attack, expressed as water activity. Dry materials with moisture content lower than the equilibrium moisture content will absorb water to reach equilibrium. On the other hand, wet materials with a moisture content higher than the equilibrium moisture content will evaporate water to reach equilibrium (Taib et al., 1987).

Air humidity affects the movement of liquid from inside to the surface of a substance. When the vapor pressure difference between the liquid inside the substance and the vapor outside the substance is small, the movement of the liquid is minimal. Vapor pressure depends on air humidity (Taib et al., 1987).

Humidity is the concentration of water vapor in the air. This concentration can be expressed in absolute humidity, specific humidity, or relative humidity. The instrument used to measure humidity is called a hygrometer. There are two types of air humidity: absolute humidity and relative humidity. Absolute humidity is a number that indicates the amount of water vapor in grams per cubic meter of air. The relative humidity is a percentage that indicates the ratio between the actual amount of water vapor contained in the air at a specific temperature and the maximum amount of water vapor the air can hold (Taib et al., 1987).

2.4.2.1 Humidity ratio

Humidity ratio is defined as the ratio of the mass of water vapor (Ww) to the mass of dry air (Wa). To calculate the humidity ratio, the ideal gas equation is used. Air is considered an ideal gas because its temperature is higher than its saturation temperature, and water vapor is considered an ideal gas because its pressure is relatively low compared to its saturation pressure.

$$p_w v \left(\frac{W_w}{M_w}\right) R_0 T_{ab} \tag{3}$$

$$an p_a v \left(\frac{W_a}{M_a}\right) R_0 T_{ab} \tag{4}$$

p_w = vapor pressure of water (Pa)

p_a = vapor pressure of dry air (Pa)

V = volume (m^3)

w_a = mass of air dry (Kg)

w_w = mass of water vapor (Kg)

T_{ab} = temperature (^oK)

R_0 = gasconstant (Nm/kg mol K)

M_a = molar mass of dry air (kg/mol)

M_w = molar mass of water (kg/mol)

According to Dalton's law of partial pressures, the total pressure is the sum of the vapor pressure of water (Pw) and the vapor pressure of dry air (Pa). This can be represented by the formula:

$$P = P_a + P_w \tag{5}$$

Keterangan:

P = Total pressure (Pa)

Pa = Vapor pressure of air dry (Pa)

Pw = Vapoe pressure of water (Pa)

Equation 3 is subtitude with Equations 1 and 2, resulting in:

$$(P - P_a)\, V = \left(\frac{W_w}{M_w}\right) R_0 T_{ab} \tag{6}$$

$$an(P - P_w)\, V = \left(\frac{W_a}{M_a}\right) R_0 T_{ab} \tag{7}$$

Based on the definition, the humidity ratio is denoted by H, so the equations becomes:

$$H = \frac{W_w}{W_a} \tag{8}$$

Where,

H = Humidity ratio (Kg water vapor/ Kg dry air)

Ww = Mass of water vapor (Kg water vapor)

Wa = Mass of dry air (Kg of air)

By substituting Equations 6 with Equations 4 and 5, Equation 6 becomes:

$$H = \frac{W_w}{W_a}$$

$$\text{the } = \frac{M_w}{M_a}\left(\frac{P-P_w}{P-P_a}\right)$$

$$= \frac{M_w}{M_a}\left(\frac{P-P_w}{P(P-P_w)}\right)$$

$$\text{the } = \frac{M_w}{M_a}\left(\frac{P_w}{P-P_w}\right)$$

(9)

The value $\frac{M_w}{M_a}$ is 0,622, so the humidity ratio equation becomes

$$H = 0{,}622\,\frac{P_w}{P-P_w} \tag{10}$$

H = Humidity ratio (Kg of water vapor / Kg of air)

P_w = Partial pressure of water vapor (Pa)

P = Total pressure (Pa)

2.4.2.2 Relative Humidity

In this case, the following formula can be used:

$$Rh = \frac{P(t)}{Ps(t)} \tag{11}$$

Where,

RH = Relative humidity (%)

P(t) = Partial pressure of water vapor at temperature T (atm)

Ps(t) = Saturation vapor pressure at temperature T (atm)

Relative humidity is expressed in percentage. Relative humidity is required to determine the air's capacity to absorb water during dehydration because air can only hold a certain amount of water, which will saturate the air. Air is said to be saturated with water vapor when its humidity is at its maximum at a specific pressure and temperature. If additional water is added to saturate the air, it must be added in the form of mist (Taib et al., 1988).

Vapor pressure is the partial pressure provided by a vapor in humid air. The pressure exerted by air when it is fully saturated with water vapor is called saturated vapor pressure, denoted as *Ps*. Isotherm sorption lines are obtained by heating material at a constant temperature. If the isotherm lines are obtained by cooling the material at a constant temperature, the two lines converge. This convergence from normal conditions is called the isotherm sorption hysteresis phenomenon, which can occur at H=0 or 0<H<100%. Storage starting from H=0 to H=100 is called total storage, while storage along part of the isotherm sorption lines is called partial or partial storage. In the H=100% region, it is technically difficult to determine the equilibrium moisture content because it is challenging to achieve at H=0% with complete drying (Taib dkk, 1988).

Water activity is the primary factor determining whether a product is suitable for marketing because excessive water activity in food will lead to microbial growth and significantly affect the food's physical and chemical properties during storage. Additionally, samples stored in a location with low relative humidity will lose weight, while those with high relative humidity will gain weight. The increase and decrease in sample weight indicate a characteristic hydration phenomenon. Hydration characteristics can be defined as physical characteristics that include interactions between food components and water molecules in the surrounding air. The interaction of water molecules with the sample is the result of differences in the sample's relative humidity and the environment. The transfer of water vapor from the environment to the sample occurs during specific storage conditions until equilibrium is reached (Syafief and Halid, 1993).

Temperature and humidity greatly affect the shelf life of food. Increasing the temperature during storage accelerates the reduction of moisture content. The higher the storage temperature, the lower the humidity. Conversely, lower humidity leads to higher humidity in storage. Water activity levels below 0.6 preserve products well during storage because the remaining water is insufficient to support enzyme activity or microbial growth. Water activity levels above 0.6 can support microbial growth due to excess moisture in the product (Aini et al., 2017).

Therefore, one way to determine the estimation of shelf life and equilibrium moisture content of a food product is to use modeling of the sorption isotherm curve. There are several mathematical models for the isotherm curve:

Table 2-2. Mathematical Models for the Sorption Isotherm Curve

No.	Kurva Isoterm Model Name	Model	Equation no
1.	Henderson (Henderson 1952)	$w = A[-\ln(1 - a_w)]^2$	(11)

2.	Oswin (Oswin 1946)	$w = A\left[\frac{a_w}{(1-a_w)}\right]^B$	(12)
3.	Chung and Pfost (Chung & Pfost 1967)	$w = A + B\ln(-\ln a_w)$	(13)
4.	BET (Brunaue et al. 1940)	$w\frac{w_m C a_w}{(1-a_w)\,(1-a_w+Ca_w)}$	(14)
5.	GAB (Guggenheim Anderson de-boer. 1966)	$w\frac{A\,B\,C\,a_w}{(1-C)\,(1-Ca_w+B\,Ca_w)}$	(15)
6.	Hasley (Hasley 1948)	$w\frac{-A}{(T\ln a_w)}$	(16)
7.	Smith (Smith 1947)	$w = A + B\log(1-a_w)$	(17)
8.	Anderson (Anderson 1946)	$w\frac{\mathrm{AB}Ca_w}{1+(\mathrm{B}-2)Ca_w+(1-\mathrm{B})C^2a_w}$	(18)
9.	Kuhn (Kuhn 1964)	$w = \left(\frac{A}{\ln a_w}\right) + \mathrm{B}$	(19)

(Source: Soleimanifard dan Naser, 2018)

Where,

A, B, C,		= Isotherm sorption model constant
Aw		= Water activity/Rh (%)
W		=Dry basis weight (%).

Each of these models has its suitability, and they can be applied to analyze experimental data. Several models, including BET, Hasley, Henderson, Oswin, Smith, Kuhn, Chung, and Pfost, have been adopted as standard equations by The American Society of Agricultural Engineers (ASAE) to describe adsorption isotherms (Hawa et al., 2020).

The Henderson model was the first empirical model proposed in 1952. The model has two constants, A and B. The Henderson model is typically used to characterize three local isotherms, indicating that each can represent a specific type of water binder (Hawa et al., 2020).

The Chung and Pfost model was first proposed in 1967 based on assumptions about how energy changes for moisture absorption are related to moisture content. However, the Chung and Pfost model cannot be used to predict the effect of temperature because the use of the temperature term (T) does not eliminate the temperature dependence of constants a and b (Hawa et al., 2020).

The Oswin, Kunh, Chung, and Pfost, Hasley Chen-Clayton, Henderson, and Caurie models are capable of describing the sorption isotherm curves in dry products. These equation models are used because previous research has shown that they can depict the sorption isotherm curve over a wide range of water activity values. In contrast, the GAB model is used for testing accuracy because it is commonly used for products with a fairly large range of water activity values (-0.9). However, the flour products used in this study are predicted to have relatively low water activity values due to their low moisture content (Sugiyono et al., 2011).

3. RESEARCH METHODS

3.1 Time and Place

This research was conducted in June-August 2022, at the Processing Laboratory, Agricultural Engineering Study Programme, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, Makassar.

3.2 Tools and Materials

The tools used in the research are digital scales, cutter, blender, knife, camera, aluminum foil, thermometer, sieve and 12 desiccators, each of which is stored at 30 ℃ and 40 ℃ containing NaOH, MgCl2, K2CO3, NaNO2, KCL, and NaCl salt solutions which have a Rh interval of about 10-80%.

The material used in the research is purple sweet potato (Ipomoea batatas L).

3.3 Research Procedure

The research procedures that will be carried out are as follows

3.3.1 Material preparation stage

a. Prepare the purple sweet potato to be studied.
b. Peeling the skin of the purple sweet potato using a knife (cutter).
c. Wash the peeled purple sweet potato using clean water to remove dirt on the purple sweet potato.
d. Slicing small samples of purple sweet potato using a cutting knife.
e. Soaking the sliced purple sweet potato to remove the sap on the purple sweet potato.
f. Draining the soaked purple sweet potato to be put in the oven.

3.3.2 Storage Process

a. Prepare the purple sweet potato slices to be oven-dried.
b. Putting the dried samples into the oven at 60℃ for 4 hours..

3.3.3 Pressing Procedure

a. Prepare the dried ingredients to be made into flour.
b. Puree the purple sweet potato sample using a blender.
c. Sifting the purple sweet potato flour sample with an 80 mesh sieve.
d. Putting the purple sweet potato flour sample into a container with a weight (sample + container) of about 10 grams.
e. Putting every 2 pieces of aluminum foil that have been filled with purple sweet potato flour samples to be stored in a desiccator with Rh and using a fixed temperature of 30 °C and 40 °C.
f. Weighing each sample manually using digital scales after storage for a certain time.
g. Removing the sample from the desiccator after the sample weight is constant.
h. Putting the material for 72 hours at a temperature of 105 °C into the oven to get the solid weight of the sample used in the calculation of equilibrium water content.
i. Calculating the moisture content of the sample.

3.4 Observation Parameters

The parameters that will be observed in this study are knowing the Rh storage space and the weight of the sample during the storage period in the desiccator which will be used as the basis for calculating Kabb and Kabk as well as in testing the isotherm model that will be used in data processing. There are several parameters used:

a. Moisture Content

A moisture content can be obtained by putting the sample into an oven with a temperature of 105 °C for 72 hours to obtain dry weight. According to Erviani (2012), the moisture content of a material is usually expressed in the percentage of wet material weight and dry material weight. The percentage of water content is calculated using the following equation:

Dry basis moisture content (Ka_{bk})

$$Ka_{bk} = \frac{W_0 - W_n}{W_n} \times 100\% \qquad (20)$$

Where

Ka_{bk} = Dry basis moisture content (%).

W_0 = Initial weight (gram).

W_n = Dry weight (gram).

Wet basis moisture content (Ka_{bb})

$$Ka_{bb} = \frac{W_0 - W_n}{W_0} \times 100\% \quad (21)$$

Where

Ka_{bb} = Wet basis moisture content (%).

W_0 = Initial weight (gram).

W_n = Dry weight (gram).

b. Isotherm Model Testing

For sorption isotherm modeling, the dry weight of the sample will be used as the basis for model testing calculations. Experimental data using 3 mathematical models namely Oswin, Kuhn, Chung and Pfost models. This follows the opinion of (Soleimanfard and Hamndani, 2018) saying that several models have been proposed for the dependence between equilibrium moisture content and water activity. Model testing using

1) Henderson Model, Equation (11)
2) Oswin Model, Equation (12)
3) Chung and Pfost Model, Equation (13)

c. Determination of the Best Model

The isotherm model is obtained by finding the constants a and b. Determining the value of constants a and b can be done using MS. Excel Solver. Input data to be entered into the solver to calculate the model constants are the Kabk and a_w values obtained from observations. Excel Solver will automatically find the value of the constants in the tested isotherm model. The R2 value is obtained from data analysis using MS Excel Solver. So it can be determined that the model that is considered the best is the model that has the largest R2 value.

3.6 Research Flow Chart

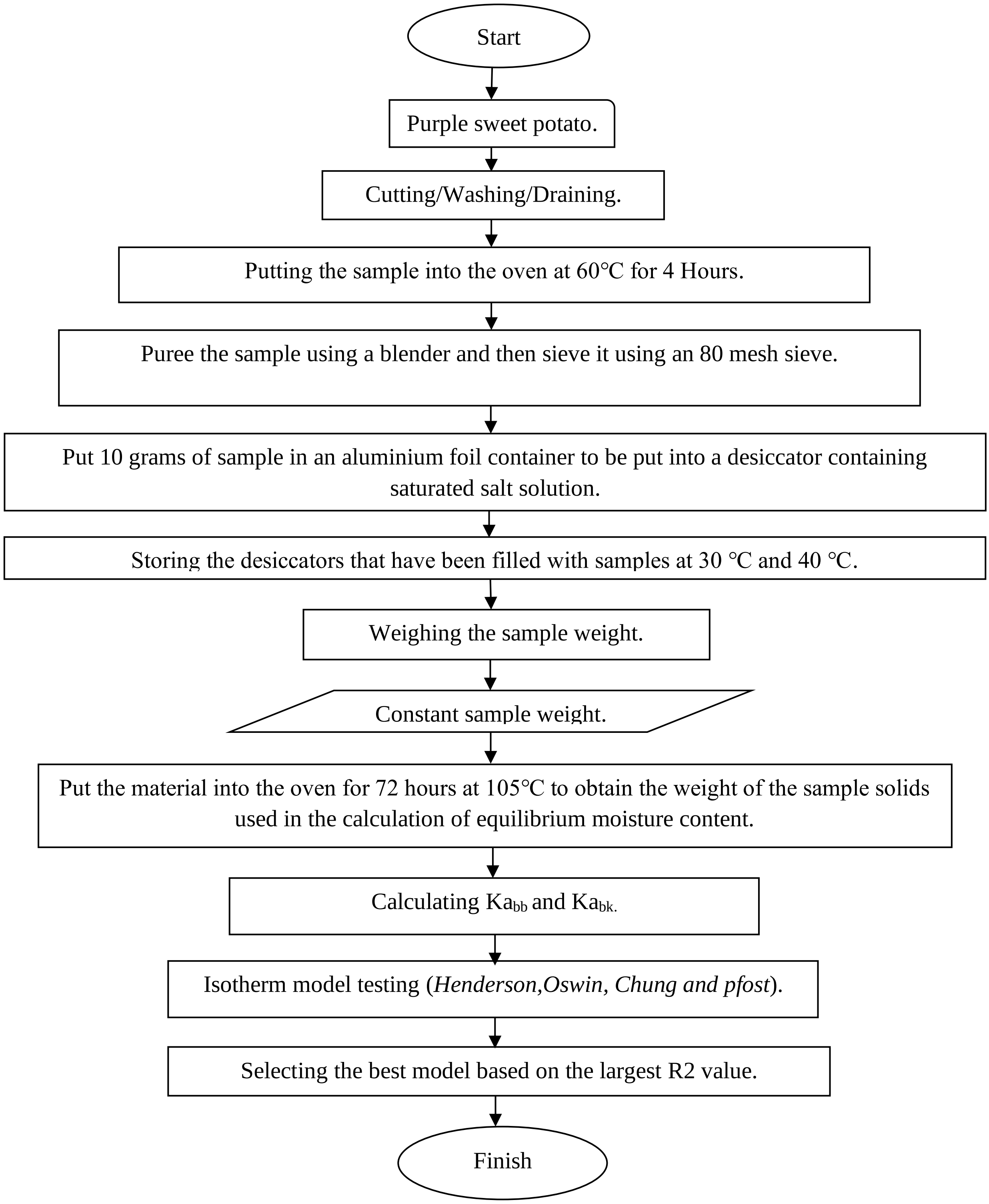


Figure 3-2. Research Flow Chart.

4. RESULTS AND DISCUSSION

4.1 Effects of Temperature and Rh on Water Content

In determining moisture content, measurements can be made using the oven method and expressed in % dry weight (%bk). Then it can be continued with the determination of the isothermic curve which is described by connecting water activity and equilibrium moisture content under a storage condition with a certain relative humidity value . The salt used consists of 6 types of saturated salt, namely NaOH, MgCl 2, K 2 CO_3, NaNO $_2$, KCl, NaCl. With an Rh range between 10-80%. The samples were kept at 2 temperatures of 30 °C and 40 °C with different salt and Rh solutions respectively. Storage is carried out until the sample reaches a balanced state characterized by the result of constant weighing. Based on references from previous research, Musdalifah (2012), said that the condition of constant sample moisture content is a condition where the moisture content of the sample no longer occurs evaporation process on the surface of the material or there is no decrease in weight in the sample. The following is the result of measuring the moisture content of purple sweet potatoes during storage using 2 temperatures, namely 30°C and 40 °C.

Table 4-3. The result of measuring moisture content before storage.

Solution	**Average rating**			
	Ka_{bb}		**Ka_{bk}**	
	Temperature 30 °C	**Temperature 40°C**	**Temperature 30 °C**	**Temperature 40°C**
NaOH	6,764707145	6,655959173	7,255522453	7,130651019
MgCl	6,705194371	6,668426126	7,187105403	7,145344495
K_2CO_3	6,523898689	6,766686158	6,979225648	7,257803469
NaNO:$_2$	6,468005054	6,443947167	6,915290357	6,88779326
Nacl	6,637909062	6,987804119	7,114132189	7,526444141
Kcl	6,333063958	6,67600013	6,761573502	7,386771295
Total	**6.572129713**	**6.699803812**	**7.035474925**	**7.222467947**

Table 4-4. Measurement Results (Ka_{bb}) of purple sweet potato flour.

Solution	Rh(%)	Water activity (%)	The average value of moisture content of wet base (Ka_{bb})	
			30°C	40°C
NaOH	17	0,17	4,547310401	3,962322215
$MgCl_2$	32	0,32	7,268748991	6,581006307
K_2CO_3	42	0,42	8,358558734	7,660629426
$NaNO_2$	64	0,64	11,56236964	10,72954517
NaCl	75	0,75	16,40903462	15,72146068
Kcl	80	0,80	16,46966067	15,91652094

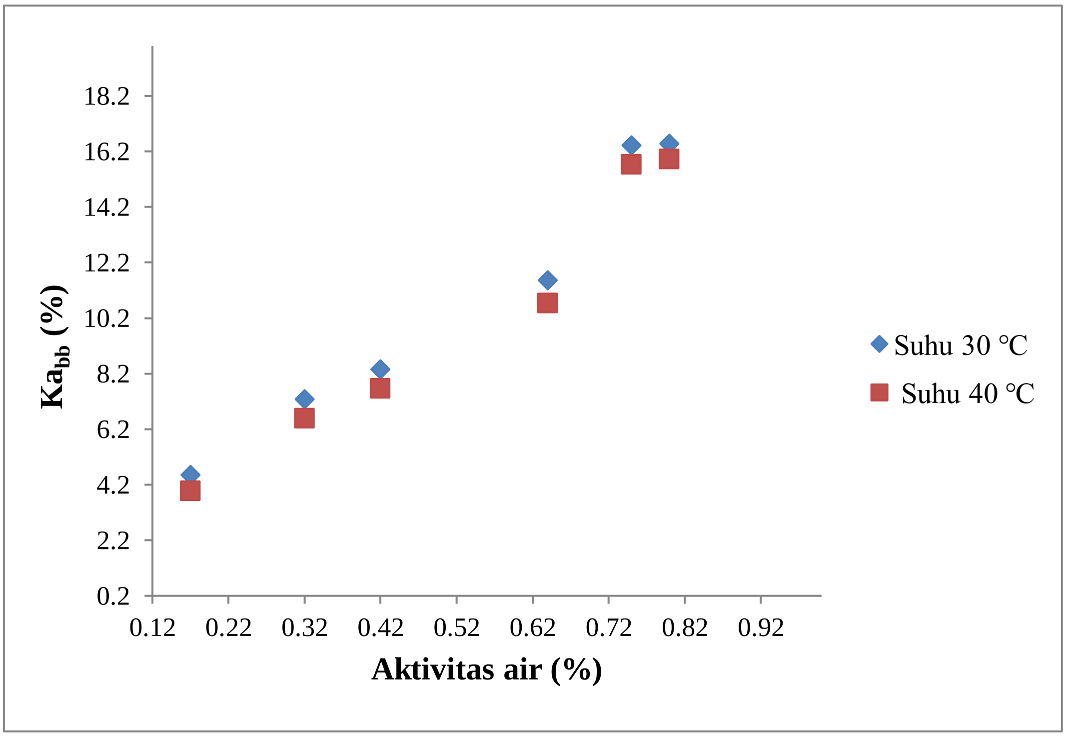


Figure 4-3. Relationship of Ka bb value and water activity of purple sweet potato flour temperature 30°C and 40°C.

Table 4-5. Measurement Results (Ka_{bk}) of purple sweet potato flour.

Solution	Rh(%)	Water activity (%)	Average value of dry base moisture content (Ka_{bk})	
			30°C	40°C
NaOH	17	0,17	4,763949101	4,125946927
MgCl2	32	0,32	7,838518287	7,044963787
K2CO3	42	0,42	9,120938905	8,296178561
NaNO2	64	0,64	13,07405434	12,01914575
NaCl	75	0,75	19,6302019	18,69648987
Kcl	80	0,80	19,71741221	19,08971825

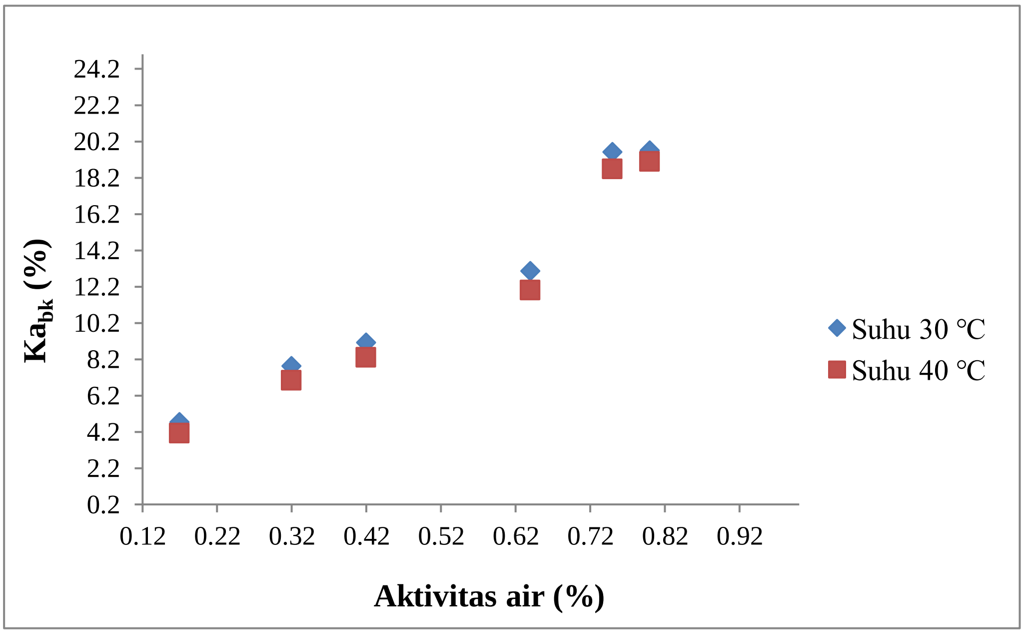


Figure 4-4. Relationship of Ka_{bk} value and water activity of purple sweet potato flour temperature 30°C and 40°C.

Based on Figures 4-3 and 4-4 show that, the values of Ka_{bb} and Ka_{bk} obtained in each salt solution with different Rh and using 2 storage temperatures experience different water content obtained. As seen in Table 4-4 the temperature of 30 °C has an increase in water content higher than the temperature of 40 °C. The same Ha l occurs in Table 4-5 for the determination of Ka_{bk}.

In addition to being affected by different storage temperatures, Rh (relative humidity) storage is also one of the important factors affecting sample storage. From Tables 4-4 and 4-5 there is a decrease and addition of water content in each solution, the higher the Rh in each salt solution, the higher the water content produced and vice versa. This is following the opinion of Budijanto (2010), which states that samples stored at low Rh will experience a decrease in weight while those at high Rh will experience an increase in weight. The addition and decrease in sample weight shows the characteristic phenomenon of hydration. In addition, temperature is the most important factor in the storage process. Regarding the difference in values obtained based on such temperatures. This is following the opinion of Hani (2012), which states that high air temperatures bring large heat energy so that the evaporation process can take place quickly and the moisture content in the material is reduced. Storage at high temperatures and Rh aims to determine the dominant quality factor has decreased. quality factors that can be seen rancidity that affects high sand softening of textures caused by storage at high Rh .

4.2 Best Model Testing

In this study, three mathematical models were used. The model is an isothermic model that is tested to detect the best model. The three models are Henderson, Oswin, Chung, and Pfost.

As for testing the three models, it can be done using *MS Excel Solver*. Use *MS. Excel Solver* to determine the value of constant values and R2 on the model.

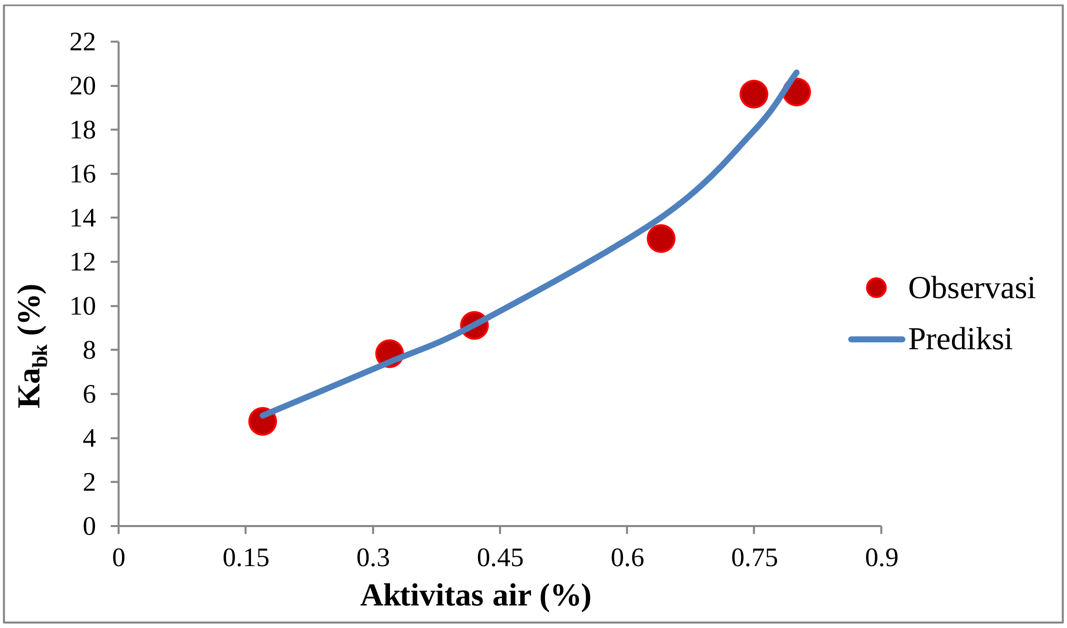
Table 4-6. Value of constant and R^2

Type	Equation	Suhu (°C)	A	B	R^2
Henderson	$w=A[-\ln(1-a_w)]^B$	30	14,38421447	0,704967026	0,947534409
		40	13,46222977	0,763934498	0,946258860
Oswin	$w = A\left[\frac{a_w}{(1-a_w)}\right]^B$	30	10.65951043	0,47521917	0,953282689
		40	9,753538599	0,512298109	0,955045191
Chung-Pfost	W=A+B ln(-ln aw)	30	8,58547251	-7,5638596	0,940917238
		40	7,99955411	-7,511348642	0,933949031

Based on Table 4-6 above, it shows that, the constant value tested based on data from storage results of purple sweet potato flour samples using 2 storage temperatures. From the data from the trial results of the three models presented in the Table, there is a model that is close to the value of one, namely the Henderson model. From the results of the analysis of the isotherm model that has been described earlier, the level of suitability of the isotherm model is the Oswin model. The value obtained at 30 °C is 0.953282689 and at 40 °C is 0.9 55045191. The model with the highest $R^{\text{value of } 2}$ indicates that it is the most suitable model that can be used to describe the water absorption of purple sweet potato flour.

4.3 Observation and prediction values in Oswin model temperatures of 30 °C and 40 °C

The following are the curves that can draw the best model tested:



Gambar 4-5. Graph of the relationship between Ka_{bk} and Oswin model water activity temperature 30 °C.

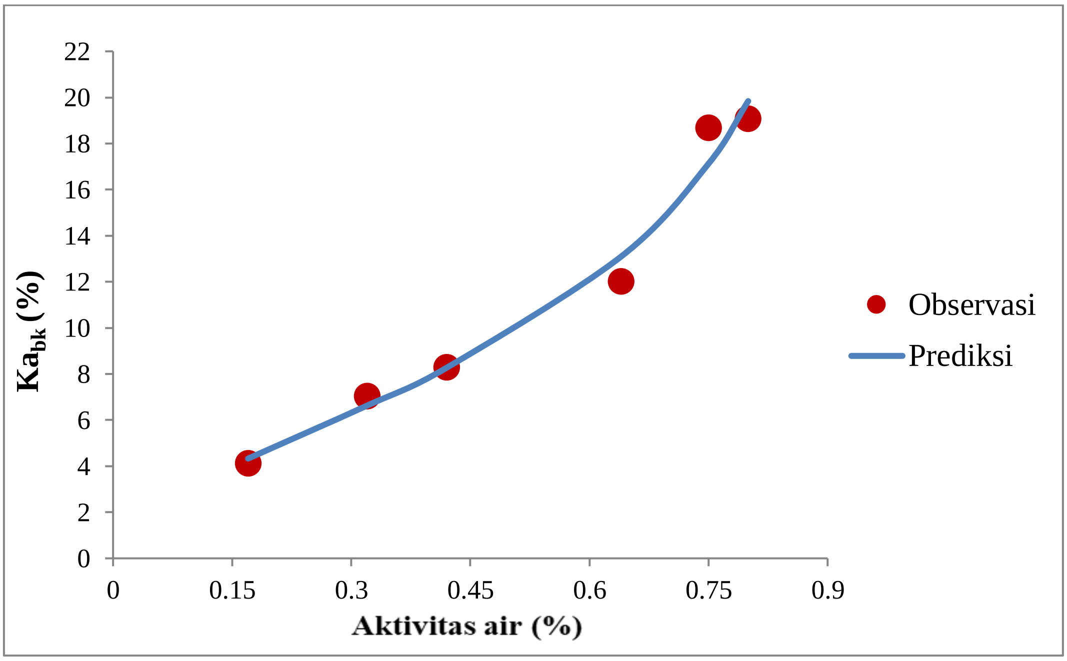


Figure 4-6. Graph of the relationship between Ka_{bk} and Oswin model water activity temperature 40 °C.

Based on Figures 4 and 5 affirm that, the Oswin model is the best model that can describe water absorption in purple sweet potato flour marked with the highest value of R^2 compared to other modes l curves, namely Henderson and Chung and Pfost models. The degree of suitability of the purple sweet potato flour isotherm model, namely the Oswin model , which is shown on the graph of the model relationship and the results of observations at two different temperatures. This graph shows the tendency between the value of the prediction line from the model and the point of observation (observation) that is getting closer. Values between 0 and 1, the closer to 1, the closer the predicted value of the observed value. This means that the model can predict well. Conversely, if it is close to 0, then the model is not able to predict which is close to the observational results. This graph increasingly shows that the storage model that matches the best water absorption in flour that has a fairly low water activity. This is in accordance with the opinion of Sugiyono et al. (2011), which states that Oswin's model is a model that can describe the isotherm curve of water sorption in dry products, besides that, it is very suitable for predicting flour that has a fairly low moisture content.

5. CONCLUSION

Conclusion

Based on the research of the purple Sweet Potato Flour Isotherm Curve Model (Ipomea Batatas L) it can be concluded that:

The best isotherm model that has the behavior of equilibrium water content of purple sweet potato flour at 30 ℃ and 40 ℃ at the interval Rh 17-80% shows that the Oswin model is the model that shows the highest R2 value and can describe the best water.

BIBLIOGRAPHY

Adnan, M. 1980. Water Activity and Food Material Stability. Agritech 1 (2). 20-26.

Arniati 2019. Production of Purple Sweet Potato Flour (Ipomoea batatas L.) with Variation in Storage Time. Thesis. State Polytechnic of Pertanin Pangkep.

Aini, N., Prihanto, V., Wijanarko, G., 2014. Characteristics of Instant Corn Flour Sorption Isotherms. Agritech, 36(1).

Budijanto, S., Azis, B., Yuni, D. K. 2010. Determination of Tortilla Shelf Life Using Accelerated Method Based on Critical Moisture Content and Modeling of Sorption Isotherm Constants. Journal of Food Technology and Industry. 21(2), 165-170.

Efendi, Z. 2019. The Effect of Relative Humidity on Mass Transfer Rate in Drying Processes. Thesis. Semarang State University.

Fatimatuzahro, D., Dian, A. T., Saifullah, H. 2019. Utilization of Purple Sweet Potato Peel Extract (Ipomoea batatas L.) as an Alternative Coloring Material for Observing Paramecium sp. Microscopic in Biology Learning. Journal of Biology and Applied Biology. 2(1), 106-112.

Hall, C. W. 1980. Drying and Storage of Agricultural Crops. AVI Publishing Company. Westport, Connecticut.

Hani, A. M. 2012. Storage of Thin-Layer Potatoes (Solanum tuberosum L.) of the Gronala Variety. Hasanuddin University: Makassar.

Hawa, L. C., Ubaidilla, U., Damayanti, R., Hendrawan, Y. 2020. Moisture Sorption Isotherm of Modified Cassava Flour During Drying and Storage. Department of Agricultural Engineering, Brawijaya University, Malang. 56, 2389–2396.

Husna, N. E., Novita, M., Rohaya, S. 2013. Anthocyanin Content and Antioxidant Activity of Fresh Purple Sweet Potatoes and Their Processed Products. Agritech, 33(3), 296-302.

Kusmiah, N., Salengke, Supratomo. 2015. Studying the Relationship Between Storage Conditions and Initial Moisture Content of Cocoa Beans (Theobroma Cacao L.) with Fungal Growth During Storage. ArgiTechno Journal. 8(2), 149-166.

Musdalifah, N. 2012. Color Production in Chili Peppers (Capsicum Frutescense) During Thin-Layer Storage. Bachelor's Degree Thesis, Department of Agricultural Engineering, Faculty of Agricultural Technology.

Nindyarani, A., Sutardi, K., Suparmo. 2011. Chemical, Physical, and Sensory Characteristics of Purple Sweet Potato Flour (Ipomoea batatas poitret) and Its Processed Products. Agritech, 31(4), 273-280.

Rosidah. 2014. Potential of Sweet Potato as a Raw Material for the Food Industry. Teknoguga Journal, 1(1), 44-52.

Rukmawati, Y. E. A., Sri, H., Margareta, M. C. 2017. Water Sorption Isotherm of Fermented Sweet Potato Flour with Red Yeast Rice (Angkak). Journal of Research and Development of Chemical Sciences, 3(1), 71-78.

Santosa, I., Winata, A. P., Sulistiawan, E. 2016. Physicochemical Study and Sensory Testing of White Sweet Potato Flour After Storage by Roasting. Chemica, 3(2), 55-60.

Setiaboma, W., Kristanti, D., Afifah, N. 2020. Estimation of Mocaf Cookie Shelf Life using Accelerated Method Based on Critical Moisture Content. Journal of Industrial Technology Research. 14(2), 166-174.

Setijahartini, S. 1980. Drying. Department of Industrial Technology, Bogor Agricultural Institute.

Soleimanifard, S., Naser, H. 2018. Modeling of Sorption and Determination of the Isosteric Heat of Split Pistachios, Pistachio Kernels, and Shells. Food Technology and Economy, Engineering, and Physical Properties, 36(3), 268-275.

Sugiyono, Edi, S., Elvira, S., Hery, S. 2011. Development of Dry Noodle Products from Sweet Potato Flour (Ipomoea Batatas) and Determination of Their Shelf Life using Sorption Isotherm Method. Journal of Food Technology and Industry. 22(2), 164-170.

Syafief, R., Halid, H. 1993. Food Storage Technology. PAU Food Process Engineering. IPB. Bogor.

Taib, G., Gumbira, S., Soledja, W. 1988. Drying Operations in Agricultural Processing. PT. Melton Putra. Jakarta.

Wahyuni, M., Salengke, Mursalim. 2018. The Effect of Ohmic Heating on the Anthocyanin Content of Red Dragon Fruit Peel (Hylocereus Polyrhizus). Agritechno Journal. 11(2), 139-146.

Wibisono, Y., Ubaidillah, U., Hawa, L. C. 2019. Microstructure Changes of Taro (Colocasia Esculenta L. Schott) Chips and Grains During Drying. Journal of Earth and Environmental Science, 1-7.

Winarto, F. G. 1984. Food Chemistry. PT. Gramedia. Jakarta.

APPENDICES

Appendix 1. Average moisture content measurement results before storage

Solutions	Average Value			
	Ka_{bb}		Ka_{bk}	
	Temp. 30 °C	**Temp. 40 °C**	**Temp. 30 °C**	**Temp. 40 °C**
NaOH	6,764707145	6,655959173	7,255522453	7,130651019
MgCl	6,705194371	6,668426126	7,187105403	7,145344495
K2CO3	6,523898689	6,766686158	6,979225648	7,257803469
NaNO2	6,468005054	6,443947167	6,915290357	6,88779326
Nacl	6,637909062	6,987804119	7,114132189	7,526444141
KCl	6,333063958	6,67600013	6,761573502	7,386771295
Total	**6.572129713**	**6.699803812**	**7.035474925**	**7.222467947**

Appendix 2. Average measurement results in Ka_{bk}

Solutions	Rh (%)	Water activity (%)	Average value of dry basis moisture content (Ka_{bk})	
			30 °C	**40 °C**
NaOH	17	0,17	4,763949101	4,125946927
MgCl2	32	0,32	7,838518287	7,044963787
K2CO3	42	0,42	9,120938905	8,296178561
NaNO2	64	0,64	13,07405434	12,01914575
NaCl	75	0,75	19,6302019	18,69648987
KCl	80	0,80	19,71741221	19,08971825

Appendix 3. Average measurement results Ka_{bb}

Solutions	Rh(%)	Water activity (%)	Average value of wet basis moisture content (Ka_{bb})	
			30 °C	40 °C
NaOH	17	0,17	4,547310401	3,962322215
$MgCl_2$	32	0,32	7,268748991	6,581006307
K_2CO_3	42	0,42	8,358558734	7,660629426
$NaNO_2$	64	0,64	11,56236964	10,72954517
NaCl	75	0,75	16,40903462	15,72146068
KCl	80	0,80	16,46966067	15,91652094

Appendix 4. Henderson temperature model test results in30 °C

Ka_{bk} Temp. 30 °C						
Solutions	Rh (%)	Water activity (%)	Observation	Prediction	Diff=obs-pred	Diff^2
NaOH	17	0.17	4.763949101	4.400062863	0.363886238	0.132413
MgCl2	32	0.32	7.838518287	7.348116017	0.490402271	0.240494
K2CO3	42	0.42	9.120938905	9.373484674	-0.252545769	0.063779
NaNO2	64	0.64	13.07405434	14.60307195	-1.529017612	2.337895
NaCl	75	0.75	19.6302019	18.1087957	1.521406195	2.314677
KCl	80	0.80	19.71741221	20.11799358	-0.400581367	0.160465

Appendix 5. Henderson model test results in temperature 40 °C

Ka_{bk} Temp. 40 °C						
Solutions	**Rh (%)**	**Water activity (%)**	**Observation**	**Prediction**	**Diff=obs-pred**	**Diff^2**
NaOH	17	0.17	4.125947	3.729581422	0.396365505	0.157105613
MgCl2	32	0.32	7.044964	6.50139495	0.543568837	0.29546708
K2CO3	42	0.42	8.296179	8.463988562	-0.167810001	0.028160196
NaNO2	64	0.64	12.01915	13.68433285	-1.665187098	2.77284807
NaCl	75	0.75	18.69649	17.27767402	1.418815844	2.013038401
KCl	80	0.80	19.08972	19.36433428	-0.274616026	0.075413962

Appendix 6. Oswin model test result inlets temperature 30 °C

Kabk Suhu 30 °C						
Solutions	**Rh (%)**	**Water activity (%)**	**Observation**	**Prediction**	**Diff=obs-pred**	**Diff^2**
NaOH	17	0.17	4.763949101	5.017501096	-0.253551995	0.064288614
MgCl2	32	0.32	7.838518287	7.450235793	0.388282495	0.150763296
K2CO3	42	0.42	9.120938905	9.143693334	-0.022754429	0.000517764
NaNO2	64	0.64	13.07405434	14.01147397	-0.93741963	0.878755563
NaCl	75	0.75	19.6302019	17.96695275	1.663249151	2.766397739
KCl	80	0.80	19.71741221	20.5990745	-0.881662285	0.777328385

Appendix 7. Oswin model test results in temperature 40 ℃

Kabk Temp. 40 ℃						
Solutions	**Rh (%)**	**Water activity (%)**	**Observation**	**Prediction**	**Diff=obs-pred**	**$Diff^2$**
NaOH	17	0.17	4.125946927	4.328912273	-0.202965346	0.041194932
MgCl2	32	0.32	7.044963787	6.629134703	0.415829084	0.172913827
K2CO3	42	0.42	8.296178561	8.267018746	0.029159815	0.000850295
NaNO2	64	0.64	12.01914575	13.09706443	-1.077918681	1.161908682
NaCl	75	0.75	18.69648987	17.12342057	1.573069294	2.474547005
KCl	80	0.80	19.08971825	19.8425006	-0.752782352	0.56668127

Appendix 8. Chung and Pfost model test results in temperature 30℃

Kabk Temp. 30 ℃						
Solutions	**Rh (%)**	**Water activity (%)**	**Observation**	**Prediction**	**Diff=obs-pred**	**$Diff^2$**
NaOH	17	0.17	4.763949101	4.258305687	0.505643414	0.255675262
MgCl2	32	0.32	7.838518287	7.59814757	0.240370717	0.057778082
K2CO3	42	0.42	9.120938905	9.660592808	-0.539653902	0.291226334
NaNO2	64	0.64	13.07405434	14.68794004	-1.613885702	2.60462706
NaCl	75	0.75	19.6302019	18.0092801	1.620921794	2.627387461
KCl	80	0.80	19.71741221	19.93080802	-0.213395804	0.045537769

Appendix 9. Chung and Pfost model test results in temperature 40℃

Kabk Temp. 40 °C						
Solutions	**Rh (%)**	**Water activity (%)**	**Observation**	**Prediction**	**Diff=obs-pred**	**Diff^2**
NaOH	17	0.17	4.125947	3.502428005	0.623518922	0.388775846
MgCl2	32	0.32	7.044964	6.819083527	0.22588026	0.051021892
K2CO3	42	0.42	8.296179	8.867210541	-0.57103198	0.326077522
NaNO2	64	0.64	12.01915	13.85965616	-1.840510408	3.387478561
NaCl	75	0.75	18.69649	17.1579383	1.538551565	2.367140919
KCl	80	0.80	19.08972	19.06612629	0.023591959	0.000556581

Appendix 10. Documentation of Research Sample

Figure 6-7. Samples of purple sweet potato flour at 30℃ and 40℃ before oven.

Figure 6-8. Samples of purple sweet potato flour at 30°C and 40°C after oven.

Figure 6-9. NaOH flour sample before the oven.

Figure 6-10. NaOH flour sample after oven.

Figure 6-11. $MgCl_2$ flour sample before baking.

Figure 6-12. $MgCl_2$ flour sample after baking.

Figure 6-13. K_2CO_3 flour sample before baking.

Figure 6-14. K_2CO_3 flour sample after baking.

Figure 6-15. $NaNO_2$ flour sample before baking.

Figure 6-16. $NaNO_2$ flour sample after baking.

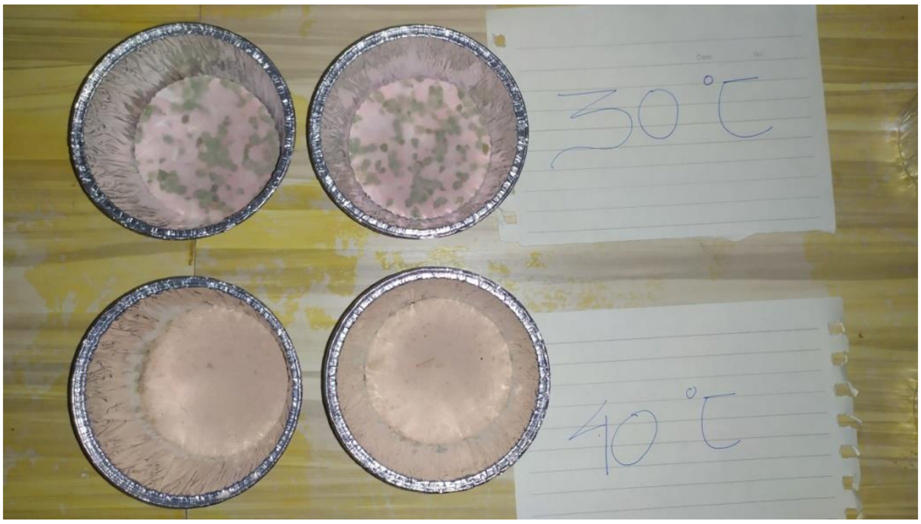


Figure 6-17. NaCl flour sample before the oven.

Figure 6-18. NaCI flour sample after baking.

Figure 6-19. KCl flour sample before the oven.

Figure 6-20. KCI flour sample after baking.

Appendix 11. Research Documentation

Figure 6-21. Sample storage at 30 ℃.

Figure 6-22. Sample storage at 40 ℃.

Figure 6-23. Storage using an oven.

Figure 6-24. The process of putting the sample into the oven.

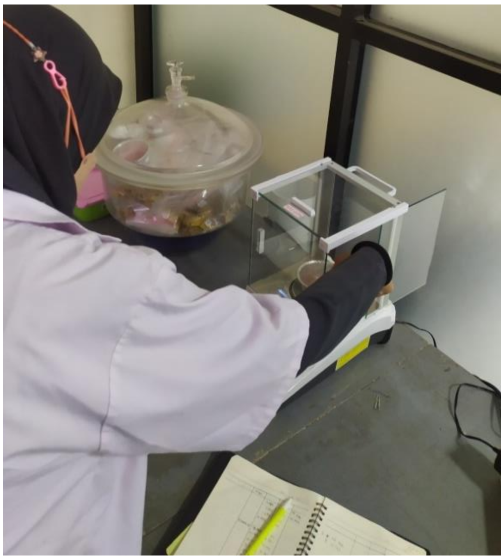


Figure 6-25. The data collection process uses digital scales.