The Shelf life Prediction of Sorghum Modified Flour Crackers Using Critical Moisture Approach

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Abstract. The objectives of this research were to produce crackers based on sorghum modified flour and to predict its shelf life using a critical moisture approach. The research was conducted in two stages. The first stage was to determine the best crackers of nine formulations. The second stage was to predict the shelf life of the best crackers formulation by using a critical moisture content approach. The best crackers were produced from a mixture of 50% sorghum modified flour, 50% wheat flour and 25% margarine. The products had a puffing ratio of 38,04 %, and hardness of 28.86 N. The moisture sorption isotherm curve of sorghum modified flour crackers could be described using a Hasley model. Using the critical moisture approach, sorghum modified flour crackers packaged in a metalized plastic and stored at 30°C and stored at 84% relative humidity, the product shelf life would be 207 days.

Keywords: *sorghum modified flour, crackers, moisture sorption isotherm, shelf life.*

1. Introduction

The needs of the Indonesian population for flour have increased from years, due to a large number of processed food products that use flour as a basic ingredient, including products such as noodles, bread, cakes, etc. This is supported by [1] which states that Indonesia is the second-largest country to consume noodles after China. This condition is one of the causes of increased demand for flour. Increased utilization of local potential can be used as an opportunity to overcome the demand for flour substitute flour. One of the local potentials that can be raised is sorghum. Sorghum is a cereal crop substitute for rice and corn, however, its use for food products is still very limited. Sorghum flour has a fairly good nutrient content, and this is supported by [2] that sorghum seeds contain carbohydrates 84.16% fat 0.355% and protein 3.58%. Sorghum also has anti-nutritional properties, namely tannin, and phytate. The content of anti-nutritional substances can be reduced by modification using fermentation [3], so as to improve digestibility. Fermentation can also increase the crystallinity of starch granules, thereby increasing rehydration power. Sorghum flour fermentation can be done by using lactic acid bacteria that are considered safe for human consumption, one of which is *Lactobacillus plantarum.*

Modified Sorghum Flour (MOSOF) can be applied to food products. [4], stated that the use of 25% eggs and partially substituted wheat flour with MOSOF, apparently can produce noodles with good physical and chemical quality. Besides noodle products, MOSOF can also be applied to crackers. Crackers are included in biscuits type, which in their manufacture can be done with/without the fermentation process and there is a lamination process so that it is flat and if broken the appearance looks layered [5]. Crackers do not use eggs in the manufacturing process, so other ingredients such as margarine are needed to improve their texture. One of the cracker's quality parameters is moisture content because it is related to shelf life. The method of determining shelf life with the critical water content approach was chosen because it was considered suitable for products that were easily damaged due to water absorption. This study was designed to determine the shelf life of the best MOSOF formula crackers with the critical water content approach.

2. Methods

2.1. Materials

The raw materials used in this study were early matured sorghum seeds, which were obtained from Madurese farmers and *Lactobacillus plantarum* FNCC 0027 bacteria from the Center for Food and Nutrition Studies (PSPG) of Universitas Gadjah Mada, Yogyakarta. The ingredients for making crackers in this study are moderate protein flour (blue triangle brand), margarine, yeast, sugar, skim milk salt and sodium bicarbonate. The chemicals used for the analysis were concentrated H2SO4, boric acid, BCG-MR indicators, HCl, aquades, K2SO4, NaOH, MRS broth.

2.2. Research Stages

This research consists of 3 stages, the preparation of materials, manufacture of crackers and physical analysis of chemical crackers. The explanation is as follows:

Stage 1. Material preparation and chemical analysis

At this stage, there are several treatments including:

a. Making Sorghum Flour Starter (Ariyanti, 2016)

Preparation of sorghum flour starter was initiated by inoculation of the rejuvenated starter Lactobacillus plantarum FNCC 0027, to 5 ml of sterile MRS broth and then incubated for 24 hours using a temperature of 37°C. Followed by transfer to 100 ml Erlenmeyer which had previously been filled with 5 g of sorghum flour and 15 ml of distilled water aseptically. Then the incubation temperature is 37°C for 24 hours.

b. Manufacture of Modified Sorghum Flour (MOSOF) and chemical analysis

The modification of sorghum flour was carried out by fermentation using the modified Ariyanti (2016) method, beginning with flour making by washing sorghum seeds using distilled water, and continued by soaking using 0.2% Na2HPO4 for 2 hours at 300C. Sorghum seeds are then washed again using distilled water, then dried at 650C for 3 hours. Dry sorghum seeds are then crushed and poured into a dish mill, then sieved using a size of 60 mesh, to obtain sorghum flour. The sorghum flour that is formed is then fermented, soaked using distilled water using a ratio of 1: 3 (w / v) and inoculated Lactobacillus plantarum FNCC 0027 by 10% for 3 days. The next stage is washing with distilled water, filtering and drying for 2 hours using a temperature of 650C. After that, the flour is refined and sieved using 80 mesh size.

Chemical analyses carried out include oven water content [6], ash content [6], protein content [6], fat content [6], starch content [6], crude fiber content [6],

Stage 2. Crackers Manufacturing and Analysis

There are 3 treatments, namely manufacturing crackers, and physical-chemical analysis

a. Making Crackers

Making these crackers using the Ariyanti method (2016). As for the formulas and explanations regarding making crackers, each can be seen in Table 1 and Figure 1.

b. Determination of the best treatment

The best treatment was chosen based on the results of the organoleptic test using the hedonic method. This test was conducted by 25 semi-trained panelists, with the test attributes including color, aroma, taste and texture/crispness.

Stage 3. Physical analysis of chemical crackers

This stage is given to the best treatment of organoleptic test results. The analysis conducted is crispness and hardness with a texture analyzer, development ratio, water content [6], ash content [6], fat content [6], protein content [6], carbohydrate by difference (Anonymous, 2005), shelf life [8].

The steps taken in calculating the shelf life (main research) are:

1. Determination of the initial moisture content (Moisture Initial / Mi (Mo)). The determination of initial water content in this study refers to [9],
2. Determination of parameters and critical water content [10]. The parameters used in this study are texture, color, aroma, and taste. From these four parameters then a ranking test was conducted by 25 panelists. The lowest rank was chosen as a critical parameter. Furthermore, the determination of critical water content begins with storage of the product at room temperature for 5 days, with daily water content testing and hedonic testing, on a scale of 1-7. Products with a value of 3 are considered as critical moisture content (panelists rejected).
3. Determination of equilibrium water content (%db) and sorption isothermic curves. The equilibrium water content is obtained by storing the product in 5 different types of saturated salts, in the humidity chamber. The five types of saturated salt can be seen in Table 2.

Table 1. Formula crackers (g/kg)

Ingredients	I	II	III	IV	V	VI	VII	VIII	IX
Wheat Flour	40	40	40	50	50	50	60	60	60
MOSOF	60	60	60	50	50	50	40	40	40
Margarine	15	25	35	15	25	35	15	25	35
Sugar	1	1	1	1	1	1	1	1	1
Salt	2	2	2	2	2	2	2	2	2
Skim Milk	2	2	2	2	2	2	2	2	2
Sodium bicarbonate	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25
Yeast	2	2	2	2	2	2	2	2	2
Totale	122,3	132,3	142,3	122,3	132,3	142,3	122,3	132,3	142,3

Source: [7]

Table 2. Types of Salt and Water for Manufacturing Saturated Salt

Types of salt	RH (%)	Totale	
		Salt (g)	Water (ml)
$MgCl_2$	32	60	8
KI	69	60	15
NaCl	75	60	25
KCl	84	60	25

$BaCl_2$	90	60	20

Source: [11]

Equilibrium water content (%db) and Aw obtained, henceforth are used to create sorption isothermic curves. Aw is obtained by dividing the RH of each humidity chamber by 100.

4. Determination of sorption isothermic models. Determination of sorption isotherm model by entering the value of equilibrium water content (Me) (%db) and Aw into the sorption isothermal equation formula, and then evaluated using MRD (Mean Relative Deviation). MRD value <5 is determined as the chosen equation because it is considered capable of representing actual conditions. The MRD calculation formula is as follows:

$$MRD = \frac{100}{n} \sum_{i=1}^{n} \left| \frac{Mi - Mpi}{Mi} \right|$$

Mi = experiment water content; MPI = calculated the moisture content; N = amount of data

Equations used in this study are Chen Clayton, Henderson, Hasley, Oswin and Caurie. The selected isothermic sorption model is then used to find the value of slope (b), by entering the calculation results of equilibrium (Me) and Aw. The linear form of the isothermic equation model [12], can be seen in Table 3.

Table 3. Form of Linear Equation Isothermic Equation Model

Model	Bentuk Linear	Nilai y= ax + b
Hasley	log [ln(1/aw)] = log P(1) – P(2) log Me	y = log [ln(1/aw)] x = log Me a = log P(1) b = – P(2)
Chen-Clayton	ln [ln(1/aw)] = ln P(1) – P(2) Me	y = ln [ln(1/aw) x = Me a = ln P(1) b = – P(2)
Henderson	log [ln(1/(1 – a_w)] = log K + n log Me	y = log [ln(1/(1 – a_w)] x = log Me a = log K b = n
Caurie	ln Me = ln P(1) – P(2) a_w	y = ln Me x = a_w a = ln P(1) b = – P(2)
Oswin	ln Me = ln P(1) + P(2) ln[aw/(1 – aw)]	y = ln Me x = ln[aw/(1 – aw)] a = ln P(1) b = P(2)

5. Calculation of shelf life, by determining the value of several variables to complete the shelf life equation. These variables include packaging permeability, product dry weight per package (Ws), packaging area (m2), and saturated water vapor pressure. The shelf life of the product is then calculated using the Labuza equation (1982). The formula for calculating the Labuza equation is as follows:

$$ts = \frac{\ln\left(\frac{Me - Mi}{Me - Mc}\right)}{\frac{k}{x}\,\frac{A}{Ws}\,\frac{Po}{b}}$$

ts = estimated shelf lifetime (days)
Me = product equilibrium moisture content (g H_2O / g solids)
Mi = initial product moisture content (g H_2O / g solids)
B = slope of the isothermic sorption curve
Mc = critical water content (g H_2O / g solids)
k / x = permeability of packaged water vapor (g / m^3.day.mmHg)
A = surface area of packaging (m^2)
Ws = product dry weight in the package (g solids)
Po = saturated vapor pressure (mmHg)

Experimental design
The experimental design used in crackers products is a single factor Randomized Complete Design (CRD), with 2 replications analysis. The data obtained were then analyzed by ANOVA and DMRT 95% using SPSS 19.

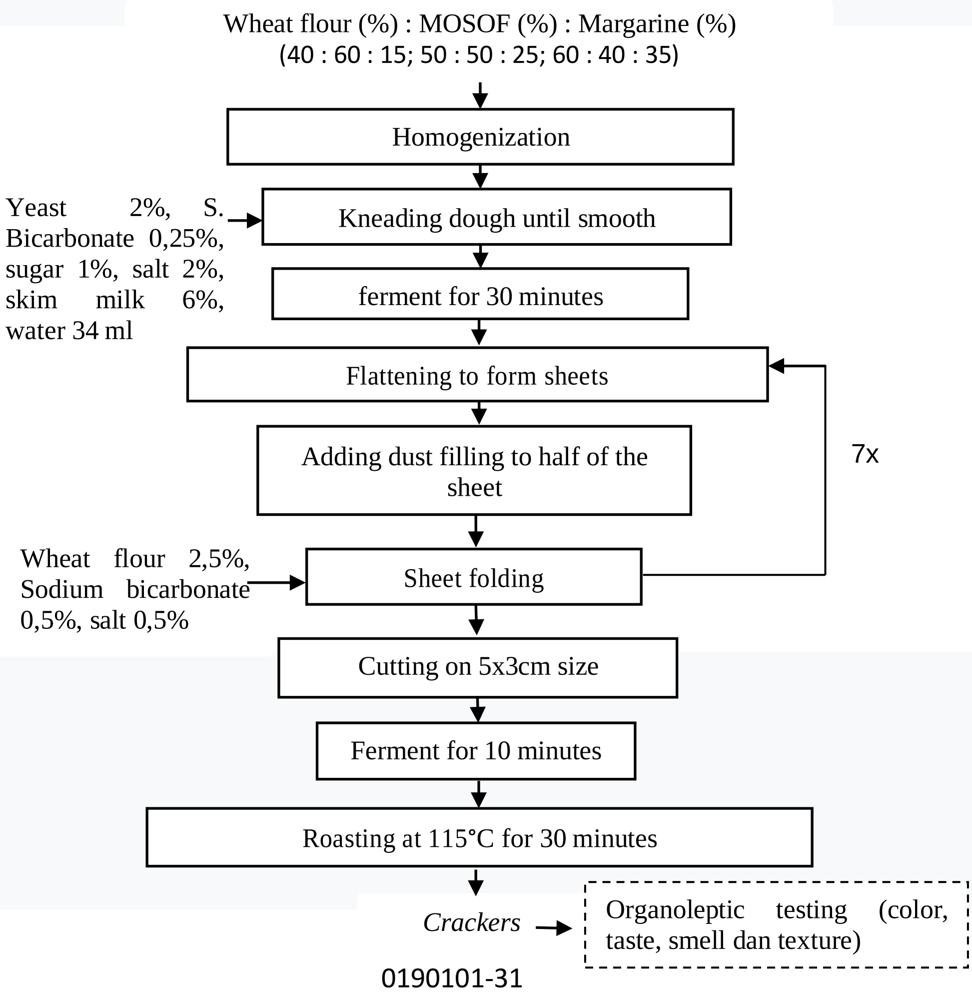

Fig 1. Making Crackers [7]

RESULTS AND DISCUSSION
Preliminary Research
Making Modified Sorghum Flour

In this study, sorghum flour was analyzed using fermentation (MOSOF), then the results were compared with the literature. The average chemical composition of MOSOF could be seen in Table 4.

From Table 1 it can be seen that the modification of sorghum flour using fermentation can increase the water content and starch, while the ash, protein, fat and crude fiber content (% wb) have decreased. This decrease is thought to be caused by the number of water-soluble components lost during immersion. In addition, fermentation can also increase starch content, especially the amylose content, so that it also has an impact on reducing non-starch content. The constituent components of starch are amylose and amylopectin. Meanwhile, the increase in water content in MOSOF is thought to be caused by amylose. [4] stated that amylose has a role in the binding of water and the formation of a strong gel that affects the increase in water content of MOSOF. Fermentation can cause the cutting of branching bonds (amylopectin), this is a result of the metabolic results of lactic acid bacteria that is able to produce pullulanase that plays a role in cutting amylopectin, thus causing an increase in amylose ratio. This is linear with the statement of [15], which states that pullulanase (pullulan 6-glucanohydolase, EC 3.2.1.41) has a role as a debranching enzyme, which is to cut off amylopectin and other polysaccharides.

Table. 4. Chemical composition MOSOF (%wb)

Component	MOSOF	Sorghum Flour
Moisture	10,42	6,78a
Ash	1,10	1,64a
Protein	3,86	12,43a
Fat	1,28	3,70a
Crude Fiber	2,13	6,38a
Starch	76,42	44,85b

Sources: a. [13]; b. [14]

MOSOF Crackers Products

MOSOF is then used to make crackers. From the formula contained in Table 1, the results obtained that the 5th formula with the formula of wheat flour: MOSOF: margarine = 50:50:25, was chosen as the best treatment because it has the highest organoleptic testing value, with the value of taste, color, aroma, and texture. each is 6.30; 5,74; 5.36 and 6.24. The results of the chemical analysis (%wb) of this formula, which includes water, protein, fat, and carbohydrates by differences, are 4.46 each; 7.20; 23.28 and 66.86. Meanwhile, the results of physical analysis including fracture (N) and developmental strength (%) were 28.86 and 38.04 respectively. This formula is then used for the main research, which is testing shelf life with the critical water content method

Main Research

The main research was carried out by calculating the best shelf life estimation of formula crackers by the critical water content method, which was then further calculated using the Labuza equation.

Initial Water Content

The initial moisture content of the MOSOF crackers was 0.0564 g H2O / g solid. This result is not too far from the results of the initial moisture content test of corn crackers which is 0.0467 g H_2O / g solid [10], so it can be categorized accordingly.

Critical Water Content Based on Organoleptic Tests

The lowest ranking value is the texture parameter, so the texture parameter is selected as a critical parameter. These texture parameters are then given hedonic testing to determine the critical water content. The results of hedonic testing conducted by 25 panelists, and carried out for 13 days showed that the longer the testing time, the level of preference has decreased. This result is also supported by the increasing levels of water crackers with increasing testing duration. From the hedonic test results, it can be determined that the critical water content value is 9.26. The selection of critical water content is based on hedonic test results with a value of 3. [10], states that a score of 3 in organoleptic testing is considered a product rejected by panelists, therefore hedonic test results with a score of 3 are considered products that have critical water content. The graph of the relationship between the hedonic test (panelist acceptance level) and the length of time the MOSOF crackers are stored can be seen in Figure 2.

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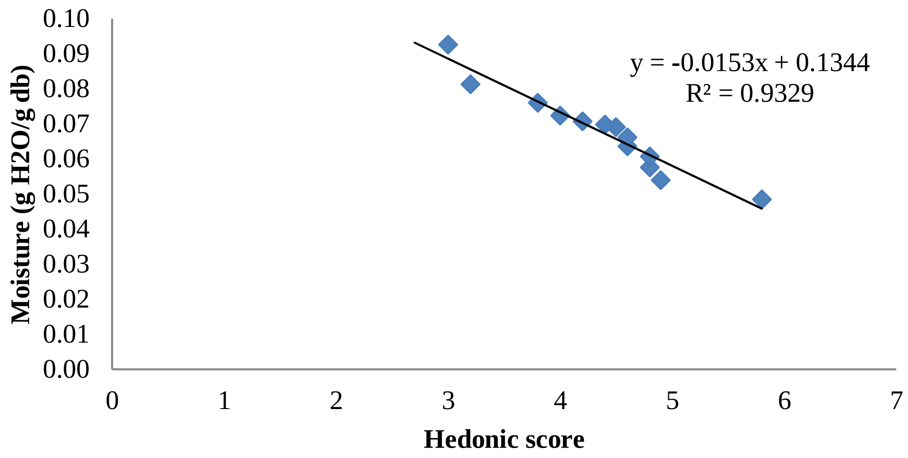

Fig 2. Determination of the critical moisture content of MOSOF crackers through hedonic tests

Equilibrium Water Content and Sorption Isothermic Curves

The equilibrium water content is obtained by storing MOSOF crackers in 4 different types of saturated salt solutions, namely MgCl2, NaCl, KCl and BaCl2. The results of the equilibrium moisture calculation are then used to make the sorption isothermic curve. The results show that the isothermal curve of sorption crackers stored in 4 kinds of saturated salt is in the form of the sigmoid. The MOSOF crackers isothermic curve can be seen in Figure 3.

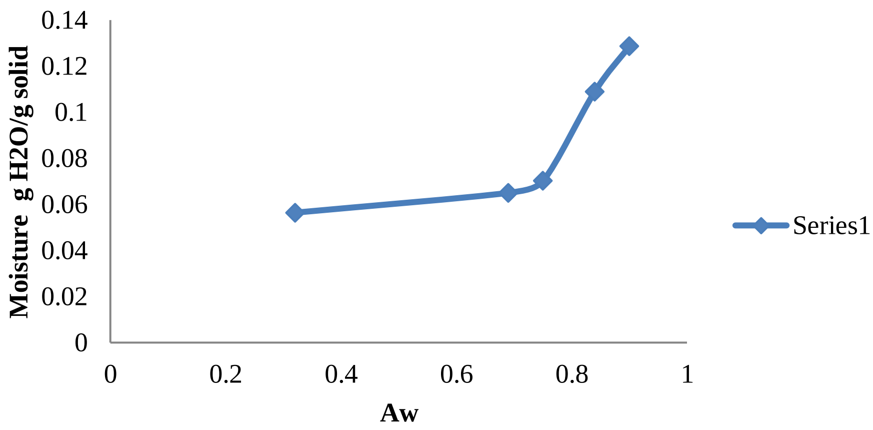

Fig 3. Isothermic Curve Sorption MOSOF Crackers

The Sorption Isothermic Model

Equations used to determine the isothermic model of sorption are Chen Clayton, Hasley, Henderson, Caurie, and Oswin. The calculation results of these equations are then corrected using MRD, with a value <5 considered to be able to represent the actual conditions. From the test results obtained that the sorption isothermal equation model that is able to describe the real condition is the Hasley equation, and this is also supported from the MRD results that show results <5. The selected isothermic sorption model is then used to find the slope (b) value. The slope value obtained in this study was 0.303 (value b). The graph of the isothermic sorption model (Hasley) can be seen in Figure 4.

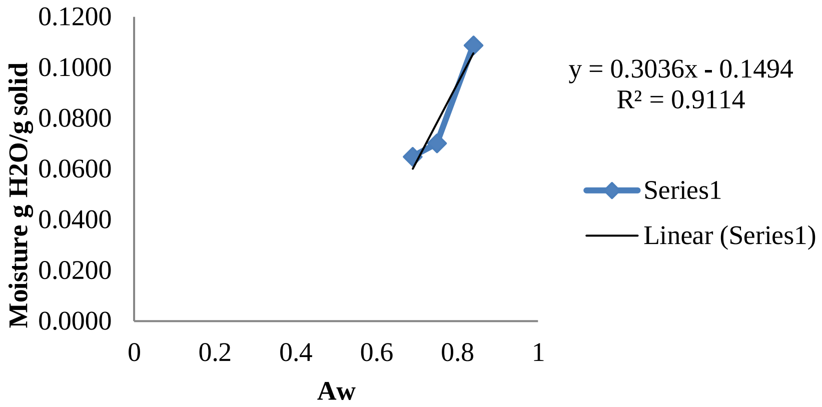

Fig 4. Sorption isothermic model (Hasley)

Estimated shelf life

The estimated shelf life is calculated using the Labuza calculation formula. The packaging permeability (k / x) used in this study is 0.0136 g / m^2.day.mmHg, packaging area (A) 0.0396 m^2, dry weight (Ws) 10 grams, the saturated vapor pressure at 30° C, (Po) 31.8240 mmHg.

Conclusion

The shelf life of MOSOF crackers packaged in metalized plastic packaging, stored at 84% RH, with storage having a saturated vapor pressure of 30°C has a shelf life of 207 days.

Acknowledgments

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