Impact of Differences in Type of Primary Packaging on the Shelf Life of Javanese Grasshopper (*Valanga nigricornis Burm.*) Snack Bars

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Abstract

One of the processed products from Javanese grasshopper (*Valanga nigricornis Burm.*) flour that is being developed is snack bars. This product was designed to introduce processed Javanese grasshopper flour (JGF) products with high protein content to consumers. However, the shelf life of the grasshopper snack bar and the best type of packaging to store the product are not yet known. This research aimed to determine the shelf life of Javanese grasshopper snack bars packaged in three different types of packaging and to identify the most effective packaging for these products. The three types of packaging chosen were plastic packaging in the form of a standing pouch (SP), aluminium foil packaging without folds (alufo), and aluminium foil packaging with folds (alumina). This research used the accelerated shelf life testing (ASLT) method with the Arrhenius approach. The parameters measured were moisture, fat, and water activity (a_w) content during eight measurement periods with three different storage temperatures (20^{o}C, 30^{o}C, 45^{o}C). There were differences in estimated shelf life based on parameters for each type of packaging. The shelf life of Javanese grasshopper snack bar products based on packaging type and estimation parameters varied from 0.68 months to 14.81 months. The best parameter to estimate shelf life was the fat content in the alufo packaging, which had the highest R^2 value from the order 1 equation in the Arrhenius method with a value of R^2 0.999. The shelf life of the Javanese grasshopper snack bar product estimated by measuring the fat content parameters on the alufo packaging was 14.81 months if stored at a temperature of around 30^{o}C.

Keywords: Shelf life; Javanese grasshopper; Snack bars; Packaging; *Valanga nigricornis Burm.*

1 Introduction

Various processed flour products have been developed using local food ingredients. One product being developed is Javanese grasshopper flour (*Valanga nigricornis* Burm.). In Indonesia, especially in the Gunungkidul Regency, grasshoppers are usually consumed fried. This development is an alternative step to make food products based on grasshopper flour more diverse. This alternative is needed in order to broaden the marketing scope of products. One of the food products converted into flour as an alternative way to consume was white oyster mushrooms. According to Astuti et al. (2019), the

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conversion to flour aims to extend the shelf life of white oyster mushrooms so that the flour can be used as main ingredient to make other food products such as sausages, nuggets, artificial meat, or crackers. The alternative to developing Javanese Grasshopper Flour (JGF) was a step to improve the image of grasshoppers as a food choice for the people of Gunungkidul district so that this product can be promoted as one of the primary products to support developing gastro tourism in the region. Local food can be one of the attractions for tourists when visiting a tourist destination (Privitera et al., 2018).

The Gunungkidul district area, as one of the leading tourist destinations in the Yogyakarta Special Region province, needs local processed food alternatives developed to accommodate the tourist demand for both current and future conditions. One of the advantages of grasshoppers, in terms of nutritional content, is that the protein content of Javanese grasshoppers in Gunungkidul district has a value of 19.31 $\pm$ 6.90% greater than the protein value of eggs as a comparative standard (Palupi et al., 2020). Efforts to focus on developing grasshopper flour as the main ingredient for food products were initiated by using the Quality Function Deployment method (Amri et al., 2023).

The next problem in developing the grasshopper snack bar was the shelf life; suitable primary packaging for marketing purposes has yet to be discovered. The shelf life of a food product is the period of consumption based on the rate of change in the quality of physical or non-physical parameters of that type of food (Bagja et al., 2015). Determining the shelf life is essential in the research and development stages of new food products because this is related to the obligation of food product producers to include information regarding the shelf life of food products and nutrition facts. This information can also be deployed for food product marketing purposes, such as branding and promotion to introduce newly developed food products into its target market (Desnilasari et al., 2019). Shelf life testing has also been done on snack bar products made from bananas as the main ingredient (Ekafitri et al., 2021; Surahman et al., 2020). Estimating shelf life can be done using the Accelerated Shelf Life Test (ASLT). This method aims to calculate the quality change in critical parameters of the food product during storage duration (Asiah et al., 2018). Therefore, this research aimed to determine the shelf life of Javanese grasshopper snack bars packaged in three types of packaging and determine the best type of packaging for these products.

2 Materials and Methods

2.1 Materials

The main ingredient used in this research was fresh grasshopper (*Valanga nigricornis Burm.*). It was purchased from Extreme Foods SMEs, Wonosari, Gunungkidul, Yogyakarta-Indonesia. The other ingredients for making the snack bar were wheat flour, cornstarch, skim milk powder, chocolate, eggs, sugar, salt, raisins, margarine, rice crispy, and peanuts. Those ingredients were purchased at Agrosari Market, Wonosari, Gunungkidul, Yogyakarta. The research was conducted in March-August 2023 at the Food Product Development Laboratory, Research Center for Food Technology and Processing, National Research and Innovation Agency, Yogyakarta, Indonesia.

2.2 Methods

The main objective of this research was to estimate the shelf life of snack bar products from JGF developed by Amri et al. (2023) using the Quality Function Deployment (QFD) method. According to Amri et al. (2023), consumers choose snack bar product packaging that is composed of aluminium foil (alufo) material, has an attractive appearance, and can be consumed practically. Standing pouch (SP) packaging, aluminium foil packaging without folds (alufo), and aluminium foil packaging with folds (alumina) were chosen as alternative packaging that could be used as primary packaging for grasshopper snack bar products based on these characteristics.

The Accelerated Shelf Life Test (ASLT) was used to calculate the product shelf life using Arrhenius equations. Water content, fat content, and activity water (a_w) were used as research parameters to indicate declining food product quality. Water content and a_w were essential quality indicators of products shelf life (Ekafitri et al., 2021; Iwansyah et al., 2022; Surahman et al., 2020). Meanwhile, fat content was chosen as one of the quality indicators of snack bars regulated by KaBPOM Decree No. HK.00.05.52.4040 (BPOM, 2006). Product storage was at three different temperatures (20^{o}C, 30^{o}C, and 45^{o}C), using three different forms of packaging (SP, alufo, and alumina) for seven weeks. The water content, fat content, and activity water (a_w) were analyzed weekly. The protein content was assessed during the initial (week 0) and final (week seven) storage periods to determine the protein content reduction rate during the shelf life measurement period.

Sample preparation

Javanese grasshopper flour (JGF) was processed and obtained by removing the grasshopper's (length 8 – 10 cm) wings, hind legs, and internal organs, then washed thoroughly using flowing water. It was then soaked in 0.3% $NaHCO_3$ solution for ±15 mins and continued by blanching with hot water at 70-80 ^{o}C for 1-2 mins. The grasshoppers were dried using tray drying at 50-60 ^{o}C for 24 hours. The dried Javanese grasshopper was mashed using a blender and sifted through a 60-mesh sieve to produce a homogeneous flour.
Snack bars were made by mixing ingredients consisting of eggs (19.5 g), margarine (55 g), chocolate bars (95 g), sugar (40 g), salt (0.5 g), Javanese grasshopper flour (33 g), wheat flour (21 g), chocolate powder (12.5 g), cornstarch (3 g), skim milk powder (40 g) and raisins (30 g) for ± 3 minutes using a mixer machine until the dough was homogeneous. The dough was moulded and baked at 120 ^{o}C for 30 mins, then the baked result was cut to size with an estimated 5 cm length and continued baked at 100 ^{o}C for 15 mins. A mixture of crispy rice (16 g), nuts (26 g), and chocolate (83.4 g) was placed on the top of the snack bar as a coating.

Product packaging and storage

The grasshopper snack bar product was packaged in three different types of packaging: alufo, alumina, and standing pouch (SP). Alufo and alumina are packaged using continuous sealer machines, whereas SP packaging provides an impervious cover that may be directly pressed. The snack bars were then stored in three incubators at 20^{o}C, 30^{o}C, and 45^{o}C temperatures. The temperature range determination was adapted from Iwansyah et al. (2022), Nisa and Kusharto (2022), and Surahman et al. (2020). The quality parameters were measured weekly throughout the seven-week storage period.

Moisture content and activity water (a_w) measurements

Moisture content was measured using thermogravimetric principles assisted by an automatic moisture content analyzer (MB95 Ohaus, China). A sample (0.5 g) was prepared on the plate, and then the instrument rapidly heated the samples and measured the moisture content. The a_w value was measured using a Pawkit Portable Water Activity Meter (Meter, Washington, USA). The sample was prepared on the cuvette and placed on the a_w meter sensor, and the activity water (a_w) value was measured (Iwansyah et al., 2022). The experiments were conducted in three replicates.

Fat contents measurements

Fat content was analyzed using an automatic Soxhlet (Buchi, Switzerland) instrument. The principle of fat analysis was done by modifying the AOAC technique (Association of Official Analytical Chemists, 1981). The sample (1 g) was weighed and wrapped in filter paper, then placed in an oven at 105^{o}C for 24 hours to obtain the constant sample weight. Fat extraction was done for 20 cycles using hexane solvent. The extracted sample was then placed in an oven at 105^{o}C and weighed until it reached a constant weight within a 0.002 g. The fat content was calculated using equation (1) and presented as a percentage comparison of fat and sample weights. The analysis was conducted with three replicates.

$$Fatcontent(\%) = \frac{W_3 - W_2}{W_1} \times 100 \qquad (1)$$

Where w_3 = constant sample weight before fat extraction (g); w_2 = constant sample weight after fat extraction (g); w_1 = sample weight (g)

Protein content measurements

The protein content was only measured during the initial (week 0) and final (week 7) storage periods. It was measured using the KjelDigester K-446 (Buchi, Switzerland) and the KjelMaster K-375 (Buchi, Switzerland) by Association of Official Analytical Chemists (1981) method. The principle of analysis was sample destruction, distillation and titration. The protein content was estimated by multiplying the percentage of N samples (%N) by the conversion factor (6.25). The analysis was conducted with three replicates.

Accelerated Shelf Life Test (ASLT) calculation

The critical parameters examined in this study were the moisture content, a_w, and fat content to determine the shelf life of Grasshopper snack bar products. The rate of change in critical parameter quality was calculated using the Arrhenius equation. The order of the Arrhenius equations was obtained by plotting critical parameter measurement results during storage periods versus temperature inverse (ln k vs 1/T). The following equations (2-5) can be used to estimate shelf life based on the change in critical parameters that have been measured (Kusnandar et al., 2010).

$$K = K_0.e^{-(Ea/RT)} \tag{2}$$

$$\ln K = \ln K_0 - (\frac{Ea}{R}) \cdot (\frac{1}{T}) \tag{3}$$

$$t = \frac{C_0 - C_t}{K} \tag{4}$$

$$t = \frac{\ln C_0 - \ln C_t}{K} \tag{5}$$

Where: C_t = the value of the quality parameter after storage; C_0 = initial quality parameter value; k = reaction rate constant; t = time (days); Ea = Activation energy (Cal/mol); R = gas constant whose value is 1.986 (Cal/mol.K); T = absolute temperature (kelvin); The initial moisture content was measured during the snack bar product formulation process, and the initial fat and a_w contents were measured before the storage process. Equation (4) was used to calculate t = time (days) if the order of the Arrhenius equation was determined as zero. Equation (5) was used to calculate t = time (days) if the order of the Arrhenius equation was determined as first order.

2.3 Data and statistical analysis

The collected data was analyzed with SPSS 24 for Windows. The normality of the data was tested using the Saphiro-Wilk test. The results of the moisture, fat, and a_w contents were analyzed using one-way ANOVA followed by the Duncan test.

3 Results and Discussion

3.1 Changes in the quality of grasshopper snack bars during storage

The shelf life of snack bars was tested by evaluating the rate of change in parameters of moisture content, fat content, and water activity of the product stored in various types of packaging and storage temperatures. Measurements were taken over seven storage periods at 1-week intervals. Table 1 displays the results of measuring changes in parameter quality for each package. The seven-week storage condition resulted in changes in quality indicators, a drop in water and fat content, and increased water activity in snack bars. Both type packaging and storage temperature significantly affected ($p<0.05$) the moisture and fat content and increased the water activity. After seven weeks of storage in alufo, alumina, and standing pouch packaging at 20^{o}C, 30^{o}C, and 45^{o}C, the moisture content of snack bars reduced significantly ($p<0.05$) from 8.08% to 1.33%, 1.73%, and 1.72% in alufo packaging; from 8.08% to 0.58%, 1.48%, and 1.25% in alumina packaging; from 8.08% to 0.46%, 1.22%, and 1.64% in standing pouch packaging, respectively. Furthermore, the fat content of snack bars decreased significantly ($p<0.05$) after seven weeks of storage at 20^{o}C, 30^{o}C, and 45^{o}C: from 0.256% to 0.234%, 0.210%, and 0.212% in

Table 1: Changes in quality parameters of Grasshopper snack bar samples

Type of packaging	Storage duration (days)	20°C			30°C			45°C		
		moisture (%)	fat (%)	aw	moisture (%)	fat (%)	aw	moisture (%)	fat (%)	aw
Alufo	0	8.08^{c}	0.256^{ab}	0.44^{a}	8.08^{d}	0.256^{de}	0.44^{a}	8.08^{d}	0.256^{de}	0.44^{a}
	7	2.15^{b}	0.229^{a}	0.50^{c}	2.90^{c}	0.196^{a}	0.55^{e}	1.86^{cd}	0.244^{bcd}	0.49^{d}
	14	1.20^{a}	0.250^{a}	0.47^{b}	0.96^{a}	0.230^{bc}	0.56^{e}	1.98^{cd}	0.257^{de}	0.47^{bc}
	21	2.41^{b}	0.248^{ab}	0.47^{b}	0.90^{a}	0.207^{ab}	0.54^{d}	1.80^{abc}	0.249^{cde}	0.46^{b}
	28	1.26^{a}	0.251^{ab}	0.56^{d}	2.09^{b}	0.230^{bc}	0.47^{b}	2.37^{c}	0.231^{abc}	0.58^{f}
	35	1.16^{a}	0.227^{a}	0.56^{d}	1.27^{a}	0.226^{bc}	0.58^{f}	1.27^{a}	0.212^{a}	0.58^{f}
	42	1.22^{a}	0.278^{b}	0.49^{c}	1.70^{b}	0.275^{e}	0.51^{c}	1.801^{abc}	0.267^{e}	0.48^{c}
	49	1.33^{a}	0.234^{a}	0.47^{b}	1.73^{b}	0.210^{ab}	0.48^{b}	1.72^{ab}	0.212^{a}	0.55^{e}
Alumina	0	8.08^{d}	0.268^{d}	0.44^{a}	8.08^{d}	0.268^{d}	0.44^{a}	8.08^{f}	0.268^{c}	0.44^{a}
	7	1.681^{bc}	0.2461^{cd}	0.52^{c}	2.46^{d}	0.229^{bc}	0.52^{c}	3.20^{d}	0.232^{ab}	0.57^{e}
	14	1.92^{bc}	0.227^{abc}	0.48^{b}	2.53^{d}	0.249^{cd}	0.48^{b}	1.69^{bc}	0.232^{ab}	0.54^{c}
	21	1.56^{b}	0.223^{ab}	0.58^{e}	1.20^{b}	0.193^{a}	0.59^{e}	2.82^{d}	0.215^{a}	0.56^{d}
	28	2.02^{c}	0.245^{cd}	0.51^{c}	0.62^{a}	0.235^{bc}	0.56^{d}	0.73^{a}	0.230^{ab}	0.58^{f}
	35	0.74^{a}	0.217^{a}	0.60^{f}	1.27^{b}	0.255^{cd}	0.52^{c}	1.96^{c}	0.230^{ab}	0.59^{g}
	42	0.48^{a}	0.251^{d}	0.55^{e}	0.38^{a}	0.209^{ab}	0.55^{e}	4.10^{e}	0.231^{ab}	0.60^{g}
	49	0.58^{a}	0.238^{bcd}	0.54^{d}	1.48^{b}	0.264^{d}	0.53^{c}	1.25^{b}	0.236^{b}	0.53^{b}
Standing pouch	0	8.08^{f}	0.255^{c}	0.44^{a}	8.08^{f}	0.255^{b}	0.44^{a}	8.08^{e}	0.255^{b}	0.44^{b}
	7	1.51^{b}	0.237^{bc}	0.51^{d}	2.96^{e}	0.198^{a}	0.54^{d}	2.16^{b}	0.238^{ab}	0.45^{c}
	14	2.49^{cd}	0.223^{ab}	0.50^{c}	2.22^{d}	0.255^{b}	0.46^{b}	2.87^{c}	0.220^{a}	0.53^{f}
	21	2.88^{de}	0.220^{ab}	0.52^{d}	1.62^{ab}	0.239	0.49^{c}	2.46^{b}	0.226^{a}	0.47^{d}
	28	2.31^{c}	0.250^{c}	0.46^{b}	1.74^{abc}	0.226^{ab}	0.56^{e}	3.35^{d}	0.218^{a}	0.49^{e}
	35	3.14	0.223^{ab}	0.56^{f}	0.65^{a}	0.240^{b}	0.58^{f}	3.56^{d}	0.217^{a}	0.48^{e}
	42	1.28^{e}	0.200^{a}	0.56^{f}	1.80^{cd}	0.251^{b}	0.50^{c}	3.41^{d}	0.229^{a}	0.44^{b}
	49	0.46^{a}	0.209^{ab}	0.54^{e}	1.22^{b}	0.206^{a}	0.55^{d}	1.64^{a}	0.235^{ab}	0.41^{a}

*Data are presented as means (n=3).
*Differences superscript alphabet means the difference level by statistical analysis.

alufo packaging; from 0.268% to 0.238%, 0.264%, and 0.236% in alumina packaging; and from 0.255% to 0.209%, 0.206%, and 0.235% in standing pouch packaging. The water activity of the snack bar, on the other hand, increased significantly ($p<0.05$) after seven weeks of storage in alufo, alumina, and standing pouch packing at 20^{o}C, 30^{o}C, and 45^{o}C, from 0.44 to 0.47, 0.48, 0.55, 0.54, 0.53, 0.53, 0.54, 0.55, and 0.41, respectively.

Kristanti and Herminiati (2021) reported that packaging permeability influences the quality properties of food products during storage, particularly moisture content and water activity. The high packaging permeability causes food product characteristics to alter more easily, resulting in a shorter shelf life. The permeability of alufo and alumina are 0.0035 and 0.0039 gH_2O/m^2.day.mmHg, respectively (Ekafitri et al., 2021). Meanwhile, the permeability of polypropylene (PP), which is a standing pouch packaging material, is 0.013 gH_2O/m^2.day.mmHg (Wibawa et al., 2019). As a result, the shelf life of products packaged in alufo and alumina may be longer than that of a standing pouch. The data in Table 1 was then combined to represent the rate of quality change (order 0 and order 1), allowing the Arrhenius equation to be constructed for each quality parameter in the variable packaging type.

All of the changes in quality indicators from various primer packaging and storage temperatures can be seen in Figure 1. The change in moisture content for grasshopper snack bar products held in packaging alufo, alumina, and SP over seven storage periods at 20^{o}C were 83.49%, 92.78%, and 94.30%, respectively. The change in moisture content for grasshopper snack bar products held in packaging alufo, alumina, and SP over seven storage periods at 30^{o}C were 78.54%, 81.68%, and 84.94%, respectively. Furthermore, the change in moisture content for grasshopper snack bar products after seven storage periods at 45^{o}C in packaging alufo, alumina, and SP were 78.67%, 84.57%, and 79.66%. The most significant change in moisture content at 20^{o}C and 30^{o}C storage temperatures was obtained on SP packaging with value changes of 92.78% and 84.94% whereas at 45^{o}C storage temperature was obtained on alumina (84.94%). Grasshopper snack bar products packaged in alufo packaging had the lowest moisture content change rate at three different storage temperatures. The permeability of packaging, storage temperature, and storage period are all factors that may lead to moisture content decrease during storage (Kristanti & Herminiati, 2021). The moisture content can be reduced due to moisture absorption in the product and interactions between the packaging material and the environment (Ekafitri et al., 2021). The moisture content of grasshopper snack bars dropped more than banana snack bars (Surahman et al., 2020) and red sorghum snack bars (Ryavanki & Hemalatha, 2018).

The percentage change in fat content for grasshopper snack bar products measured from the beginning to the end of storage at 20^{o}C was 8.59% (alufo), 11.26% (alumina), and 18.1% (SP). The percentage change in fat content of grasshopper snack bar products assessed throughout seven storage periods at 30^{o}C in alufo, alumina, and SP packaging was 17.93%, 1.7%, and 19.01%, respectively. Furthermore, the percentage change in fat content of grasshopper snack bar products over seven storage periods at 45^{o}C was 17.13% (alufo), 12.05% (alumina), and 7.55% (SP). The minimum change in fat content at 20^{o}C, 30^{o}C, and 45^{o}C were obtained on alufo (8.59%), alumina (1.72%), and SP (7.55%) packaging, respectively. The oxidation of unsaturated fatty acids results in a decrease in fat content. The speed of the process is determined by the type of fat and the storage conditions of food products (Fitria et al., 2021).

The percentage change in the a_w value of snack bar products over seven storage periods at 20^{o}C was 6.38%, 19.01%, and 19.01% in alufo, alumina and SP packaging, respectively. The percentage change in the a_w value of snack bar products over seven storage periods at 30^{o}C was 8.33% (alufo), 16.45% (alumina), and 20% (SP). Furthermore, the percentage change of a_w value in snack bar products was 20%; 16.45%; and 7.31% over seven storage periods in alufo, alumina and SP packaging, respectively at 45^{o}C. The most significant change in a_w value was obtained on SP (20^{o}C and 30^{o}C) and alufo (45^{o}C). The percentage change in a_w value from three different storage temperatures and packing types ranges from 6.38% to 20%. According to Prazeres et

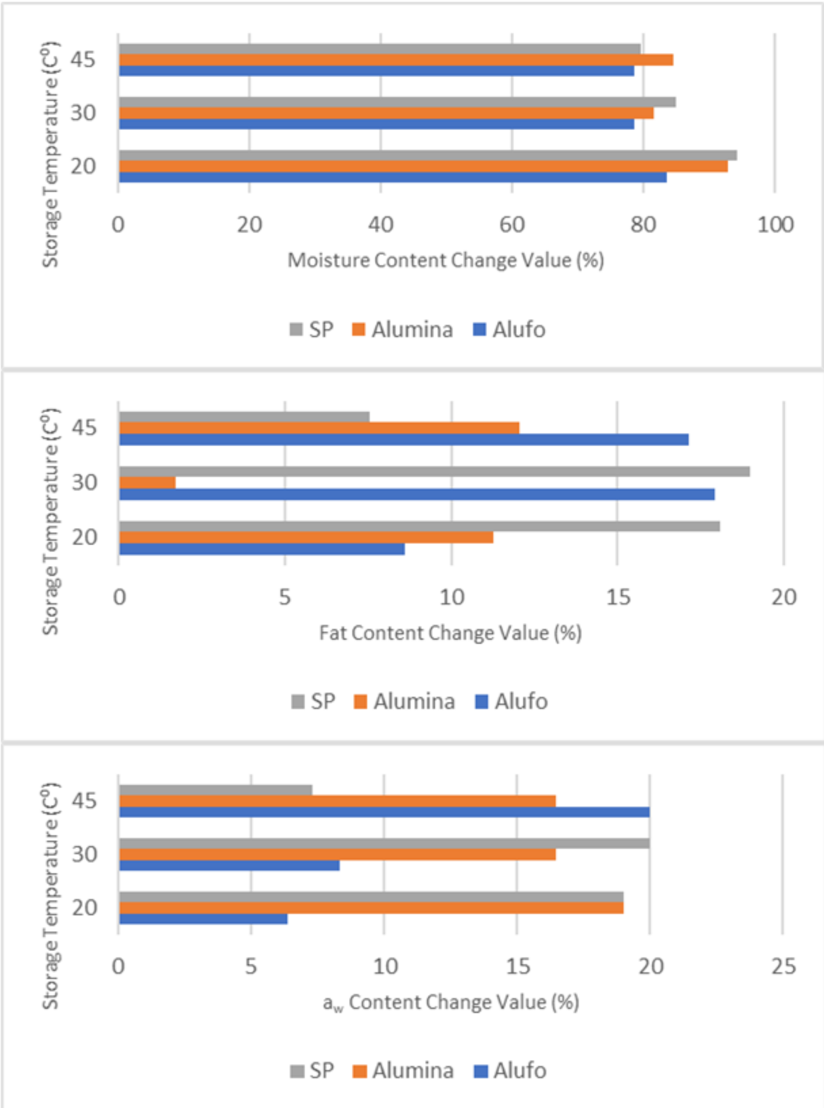

Figure 1: Change value from moisture, fat, and a_w contents based on the differences in primer packaging type and storage temperatures (%).

al. (2020), changes in a_w values in these ranges represent the influence of packaging permeability. They may also be attributable to slight gaps in the packaging closing process.

In this study, protein contents were also calculated at the beginning and end of the storage period. The protein content of snack bars in the three types of packaging changed consecutively by 29.36% (alufo), 36.20% (alumina), and 29.52% (SP). Compared to the other two packaging options, alufo packaging provided higher product protection, as indicated by the smaller change in protein content.

3.2 Estimation of shelf life of Javanese grasshopper snack bars

A regression equation was calculated based on data on changes in quality parameters during the storage duration of grasshopper snack bars. The regression equation was used as a reference to create the Arhennius calculation model. The regression equations were obtained by plotting the ln k vs 1/T data in each order from the experiment parameters (Table 2, Table 3, Table 4). The chosen equation to estimate the shelf life of the snack barsin three packages (alufo, alumina, and SP) was based on the highest R^2 value between orders 0 and 1.

The Arrhenius approach was used to examine the shelf life of the snack bars depending on the order determined in Table 2, Table 3, and Table 4. The orders used in the alufo, alumina, and SP packaging were order 0, order 1, and order 1 (moisture content parameter); order 0, order 0, and order 1 (fat content parameter), and order 1, order 1, and order 1 (water activity parameter), respectively. The results of estimating the shelf life of grasshopper snack bars are shown in Tables 5, 6, and 7.

Based on Table 5, the shelf life for grasshopper snack bars ranges from 47.23 to 143.63 days, according to the quality parameters of moisture content. The grasshopper snack bar had the shortest shelf life when stored in alumina packaging at 30^{o}C, while the longest was stored in SP packaging at 45^{o}C. However, alufo packaging had the highest R^2 value (0.9442), indicating that it had the best-predicted shelf life depending on the type of packaging used in the examination of the moisture contents. The expected shelf life in the alufo packaging was 71.73 - 109.98 days at 20^{o}C - 45^{o}C.

Based on Table 6, the shelf life of grasshopper snack bar products ranged from 40.59 to 685.81 days, according to the quality parameters of fat content. The R^2 values in alumina (0.0819) and SP packaging (0.0111) were relatively low, while alufo packaging had the highest R^2 value (0.9994). Based on the R^2 value, alufo packaging had the best-predicted shelf life based on the quality parameters of fat content. The estimated shelf life was 111.29 - 561.21 days at 20^{o}C - 45^{o}C. Furthermore, as the storage temperature was raised, the rates of quality degradation in the quality parameters of fat content were increased. The rate of quality degradation at 20^{o}C, 30^{o}C, and 45^{o}C were 0.0039%, 0.0103%, and 0.039%, respectively. These results are in accordance with research results from Fitria et al. (2021), whereas the rate of fat quality degradation in cookies from manyung utik fish (*Arius thalassinus*) flour stored in aluminium foil packaging for 12 weeks had a range of 0.1 – 0.2%.

The highest R^2 value in the a_w quality parameters was attained on SP packaging (0.8387). As a result, SP packaging had the highest R^2 value, indicating that it has the best-predicted shelf life depending on the type of packaging used in the examination of activity water. The predicted shelf life on the SP packaging was 38.86 - 257.01 days at 20^{o}C - 45^{o}C. Based on the results from this accelerated shelf life test, the best estimator for the shelf life of the grasshopper snack bars was the fat content in the alufo packaging because the R^2 value was the highest compared to others. This finding was consistent with Amri et al. (2023) study, in which aluminium foil packaging was chosen for grasshopper snack bar products based on consumer preferences.

4 Conclusions

In this research, the shelf life of the grasshopper snack bar was estimated based on quality parameter changes in primer packaging and storage temperature differences. Aluminium foil pack-

Table 2: Regression equation ln k vs 1/T of moisture contents

Type of packaging	Temp. (^oC)	Regression equation Order 0	Regression equation Order 1	R^2 Order 0	R^2 Order 1	Selected order	Estimation of shelf life order
Alufo	20	y = - 0.0904x + 4.5669	y = - 0.0275x + 1.273	0.4299	0.5041	1	0
	30	y = -0.0821x + 4.4667	y = -0.02x + 1.1231	0.355	0.2359	0	
	45	y = -0.0562x + 4.5428	y = -0.0128x + 1.2788	0.1618	0.1331	0	
Alumina	20	y = - 0.1047x + 4.6972	y = - 0.0464x + 1.4899	0.524	0.7806	1	1
	30	y = -0.1036x + 4.7914	y = -0.0407x + 1.4081	0.515	0.5594	1	
	45	y = -0.0758x + 4.8353	y = -0.0217x + 1.3806	0.31	0.2485	0	
Standing Pouch	20	y = - 0.0904x + 4.5669	y = - 0.0275x + 1.273	0.4299	0.5041	1	1
	30	y = -0.00993x + 4.9703	y = -0.0329x + 1.4766	0.53	0.6019	1	
	45	y = -0.0533x + 4.5631	y = -0.0097x + 1.2738	0.1868	0.0916	0	

Table 3: Regression equation ln k vs 1/T of fat contents

Type of packaging	Temp. (^{o}C)	Regresi equation Order 0	Regression equation Order 1	R^2 Order 0	R^2 Order 1	Selected order	Estimation of shelf life order
Alufo	20	y = 0.00004x + 0.2458	y = 0.00009x - 1.4034	0.0015	0.0005	0	0
	30	y = 0.0001x + 0.2254	y = 0.0006x -1.495	0.0088	0.0088	0	
	45	y = -0.0004x + 0.2553	y = -0.0019x -1.3634	0.1844	0.2026	1	
Alumina	20	y = - 0.0003x + 0.2475	y = - 0.0013x - 1.3992	0.1182	0.1094	0	0
	30	y = -0.0001x + 2.406	y = -0.0005x -1.4299	0.006	0.0058	0	
	45	y = -0.0004x + 0.2434	y = -0.0015x - 1.4172	0.182	0.1683	0	
Standing Pouch	20	y = - 0.0008x + 0.2471	y = - 0.0036x - 1.3968	0.5447	0.5539	1	1
	30	y = -0.0002x + 0.2391	y = -0.0009x - 1.4363	0.0306	0.0249	0	
	45	y = -0.0007x + 0.2544	y = -0.0027x -1.3726	0.2516	0.2594	1	

Table 4: Regression equation ln k vs 1/T of a_w contents

Type of packaging	Temp. (^{o}C)	Regression equation Order 0	Regression equation Order 1	R^2 Order 0	R^2 Order 1	Selected order	Estimation of shelf life order
Alufo	20	y = 0.0.001x + 0.4717	y = 0.0019x - 0.754	0.1395	0.1479	1	1
	30	y = 0.00003x + 0.5156	y = 0.0002x - 0.6694	0.0001	0.0009	1	
	45	y = 0.0019x + 0.4575	y = 0.0037x - 0.7825	0.3791	0.3909	1	
Alumina	20	y = 0.002x + 0.4775	y = 0.004x - 0.7429	0.4268	0.4459	1	1
	30	y = 0.001x + 0.505	y = 0.0022x - 0.6923	0.1214	0.1441	1	
	45	y = 0.0016x + 0.5136	y = 0.0031x - 0.6737	0.2693	0.275	1	
Standing Pouch	20	y = 0.0018x + 0.4667	y = 0.0035x - 0.7625	0.491	0.4781	0	1
	30	y = 0.0017x + 0.4747	y = 0.0033x - 0.7486	0.3214	0.3333	1	
	45	y = 0.00007x + 0.4506	y = 0.0002x - 0.7984	0.0016	0.0026	1	

Table 5: Estimation of the Grasshopper snack bar shelf life based on moisture contents

Type of packaging	Temp. (^oC)	(1/T) K	k	ln k	t (days)	R^2
Alufo	20	0.0034	0.0941	-2.3640	71.7383	
Ea = 3599.2278	30	0.0033	0.0767	-2.5681	82.8115	0.9442
k0 = 0.000194	45	0.0031	0.0578	-2.8502	109.9771	
Alumina	20	0.0034	0.0499	-2.9985	52.7146	
Ea = 5772.7062	30	0.0033	0.0359	-3.3259	47.2286	0.9292
k0 = 2.45E-06	45	0.0031	0.0229	-3.7784	81.7605	
Standing Pouch	20	0.0034	0.0417	-3.1762	68.6548	
Ea = 9812.4288	30	0.0033	0.0239	-3.7327	79.1258	0.8524
k0 = 1.98E-09	45	0.0031	0.0111	-4.5019	143.6388	

Table 6: Estimation of the Grasshopper snack bar shelf life based on fat contents

Type of packaging	Temp. (^oC)	(1/T) K	k	ln k	t (days)	R^2
Alufo	20	0.00341	0.00004	-10.1457	561.2141	
Ea = 17082.579	30	0.0033	0.0001	-9.17679	444.3749	0.9994
k0 = 2.2E+08	45	0.00314	0.00039	-7.83774	111.2866	
Alumina	20	0.00341	0.00019	-8.57935	635.8189	
Ea = 3086.244	30	0.0033	0.00022	-8.40431	76.8493	0.0819
k0 = 0.03779	45	0.00314	0.00029	-8.16239	450.2436	
Standing Pouch	20	0.00341	0.00226	-6.09417	88.5418	
Ea = 1136.230	30	0.0033	0.00212	-6.15862	99.6570	0.0111
k0 = 0.16734	45	0.00314	0.00193	-6.24768	40.5927	

Table 7: Estimation of the Grasshopper snack bar shelf life based on aW contents

Type of packaging	Temp. (^oC)	(1/T) K	k	ln k	t (days)	R^2
Alufo	20	0.00341	0.00072	-7.23673	91.65107	
Ea = 6919.4226	30	0.00330	0.00107	-6.84428	81.65993	0.0943
k0 = 105.0462	45	0.00314	0.00183	-6.30189	121.74751	
Alumina	20	0.00341	0.00312	-5.76933	67.57167	
Ea = 470.56284	30	0.00330	0.00304	-5.79602	59.14969	0.0063
k0 = 0.001391	45	0.00314	0.00293	-5.83291	61.37221	
Standing Pouch	20	0.00341	0.00543	-5.21619	38.86337	
Ea = 22082.334	30	0.00330	0.00155	-6.46863	143.83839	0.8387
k0 = 1.79E-19	45	0.00314	0.00027	-8.19959	257.00996	

aging was chosen for use in grasshopper snack bar products because it had the longest shelf life and the highest R^2 value regarding two quality factors (moisture content and fat content). Furthermore, the change in protein content in aluminium foil packaging was the smallest compared to other packaging (29.36%). The estimated shelf life of snack bar products packed in aluminium foil was 111.29 - 561.21 days at 20^{o}C to 45^{o}C. It is recommended that aluminium foil packaging is utilized as the primary packaging for the grasshopper snack bar products.

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