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FORMULATION AND SHELF LIFE PREDICTION OF A PUMPKIN-SOYBEAN FLOUR EMERGENCY FOOD BAR USING THE ACCELERATED SHELF-LIFE TESTING (ASLT) METHOD AND ARRHENIUS MODEL

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ABSTRACT

This study focuses on developing emergency food bars made from pumpkin flour and soybean flour, aimed at providing sustenance for victims of natural disasters. Each bar delivers 233–250 kcal per 50 grams and is designed to last for 15 days until further aid arrives. The research is divided into two phases: the first phase involves formulating the food bars using a Completely Randomized Design (CRD) with five different flour ratios (70:30, 60:40, 50:50, 40:60, and 30:70). The study evaluates various parameters, including chemical composition (moisture, ash, protein, fat, carbohydrates), caloric content, and sensory attributes assessed by 25 panelists. The results indicate that the optimal formulation is the F4 ratio (40:60), which has a moisture content of 10.88%, ash at 4.89%, fat at 16.89%, protein at 28.50%, carbohydrates at 39.83%, and a caloric value of 235.05 kcal per 50 g. The second phase assesses the shelf life of the F4 food bar using the Accelerated Shelf-Life Testing (ASLT) method and the Arrhenius model, conducted at varying temperatures (25°C, 35°C, and 45°C) over 12 days. The findings reveal that the F4 food bar has a shelf life of 31 days at 25°C, 32 days at 35°C, and 33 days at 45°C, based on mold and yeast growth and activation energy calculations.

Keywords: emergency food; food bar; pumpkin flour; soybean flour; shelf life; ASLT; Arrhenius

INTRODUCTION

Indonesia is a nation vulnerable to disasters caused by nature. According to data from the National Disaster Management Agency **(BNPB, 2013)**, Indonesia is the third most disaster-prone country globally, following India and China. In emergency situations, a primary necessity for disaster victims is sustenance. Consequently, there is a necessity for a specialized food design that is ready-to-eat, easily distributable, and possesses adequate nutritional value. Emergency food is one of the solutions available **(Aini et al., 2018)**. Emergency food refers to manufactured sustenance specifically formulated for consumption during crises, such as post-disaster scenarios, when routine operations are interrupted. Under such circumstances, infrastructure damage frequently transpires, hindering victims' ability to satisfy their nutritional requirements. The primary aim of emergency food is to diminish disease prevalence and mortality rates among refugees by supplying nutritional provisions that fulfill energy requirements of 2,100 kcal for a duration of 15 days **(Zoumas et al., 2002)**.

A food bar is a product that can serve as an emergency sustenance source. Food bars are calorie-dense products composed of a blend of diverse ingredients, molded into a solid and compact form **(Ladamay & Yuwono, 2014)**. **Luthfiyanti et al. (2011)** assert that the development of food bars with local raw materials in Indonesia can enhance national food security.

Employing alternate carbohydrate sources beyond rice and wheat may strategically enhance Indonesia's food security. **Widowati et al. (2010)** noted that pumpkin (*Cucurbita maxima*), a local item in Indonesia, holds promise as an alternative carbohydrate source, with its carbohydrate content of 77.65%. To satisfy the nutritional criteria for emergency meals, supplementary protein sources such as soybeans, a locally available Indonesian resource, are required. **Mahmud et al. (2018)** report that the protein content of soybeans is 35.9%.

According to a study by **Fajri et al. (2013)**, the food bar made of pumpkin flour and soybean flour has the following chemical properties: a moisture content of 14.76%, an ash content of 4.28%, a protein content of 14.31%, a fat content of 19.87%, a carbohydrate content of 46.78%, and a caloric value of 211.56 kcal per 50 grams. It also has a dark color, no rancid smell or taste, and a texture that is moderately firm without a rancid aftertaste. Nonetheless, the caloric content of this product fails to satisfy the minimum emergency food guidelines, so it is imperative to amend the formulation from **Fajri et al. (2013)** to comply with these standards.

Food safety standards mandate that all food products display an expiration date on their labels, making shelf life a critical factor to consider. The deterioration of food product quality may arise spontaneously or as a result of environmental factors **(Nur, 2009)**. Product deterioration may result from exposure to air, oxygen, humidity, light, microbes, or fluctuations in temperature.

Utilizing appropriate packaging is one method to prolong a product's shelf life. Packaging safeguards products from numerous environmental variables that may expedite deterioration. People frequently use aluminum foil packaging because of its heat resistance, airtight properties, low water vapor permeability, non-corrosiveness, and ability to shield items from light **(Astuti et al., 2017)**.

We aim to ensure food safety by estimating the shelf life of food bar items using the Accelerated Shelf-Life Testing (ASLT) method, which employs the Arrhenius model approach. This technique entails preserving the product in climatic conditions that expedite its degradation **(Calligaris et al., 2019)**. We selected the ASLT methodology because of its ability to produce precise results quickly. The Arrhenius model is appropriate for temperature-sensitive items, as it employs three distinct temperatures to forecast shelf life at the specified storage temperature **(Haryati et al., 2015)**.

Research is essential to identify the optimal food bar formulation, using pumpkin flour and soybean flour, that meets the nutritional and caloric criteria for emergency food. Additionally, the study will involve estimating the shelf life of the food bar in aluminum foil packaging employing the ASLT Arrhenius model under varying storage temperature conditions.

MATERIAL AND METHODS

Food bar preparation

The production of food bars follows the formulation from the research of **Fajri et al. (2013)**, incorporating modifications such as adjusting the raw material proportions (flour) and adding complementary ingredients like eggs, honey, raisins, and almonds to improve the product's nutritional value, calories, and sensory quality. The ingredients used include pumpkin flour, soybean flour, margarine, powdered sugar, full cream milk powder, honey, eggs, raisins, and almonds. The process of making the food bar begins with the preparation of all the ingredients, followed by the mixing stage, which is done gradually using a mixer at medium speed. In the first mixing stage, 28 grams of margarine, 30 grams of eggs, 26 grams of powdered sugar, and 40 grams of honey are mixed until homogeneous and form a cream-like texture. During the second mixing stage, the formulation gradually added 26 grams of powdered milk, pumpkin flour, and soybean flour until they formed a homogeneous dough. In the final stage, evenly mix 20 grams of raisins and 10 grams of almonds. The homogeneous batter is poured onto a baking tray that has been evenly greased with margarine. The baking process is carried out using an oven at a temperature of 120°C for 30 minutes. After baking, the food bar is cooled to room temperature. The cutting size is 10 × 3 × 1.5 cm.

Chemical assessment and caloric content

The chemical analysis encompasses moisture content assessment via the oven method **(AOAC, 2016)**, ash content determination through the oven method **(AOAC, 2016)**, protein content evaluation using the Kjeldahl method **(AOAC, 2005)**, fat content analysis via the Soxhlet method **(AOAC, 2005)**, carbohydrate content calculation by the difference method **(Setyorini & Puspitasari, 2021)**, and caloric value quantification employing the bomb calorimeter method.

Sensory analysis

The sensory testing of the food bar aims to obtain the best formula for the pumpkin-soy flour food bar based on the highest preference score. This test refers to the method used in **Utomo's (2019)** research, involving 25 panelists. Panelists were asked to evaluate five samples presented randomly, each assigned a different code. The assessment was conducted using a hedonic scale with 7 hedonic scales, namely (1) very dislike, (2) dislike, (3) somewhat dislike, (4) neutral, (5) somewhat like, (6) like, and (7) very like, which includes evaluation of product quality attributes, namely color, aroma, taste, and texture.

Statistical analysis

The first stage of the research used a Completely Randomized Design (CRD) at a 5% level, with five treatments and three replications. The treatments studied were the proportions of pumpkin flour to soybean flour, which included 70:30 (F1), 60:40 (F2), 50:50 (F3), 40:60 (F4), and 30:70 (F5).Data analysis was conducted using the IBM SPSS Statistics 22 program. If there are significant differences between treatments, the analysis is continued with Duncan's Multiple Range Test (DMRT) at the 5% level. The Friedman test was used for the analysis of the sensory test data **(Hermayanti et al., 2016)**.

Analytical decision-making

The optimal meal bar formula is determined by its chemical properties, caloric content, and sensory evaluation results with the De Garmo method **(De Garmo et al., 1984)**. This method is related to the research done by **Nafi et al. (2016)**, who used the De Garmo test to find the best formula by giving each parameter a weight value between 0 and 1. The weight of each value is determined by the significance of its corresponding parameter, which is affected by the treatment outcomes. The values of all parameters are aggregated, and the treatment combination with the highest aggregate value is identified as the optimal treatment. The treatment with the greatest efficacy is designated as the optimal formula.

Estimating the shelf life of food bars

The shelf life of the food bar was estimated using the Accelerated Shelf-Life Testing (ASLT) method based on the Arrhenius model **(Hariyadi, 2019)**. The food bar items are encased in aluminum foil and maintained at temperatures of 25°C, 35°C, and 45°C. The evaluation occurred over a span of 12 days, including assessments on days 0, 3, 6, 9, and 12. The observational data were structured in a table and graphed to derive a linear regression utilizing Microsoft Excel 2010. This method relies on the idea that elevated storage temperatures expedite product breakdown, hence facilitating a more rapid prediction of its shelf life **(Diniyah et al., 2015)**. The study initiates by graphing six observation points to illustrate the correlation between quality variations and time, yielding a linear equation $y = a + bx$, where b represents the constant rate of quality deterioration (k). The reaction order is established according to the curve with the highest coefficient of determination (R^2) value. After plotting the rate constant (ln k) against temperature (1/T), we get the Arrhenius equation, which looks like this: $\ln k = \ln k0 - (Ea/R)(1/T)$, where ln k0 is the pre-exponential constant, Ea is the activation energy, and R is the ideal gas constant (1.986 cal·mol K). To find the activation energy, multiply the slope (b) by R. To find the shelf life, compare the quality change at the start (A0) to the quality change at the end (At) and divide the result by the quality degradation rate constant (k). The formula for calculating shelf life is derived from the zero-order equation, $t = (A0 - At)/k$, or the first-order equation, $t = \ln (A0 - At)/k$, where t represents shelf life (in days), A0 denotes the critical value of the quality attribute, At signifies the value of the quality attribute at the conclusion of storage, and k is the constant for the rate of deterioration.

RESULTS AND DISCUSSION

Raw aterial analysis results

The results of the raw material analysis, namely the characteristics of pumpkin flour and soybean flour, include moisture content, ash content, protein content, fat content, and carbohydrate content, as presented in **Table 1**.

Table 1 Analysis results of pumpkin flour and soybean flour

Parameter	Yellow Pumpkin Flour		Soybean Flour	
	Analysis Results (%)	Literature (%)	Analysis Result (%)	Literature (%)
Moisture content	7,87	11,14[a]	6,19	6,27[b]
Ash content	5,81	5,89[a]	4,79	2,89[b]
Protein content	7,37	5,04[a]	33,59	47,8[b]
Fat content	2,72	0,08[a]	19,78	17,76[b]
Carbohydrate content	76,20	77,65[a]	35,67	26,28[b]

Source: a) Widowati et al. (2003), b) Astuti et al. (2014)

The results of the raw material analysis (**Table 1**) show that pumpkin flour has a moisture content of 7.87%, ash content of 5.81%, protein content of 7.37%, fat content of 2.72%, and carbohydrate content of 76.20%. According to **Widowati et al. (2017)**, pumpkin flour has a moisture content of 11.14%, ash content of 5.89%, protein content of 5.04%, fat content of 0.08%, and carbohydrate content of 77.65%. The analysis results of soybean flour show a moisture content of 6.19%, ash content of 4.79%, protein content of 33.59%, fat content of 19.78%, and carbohydrate content of 35.67%. Based on the report by **Astuti et al. (2018)**, soybean flour has a moisture content of 6.27%, ash content of 2.89%, protein content of 47.8%, fat content of 17.76%, and carbohydrate content of 26.28%. The differences in analysis results compared to the literature may be due to variations in harvest age, variety, and post-harvest conditions, which can affect the physicochemical properties of the raw materials. **Wang et al. (2019)** revealed that the harvest age, variety, and post-harvest conditions can affect the physicochemical properties of the raw materials. Additionally, **Syamsyir et al. (2020)** stated that the method of flour production has a significant impact on the results of flour characteristic analysis.

Nutrition composition of food bars

The food bars produced were subsequently analyzed for their nutritional composition, and the results for each treatment are presented in **Table 2**.

Table 2 The mean value of nutritional composition of food bars yellow pumpkin flour-soybean flour

Nutrition	Treatment (yellow pumpkin flour : soybean flour)				
	F1 (70:30)	F2 (60:40)	F3 (50:50)	F4 (40:60)	F5 (30:70)
Moisture (%)	11,75 ± 0,030[e]	11,64 ± 0,010[d]	11,2 ± 0,065[c]	10,88 ± 0,035[b]	10,48 ± 0,035[a]
Ash (%)	5,51 ± 0,015[e]	5,31 ± 0,010[d]	5,10 ± 0,010[c]	4,89 ± 0,010[b]	4,68 ± 0,020[a]
Protein (%)	15,24 ± 0,020[a]	19,35 ± 0,025[b]	23,43 ± 0,040[c]	27,50 ± 0,030[d]	31,61 ± 0,035[e]
Fat (%)	7,41 ± 0,020[a]	10,57 ± 0,025[b]	13,75 ± 0,025[c]	16,89 ± 0,025[d]	20,09 ± 0,025[e]
Carbohydrate (%)	60,07 ± 0,025[e]	53,12 ± 0,070[d]	46,44 ± 0,051[c]	39,83 ± 0,062[b]	35,12 ± 0,436[a]
Calories (kcal/g)	4,563 ± 0,034[a]	4,585 ± 0,020[a]	4,618 ± 0,092[ab]	4,701 ± 0,026[b]	4,836 ± 0,043[c]

The analysis of variance results demonstrate that the ratio of pumpkin flour to soybean flour significantly influences ($p < 0.05$) the moisture content, ash, protein, fat, carbs, and caloric value of the pumpkin-soybean flour food bar. The moisture content of the snack bar varies between 10.48% and 11.75%, with formula F5 exhibiting the lowest moisture content at 10.48% and formula F1 displaying the highest at 11.75%. Reduced moisture content can prolong the product's shelf life, whereas elevated moisture levels can facilitate microbial and mold proliferation, thus compromising the product's quality and freshness **(Almasyhuri et al., 2012)**. The utilization of desiccated raw materials and the roasting procedure contribute to the diminution of moisture content and water activity in the product **(Ekafitri & Isworo, 2014)**. The ash concentration of the food bar varies between 4.68% and 5.51%, with formulation F5 exhibiting the lowest ash content at 4.68% and formulation F1 displaying the highest at 5.51%. Ash content indicates the mineral composition of food products, correlating with their nutritional value and general quality **(Salamah et al., 2012)**. The protein content of the food bar varies between 15.24% and 31.61%, with formula F1 yielding the minimum protein content (15.24%) and formula F5 yielding the maximum protein content (31.61%). The augmentation of protein content results from the incorporation of soybean flour, which possesses a high protein level of 33.59%. Protein is essential for energy provision, tissue construction and repair, and metabolic processes **(Ekafitri & Isworo, 2014)**. The meal bar's fat content ranges from 7.41% to 20.09%, with formula F1 exhibiting the lowest fat content at 7.41% and formula F5 displaying the highest at 20.09%. The fat level of the food bar is predominantly determined by the ratio of soybean flour, which contains 24.84% fat.Fat has a crucial function as an energy source, facilitates the absorption of fat-soluble vitamins A, D, E, and K, and amplifies the umami flavor in meals **(Ekafitri & Isworo, 2014)**. The carbohydrate amount of the meal bar varies between 35.12% and 60.07%, with formula F5 exhibiting the lowest carbohydrate content (35.12%) and formula F1 displaying the highest (60.07%). Carbohydrates in food items are the primary energy source and influence the flavor, texture, and color of food **(Ekafitri & Isworo, 2014)**. The carbohydrate content in this study was assessed using the by-difference approach, indicating its reliance on the quantities of other components in the meal bar. The caloric value of the meal bar ranges from 4.563 kcal/g to 4.836 kcal/g, with formula F1 producing 4.563 kcal/g and formula F5 producing 4.836 kcal/g. The disparity in calorie numbers arises from the differing ratios of pumpkin flour and soybean flour, which influence the nutritional profile of the final product **(Sundari et al., 2015)**.

Sensory properties of food bars

Sensory analysis was performed to ascertain the panelists' preferences for each food bar treatment, encompassing qualities of color, scent, flavor, and texture. The findings of the sensory evaluation are displayed in **Table 3**.

Table 3 Mean preference score for food bars made with pumpkin flour and soybean flour

Parameter	Treatment (yellow pumpkin flour : soybean flour)				
	F1 (70:30)	F2 (60:40)	F3 (50:50)	F4 (40:60)	F5 (30:70)
Color	5,00 ± 1,323	4,80 ± 1,354	5,64 ± 1,411	5,08 ± 1,352	5,12 ± 1,092
Aroma	4,88 ± 1,269	4,48 ± 1,418	4,84 ± 1,068	4,68 ± 0,748	5,12 ± 1,166
Taste	4,72 ± 1,487	4,96 ± 1,020	5,48 ± 1,358	4,56 ± 1,474	4,12 ± 1,740
Texture	4,84 ± 1,405	5,12 ± 1,509	5,64 ± 1,350	5,20 ± 1,683	2,84 ± 1,650

The results of the Friedman test on color preference indicate that the difference in the proportion of yellow pumpkin flour and soybean flour significantly affects color ($p \leq 0.05$), with color scores ranging from 4.80 to 5.64 (neutral–somewhat like). Formula F2 (60:40) has the lowest color score (4.80), while F3 (50:50) has the highest color score (5.64). The color of the food bar can be influenced by the Maillard reaction and changes in starch structure that occur during baking **(Pradipta et al., 2015)**. For aroma, the test results show that the proportion of pumpkin flour and soybean flour does not significantly affect the aroma ($p \geq 0.05$), with scores ranging from 4.48 to 5.12 (neutral–somewhat like). Formula F2 has the lowest aroma score (4.48), while F5 (30:70) receives the highest aroma score (5.12). Aroma plays an important role in consumer preference, where pumpkin flour has a distinctive aroma that is more favored **(Lestario et al., 2012)**. On the taste parameter, the test results showed a significant influence ($p \leq 0.05$) on the taste score, with values ranging from 4.12 to 5.48 (neutral—somewhat liked). F5 (30:70) has the lowest taste score (4.12), while F3 (50:50) has the highest taste score (5.48). This difference in taste is influenced by the composition of the ingredients, where pumpkin flour provides a stronger flavor, while soybean flour tends to impart a bitter taste that can lower the overall flavor score if not balanced with other ingredients **(Agustiana et al., 2023)**. For the texture parameter, the proportion of pumpkin flour and soybean flour significantly affects the texture score ($p \leq 0.05$), with texture scores ranging from 2.84 to 5.64 (dislike–somewhat like). Formula F5 (30:70) has the lowest texture score (2.84), while F3 (50:50) has the highest texture score of 5.64. The texture of the food bar is influenced by the base ingredients, mold thickness, and oven temperature, where the addition of honey, margarine, and cream milk powder enhances the softness and chewiness of the product **(Kusumastuty et al., 2015; Issutarti, 2006)**. The higher the proportion of pumpkin flour, the softer and chewier the product texture becomes, whereas a higher proportion of soybean flour tends to produce a harder and rougher texture **(Nafi et al., 2016)**.

Analytical decision-making

Decision analysis employs the De Garmo method **(Nafi et al., 2016)** to assess efficiency and identify the optimal treatment. The De Garmo method is a systematic approach to determining the most efficacious treatment, with the efficacy index serving as the primary metric. The determination of the optimal treatment is achieved through a comparative analysis of the product values of each treatment, employing the effectiveness index based on the specified values. The best treatment is determined by comparing the product value of each treatment using an effectiveness index based on predetermined values. The treatment with the highest product value (PV) or yield value (YV) is considered the best treatment because this value is obtained by taking into account all variables that play a role in determining product quality. The De Garmo method aims to identify the treatment sample that provides the greatest value, thereby facilitating the establishment of the ideal formula for the food bar. The food bar is assessed with the effectiveness index or De Garmo technique, taking into account all elements influencing its quality, including caloric value, color, scent, taste, texture, and chemical qualities (such as moisture, ash, protein, fat, and carbs). The weight of a variable is directly proportional to its importance **(De Garmo et al., 1984)**.

Formula F4 (40:60) was determined to be the optimal formulation, featuring a nutritional profile of 27.50% protein, 16.89% fat, 10.88% moisture, 4.89% ash, and 39.83% carbs, yielding a caloric value of 4.701 kcal/g. The organoleptic qualities were rated as follows: color 5.08 (like), fragrance 4.68 (somewhat like), taste 4.56 (somewhat like), and texture 5.2 (like). The food bar, composed of pumpkin flour and soybean flour, is intended for emergency food requirements, ensuring that the caloric content satisfies daily energy needs. The nutritional profile of emergency food must adhere to the prescribed standard of around 2100 kcal, as advised in the dietary guidelines from the United States and Canada (Institute of Medicine, 1995). Information on daily energy needs per person can be utilized as a benchmark in the creation of emergency food prototypes **(Zoumas et al., 2002)**. The design of this emergency food formulation distributes a daily energy need of 2100 kcal among three meals, each providing 700 kcal. A single meal portion consists of three bars, with each bar weighing 50 grams and anticipated to deliver 233–250 kcal. The chosen F4 formula meal bar satisfies the emergency food standards, providing a total energy of 235.05 kcal per 50 grams. This energy content satisfies the minimum criteria established for Emergency Food Products (EFP).

The De Garmo decision-making approach found formulation F4 (40:60 pumpkin flour to soybean flour) as optimal because of its superior nutritional quality and sensory appeal. Formulations F3 and F5 exhibited increased caloric and protein values; however, they also displayed shortcomings in sensory characteristics and moisture content. For instance, F5 exhibited the highest protein content (31.61%) and caloric value (4.836 kcal/g) but attained the lowest ratings in texture (2.84) and taste (4.12), which are critical for customer appeal in emergency situations. Moreover, F4 had one of the lowest moisture contents (10.88%), which is beneficial for preventing microbial growth and extending shelf life. Thus, F4 was chosen not only for its nutritional adequacy (235.05 kcal/50g) but also for its microbiological stability and enhanced hedonic acceptance, making it the most suitable candidate for shelf life assessment under ASLT conditions.

Estimating the shelf life of food bars

The shelf life estimation of pumpkin flour and soybean flour food bars in aluminum foil packaging was conducted using the Accelerated Shelf-Life Testing (ASLT) method with the Arrhenius model approach. The ASLT method can be performed more quickly and accurately to optimize storage conditions according to the specified requirements (Asiah et al., 2018). This study used storage temperatures of 25°C, 35°C, and 45°C, referring to the literature by **Herawati (2008)**, which states that the testing temperatures for dry food products range from 25°C to 50°C. The testing was conducted over 12 days with observations made on days 0, 3, 6, 9, and 12, based on the guidelines of **Asiah et al. (2016)**, which recommend five observation points: one at the beginning of storage, three in the middle of storage, and one at the end of storage, when product damage is expected to occur. The parameters assessed include the total yeast and mold counts and the thiobarbituric acid (TBA) value. This is because chemical reactions like the Maillard reaction and lipid oxidation, along with biological changes like microbial growth and enzymatic or non-enzymatic reactions, can lead to a reduction in the quality of the food bar product. Both internal and external factors significantly affect the quality and safety of the product during storage **(Asiah et al., 2016)**.

Rancidity, an issue that can reduce quality in food products containing fat, is characterized by an unpleasant odor. According to Winarno (2002), the main degradation of lipids causes the development of rancid smell and taste in the product. The Thiobarbituric Acid (TBA) value in the food bar product was observed over 12 days, with measurements taken every 3 days. The results of the TBA value measurements during storage can be seen in **Table 4**.

Table 4 Changes in food bar quality over a 12-day storage period.

Parameter	Storage duration (days)	Temperature storage (ºC)		
		25ºC	35ºC	45ºC
Thiobarbituric acid (mg MDA/kg sample)	0	0,3042	0,3042	0,3042
	3	0,5070	0,5226	0,5850
	6	0,6942	0,8814	0,9048
	9	0,7332	0,9048	0,9984
	12	0,7878	0,9282	1,3962
Total mold yeast(log CFU/g)	0	2,13033	2,19033	2,24303
	3	2,90034	2,42324	2,47712
	6	2,72835	3,83250	2,58546
	9	3,55630	4	3,74818
	12	3,95424	4,05307	3,88930

The storage of items at elevated temperatures and for extended periods correlates with an increase in the TBA (Thiobarbituric Acid) value of food bars, signifying a decline in product quality. The findings of this study align with the studies conducted by **Sammet et al. (2006)**, indicating that TBA levels will rise over the storage duration. The TBA value is chiefly affected by the generation of malondialdehyde and other volatile chemicals resulting from lipid oxidation. Lipid oxidation, occurring when lipids in a product react with oxygen at elevated temperatures, generates a rancid odor akin to that of dicarboxylic acids. The rise in TBA value signifies that an oxidation process transpires throughout the storage period, evidenced by the existence of malondialdehyde. **Maulinda et al. (2017)** assert that temperature is the factor influencing the reaction. Elevated temperatures will accelerate the reaction rate of the chemical components inside the product, leading to product degradation. The proliferation of microorganisms, particularly mold, is directly correlated with storage temperature and length. Mold, a tiny fungus characterized by mycelium and filamentous spore masses, can proliferate swiftly at elevated temperatures, particularly between 25°C and 35°C **(Negara et al., 2016; Prabandari, 2023)**. **Babay's (2013)** study indicates that the quantity of molds and yeasts in items will rise with time and with elevated storage temperatures, as warmer conditions facilitate accelerated microbial proliferation.
The alterations in the quality of pumpkin flour and soybean flour food bars throughout the storage duration can be depicted using linear and exponential curves. A linear curve signifies a zero-order reaction, whereas an exponential curve denotes a first-order reaction. This decision is affected by the rate of variation in product quality. Zero-order reactions demonstrate uniform degradation, whereas first-order reactions display logarithmic or exponential decline. The quality deterioration data derived from the zero-order and first-order reactions were subsequently plotted, and a linear regression equation was created for each reaction. This seeks to determine the suitable reaction order. The reaction order is determined by the curve equation exhibiting a superior R^2 value **(Diniyah et al., 2015)**. **Table 5** displays the values of the graph equations and the R^2 values of the quality parameters under different storage circumstances.

Table 5 Reaction equations for quality parameters at different storage temperatures.

Parameter	Temperature (ºC)	Order 0		Order 1		Choosen reaction order
		Reaction equation	R^2	Reaction equation	R^2	
Thiobarbituric acid (TBA)	25	y = 0,0398x + 0,3666	0,902	y = 0,0757x - 1,011	0,8396	0
	35	y = 0,543x + 0,3822	0,8444	y = 0,0927x - 0,984	0,8109	
	45	y = 0,0866x + 0,3182	0,9767	y = 0,1194x – 1,0153	0,9308	
Total mold yeast	25	y = 0,1638x + 1,949	0,9541	y = 0,0559x + 0,711	0,9676	1
	35	y = 0,1767x + 2,2394	0,8415	y = 0,0577x + 0,8133	0,8353	
	45	y = 0,2188x + 1,8759	0,8669	y = 0,0505x + 0,7659	0,8969	

For each parameter, zero-order and first-order reactions were tested, and the R^2 values of both were compared. The model with the higher R^2 value was selected as the most appropriate model to describe the degradation process. For TBA (Thiobarbituric Acid), the R^2 value at 45°C is 0.9767, indicating that degradation follows a zero-order reaction, as the data show better agreement with the zero-order model. Meanwhile, for total mold yeast, the R^2 value at 25°C is 0.9676, indicating that degradation follows a first-order reaction because the R^2 value is close to 1, indicating good fit for first-order.
After determining the order of the reaction, a pre-exponential factor curve (ln k) against the inverse temperature (ln k with 1/T) was created, resulting in the Arrhenius equation. This equation is in the form of a linear equation, y = a + bx, or ln k = ln ko – (Ea/R) (1/T). Based on the Arrhenius equation, the value of Ea (activation energy) and the quality degradation constant can be obtained. The quality degradation constant, or the rate of quality degradation, is one of the key factors that affect the shelf life of a food product. The higher the rate of product quality degradation, the faster the degradation reaction occurs. The value of Ea, the quality degradation constant, and the shelf life of food products under each observation parameter at each storage temperature can be seen in **Table 6**.

Table 6 Activation energy (Ea) and shelf life stimation for the food bar.

Parameter	Temperature (ºC)	(1/T)	Slope (k)	ln k	Ea	k	Shelf life (days)
Thiobarbituric acid	25	0,00336	0,0398	-3,22389	7297,16	0,0386594	43
	35	0,00325	0,0543	-2,91323		0,0576915	29
	45	0,00314	0,0866	-2,44646		0,0386592	20
Total mold yeast	25	0,00336	0,0559	-2,88419	938,84	0,05743	31
	35	0,00325	0,0577	-2,85250		0,05455	32
	45	0,00314	0,0658	-2,98578		0,05198	33

Asiah et al. (2016) assert that, in determining the parameter most crucial to product quality deterioration, the parameter exhibiting the lowest activation energy value is deemed most influential. The total yeast mold exhibits the lowest activation energy at 938.84 cal/mol, rendering it a crucial factor that substantially influences the deterioration of product quality. The food bar, composed of pumpkin flour and soybean flour, encased in aluminum foil, exhibits a shelf life of 31 days at 25°C, 32 days at 35°C, and 33 days at 45°C.
According to the World Health Organization (WHO), the daily caloric requirement for emergency food is approximately 2,100 kcal per person, distributed across three meals, with each meal providing approximately 700 kcal **(Institute of Medicine, 1995)**. According to the most recent nutritional analysis, 50 grams of F4 provides 235.05 kcal. When consumed in accordance with the recommended daily intake of three bars, it has been demonstrated to satisfy the energy requirements necessary for emergency relief. Consequently, F4 is congruent with global recommendations concerning the provision of short-term energy supplies in contexts of disaster relief. The military rations utilized by the U.S. and Canadian militaries are designed to provide a balanced nutritional profile, comprising adequate amounts of carbohydrates, protein, fat, and micronutrients. Formulation F4 provides 27.50% protein and 39.83% carbohydrates in each 50-gram serving, which meets the general protein and energy needs of emergency food requirements. The microbial safety of the food bar was assessed by measuring total mold and yeast counts over time. The shelf life of 31-33 days under controlled temperatures (25°C, 35°C, 45°C) corresponds with minimal microbial growth during the study period. However, in real-world emergency situations, environmental conditions (e.g., high humidity or fluctuating temperatures) may lead to accelerated microbial growth and quality deterioration (Zoumas et al., 2002). The World Food Programme (WFP) has established a recommendation for the shelf life of emergency food products, stipulating that they should have a shelf life of at least six months when stored at room temperature **(Zoumas et al., 2002)**. However, the shelf life of our F4 formulation is 31-33 days, which, while shorter, is still viable for short-term emergency situations, such as immediate post-disaster scenarios, where longer shelf life is typically ensured by additional food reserves. In order to enhance microbial safety and extend shelf life, active packaging technologies could be incorporated, such as antimicrobial packaging films or oxygen scavengers that help inhibit microbial growth and slow down oxidation **(Winarno, 2002)**. Furthermore, the exploration of natural preservatives or modified atmosphere packaging (MAP) has the potential to markedly extend the shelf life of products in hot and humid climates, which are prevalent in emergency relief settings **(Hariyadi, 2019)**.

CONCLUSION

The food bar formula F4, which has a treatment proportion of 40:60 between yellow pumpkin flour and soybean flour, is the optimal formulation for emergency use. It boasts a calorie value of 233.05 kcal/50 g, a moisture content of 10.88%, a fat content of 16.89%, an ash content of 4.89%, and a carbohydrate content of 39.83%. The organoleptic assessment indicates that the color is 5.08 (like), the aroma is 4.68 (somewhat like), the taste is 4.56 (somewhat like), and the texture is 5.2 (like). Based on the total mold and yeast parameters as well as the lowest calculated activation energy (Ea), the shelf life of the pumpkin flour-soybean flour food bar in aluminum foil packaging is estimated to reach 31 days at 25°C, 32 days at 35°C, and 33 days at 45°C. Since the shelf life is only short-term, active packaging technologies can be applied to extend it, such as antimicrobial packaging films or oxygen absorbers that help inhibit microbial growth and slow down oxidation. In addition, the search for natural preservatives or modified atmosphere packaging (MAP) has the potential to significantly extend the shelf life of products in hot and humid climates, which are commonly found in emergency relief environments.

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