Accelerated shelf life determination of corn snack bars

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Abstract

Corn snack bars are a product made from corn extrudate and additional ingredients in the form of sorghum flour and can be consumed as a nutritious snack. The shelf life of snack bar products needs to be known to ensure product quality reaches consumers. This study aims to determine the shelf life changes in critical parameters during storage using the accelerated shelf life testing Arrhenius method. Tests on the estimation of shelf life with the Arrhenius method were carried out at 3 different storage temperatures (10°C, 30°C, and 47°C) for 35 days with an observation time of every 7 days. The shelf life of corn snack bars was tested using parameters of quality changes such as water content, texture hardness, and springiness. Based on the results obtained, the final shelf life of the corn snack bar is determined by the crispness parameter; shelf life at 10°C is 233 days, at 30°C is 111 days, and at 47°C is 363 days.

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Introduction

The formulation of innovative food products that are healthy and nutritious for consumers has become one of the recommendations of the World Health Organization for the last 10 years. Based on this, from 2005 to 2014, there was an increase in consumer demand for natural, nutritious, and safe food products to be stored or consumed; in this case, snack bar products became the choice of the community with sales reaching 1.3 billion US dollars (Ho *et al*., 2016). Snack bars (SB) are snacks that are solid, practical, rich in nutrients, and have a relatively long shelf life (Murdiani *et al.,* 2022). The physical characteristics of the SB are brown in color, sweet in taste, dense in texture, and uniform in shape. The SB quality requirement is that it contains a water content of 6.1%, while the value of the texture, hardness, and crispness is determined by the raw materials used (USDA, 2019). The basic ingredients for making SB are a mixture of cereals, nuts, and imported commodities such as wheat flour (Asriasih *et al.,* 2020). The utilization of local food commodities in the form of corn and sorghum flour has the potential to substitute wheat flour and cereals in SB. Corn is one of the local commodities that has the opportunity to be developed because it is high in carbohydrates and protein and contains nutrients that are good for the body, such as provitamin A (Goredema-Matongera *et al*., 2021). Other alternative materials for making SB include corn flour and bran flour (Kusumastuty *et al.,* 2015). The corn snack bar (CSB) research has not studied the shelf life. Based on this, the new CSB formulation with the main ingredients in the form of corn extrudate and sorghum flour will examine the product's shelf life for 35 days.

The period between the product starting to be packaged and the quality of the product that still meets the requirements for consumption is called shelf life. Shelf life is used as an important parameter during storage so that it meets quality requirements in determining product durability. The selection of the method of estimating the shelf life of CSB products is based on conformity to product characteristics; it is easy, fast, and gives precise results. Estimating the shelf life of food products can be done using 2 methods: the accelerated shelf life test (ASLT) and the extended storage studies. The ASLT method conditions the product in an environment that can accelerate the reaction of food product quality degradation (Arif, 2016). The selection of the ASLT method provides faster results with high accuracy, where the process of food spoilage is accelerated and calculated mathematically (Nuraini and Widanti*,* 2020). The higher the storage temperature, the faster the reaction rate of chemical compounds in the product will change, thus triggering a shorter shelf life (Buvé *et al.,* 2018). Using the Arrhenius approach to estimate the shelf life of CSB (corn snack bar) is useful because the damage is more influenced by temperature, which plays a role in product damage (Yuniastri *et al.,* 2019). This study aims to determine the shelf life of SBJ at 3 different storage temperatures using ASLT with the Arrhenius approach to quality changes in the characteristics of moisture content, hardness, and crispness. The benefit of this research is to provide information on the shelf life of CSB, which, hopefully, can be included in the product packaging. Information on the shelf life of food products is very important for producers, consumers, and sellers as it is related to the safety of food products.

Materials and Methods

Making the corn snack bar

Corn as the main ingredient of the CSB will be processed into extrudate first, where the corn variety used is classified as yellow corn, the bisma variety. Furthermore, in the weighing stage of raw materials, there is a process of mixing raw materials in stages 1 and 2. Stage 1 mixing consists of maltodextrin, refined sugar, eggs, margarine, honey, and salt. The stage 2 mixing process includes white sorghum flour (Lingkar Organik, Tangerang City, Indonesia), boiled green beans, roasted peanuts, pre-prepared corn extrudates, and sunflower seeds. Stages 1 and 2 have been mixed well, added vanilla, and then stirred until evenly distributed. The dough is formed, molded, and baked in the oven at 120 for 40-50 minutes, then packaged in 32 packages and stored at 3 different temperatures for 35 days.

Determination of the characteristics of the corn snack bar

Moisture content

The porcelain dish is in the oven for 1 hour. The cup that had been removed from the oven was cooled in a desiccator for 15 minutes and weighed as weight A. The SB sample was mashed with a mortar, then weighed at 2 g and put into a pre-dried cup as weight B. The cup contains the sample, which was dried in an oven at a temperature of 100-105 for 4 hours, then cooled in a desiccator for 15 minutes and reweighed. The moisture content of each sample was tested in duplicate (2 times). These steps are repeated until a constant weight is obtained.

Texture (hardness and springiness)

The process of analyzing the value of texture hardness is done by cutting the sample to a size of 1.5×1.5×1.5 cm in cubic form. The sample was pressed twice with a cylindrical probe no. 35 to 40% of the initial height and with a constant pressing speed of 1 mm/s. Sample measurements were carried out in duplicate, where the parameters of hardness and crispness were observed and discussed. The value of hardness as the peak strength during the first compression cycle is expressed in gf (gram force). The value of crispness is one of the quality parameters of dry food products. The crispness of a food product is expressed in N or mm (millimeters).

Accelerated shelf life test

Determination of the shelf life of food products using the Arrhenius model based on Diniyah *et al*. (2015) consists of several stages, namely plotting the results of observations at 6 observation points, plotting the quality and time change curve, which produces a linear equation y=ax+b, then determining the order of the reaction based on the equation of the curve value with an R^2 value and calculations using the Arrhenius. The calculation is done by plotting the pre-exponential curve k (ln k) with the inverse temperature (lnk with 1/T), so that the linear equation is y=a+bx, and then the activation energy is determined from the Arrhenius equation. The last stage is the prediction of shelf life calculated from changes in product quality before and after storage divided by the value of k. The estimated shelf life of an SB can be calculated using the following equations (1 and 2).

Equation of order 0:

$$T=(A0-At)/k \tag{1}$$

Equation of order 1:

$$T=\ln(A0-At) \tag{2}$$

where T is the shelf life (days), A0 is the critical value of the initial quality attribute, At is the value of the final storage quality attribute and K is the constant of quality degradation.

Table 1. Changes in the quality of corn snack bars during 35 days of storage.

Changes of quality	Storage time (days)	Storage temperature 10°C	30°C	47°C
Water content (%)	0	8.30	8.30	8.30
	7	5.51	5.02	2.03
	14	7.20	8.03	6.03
	21	6.80	7.22	7.30
	28	7.54	7.72	5.30
	35	7.58	9.18	5.41
Hardness (gram force)	0	1,434.78	1,434.8	1,434.8
	7	2,330.0	786.0	4,610.0
	14	3,694.3	2,012.0	1,286.5
	21	2,161.5	2,244.3	2,812.5
	28	2,363.8	955.8	4,584.5
	35	2,809.0	1,191.7	3,080.0
Springiness (mm)	0	5.9	5.9	5.9
	7	1.5	2.2	1.6
	14	1.4	1.9	1.4
	21	1.3	2.1	1.7
	28	1.2	1.4	1.4
	35	1.2	6.2	9.1

Results and Discussion

Characteristics of corn snack bar

CSB physical characteristics include the form of a solid stick and a crunchy texture, which is in line with SB in general. During storage, food products such as SB experience quality changes, such as a decrease in the hardness and crispness of the product (Wijaya *et al*., 2014).

The characteristics considered in this study include water content, texture hardness, and springiness.

The parameters used are water content, hardness, and crispness, which among these results has the lowest activation energy value and shortest shelf life. The value of the initial moisture content of the SB is very influential on the quality of the product during storage. The initial moisture content of the CSB is 8.30%. SB generally has a water content ranging from 6.85-16.91% (Sarno *et al*., 2019). CSB has a fairly high water content value. The value of the moisture content of the SB tends to vary because it is influenced by the use of raw materials. The use of raw materials is one of the causes of the increase in the water content of food products (Sari *et al*., 2017). The initial texture of the CSB has a hardness of 1434.8 gf and a springiness of 5.9 mm. The formation of the SB texture is influenced by the moisture content of the raw materials used and the roasting process. SB with high water content will produce a texture that is not hard and brittle; on the contrary, SB with low water content will produce a dense and hard texture (Ningsih *et al*., 2021). CSB produced from this research has a high moisture content and hardness value. Based on the research of Figueiredo de Sousa *et al*. (2019), the use of corn as the basic ingredient for snack bars resulted in the highest hardness value of 1262.6 gf. Changes in the characteristics of CSB occurred during 35 days of storage.

Moisture content

The water content contained in a food product is an important factor in determining the shelf life of the product because it affects the physical, chemical, microbiological, and enzymatic changes of the resulting product (Nurhayati and Andayani, 2014). The moisture content of the CSB produced during 35 days of storage at 3 different temperatures can be seen in Table 1.

CSB was stored for 35 days, with observations every 7 days. The results of testing changes in the quality of water content stored at 10°C and 47°C showed a decrease in water content, where the initial water content value was 8.30%, in the 5 weeks of observation, the water content value at 10°C was 7.58% and at 47°C was 5.41%. The decrease in the value of water content is caused by the process of transferring water vapor from the product to the environment caused by high temperatures during storage. Besides, the difference in humidity between the environment and the product can cause water vapor to move from the environment to the product or *vice versa* (Wasono and Yuwono, 2014). Table 2 shows that the increase in water content is caused by the temperature and humidity of the room during storage, which affects the evaporation of water from the product to the environment, where water vapor will move from high to low humidity (Iwansyah *et al*., 2022). The moisture content of the CSB at 35 days of storage was 9.18% at 30°C, which was higher than the banana SB at the same storage time and temperature (5.16%). The United States Department of Agriculture (USDA, 2019) states that for SB standard product quality, the water content is 6.1% per 100 g.

Hardness

The amount of force applied until the object changes shape is referred to as the hardness value of a food product (Ekafitri *et al*., 2013). Table 2 shows the hardness of the CSB during the 35 days of storage. According to Table 2, there was an increasing trend between 10°C and 47°C: 5-week observations were 2,809.0 gf and 3,080.0 gf. This increase is in line with the hardness value of banana SB for 35 days of storage at 15°C, 30°C, and 45°C (Surahman *et al*., 2020). The hardness value of the CSB increased in the fifth week of observation at 10°C and 47°C; CSB water content values also increased in the fifth week of observation at temperatures of 10°C and 47°C. The lower the value of the water content of a food product, the harder the texture of the product becomes (Azizah *et al*., 2019). The hardness of the product can be affected by the availability of water; in this case, it affects gel formation due to the starch retrogradation process (Iwansyah *et al*., 2022). The hardness value of the CSB in the last week of observation, stored at 30°C, was 1,191.7 gf, meaning that the CSB was easier to break, compared to the CSB stored at 10°C and 47°C (respectively, 2,809.0 gf and 3,080.0 gf) (Rahardjo *et al*., 2020).

Springiness

The level of springiness in a food product is related to sensory reception, namely taste and chewing time (Sayangbati *et al*., 2013). Table 2 details the springiness of the CSB. Table 2 also shows that during 35 days of storage, springiness tends to decrease compared to the initial crispness value. The decrease in the springiness value was indicated by higher fracture distance values at 30°C and 47°C (6.2 mm and 9.1 mm), while at 10°C, the fracture distance was lower. The springiness value at a storage temperature of 10°C decreased from the value in the first week of observation, namely 1.5 mm, while in the fifth week of observation, it was 1.2 mm. The decreased crispness value during storage is correlated with the value of water content: the higher the absorption of water vapor from the environment, the higher the water content value, which can affect the crispness of the product (Puspitasari *et al*., 2020). The hardness texture will increase during storage, while the crispness value will decrease (Pangestika et al., 2021). CSB products have a lower crispness value of 5.9 mm compared to banana-based SB, whose crispness is 0.63 mm (Sarifudin *et al*., 2015).

Shelf life of corn snack bar

The Arrhenius model was carried out by plotting a graph between the parameters of quality change and storage time. The graph plot is used for equations of order 0, while for equations of order 1, it plots the ln of the change in quality with storage time. Reaction order selection is used to determine product shelf life using the Arrhenius method. The reaction order is determined by comparing the R^2 value and coefficient of determination in each linear regression equation at the same temperature (Kurniawan *et al*., 2018). The value of the coefficient of determination is 0 and 1, so a value of R^2 close to 1 means that the accuracy of the data shown is better (Imamah *et al*., 2016).

The estimation of the shelf life of CSB was carried out by the ASLT using the Arrhenius approach. The shelf life of the product using this approach is determined by selecting the reaction order first, and then plotting the value of the quality degradation constant (k) with the inverse temperature (1/T) and ln k. Based on the

Table 2. Physical characteristics of corn snack bars.

Physical characteristics	Score
Water content (%)	8.30
Hardness (gram force)	1,434.8
Springiness (mm)	5.9

Arrhenius equation, the value of the activation energy (Ea) is obtained, and the value of k is a constant for decreasing product quality during storage (Pertiwi *et al*., 2020). The results of the calculation of the value of Ea, quality degradation constant, and estimated shelf life of CSB products are presented in Table 3.

The value of k, or the rate of decline in product quality during storage, is very influential in determining shelf life. Table 3 shows an increase in the rate of decline along with the high temperature. Storage temperature affects the rate of product decline; the higher the temperature, the greater the rate of product quality decline (Mongdong *et al*., 2019). Based on Table 3, parameters of the moisture content of the CSB show that the higher the temperature, the higher the value of the rate of decline in quality. The rate of deterioration (k) of CSB at 10°C, 30°C, and 47°C is 0.23, 0.38, and 0.54%, respectively. Corn snack bars at storage temperatures of 10°C, 30°C, and 47°C have a higher rate of quality loss compared to banana snack bars at 0.20% at 15°C, while at 30°C and 45° C values are 0.22% and 0.24% (Surahman *et al*., 2020).

The level of springiness of the CSB during storage can be seen in Table 3. Shelf life at 10°C, 30°C, and 47°C is respectively 233, 111, and 363 days. Storage temperature can affect the shelf life of CSB. The shelf life of SB becomes shorter as the temperature increases during storage (Mongdong *et al*., 2019). The shelf life of CSB at storage temperatures of 10°C, 30°C, and 47°C is longer compared to the shelf life of banana SB. The shelf life of banana snack bars at storage temperatures of 15°C, 30°C, and 45°C is 84.96, 75.67, and 69.19 days (Surahman *et al*., 2020). The difference in the shelf life of the SB is influenced by its initial moisture content, the method of testing the shelf life, and the weight of the product being tested. The rate of product decline, in addition to being affected by temperature, is also influenced by the storage time of the product. The shelf life based on the hardness parameter is presented in Table 3, which shows the same trend as the springiness parameter. CSB has a calculated estimated shelf life, as shown in Table 4. The estimated shelf life of corn snack bars is 128.43 days at 10°C and at 30°C the shelf life is 70.84 days. The shelf life of CSB at 30°C is 95.42 days according to Iwansyah *et al*. (2022). A shorter shelf life of SB is caused by the increasing rate of product quality degradation (Harris and Fadli, 2014).

Conclusions

CSB at 10°C has a shelf life of 233 days, 364 days at 47°C, and 111 days at 30°C. The critical parameter that is used as a reference in determining the shelf life of the CSB is springiness, with an R^2 of 0.5562. The decrease in the quality of CSB during storage is influenced by the use of raw materials, temperature, and storage time.

Table 3. Equation and reaction order for each observation parameter and storage temperature.

Parameter	Temperature (°C)	Order 0 regression equation	Order 1 regression equation	R^2 order 0	R^2 order 1	Selected order	Order of choice for the calculation of shelf life
Water content	10	Y=0.0085x+7.0046	Y=0.0018x+1.9289	0.0139	0.0267	1	1
	30	Y=0.0476x+6.7427	Y=0.0069x+1.8876	0.1947	0.1854	0	
	47	Y=-0.0137x+5.9668	Y=0.0038x+1.5935	0.0069	0.0101	1	
Hardness	10	Y=22.203x+2.077	Y=0.0117x+7.5659	0.1504	0.2412	1	1
	30	Y=-1.9347x+1471.3	Y=-0.0009x+7.2173	0.0019	0.0009	0	
	47	Y=39.493x+2276.9	Y= 0.0187x+7.5507	0.1271	0.1961	1	
Springiness	10	Y=-0.0998x+3.8214	Y=-0.0354x+1,1372	0.4847	0.5562	1	1
	30	Y=-0.0029x+3.3	Y=-0.0043x+1.0744	0.0003	0.0076	1	
	47	Y=0.0641x+2.3952	Y=0.008x+0.8028	0.0667	0.016	0	

Table 4. Calculation results of the estimated shelf life of corn snack bars.

Parameter	Temperature (°C)	(1/T) K	K	ln K	Ea	K_0	Rate of deterioration (k)	Shelf life (days)
Water content	10	0.0035	0.0018	-6.31997	4050.6456	3.1506	0.0023	311.19
	30	0.0033	0.0069	-4.97623			0.0038	233.50
	47	0.0031	0.0038	-5.57275			0.0054	537.48
Hardness	10	0.0035	0.0117	-4.44817	987.02214	0.0303	0.0052	128.43
	30	0.0033	0.0009	-7.01312			0.0059	70.84
	47	0.0031	0.0187	-3.97923			0.0064	119.20
Springiness	10	0.0035	0.0354	-3.34104	7803-7884	0.0023	0.0002	232.69
	30	0.0033	0.0043	-5.44914			0.0005	111.08
	47	0.0031	0.0080	-4.82831			0.0010	363.59

T, temperature; K, constant of quality degradation; ln K, pre-exponential curve k; Ea, activation energy.

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