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Research Article

Shelf-life Determination of Fish *Koya* using Critical Moisture Content Approach

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Abstract: The objective of this study was to determine shelf-life of fish *koya* prepared from Snakehead Murrel [*Channa striata* Bloch, 1793)] and tempeh powder and packed in metalized plastic. Moisture adsorption isotherm of fish *koya* at 30 °C was determined by static gravimetric method over a wide range of water activity, *i.e*., from 0.113 to 0.843. The obtained moisture adsorption isotherm curve was expressed by employing Guggenheim-Anderson-de Boer equation. Accelerated shelf-life testing (ASLT) with critical moisture content approach was used to predict shelf-life of fish *koya*. The critical moisture content obtained by caking fish *koya* was 7.6 g H_2O 100 g^{-1} solids. *Koya* stored at 30 ^{o}C with 75 %, 80 %, and 85 % of relative humidity (RH) had shelf-life of 234 d, 203 d, and 180 d, respectively.

Keywords: Accelerated shelf-life testing, critical moisture content, fish *koya*

1. INTRODUCTION

Koya is a savory powder used as a topping on food. *Koya* powder is usually added to Indonesian traditional foods such as *soto* and noodles in East Java, especially in *Soto* Lamongan. *Koya* is made by mixing the softened fried garlic along prawn crackers. Regina et al. [1] conducted a research study about *koya* based in soy flour and different kinds of fish, such as catfish, tilapia, tuna, and mackerel. The results indicated that the fish *koya* had a moisture content of 13.10 % to 21.21 %, ash content of 5.54 % to 5.99 %, protein content of 27.13 % to 29.83 %, lipid content of 15.55 % to 21.76 %, and carbohydrate content of 30.28 % to 31.92 %.

In this research, fish *koya* was made from Snakehead Murrel (*Channa striata* Bloch, 1793) with addition of tempeh powder. Snakehead Murrel is wild freshwaters fish, which can be found in all parts of Indonesia. Snakehead Murrel in Indonesia is known as "gabus fish". Several studies on snakehead fish had been reported. Sugito & Ari [2] conducted a research on the addition of snakehead fish flesh and chilling applications in gluten *pempek,* while Sari et al. [3] reported that 15 % addition of snakehead fish flour gave the best texture of the biscuit.

Tempeh is a traditional food in Indonesia which is made from soybean grains fermentation. Bavia et al. [4] reported that the steps of tempeh processing are dehulling, cooking, inoculation, and is fermented by fungus like *Rhizopus oligosporus*. Tempeh from soy cultivar BRS 216 has high protein content (51.99 %), isoflavone (123 mg 100 g^{-1}), aglycone (49.00 mg 100 g^{-1} on average), and phytic acid (1.00 g 100 g^{-1}). The nutrient content of tempeh has benefits for human health, such as protection against chronic diseases. The addition of tempeh will increase the protein content in fish *koya.*

Fish *koya* is a hygroscopic dried food product and can be easily damaged by moisture absorption from the environment. The main physical damage is caking which can change the solubility, increase

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lipid oxidation and enzyme activity, alternate taste, and crispiness, and lower sensory qualities and shelf-life [5]. Knowledge about moisture sorption isotherm is needed to determine the quality, stability, and shelf-life of the product, especially in dried food [6].

Moisture sorption isotherm is a curve that describes the relationship between water activity (a_w) and moisture content [7]. This curve describes the ability of food to absorb moisture from the surrounding air and vice versa. Research on moisture sorption isotherms of food products has been widely conducted [7−10].

According to Labuza [11], shelf-life is the length of time a product is able to meet the expected quality of consumers, so it's very important to study. Ellis [12] reported that the shelf-life of product can be determined by two methods, *i.e.* Extended Storage Studies (ESS) and the Accelerated Shelf Life Testing (ASLT). The ASLT method can be done with two approaches, Arrhenius approach and critical moisture content approach. Arrhenius approach is used for food products which damaged due to chemical reactions triggered by storage temperature. The critical moisture content approach is used for food products which damaged due to moisture absorption [11]. The aim of this study was to determine the shelf-life of fish *koya* based on Snakehead Murrel [*Channa striata* (Bloch, 1793)] and tempeh powder using ASLT with critical moisture content approach.

2. MATERIALS AND METHODS

2.1 Fish Grinding

Snakehead Murrel was obtained from Cengklik reservoir, Boyolali, Central Java, Indonesia. Fresh fish was eviscerated and washed thoroughly then steamed for 10 min. After that, the fish was separated from its bone and ground. Then, the ground fish was stored in a refrigerator prior to analysis.

2.2 Tempeh Powder Production

The tempeh was produced in a home industry in Babad, Manang, Sukoharjo, Indonesia. The fresh tempeh was cut into 0.5 cm, then blanched at 80 °C to 90 °C for 10 min. After that, the pieces of tempeh were dried with cabinet dryer at 70 °C for 6 h to 7 h. The size was reduced to 60 mesh. The tempeh powder was then stored at room temperature in sealed jars equipped with silica gel.

2.3 Fish *Koya* Production

Based on the method by Regina et al. [1], *koya* seasoning consists of onion *(Allium cepa* var. *ascalonicum* (L) Back)*,* garlic (*Allium sativum* L.)*,* walnut (*Aleurites moluccana* (L.) Willd*)* and coriander (*Coriandrum sativum* L). The ingredients were mixed with thick coconut milk, ginger, galangal *(Alpinia galangal* (L). Willd.)*,* crushed leaves of lemongrass *(Cymbopogon citratus* (DC.) Stapf, 1906), bay leaf *(Syzygium polyanthum* (Wight) Walp.), lime leaves *(Citrus hystrix* DC.*)*, brown sugar and salt then the mixture was boiled. After that, ground fish was inserted and stirred until dry. Once dry, tempeh powder was mixed in the mixture until the color became brown. Comparison between minced fish meat and tempeh powder was 3:2. The *koya* powder was placed on metalized plastic and then transferred into a jar equipped with silica gel, and was stored at room temperature.

2.4 Determination of Moisture Content (M_i)

The moisture content was determined using the thermogravimetric method [13]. Initial moisture content is expressed as g H_2O 100 g^{-1} solids.

2.5 Determination of Critical Water Content (M_c)

The critical moisture content was determined by storing unpacking fish *koya* at room temperature (30°C) in RH 75 % to 80 %. During storage, the sensory evaluation was conducted daily towards *koya* caking. The assay was conducted until the powder underwent caking. Scale ratings of the sensory test were 1 to 7, conducted by 25 panelists. Score 1 indicated that *koya* strongly formed lumps/caking, while the score of 7 indicated that *koya* did not form lumps. The moisture content was analyzed using thermogravimetry methods [13] periodically and expressed in g H_2O per 100 g solids. Curve relationship between moisture content and *koya* coagulation score was made from experimental data. The *koya* can be assumed to form lumps/cake if the score was 3 (rather caking). By using the relationship curve between moisture content and *koya* coagulation score, the moisture content of fish *koya* when reached score 3 can be determined. This moisture content was called the critical moisture content.

2.6 Determination of Moisture Adsorption Isotherms

Determination of moisture adsorption isotherms using thermogravimetric static methods [6] and adsorption isotherm curve was carried out at 30 °C. To obtain the different relative humidity (RH) 11.3 % to 84.3 %, saturated salt solution was used, ie: LiCl (11.3 %), KCH_3CO_2 (22.5 %), $MgCl_2$ (32.8 %), K_2CO_3 (43.2 %), Mg $(NO_3)_2$ (52.9 %), $NaNO_2$ (65.4 %), NaCl (75.3 %), and KCl (84.3 %). In equilibrium conditions, water activity (a_w) expressed as equilibrium relative humidity (ERH) divided by 100. Moisture adsorption isotherm curve was expressed in GAB (Guggenheim Anderson de Boer) model equations:

$$\frac{M}{Mo} = \frac{K \cdot c \cdot a_w}{(1 - K \cdot a_w)(1 - K \cdot a_w + c \cdot K \cdot a_w)} \quad (1)$$

with M for the moisture content, M_o for the monolayer moisture content, a_w for water activity, c and k were constants for GAB equation [6]. The value of K, C and M_o was determined by Bizot [14] method, *i.e.*:

(i) Modification of GAB equation becomes:

$$\frac{a_w}{M} = \frac{(1 - K.a_w)(1 - K.a_w + C.K.a_w)}{K.C.M_o} \quad (2)$$

(ii)Rearrangements of GAB equation:

$$\frac{a_w}{M} = \frac{1}{K.C.M_o} + \frac{(C-2)}{C.M_o} + \frac{K}{C.M_o}(1-C)a_w^2 \quad (3)$$

$$\frac{a_w}{M} = a_1 + a_2.a_w + a_3.a_w^2$$

with

$$a_1 = \frac{1}{K.C.M_o};\ a_2 = \frac{(C-2)}{C.M_o};\ a_3 = \frac{K}{C.M_o}(1-C) \quad (4)$$

(iii) The value of M_o, K, and C were determined as a function of the coefficients (a_1, a_2 and a_3), in order to obtain:

$$K = \frac{-a_2 \pm \sqrt{a_2^2 - 4.a_1.a_3}}{2.a_1} \quad (5)$$

$$C = 2 + \frac{a_2}{a_1.K} \quad (6)$$

$$M_0 = \frac{1}{a_1.K.C} \quad (7)$$

2.7 Determination of Packaging Water Vapor Permeability

Metalized plastic used as the packaging material was obtained from a local market in Surakarta, Central Java, Indonesia. Determination of packaging vapor permeability was performed using ASTM F1249-01 procedure with Mocon Permatran-W 3/31 at 38.7 °C. The value of Water Vapor Transmission Rate (WVTR) was obtained. This following equation is used to determine the packaging vapor:

$$k / x = \frac{WVTR}{P_{out}} \quad (8)$$

with *k/x* is the packaging permeability (g H_2O / day m^2 mm Hg), and P_{out} was the water vapor pressure at storage temperature × RH (mm Hg).

2.8 Determination of *Koya* Shelf-Life

The *Koya* fish shelf-life was determined by the ASLT critical water content approach [6] using the following equation:

$$ln\left(\frac{M_e - M_i}{M_e - M_c}\right) = \left(\frac{k}{x}\right)\left(\frac{A}{W_s}\right)\left(\frac{Po}{b}\right)\theta \quad (9)$$

with M_e for the equilibrium moisture content (the moisture content level when the product is in equilibrium with the external RH) (g H_2O per 100 g solids); M_i for the initial moisture content (g H_2O per 100 g solids); M_c for the critical moisture content (g H_2O per 100 g solids); *k/x* for the moisture permeability through packaging material (g H_2O (m^2 days mm Hg)$^{-1}$); *A* for the packaging area (m^2); W_s for weight of dry food solids (g); P_0 for the water vapor pressure at the storage temperature (mmHg); b for the slope of the linearized isotherm portion (*i.e.,* from M_i to M_c); Θ for the estimated shelf-life (days).

Koya shelf-life was determined at 30 °C in three storages of RH, *i.e.,* 75 %, 80 % and 85 %. Shelf-life expressed in days. The size of packaging was 10 cm × 10 cm with 25 g of *koya* per each pack.

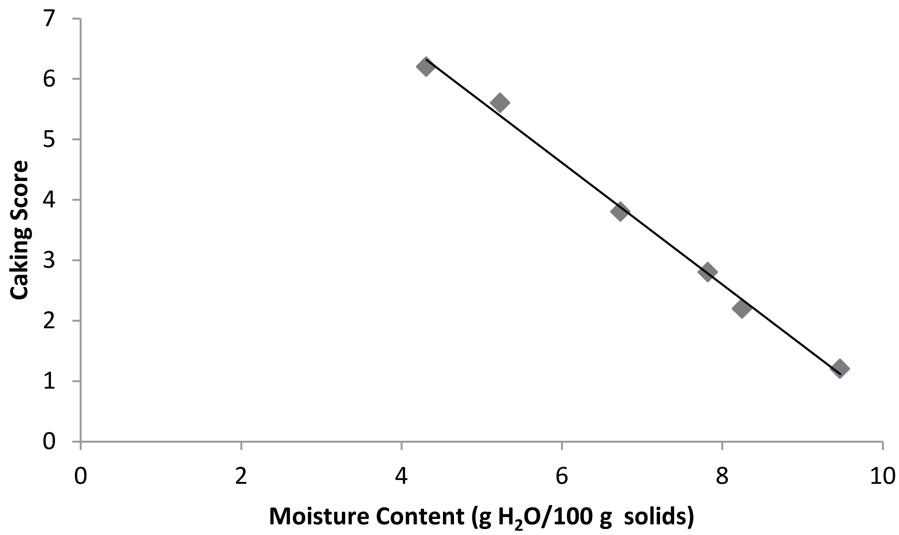

Fig. 1. Relationship between moisture content and caking score.

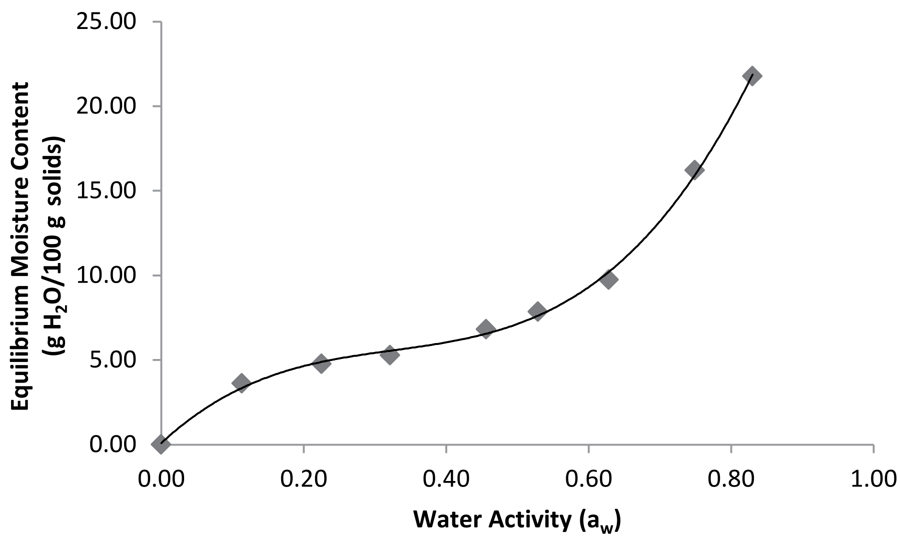

Fig. 2. Moisture adsorption isotherm of Koya at 30 °C.

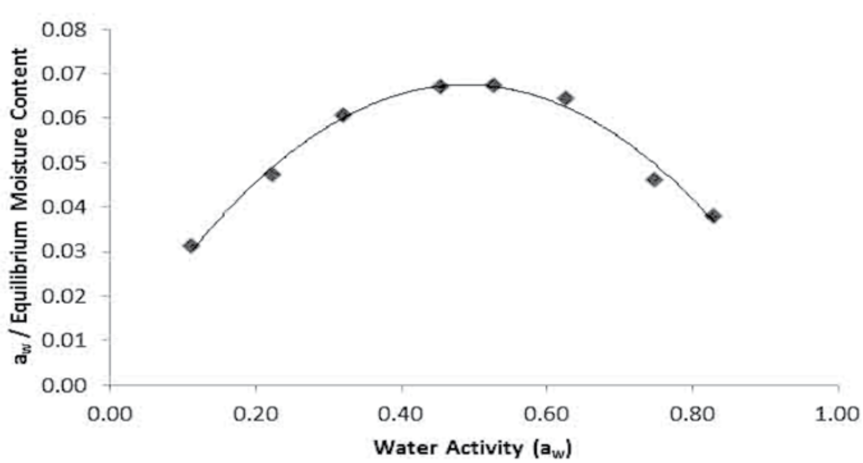

Fig. 3. Relationship between water activity and (aw/EMC),

Table 1. Calculation parameters for *Koya* shelf-life,

Parameter	Relative humidity		
	75 %	**80 %**	**85 %**
M_i (g H_2O per 100 g solids)	4.31	4.31	4.31
M_c (g H_2O per 100 g solids)	7.60	7.60	7.60
M_e (g H_2O per 100 g solids)	9.63	10.12	10.60
k/x (g H_2O (m^2 d mm Hg^{-1})	0.015	0.015	0.015
A (m^2)	0.02	0.02	0.02
P_0 (mm Hg)	31.82	31.82	31.82
B	0.097	0.097	0.097

3. RESULTS AND DISCUSSION

3.1 Initial Moisture Content and Critical Moisture Content

Initial moisture content (M_i) is one of the most important parameters. Initial moisture content of *koya* was 4.31 g H_2O per 100 g solids. The weight of packed *koya* was 25 g, so the amount of *koya* in each pack was 23.92 g (W_s).

The critical moisture content (M_c) was important to discover the consumer acceptance limits of *koya*. The critical moisture content is determined by the caking quality attributes. Fig. 1 indicated the relationship curve between moisture content and caking score, resulting in equation: caking score = -1.0077 (moisture content) + 10 655 (R^2 = 0.995).

The critical moisture content was determined when the *koya* caking score was 3. From the equation, the *koya* moisture content was 7.6 g H_2O per 100 g solids (*Mc*) while the caking score was 3.

3.2 Moisture Adsorption Isotherm

Water vapor adsorption pattern of *koya* made from Snakehead Murrel and tempeh powder was performed by storing *koya* at different levels of water activity (a_w) using eight types of saturated salt at 30 °C. During storage, the water from saturated salt will evaporate and be absorbed by *koya* or vice versa. The process will continue until the moisture content reached equilibrium with the constant weight of fish *koya*.

The relationship curve between *koya* equilibrium moisture content and a_w showed in Fig. 2 indicates that *koya* moisture adsorption isotherm curve was sigmoid shaped (like letter S). Labuza [6] stated that dry food and cereals have a sigmoid shape of moisture adsorption isotherm curve. Sigmoid shape occurred due to differential water attachment in food. *Koya* is one of the dried food product so the moisture adsorption isotherm curve is sigmoid. In the *koya* sigmoid shaped curve, there were two arches, first at a_w 0.2 and the second at a_w 0.6. Two arches of the curve indicated the physical-chemical properties change of the water binding in the material.

Koya moisture adsorption isotherm curve was expressed by employing Guggenheim-Anderson-de Boer (GAB) equation. To determine the constants C, K, and M_0 in the GAB equation, data relationship between water activity (a_w) and a_w/M_C (Fig. 3) were required. From these curves, an equation was generated, *i.e.*, $y = -0.2639x^2 + 0.2577x + 0.0046$. From the equation, the value of K, C and M_0 were obtained, *i.e.,* 0.943, 61.408, 3.754, respectively. The GAB equation for fish *koya* moisture adsorption isotherm as follows:

$$\frac{M}{3.754} = \frac{57.91a_w}{(1 + 56.024a_w - 53.72a_w^2)} \tag{10}$$

GAB equation produced good precision for a material which had sigmoid shaped curve [15]. Several studies also reported that the GAB equation was the right model for tapioca [16], potatoes [17], as well as dried strawberry [18].

3.3 Fish *Koya* Shelf-life

Based on Labuza equation about shelf-life, there were some parameters that determine the shelf-life by critical moisture content approach. *Koya* initial moisture content (Mi), critical moisture content (Mc), and solids of product (Ws) had been determined in the earlier discussion. The results of packaging moisture vapor permeability indicated that metalized plastic as packaging material had a permeability (k/x) of 0.015 g H_2O (m^2 d mm $Hg)^{-1}$. The size of packaging was 10 cm × 10 cm and the surface area (A) was 0.02 m^2. Saturated moisture vapor pressure at 30 °C according to the saturated moisture vapor table was 31.82 mmHg. The equilibrium moisture content (Me) and slope (b) were determined using a moisture adsorption isotherm curve. The parameters used to determine the shelf-life showed in Table 1. Furthermore, those parameters were entered into the shelf-life equation. The *koya* shelf-life based on critical moisture content approach was determined at 30 °C with RH of 75 %, 80 % and 85 % and the results showed that the shelf-life was 234 d, 203 d and 180 d, respectively.

4. CONCLUSIONS

The deterioration of fish *koya* due to its caking started at moisture content of 7.60 g H_2O 100 g^{-1} solids. The shelf-life of fish *koya* packed in metalized plastic and stored at 30 °C was reduced with increase in relative humidity (RH); the shelf-life was 234 d at 75 % RH; 203 d at 80 % RH; and 180 d at 85 % RH.

5. ACKNOWLEDGEMENTS

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