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 H2O 100 g–1 solids. Koya stored at 30 °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

Received, February 2017; Accepted, September 2017
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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\(_2\)O 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\(_2\)O 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
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, i.e: LiCl (11.3 %), KCH₃CO₂ (22.5 %), MgCl₂ (32.8 %), K₂CO₃ (43.2 %), Mg(NO₃)₂ (52.9 %), NaNO₂ (65.4 %), NaCl (75.3 %), and KCl (84.3 %). In equilibrium conditions, water activity (aₗ) expressed as equilibrium relative humidity (ERH) divided by 100. Moisture adsorption isotherm curve was expressed in GAB (Guggenheim Anderson de Boer) model equations:

\[
\frac{M}{M_o} = \frac{K_c a_w}{1 + K_c a_w + c K a_w}
\]

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:

\[
\frac{a_w}{M} = \frac{(1-K_c a_w)(1-K_c a_w + c K a_w)}{K_c M_o}
\]

(ii) Rearrangements of GAB equation:

\[
\frac{a_w}{M} = \frac{a_1 + a_2 a_w + a_3 a_w^2}{M_o}
\]

with

\[
a_1 = \frac{1}{K C M_o} ; a_2 = \frac{K_c}{C M_o} ; a_3 = \frac{K}{C M_o} - 1
\]

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

\[
K = \frac{-a_2 \pm \sqrt{a_2^2 - 4 a_1 a_3}}{2 a_1}
\]

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:

\[
k/x = \frac{WVTR}{P_{out}}
\]

with \(k/x\) is the packaging permeability (g H₂O / day m² 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:

\[
\ln\left(\frac{M_e - M_i}{M_e - M_c}\right) = \left(\frac{k}{x}\right)\left(\frac{A}{W_s}\right) W \frac{P_o}{b}\Theta
\]

with \(M_e\) for the equilibrium moisture content (the moisture content level when the product is in equilibrium with the external RH) (g H₂O per 100 g solids); \(M_i\) for the initial moisture content (g H₂O per 100 g solids); \(M_c\) for the critical moisture content (g H₂O per 100 g solids); \(k/x\) for the moisture permeability through packaging material (g H₂O (m² days mm Hg)⁻¹); \(A\) for the packaging area (m²); \(W\) for weight of dry food solids (g); \(P_o\) 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 \(M_c\)); \(\Theta\) 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).
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$_2$O 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$_2$O per 100 g solids ($M_c$) 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:

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

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 ($M_i$), critical moisture content ($M_c$), and solids of product ($W_s$) had been

<table>
<thead>
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<th>Parameter</th>
<th>75%</th>
<th>80%</th>
<th>85%</th>
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<tr>
<td>$M_i$ (g H$_2$O per 100 g solids)</td>
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<td>4.31</td>
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<tr>
<td>$M_c$ (g H$_2$O per 100 g solids)</td>
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<tr>
<td>$M_e$ (g H$_2$O per 100 g solids)</td>
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<td>10.12</td>
<td>10.60</td>
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<tr>
<td>$k/x$ (g H$_2$O (m$^2$ d mm Hg$^{-1}$))</td>
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<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>$A$ (m$^2$)</td>
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<td>0.02</td>
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<tr>
<td>$P_0$ (mm Hg)</td>
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<tr>
<td>$B$</td>
<td>0.097</td>
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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 H₂O (m² d mm Hg)⁻¹. The size of packaging was 10 cm × 10 cm and the surface area (A) was 0.02 m². 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 H₂O 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
This research was financially supported by The Grant Scheme Center of Excellence of the Sebelas Maret University, Indonesia.

6. REFERENCES