Shelf life prediction of straw mushrooms (*Volvariella volvacea*) based food enhancer using accelerated shelf life testing method

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Abstract. Food shelf life is related to food safety since consumers need to be informed an expired date of the food product. This study aims to determine shelf life of natural food enhancer based on straw mushroom (*Volvariella volvacea*) using Accelerated Shelf Life Testing (ASLT). Determination of shelf life was carried out at 30, 40, 50ºC followed by descriptive sensory (colour, aroma, taste) and moisture content analysis for 28 days. Further data of those parameter over storage time were plotted into a graph to obtain a linear regression equation of zero-order and first-order. Then relationship between In slope (k) and storage temperature 1/T (°K) was plotted in a linear regression to determine activation energy. Equation of linear regression from the lowest activation value then was used to calculate the shelf life of the product. The taste parameter on zero-order was used in shelf life determination as the critical quality because it has the smallest activation energy as 1708.39 cal/mol. The Arrhenius equation then was calculated using this value to obtain degradation constant (k). The results showed that shelf life of the straw mushroom based food enhancer were 77.58 days at 30ºC, 70.85 days at 40ºC and 65.07 days at 50ºC.

1. Introduction
The delicacy of food can be judged by the taste of a food. Taste is generally produced from natural compounds or synthetic compounds. One of the food taste enhancers is monosodium glutamate (MSG) produced commonly from synthetic compounds. MSG has a savory taste and mostly contain high sodium. High sodium content in MSG can reach to 20-30% of the body's need for salt, consequently excessive use of MSG will increase the concentration of salt in the blood and furtherly it can be carcinogenic [1] [2]. The World Health Organization (WHO) has set an Acceptable Daily Intake (ADI) of MSG which is 120 mg/kg body weight, thus it safe for human consumption [3].

Natural based ingredients should be used as food enhancer to produce natural savory taste with low content of sodium. One of the natural ingredients that have a potential for this purpose is straw mushroom (*Volvariella volvacea*) which contains protein of 16.9 g/100 g in dry weight and glutamic
acid of 4.0428 g/100 g in dry weight [2,4]. In addition, mushroom can offer other benefits as an anti-toxin, lowering high blood pressure, preventing cancer and overcoming blood deficiency [5]. Based on the previous study of organoleptic test (colour, aroma and savory), the mushroom based food enhancer had a higher savory value [4].

Food shelf life is related to food safety and for food product it can be informed by an expired date in food packaging. This information is one of consumer needs in order to provide a safety product. Prediction of food shelf life can be determined by two methods, i.e., extended storage studies (ESS) and accelerated shelf life testing (ASLT). The first one method is time consuming and need to measure many quality parameters, while the second method can be conducted in shorter time, inexpensive and applicable for flour and powder products [6,7]. However, information about shelf life of natural food enhancer is infrequent in previous studies. Moreover, production of commercial straw mushroom (V. volvacea) based food enhancer powder requires shelf life information, thus producer can estimate the expired date of the product. Therefore, in this study ASLT was applied in order to predict the shelf life of the food enhancer. Estimation of shelf life the Accelerated Shelf Life Testing (ASLT) method is carried out by storing food products above room temperature [8]. The ASLT method can be combined with the Arrhenius model. The application of the Arrhenius model ASLT method is often used to determine the shelf life of food products in the form of flour, for example fried banana flour, fried chicken flour and sesame seed flour [6]. The aim of this study was to determine shelf life of natural food enhancer based on straw mushroom (Volvariella volvacea) using Accelerated Shelf Life Testing (ASLT) followed the Arrhenius model.

2. Materials and methods

2.1. Materials
Straw mushrooms (V. volvacea) were taken from its cultivation site in Penyeurat Village, Banda Aceh, Indonesia, in criteria as good characteristics and fresh marked by the shape of a bud at the button stage (button shaped). Determination of the mushrooms was carried out at the Herbarium Bogoriense Department of Botany, Indonesian Institute of Sciences (LIPI), Bogor. Other materials, i.e. tapioca flour, white pepper, shallots, garlic, salt and sugar were purchased from a local traditional market.

2.2. Production of mushroom (V. volvacea) flour
A number of fresh straw mushroom were washed under water flow, thinly sliced and dried at room temperature for 14 days. Furthermore, the straw mushrooms were dried using an oven at a temperature of 60ºC for 6 hours. The dried mushrooms were mashed with a blender until it becomes flour.

2.3. Production of mushroom (V. volvacea) based food enhancer
Straw mushroom based food enhancer were produced by mixing white pepper, shallot and garlic using a blender. After the spices were smooth, then mushroom flour, salt, and sugar were added and mixed into the spices. Amount of those material was shown in Table 1. Further the mixture of material was cooked under low heat for 15 minutes, then roasted tapioca flour was added and until the mixture formed a thick paste. Furthermore, the paste was poured into a baking sheet, and dried using an oven at 60ºC for 32 hours. Moreover, to obtain the food enhancer powder the dried mixture then was mashed with a blender and sieved using a 60 mesh sieve.
Table 1. Formula for production of straw mushroom (V. volvacea) based food enhancer.

| Material                        | Amount (%) |
|--------------------------------|------------|
| Mushroom flour (V. volvacea)    | 12.36      |
| Tapioca flour                   | 2.47       |
| White pepper (Piper nigrum)     | 6.18       |
| Shallots (Allium cepa)          | 1.11       |
| Garlic (Allium sativum)         | 67.99      |
| Salt                            | 8.65       |
| Sugar                           | 1.24       |
| Total                           | 100        |

2.4. Packaging
The food enhancer powder was packed in an aluminium foil pouch obtained from the Packaging House, Agriculture Department Office, Gampong Pande, Banda Aceh City.

2.5. Determination of moisture content
Moisture content determination of the food enhancer samples was carried out 3 times every week during storage time of the samples for 4 weeks. The analysis was conducted by oven drying method as the following procedure, firstly, 2 g sample (W1) was weighed in a porcelain dish which was known its weight. Porcelain cup containing sample was placed in the oven and dried at 105°C for 3 hours. Next, it was cooled in a desiccator and the weight of the porcelain dish and the sample was weighed. These steps were repeated to obtain a constant weight of the sample (W2). The moisture content (% wet basis) of the sample was calculated using the following equation [9]

\[
\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100
\]  

(1)

2.6. Sensory analysis
A descriptive test of sensory analysis was carried out on sensory attributes as colour, aroma and taste of mushroom based food enhancer samples. The colour, aroma and taste description were scored from 7 to 1 as described in Table 2. In colour and aroma descriptive test, the panellist was served about 1 gram of the food enhancer powder per person. For taste descriptive test, the food enhancer was prepared as solution in warm water since commonly the food enhancer is mixed into food in cooking. The solution was prepared by dissolve 0.25 grams of the powder in 100 mL of warm water [10]. The descriptive test was carried out every week during storage time of the samples for 4 weeks by 20 panellists assessing samples and scoring the sensory attributes as shown in Table 2 on the provided questionnaire [11]. The panellist were semi-trained panellists and 19-22 years old.

Table 2. Descriptive scoring for descriptive test of sensory analysis.

| Score | Colour       | Aroma                      | Taste              |
|-------|--------------|----------------------------|--------------------|
| 7     | normal       | normal                     | normal umami taste|
| 6     | very light   | rancid aroma was not smelled| strong umami taste |
| 5     | light        | very weak rancid smell     | clear umami taste  |
| 4     | quite light  | weak rancid smell          | weak umami taste   |
| 3     | slightly dark| clear rancid smells        | very weak umami taste|
| 2     | dark         | strong rancid smells       | no umami taste     |
| 1     | very dark    | very strong rancid smells  | plain              |
2.7. **Determination of shelf life**

Mushroom (*V. volvacea*) based food enhancer powder was packed in aluminium foil pouch, then stored in three different incubators at 30, 40, and 50°C. Analysis of the samples were carried out on days 0, 7, 14, 21, and 28, including moisture content and sensory analysis. According to the data of moisture content and descriptive sensory test, then the Arrhenius model acceleration was applied to determine shelf life of the samples. The data of moisture content and descriptive test (colour, aroma and taste) were plotted against the storage time (days) to obtain the linear regression equation resulting in value of the slope (k), intercept (constant) and correlation coefficient ($R^2$). Furthermore, ln slope (k) over storage temperature was plotted to obtain further linear regression equation, then referring to this equation the activation energy ($E_a$) was calculated as $-E_a/R = $ slope (k). The smallest activation energy value from the parameters of colour, aroma, taste and moisture content were applied into the Arrhenius equation as follows [12]

$$k = k_0 \cdot e^{\frac{E_a}{RT}} \quad (2)$$

$$\ln k = \ln k_0 - \frac{E_a}{RT} \quad (3)$$

Where $k_0$ is constant (without temperature dependent), R is gas constant value (1.986 cal.mol$^{-1}$, $^\circ$K$^{-1}$), and T is absolute temperature in $^\circ$K ($^\circ$C+273). According to the Arrhenius equation (equation 2), the quality reduction constant (k) of the sample was calculated. Shelf life can be calculated based on the order of the reaction by following equations

$$A_t = A_0 - k \cdot t \quad (order \ 0)$$

$$\ln A_t = \ln A_0 - k \cdot t \quad (order \ 1)$$

3. **Results and discussion**

3.1. **Determination of edible mushroom (*V. volvacea*)**

The results of the determination showed that the edible mushroom used in this study was the species of *Volvariella volvacea* (Bull.) Singer of the family *Pluteaceae*. The mushroom is provided in Figure 1.

![Figure 1. Straw mushroom (*V. volvacea*).](image)

3.2. **Production of mushroom (*V. volvacea*) based food enhancer**

In this study 8 kg (wet weight) the fresh mushroom produced 533.43 g mushroom flour indicating that fresh mushroom provided up to 6.7 % yield of mushroom flour. Furthermore, the mushroom based food enhancer powder produced in this study, as in Figures 1, was packed in aluminium pouch as showed in Figure 2 for further storage treatment. The food enhancer had light brown colour and strong flavour due to its spices content.
3.3. Moisture content of straw mushroom (V. volvacea) based food enhancer
The results of the moisture content analysis for the food enhancer can be seen in Table 3. Based on Table 3, the initial moisture content of the food enhancer (day 0) before being stored in the incubator was 8.65%. While the moisture content of food enhancer on the 7th to 28th days varied, there was a decrease and an increase in the moisture content. This could be due to the water attached to the aluminum foil package falling back into the food enhancer, thus the moisture content of the food enhancer stored on days 21 and 28 fluctuated. Storage temperature did not affect moisture content of the food enhancer. Overall, from day 0 to 28, the value of the moisture content of the food enhancer was in accordance with the requirements for the quality of the moisture content of the seasoning flour as maximum 12% (SNI 01-4476-1998). The purpose of the moisture content test is to determine the amount of water contained in the food enhancer. If the moisture content is too high, then quality of the food enhancer can be deteriorated physically, chemically, and by microorganisms.

Table 3. Moisture content of straw mushroom (V. volvacea) based food enhancer during storage at various temperature for 28 days.

| Temperature (°C) | Storage time (Day) | Moisture content (x̅) |
|-----------------|--------------------|-----------------------|
| 30              | 0                  | 8.65                  |
|                 | 7                  | 8.41                  |
|                 | 14                 | 8.36                  |
|                 | 21                 | 9.04                  |
|                 | 28                 | 8.98                  |
| 40              | 0                  | 8.65                  |
|                 | 7                  | 7.38                  |
|                 | 14                 | 7.2                   |
|                 | 21                 | 7.76                  |
|                 | 28                 | 7.97                  |
| 50              | 0                  | 8.65                  |
|                 | 7                  | 7.59                  |
|                 | 14                 | 7.34                  |
|                 | 21                 | 7.44                  |
|                 | 28                 | 7.84                  |

3.4. Sensory characteristics of mushroom based food enhancer
The results of the food enhancer descriptive sensory test are exhibited in Table 4. Overall sensory attributes of the colour, aroma and taste of the food enhancer decreased during storage, indicating the sensory attributes of the food enhancer deteriorated during storage. The colour changed from normal to a slightly dark colour which could be caused by Maillard reaction due to the presence of reduction sugars.
and proteins in food material and high temperature during storage initiated the reaction [6]. During storage, the food enhancer was stored above room temperature, consequently the colour of the food enhancer altered to darker and its sensory score decreased.

The aroma of food enhancer comes from odour substances which are volatile. Volatile substances can come from essential oils composed in spice ingredients such as shallots, garlic and white pepper. Those spices provided strong aroma in the food enhancer. The aroma can also be produced from the main ingredient, straw mushroom (V. volvacea), which has a distinctive mushroom odour. Referring to Table 4, the aroma value generally decreased during storage that the aroma changed from normal (score 7) to a very weak rancid aroma to smell (score 5). During storage the distinctive aroma of the food enhancer decreased due to the evaporation of the volatile substances, while the rancid aroma became stronger due to damage to the fat content in the food enhancer.

The food enhancer taste is also influenced by the volatile compounds, which the volatile compounds are not resistant to high temperatures. The declining in taste of the food enhancer relate to a decrease in aroma. If the aroma of food enhancer decreases, then the taste will also decrease. During storage, chemical composition in the food enhancer powder altered and resulted in changes in various flavour components.

| Temperature (ºC) | Storage Time (Days to) | Parameter | Colour average score | Aroma average score | Taste average score |
|------------------|------------------------|-----------|----------------------|---------------------|---------------------|
| 30               | 0                      |           | 7                    | 7                   | 7                   |
|                  | 7                      |           | 5                    | 6                   | 4                   |
|                  | 14                     |           | 5                    | 6                   | 4                   |
|                  | 21                     |           | 5                    | 5                   | 5                   |
|                  | 28                     |           | 4                    | 6                   | 4                   |
| 40               | 0                      |           | 7                    | 7                   | 7                   |
|                  | 7                      |           | 5                    | 5                   | 4                   |
|                  | 14                     |           | 5                    | 5                   | 4                   |
|                  | 21                     |           | 5                    | 5                   | 4                   |
|                  | 28                     |           | 5                    | 5                   | 5                   |
| 50               | 0                      |           | 7                    | 7                   | 7                   |
|                  | 7                      |           | 4                    | 6                   | 4                   |
|                  | 14                     |           | 4                    | 5                   | 5                   |
|                  | 21                     |           | 3                    | 5                   | 4                   |
|                  | 28                     |           | 3                    | 5                   | 4                   |

3.5. **Determination of shelf life of straw mushroom (V. volvacea) based food enhancer**

In sensory analysis, the score 7 was initial sample quality, and 2 was limit of rejected sample quality. Therefore, when the sensory score of samples reached 2, then moisture content of the sample was defined as the lowest quality. Based on the sensory analysis data, some panellist showed rejection on aroma and taste by scored 2 and 1 for samples stored at 40 ºC for 14 days, although average score of those attributes in Table 4 showed higher score of the sample. As a consequence, moisture content the food enhancer stored at 40 ºC for 14 days was determined as the rejected quality, which was 7.2%. Furthermore, linear regression equations for order 0 and order 1 were calculated from data of the descriptive test (Table 4) and moisture content (Table 3) and showed in Figure 4 to 11. Moreover, the
slope value (k) obtained from each linear regression equations of sensory and moisture content analysis were provided in Table 5. Furthermore, value of ln slope (k) from Table 5 were plotted over the storage temperature 1/T (°K) in linear regressions, then the equations of those linear regressions were applied to calculate the activation energy value of each parameter, as shown in Table 6.

Figure 4. Linear regression equation graph of colour sensory for zero order.

Figure 5. Linear regression equation graph of colour sensory for first order.

Figure 6. Linear regression equation graph of aroma sensory for zero order.
**Figure 7.** Linear regression equation graph of aroma sensory for first order.

![Graph of Aroma Sensory](image1)

**Figure 8.** Linear regression equation graph of taste sensory for zero order.

![Graph of Taste Sensory](image2)

**Figure 9.** Linear regression equation graph of taste sensory for first order.

![Graph of Taste Sensory](image3)

**Figure 10.** Linear regression equation graph of moisture content for zero order.

![Graph of Moisture Content](image4)
Figure 11. Linear regression equation of the moisture content for the first order.

Table 5. Value of slope (k) and ln slope (k) descriptive test and moisture content test.

| Colour | Temperature | Zero order | First order |
|--------|-------------|------------|-------------|
|        | °C          | °K {1/T (°K)} | Slope (k) | ln Slope (k) | Slope (k) | ln Slope (k) |
|        | 30          | 303        | -0.0857    | -2.4569     | -0.0160   | -4.1352     |
|        | 40          | 313        | -0.0714    | -2.6395     | -0.0128   | -4.3583     |
|        | 50          | 323        | -0.1286    | -2.0510     | -0.0283   | -3.5649     |

| Aroma | 30          | 303        | -0.0429    | -3.1489     | -0.0070   | -4.9618     |
|       | 40          | 313        | -0.0571    | -2.8630     | -0.0096   | -4.6460     |
|       | 50          | 323        | -0.0714    | -2.6395     | -0.0122   | -4.4063     |

| Taste | 30          | 303        | -0.0714    | -2.6395     | -0.0128   | -4.3583     |
|       | 40          | 313        | -0.0571    | -2.8630     | -0.0096   | -4.6460     |
|       | 50          | 323        | -0.0857    | -2.4569     | -0.0160   | -4.1352     |

| Moisture content | 30          | 303        | 0.0184     | -3.9954     | 0.0021    | -6.1658     |
|                 | 40          | 313        | 0.0140     | -4.2687     | 0.0016    | -6.4378     |
|                 | 50          | 323        | 0.0253     | -3.6770     | 0.0031    | -5.7764     |

Table 6. Activation energy of sensory attributes and moisture content.

| Parameter           | Zero Order (cal/mol) | First Order (cal/mol) |
|---------------------|----------------------|-----------------------|
| Colour              | 3863.16              | 5435.08               |
| Aroma               | 4955.66              | 5404.89               |
| Taste               | 1708.39              | 2085.30               |
| Moisture content    | 3004.22              | 3687.20               |

Determination of shelf life was based on the linear regression equation of the parameter that has the smallest activation energy value. According to Table 5, activation energy on the zero order had smaller value than first order for each parameters of colour, aroma, taste and moisture content, and the smallest activation energy (1708.39 cal/mol) was showed on the taste parameter. As a result, the critical quality
parameter on shelf life determination for the food enhancer in this study is the taste attribute. The smaller the activation energy value, then a reaction to deteriorate food enhancer become faster. This can affect shelf life of the food enhancer product. In addition, zero order indicates the presence of non enzymatic browning and lipid oxidation in food product. Non enzymatic browning is caused by the Maillard reaction in food enhancer due to the reaction of reduction sugars with amino acids and it can be occurred due to heating above ambient temperature [12].

The smallest activation energy value was then applied in determine shelf life of the food enhancer using a zero order reaction (equation 5), where \( t = \frac{A_o - A_t}{k} \). The shelf life prediction of the food enhancer is exhibited in Table 7. The results of this study indicate that the shelf life of the food enhancer was from 65-77 days. The shelf life of food enhancer is shorter when the temperature increase, i.e. 77.58 days at a temperature of 30ºC, 70.85 days at 40ºC, and 65.07 days at 50ºC. Storage temperature has strong impact to the food enhancer alteration, because the higher the storage temperature then the faster spoilage reaction, and subsequently causes shorter of the food shelf life.

### Table 7. Shelf life prediction of the straw mushroom based food enhancer.

| Parameter | Temperature (ºC) | Temperature \( \{1/T \ (ºK)\} \) | \( \ln k \) | \( k \) | Days |
|-----------|------------------|-------------------------------|-----------|-------|------|
| Taste     | 30               | 0.0033                        | -2.7419   | 0.0644| 77.58|
|           | 40               | 0.0031                        | -2.6512   | 0.0706| 70.85|
|           | 50               | 0.0031                        | -2.5661   | 0.0768| 65.07|

### 4. Conclusions

Shelf life of straw mushroom (V. volvacea) based food enhancer was determined above ambient temperature for 28 days by ASLT combined with Arrhenius equation. The result showed that taste sensory attribute was a critical quality parameter on shelf life determination of the food enhancer, indicated by the smallest value of activation energy for this parameter. In addition, the shelf life of the food enhancer was predicted for 77.58 days at 30ºC storage temperature, 70.85 days at temperature storage 40ºC and 65.07 days at storage temperature 50ºC.

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