Improvement of Malang Tahu Quality Using Sweet Potato Natural Dyes by Adsorption Technology

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Abstract. Tahu is a popular culinary product in Malang town. This product is produced from soyabean and rich of protein. Besides, tahu is also rich of water, so that surface of tahu tends to polar. Colorization of tahu by extract of yellow and sweet potatoes is interesting because both sweet potatoes contain different polarity molecular dyes, i.e. polar anthocyanin in the purple sweet potato but non-polar beta carotene in the yellow sweet potato. In this paper, changing of tahu’s color after colorization by extract of both sweet potatoes was observed at different times of adsorption process (2, 4, 6 h), different compositions of the sweet potato and water (100g/1L and 300g/1L), and effect of palm oil addition (250 mL oil/1L water). Result of observation showed that the higher time of adsorption process, the higher ratio of the sweet potato weight and water volume, the darker color of the colorized tahu. Addition of the palm oil just improved extraction of β - carotene from the yellow sweet potato but did not improve the adsorption of the dyes on the tahu surface. Results of this study are used for supporting program of community service DPP SPP 2020 of Inorganic lecturers, as application of adsorption technology using tahu food as adsorbent and application of intermolecular force theory as part of Inorganic Chemistry I course.

1. Introduction
Malang is a picnic city which provides various traditional culinary products. Tahu is one of popular traditional foods in Malang, because this food is used as a daily food in society. Various creations of foods based on tahu can be found in Malang, such as tahu campur, tahu bakso, tahu lontong, tahu brontak, tahu gajah, tahu petis, etc.

Tahu is made from coagulation of soyabean milk. Like its precursor, tahu is rich of nutrients, such as protein, carbohydrate, fat, fiber, minerals, and vitamins [1]. List of nutrients in tahu are presented in Table 1. Tahu keeps being a smart food if without dangerous additives such as methanyl yellow dyes [2]. Dangerous synthetic dyes can cause cancer and damage of liver [3].

Original color of tahu is white. Tahu can be colorized by natural dyes through adsorption process. Colorization of food sometimes is needed, not only to improve the product appearance, but also to increase quality of product based on nutrients and bioactive substances such as anti-fungi and antimicrobial agent. It has been applied for salty duck eggs using various extracts of natural dyes, such as rossela flower, black tea, dragon fruit peel, etc [4]. There are many natural products as natural dyes,
one of them is sweet potato which is popular in Malang. The purple sweet potato has been used for flour as partial substitution of wheat flour for production of plain bread [5], as colorant of syrup [6], for staining of Staphylococcus aureus bacteria [7], and detection of borax [8].

In Program of Community Service DPP/SPP 2020, Faculty of Mathematics and Natural Sciences, Brawijaya University, we have introduced usage of purple and yellow sweet potatoes for dyes of tahu toward some culinary society in Malang, especially tahu sellers and some other sellers such as cilok, sempol, etc.

Polarity matches of tahu’s surface and dyes molecule is a key of success in colorization of tahu. The yellow and purple sweet potatoes are natural dyes which are rich of antioxidant molecules, i.e \( \beta \)-carotene [9] and anthocyanin [10], respectively, as listed in Table 2. There are 2 types of anthocyanins in the purple sweet potato, including peonidin and cyanidin. Chemical structures of \( \beta \)-carotene and anthocyanin are presented in Figure 1 and 2, respectively.

### Table 1. Nutrients in tahu [11]

| Nutrient       | Content per 100 g |
|----------------|-------------------|
| Energy (cal)   | 63                |
| Protein (g)    | 0.49              |
| Fat (g)        | 0.27              |
| Carbohydrate (g)| 0.14             |
| Fiber (μg)     | 0                 |
| Calcium (mg)   | 0.13              |
| Sodium (mg)    | 0.38              |
| Vitamine B1 (mg) | 0.004          |
| Phosphorus (mg)  | 6.56             |
| Iron (mg)      | 0.11              |
| Vitamine B1 (mg) | 0.001           |
| Vitamine B2 (mg) | 0.001           |
| Vitamine B3 (mg) | 0.03            |
| Niacin (mg)    | 0.4               |

### Table 2. Nutrients in purple and yellow sweet potatoes [12]

| Nutrient       | Purple sweet potato | Yellow sweet potato |
|----------------|---------------------|---------------------|
| Calor (cal)    | 123                 | 136                 |
| Protein (μg)   | 1.8                 | 1.1                 |
| Fat (μg)       | 0.7                 | 0.4                 |
| Carbohydrate (μg)| 27.9              | 32.3                |
| Water (μg)     | 68.5                | 71.2                |
| Crude fiber (μg)| 1.2                | 1.4                 |
| Sugar (μg)     | 0.4                 | 0.3                 |
| \( \beta \)-carotene (μg)| 30.2       | 114                 |
| Anthocyanin (μg) | 110.15            | 32.2                |
Based on the chemical structures in Figure 1, anthocyanin has the chemical structures which have some polar functional groups. In other side, beta carotene has a structure which has some less polar functional groups, such as methyl functional groups, as presented in Figure 2. Effect of this difference of polarities toward solubility of the dyes molecules in water and colorization of tahu was studied.

![Figure 1. Chemical structure of anthocyanin: a) peonidin, b) cyanidin [12].](image)

2. Methods

Yellow and purple sweet potatoes were peeled, washed, and shredded. Tahu was cut to get box shapes and size of 2 cm x 2 cm x 2 cm. Each sweet potato was weighed (300 g and 100 g) and poured by 1 L of water, then heated together with 15 pieces of tahu for boiling for about 10 minutes, and finally taken away from stove and stayed for 2, 4, and 6 h at room temperature. The colorized tahu were separated from the mixture and observed.

Effect of palm oil toward solubility was conducted by adding 250 mL of palm oil into mixture of 15 tahu pieces, 300 g of sweet potato and 1 L of water. Solubility of the dyes and color of the products were observed.

3. Results and discussions

Colorization of tahu by adsorption process has been conducted. Steps of colorization process is presented in Figure 3. After pouring water into the pan (B), the mixture which contains purple sweet potato quickly showed purple colorized water. It means that anthocyanin in the purple sweet potato can be dissolved easily. This easy dissolution is caused by strong attraction force between polar functional groups of anthocyanin and H₂O molecules through their dipole-dipole force, named hydrogen bonding.

Heating process improves dissolution of the anthocyanin dyes molecules so that the mixture showed dark purple. In other side, the yellow sweet potato showed lighter color of mixture. It is because molecules of β-carotene tend to less polar so that attraction force between H₂O molecules and β-carotene is dipole - non dipole (induction force). This attraction is weaker than hydrogen bonding.

Addition of palm oil improved solubility of beta carotene indicated by deeper yellow color of the mixture in Figure 4. Palm oil contains fat acids which have long chains of hydrocarbons. The fattest acid type in the palm oil is palmitic acid [14]. These long chains are non-polar parts of the fat acids. These parts are more available to dissolve less polar or non-polar molecules such as β-carotene.
Figure 3. Process of colorization: A. Weigh of sweet potatoes; B. pouring of water; C. boiling process; D. sinking process.

Figure 4. Effect of palm oil addition into mixture.

Sinking time is process of dyes adsorption on surface of tahu. Results of colorization in Figure 5 shows that the higher concentration of sweet potato extract, the darker colorized tahu. It is because more concentration of the purple sweet potato extract means more molecules of anthocyanin provided to contact with surface of tahu. The longer of sinking time, the darker color of tahu, due to more chance for contact between molecules of dyes with surface of tahu.
By assuming that the morphology of tahu is same as morphology of tofu in Figure 8, so that physically it can be explained that more time of sinking, more chance for dyes molecules to enter caves of tahu. Tofu is similar to tahu, prepared by coagulation of soyabean milk but using different coagulant agent. In Japan, tofu is produced by various coagulants such as citric acid, CaSO₄, CaCl₂, MgCl₂ [15]. Tahu is prepared using acetic acid coagulant [16].

As listed in Table 1, the second highest content of nutritions in tahu is protein. Protein is a macromolecule which is formed by amino acids through peptide bonding. The protein has polar functional groups related to carboxyl and amine groups. The carboxyl can be deprotonated to form negative ion. In other side, the ammine group can form positive ion. Therefore, chemically, there are two kinds of attraction forces can be formed by anthocyanin molecules and protein, i.e hydrogen bonding and ion - dipole attraction forces, like presented in Figure 7. More contact time between anthocyanin dyes molecules and surface of tahu, more chance of chemical interaction between functional groups of anthocyanin molecules and proteins so that stronger attraction forces can be achieved.
Figure 6 Prediction of anthocyanin adsorption by tahu through physically entering caves of tahu by assumption of its same morphology with tofu.

Result of tahu colorization using extract of yellow sweet potato is presented in Figure 8. Color of beta carotene colorized tahu in Figure 8 looks lighter than anthocyanin colorized tahu in Figure 5. Beta carotene has long chain molecules so that it is bigger than anthocyanin molecules. This bigger size causes the β - carotene molecules physically more difficult to enter caves of tahu than anthocyanin, as illustrated in Figure 9.

Figure 7. Prediction of molecular attraction force between protein in tahu and anthocyanin molecules in the extract of purple sweet potato.
Figure 8. The colorized tahu by extract of yellow sweet potato at various composition of the sweet potato-water and adsorption time.

Figure 9. Prediction of β-carotene adsorption by tahu through physically entering cave of tahu by assumption that its morphology as same as morphology of tofu.
The β-carotene has methyl functional groups. This groups contain C-H bond which has low polarity due to small negativity difference of C and H atoms. Therefore, β-carotene tends non-polar. Therefore, chemical interaction between beta carotene molecules in sweet potato extract and protein of tahu is dipole - non-dipole and ion - non-dipole. Both are induction attraction forces. These forces are weaker than dipole - dipole attraction forces of anthocyanin-protein of tahu, therefore, less beta carotene can be adsorbed by surface of tahu and the lighter color is obtained.

**Figure 10.** Prediction of molecular attraction force between protein in tahu and β-carotene molecules in the extract of yellow sweet potato.

Although the presence of palm oil can increase dissolution of beta carotene into water as shown in Figure 4, the β-carotene colorized tahu with oil palm addition is lighter than without palm oil, as shown in Figure 11. It means that that improvement of dissolution does not influence adsorption of beta
carotene by tahu surface. During adsorption process, there is competition between attraction force of non-polar β-carotene polar protein of tahu and non-polar beta carotene-non-polar fat acids of palm oil. It means that fatty acids of palm oil inhibit adsorption of dyes molecules on surface of tahu.

4. Conclusions
Colorization of tahu using extract of purple and yellow sweet potatoes have been performed. The colorized tahu by extract of purple sweet potato had darker color than by extract of yellow sweet potato. Addition of palm oil into the mixture of water solvent and yellow sweet potato just improved dissolution of β-carotene but did not increase colorization of tahu.

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