Drying characteristics of Edamame (Glycine max. L. Merill) during freeze drying

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Abstract. Edamame (Glycine max. L. Merill) has been consumed due to its savory taste and high nutrient content. Edamame can be dried and consumed as a crunchy snack through the drying process which is able to retain nutrition loss during it, that is freeze drying. There were still least information about freeze drying of edamame. Therefore, the objective of this study was to investigate the edamame’s moisture content and physical quality decreasing kinetics during freeze drying. Fresh edamame with initial water content of 60-70% was steam-blanched to 9 minutes before drying. 1.5 kg capacity freeze dryer was used with freezing temperature was set at -18°C and pressure at -76 cmHg. Its parameters was measured at 0 h, 12 h, 18 h, 24 h, 30 h, and 36 h. The drying rate of edamame freeze drying was 6.9355 g/g db per hour. Edamame shrunk 12.64% during 12 hours drying and shrunk more until 22.0046% to the final time. As it dried, edamame became harder due to crispiness at second phase of drying, or more than 24 hours of drying. There were not a significant change of colour.

1. Introduction
Edamame (Glycine max. L. Merill) is immature soybean harvested three month before matured and dried. Edamame has been consumed as traditional food from Japaness culture since Nara era (794 M) [1]. Indonesia began corping edamame at 1990 in Bogor, West Java and distributed domestically. At 1992, edamame was began to be developed in Jember, East Java, to be exported since 1995 as frozen edamame [2]. Edamame production in Jember during 2017 reached 5,400 tons [3].

Edamame is one of high-value crop due to its savory taste and high nutrient content. Edamame was consumed due to its protein content, calcium, vitamin A, and phytoestrogens or isoflavone [4]. Fresh edamame can be consumed after simple cooking such as boiling with a salt, stir-frying with another ingredients, or steamed. However, these cooked edamame must be consumed soon or it would rot. Beside frozen and cooked from fresh, edamame also can be consumed as healthy crunchy dried snack. Drying can prolong the shelf life when mostly objected to produce dried snack. Crops can be dried conventionally by sunlight or mechanically by drying machine. Dried product would has better quality, physically and chemically, if dried mechanically than conventional method [5]. In case of edamame, it was found shrunk and tough when it dried. Hu, et.al., (2006) found that freeze drying produced better product than using hot air, vacuum microwave, or both combined. Using this method, high cost and energy was needed during operation but it can maintain product quality so freeze drying was suitable for producing snack from high value crops [6]. Faculty of Agrotechnology of Universitas Gadjah Mada was developing freeze drying using lab-made freeze dryer.
In freeze drying, crop’s moisture content was released by sublimation. Water inside it was frozen quickly to form soft ice molecules that didn’t break product’s cells. After being frozen, it was given vacuumed warm air when still maintaining the product’s temperature under 0°C. This point is a triple point where solid, water, and gas are under equilibrium state so ice can be sublimated and leave the dried product [7]. As written by Duan (2017) in his review, freeze dried products quality was not significantly decreased in nutrition content, dimension, and color. This dried products were in best condition in taste, texture, and structure [8].

There was least information about freeze drying of blanched edamame. Therefore, this study was aimed to analyze physical quality degradation of blanched edamame during freeze drying to produce best quality dried edamame. Its quality was measured through physical observation, that is dimension, color, and texture.

2. Methodology

Fresh edamame was brought from local supermarket. It was wrapped and labelled by its pick date and brand so it was certained fresh and from one supplier which means no big chance it was different variance of local edamame. In a process of drying, 0.5 kg granular edamame was needed as peeling result of 1.2 kg of fresh edamame. The drying unit was lab-made freeze dryer in Laboratorium of food and Postharvesting Engineering, Faculty of Agrotechnology, Universitas Gadjah Mada. This unit’s main material was stainless steel and its capacity was about 0.5 to 1 kg per batch. Edamame was blanched manually using steaming pan and 2 liters of water. After blanching, edamame was cooled twice in 5 liters of water at environment temperature (28-31°C) until the temperature was almost equal. Blanched edamame that was still in its pod was peeled and inserted to drying tube of freeze dryer. Freezing phase temperature was 18°C in vacuum condition for 6 hours, 6 hours was used to prepare sublimation and the heater was turned on at 10°C. First drying phase was occurred for 12 hours at 18°C of warm air and second drying phase was either 12 hours using hotter air that at 60°C. 20 minutes before removing dried product from drying tube, heater was turned off to cool the product down until it reached almost at environment temperature.

This study was using experimental method that take place at laboratory of six different drying time, 0 hour, 12 hours, 18 hours, 24 hours, 30 hours, and 36 hours. Every stopping process was done three times as replication. Drying rate was determined based on this formula,

$$dMC_t = \frac{MC_0 - MC_t}{T_t}$$  \((1)\)

MC, the moisture content at \(0\) (initial) and \(t\) hours of drying. This moisture content was measured using gravimetric method for 24 hours. Drying kinetic was also observed by pressure and temperature of drying air and sample temperature in both upper and bottom stack inside the tube. Product quality parameter was measured, including shrinkage (length, width, and thickness was measured by caliper) which was determined using formula :

$$SR_t = \frac{D_t - D_0}{D_0} \times 100\%$$  \((2)\)

Whereas \(D\), dimension was determined using formula :

$$D = \frac{L+W+T}{3}$$  \((3)\)

\(D\) here is not volume, it is in centimeter unit as \(L\), length, \(W\), width, and \(T\), thickness. Another quality parameter was hardness using Texture Analyzer and color in L*a*b method using colorimeter. Color change was determined using formula :
\[ \Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \]  

These results were analyzed using variance analysis (ANOVA) followed by Least Significant Difference (LSD) test at 0.05.

3. Results and Discussion

3.1. Drying Kinetics

Drying kinetics can be represented in two curves, drying curve and drying rate curve [9], as shown in figure 1. Drying curve shows moisture content change in dry basis during drying. In an hour, edamame was lost 6.5945% (db) moisture content with initial point was 235.8635% (db). Its final moisture content, 8.8199% (db) or 8.0888% (wb) was under the save moisture content point to store dried edamame, that it 12% wb, and save to store in temperature up to 18 °C [10]. Moisture content which related to water activity is the most dependable parameter to prolong shelf life of dried vegetable or maintain its quality during storage [11].

Drying rate curve shows that edamame’s freeze drying was working at rate of 6.9355 g/g.h per hour. This drying kinetics was increased as air temperature was increased [12] so this drying rate was effected by drying temperature setting. Other study was found freeze drying and some other drying method’s drying rate and it was sure depend to air temperature set [9].

![Figure 1. Drying curve and drying rate curve.](image)

Freeze drying process was effected by drying air condition, in what pressure and temperature it was so it was shown in figure 2, including the change of product’s temperature in both stack, upper and bottom. The air inside drying tube was vacuumed so it was reached almost vacuum point quickly after an hour of drying and continued getting closer to vacuum point. The drying air temperature was just around 10°C to 20°C except at first 15 minutes that it was under zero. Whereas product’s temperature was effected to the temperature set of freezer and heater. Highest product temperature in upper stack was 54°C and bottom stack was 45°C. It was occurred due to heater plate position which is in the top of the tube where freezer’s conductor was constructed spirally around the stacks. This can effect drying uniformity so product’s quality can be different too [13]. However, quality uniformity is very important for determining dried product’s quality [14].
3.2. Quality Parameter

As shown in table 1, edamame was shrunk during freeze drying. It was mostly shrunk in length than width or thickness. Overall shrinkage was high at 24 hours (21.05%) and final time (20.87%) of drying due to higher releases of exudates derived from disruption of system cell membrane as effected by high temperature for long time. Shrinkage was effected by drying air temperature and not effected by initial moisture content [15]. Edamame was became chewy during 12 until 24 hours of drying as moisture was still inside its cell. In freezing phase, the water was frozen but it was already melted again as it was moved to test its texture (table 2). As moisture content was released from dried product, it became crispier and the hardness value was much higher at 30 hours either at final time of drying, 78,163.48 g/cm² and 88,726.11 g/cm², as shown in table 2. Freeze dried product is porous and had non-compact hole wall so it hardness is more likely to be crispiness than product of hot air or microwave drying like okra snack [16]. Visual appearance change was shown in figure 3, dried edamame’s shrinkage can be seen directly as the moisture was released from the begining of drying phase (after 12 hours). Appearance and texture of dried food are results of complex interaction between its component. This parameter is one of main quality parameters of dried food, along with flavor, nutrients, rehydration, and quality uniformity [14].

Table 1. Physical quality parameter during drying

| Drying Time (h) | Dimention (mm) | Shrinkage (%) | Hardness (g/cm²) | Colour |
|----------------|----------------|---------------|-------------------|--------|
|                | Length | Width | Thickness |                | L*     | a* | b* | ΔE |
| 0              | 14.354a | 8909a  | 6.011a     | - | 14,564.76a | 56.3865a | -15.3795b | 35.0213a |
| 12             | 12.937b | 7.512b | 5.361ab    | 11.83a | 10,668.79a | 51.7000bc | -14.4317ab | 36.1344a | 4.90a |
| 18             | 12.805b | 7.339b | 5.282ab    | 13.15b | 11,178.34a | 48.6933bc | -11.6211b | 36.1067a | 8.63b |
| 24             | 11.826b | 6.698b | 4.588ab    | 21.05b | 22,951.17a | 39.2744bc | -5.8772bc | 24.4049a | 16.58c |
| 30             | 12.638b | 7.616b | 5.361ab    | 12.50b | 78,163.48b | 49.4933bc | -7.6933bc | 29.9078a | 11.52bc |
| 36             | 11.364b | 7.036bc | 4.764bc   | 20.87b | 88,726.11b | 54.2944a | -20.5600a | 29.6867a | 7.72b |

Figure 2. Pressure, air and product’s temperature during drying.
Numbers followed by the different superscript letter in a row mean significantly different from each comparison variety based LSD_{0.05} test.

![Figure 3](image)

Figure 3. Appearance change during drying from 0 hour (a), 12 hours (b), 18 hours (c), 24 hours (d), 30 hours (e), and 36 hours (f).

In figure 3, edamame’s colour change can be seen. Colour value in L*a*b* is shown in table 2. Its yellowness is not significantly change as b* value was marked as same superscript letter. A 24 hours dried edamame was the darkest as it has lowest L* value at 39.2744. Edamame in fully freeze dried was in lowest a* value that means freeze drying final product can be increased in greeness. This final product would be able to gain interest in consuming due to the green and bright colour. ΔE was high at 24 and 30 hours of drying. The unfinished drying allow water activity that can interact with open air when the sample is removed to be tested. Meanwhile, at 12 and 18 hours of drying, ΔE is not that high because that was not too long from blanching (0 hour). Freeze drying is yet a drying method that can maintain colour, odor, and appearance, as in carrot [17], and freeze drying is preffered drying method with low drying temperature that provides high quality product [18].

4. Conclusion

During freeze drying, blanched edamame was was lost 6.5945% (db) moisture content with initial point was 235.8635% (db) and final point was 8.8199% (db). Drying rate of edamame's freeze drying was 6.9355 g/g.h per hour with 54°C and 45°C as highest temperature of sample in upper and bottom stack. This condition change the edamame quality as its shrinkage was 20.87%, its hardness was 88,726.1 g/cm², and its colour change was 7.72 in final drying time. Unfinished freeze drying was still save for
edamame quality up to 18 hours and it is better not to remove the product until the drying process is over.

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