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The Effect of Blanching on the Quality of Freeze-Dried Edamame

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***Abstract*— Edamame (*Glycine max*. L. Merill) has been consumed due to its savory taste and high nutrient content. The Edamame can be dried and consumed as a crunchy snack through the freeze-drying process. However, this drying method has its drawbacks, such as a decrease in shrinkage ratio. One of the solutions to this is by blanching treatment before the freeze-drying process. This study aimed to investigate the effect of blanching pre-treatment on the quality of freeze-dried edamame. The properties assessed include moisture content, color, texture, shrinkage ratio, protein content, chlorophyll content, and morphology examination. Fresh edamame with the initial moisture content of 70% w.b. was introduced to the variation of steam-blanching and water-blanching before the freeze-drying process. Each blanching was done for 3, 9, and 15 minutes. The laboratory freeze-dryer used in this study was constructed with a stainless-steel plate (3 mm thickness) and had total dimensions of 1.0 x 0.8 x 1.0 m. The blanching treatment was proven to help promote the product quality, such as a higher shrinkage ratio ($p < 0.05$) and retain protein and chlorophyll content during the drying process. Hot-water blanching treatment was justified to be better than steam blanching treatment, gave the lowest final moisture content ranged from 3 – 6% d.b. Hot-water blanching also gave better results in terms of textural analysis and chlorophyll retention. The consumer acceptance test showed that freeze-dried edamame with hot-water blanching treatment gave a higher mean liking score than that with steam blanching treatment.**

***Keywords*— Edamame; freeze-drying; kinetic; physical quality; chemical quality.**

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I. Introduction

Edamame [*Glycine max.* (L.) Merr] or vegetable soybean has been known globally as a famous export commodity due to its high economic value. Especially in Indonesia, this crop grows well because of its soil and climate. One of them is in the Jember Regency of East Java since 1994 [1]. The export of edamame from Indonesia has grown substantially year by year. For example, from Indonesia to Japan, the total export has expanded from 55 metric tons (0.1% of Japan import market share) in 1995 to 3,997 metric tons (5.66% of Japan import market share) in 2011 and slightly reached 6.94% (3,107 metric tons) in 2015 [2].

The demand for edamame in Indonesia also increases along with the high awareness of the importance of consuming healthy food. Some studies have been conducted to evaluate the nutritional benefit of edamame. They reported that edamame has important ingredients such as protein, calcium, vitamin A and phytoestrogens or isoflavones [3]. Xu et al. reported the influence of the edamame development stage on the characteristics of edamame. They suggest harvesting edamame at the reproductive stage of R6, where it was described as a full green seed size at least one of the four top nodes [4].

Edamame is unique because, unlike grain-type soybeans, consumed fresh as a healthy snack after boiling. As a result, edamame should be consumed immediately after the harvesting process. Edamame seeds that are not processed can be stored after it is frozen or dried. One technique to preserve edamame is using the freeze-drying method. Vegetables resulting from freeze-drying did not experience a significant reduction in nutritional content, dimensions, and color [5]. One study suggests freeze-dried vegetables such as celery, celery juice, parsnips, and leek are marked by excellent preservation of shape, color, and flavor [6], [7].

Especially for edamame, the freeze-drying process was done to retain its properties such as vitamin C and chlorophyll since freeze-drying can evaporate the liquid in the sample at a low temperature [8], [9]. Another study showed that the drying process could reduce the moisture content of edamame to 8.82% d.b. during 36 hours of drying time and maintain the original color of edamame. However, the shrinkage ratio of freeze-dried edamame has decreased distinctly [10].

One solution to increase the shrinkage ratio of freeze-dried edamame is through the blanching process. Vegetables are introduced to boiling water quickly before the low-temperature storage in a blanching process. This process is done to preserve and prolong the shelf life of the vegetable. Wang *et al.* [11] reported the effect of hot-water blanching pre-treatment for the freeze-dried apple slices. They stated that hot water blanching before the drying process improves the freezing, increasing the mass loss, rehydration ratio, shrinkage ratio, lower hardness, and better apparent shapes.

Previous studies revealed that blanching could inhibit the peroxidase activity and decrease the total yeast, mold, and coliform bacteria count in edamame seeds during storage [11], [12]. However, there has been no study to evaluate whether the blanching process as pre-treatment can improve the quality of freeze-dried edamame, particularly its shrinkage ratio. Therefore, the object of the recent study was to investigate further the impact of blanching on the quality of edamame dried using freeze-drying. Apart from the physical, the chemical characteristics such as protein and chlorophyll of freeze-dried edamame were also evaluated.

II. MATERIAL AND METHOD

A. Sample Preparation

Fig.1. shows the flow diagram of the research method. Fresh edamame was brought from a local supermarket in Yogyakarta, Indonesia. One particular brand was picked to maintain the same variety and quality of edamame used. Pods were segregated from the vines before the hand sorting. The hand sortation method was done to remove any defective such as discarded matters. After that, 1.2 kg of pods were washed and drained before blanching. The initial moisture content of edamame used in this study was around 235.86% d.b., or 70.23% w.b.

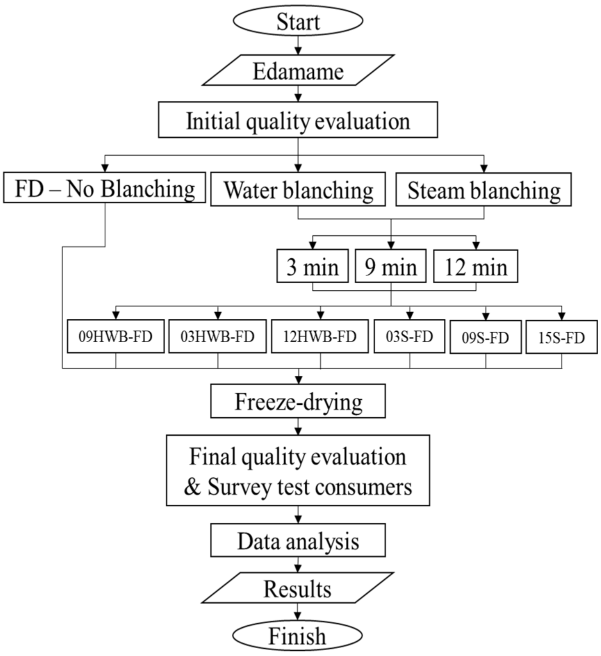


Fig. 1 Flow diagram of research method

B. Blanching Process

In-pod edamame was blanched with two methods. Firstly, the water blanching method (HWB-FD), where the edamame was blanched in hot water (90°C) using a water bath (ADVANTEC TX272DA, Dublin, CA). The second method was steam blanching (S-FD), where the edamame was put inside a steamer pan that was filled with 2 liters of water. The water steam temperature to be used was around 100°C, measured using a temperature data logger (EXTECH SDL200, Nashua, USA). Each blanching process was done for 3, 9, or 15 minutes. After the blanching process, each blanched sample was rapidly cooled in room temperature water (28-31°C) before edamame was drained and peeled.

C. Freeze Drying

Fig. 2. shows a schematic of the constructed laboratory freeze dryer used in this work. The freeze dryer was made with the total dimensions of 1.0 x 0.8 x 1.0 m. The drying chamber had the dimensions of 0.3 m diameter and 0.5 m length. The vacuum chambers, doors, and cold trap were made using stainless steel with 3 mm thickness. The freeze dryer is equipped with a compressor (Tecumseh L'Unite Hermetique R404A, Michigan, USA) and a two-stage vacuum pump (Robin air 15601/068495, Warren, USA). The heating system used three rectangular heater plates (30 x 15) cm^2, with a total power of 500 watts.

The 0.5 kg pre-treatment samples were outspread in a thin layer on the sample tray of freeze dryer and frozen to -18°C in vacuum condition for 12 hours. The freeze-drying process occurred at 76.0 cmHg for 36 hours. The heating plate temperature was controlled at 60°C. After the drying process finishes, the freeze-dried products were balanced, and their physical and nutritional characteristics were defined.

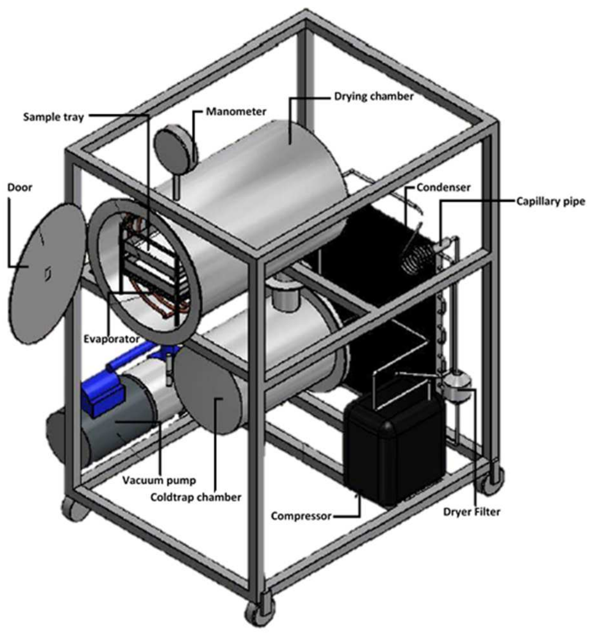


Fig. 2 Schematic freeze dryer

D. Quality Evaluation

1) Moisture content: The moisture content of the samples was measured using the oven drying method [13]. 5 g sample was dried in the oven at 105°C for 24 hours (Memmert UM-

400, Memmert GmbH + Co.KG, Schwabach, Germany). The loss of weight during the drying was considered as the water amount contained in the sample, which is presented below:

$$M = \frac{W_0 - W_1}{W_1} \quad (1)$$

Since the equilibrium moisture content M_e was very low and imperceptible, the moisture ratio *(MR)* was simplified [14], as presented below:

$$MR = \frac{M - M_e}{M_0 - M_e} \approx \frac{M}{M_0} \quad (2)$$

The moisture ratio during drying was then described by a zero-order kinetic model, which is presented below:

$$MR = MR_0 - kt \quad (3)$$

2) Color analysis: Color analysis was performed using Color Meter (Color Meter TES-135A, TES Electrical Electronic Corp., Taipei, Taiwan). The lightness (L*), redness/greenness (a*) and yellowness/blueness (b)* were evaluated. These parameters were then used to calculate edamame's color changes (ΔE) from before to after the drying process. The color changes formula is presented below [15]:

$$\Delta E = \sqrt{(L* - L_0)^2 + (a* - a_0)^2 + (b* - b_0)^2} \quad (4)$$

3) Texture analysis: Texture analysis was carried out by measuring the hardness of the edamame with a Texture Analyzer (Brookfield CT3 Texture Analyzer, Middleboro, MA, USA). An aluminum cylindrical probe TA39 (diameter = 2 mm) and compression rate of 1 mm/s were used as the analysis condition. After the seed was put in an undisturbed position, it was pressed to half its initial height. Seed hardness was quantified as the peak of compression force (g_f).

4) Shrinkage Ratio: The volume of edamame before and after the freeze-drying process was measured using geometric mean diameter (D_g) [16], shown the equations below.

$$D_g = (L \times W \times T)^{1/3} \quad \text{(Eq. 5)}$$

$$V = \frac{\pi \times L \times W \times T}{6} \quad \text{(Eq. 6)}$$

Finally, shrinkage ratio was calculated using the ratio between volume of the sample before drying (V_0) and after drying (V_d) presented by equation below[11]:

$$SR = \frac{V_d}{V_0} \quad \text{(Eq. 7)}$$

5) Protein and Chlorophyll Contents: Protein determination was made using The Kjeldahl method of total nitrogen measurement [17]. Chlorophyll calculation was adopted from ARNON [18], using a spectrophotometer (Thermo Scientific Genesis 20, Thermo Fisher Scientific, MA, USA). Data were calculated on a dry weight basis and expressed in percent (%).

6) Scanning electron microscopy (SEM): The morphology examination of freeze-dried edamame was observed using Scanning electron microscopy (SEM; JSM 6510LA JEOL Ltd., Tokyo, Japan), with Pt-Pd used as the coater.

E. Survey Test of Consumers

A survey for acceptance of target consumers (50 people, whose age was from 10 to 30 years old) consume freeze-dried edamame once for each variance using a questionnaire, including data of consumers' liking scores toward the product using 7-point hedonic scale.

F. Statistical Analysis

Statistical analysis of variance (ANOVA) was performed using IBM SPSS Statistics 23 software (SPSS Inc., Chicago, IL). Tests of significant differences between means were determined by Duncan Multiple Range Test (DMRT) at a confidence level of 95% ($p < 0.05$).

III. Result and Discussion

A. Moisture Content and Color Changes

Fig. 3 shows the moisture ratio during the primary and secondary stages of edamame freeze-drying. The drying process was conducted for 36 hours, with the rate constant of moisture ratio was 0.0313 h^{-1}. The coefficient of determination was obtained for the zero-order kinetic model ($R^2 = 1$), indicating the suitability of this model to explain the degradation of moisture ratio during drying. In general, the final moisture content of edamame for all treatments ranged from 3 – 9% d.b., with the average value different among each sample (Table 1). This range of moisture content is stored able level, as stated by Ferreira et al., who stored dried edamame at 18ºC with the moisture content of 12% d.b. [19]. The hot-water blanching gave significantly lower final moisture content of edamame compared to other treatments ($p < 0.05$) ranged from 3 – 6% d.b, indicating that hot-water blanching treatment gave resulted in a faster drying rate than that with steam blanching treatment. The blanching process prevents the hardening of the sample surfaces, in which that hardening can inhibit facile moisture movement within dried edamame [20].

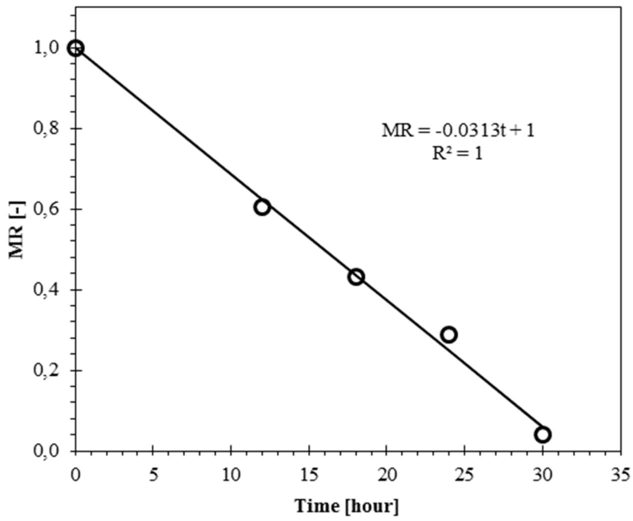


Fig. 3 Dependence of moisture ration (MR) on time during the freeze-drying process

Retaining the color after the drying process is one of the indices for the quality of processed vegetables, including freeze-dried edamame. Freeze-drying exhibited the highest lightness degree compared to other drying methods, with it is *a** and *b** values were almost the same as that in a fresh sample of edamame. Similar results were also found for freeze-dried quince fruit [21] and *Ziziphus jujube* Mill [22]. Table 1 shows the color difference (Δ*E*) of samples for two different blanching treatments. In general, pre-treatment resulted in varieties of color differences, ranged from 10 – 40. The fast and uniform heating rate delivered by the blanching also increased enzymes inactivation rate, resulting in dried edamame with retained color [23]. Hot-water blanching treatment for 3 and 9 minutes gave significantly lower color differences compared to other treatments ($p < 0.05$), confirms the pre-treatment function of hot water blanching to retain the color and flavor quality over-drying process [23].

TABLE I
MOISTURE CONTENT AND COLOR DIFFERENCE OF FRESH AND FREEZE-DRIED EDAMAME

Blanching method	**Moisture content (% d.b.)**	**ΔE (-)**
FD	8.72 ± 0.18^{d}	23.14 ± 3.22^{c}
03S-FD	5.74 ± 0.42^{b}	25.84 ± 1.37^{cd}
09S-FD	8.76 ± 0.45^{d}	23.19 ± 2.18^{c}
15S-FD	7.66 ± 0.43^{c}	37.67 ± 1.38^{e}
03HWB-FD	5.87 ± 0.33^{b}	10.67 ± 0.80^{a}
09HWB-FD	6.13 ± 0.14^{b}	19.34 ± 1.20^{b}
15HWB-FD	3.68 ± 0.86^{a}	28.01 ± 1.33^{d}
Fresh sample (% w.b.)	69.00 ± 0.72^{e}	-

Different letters on the same columns indicate significant differences at $p < 0.05$

B. Hardness

Fig. 4 shows the hardness of fresh and freeze-dried edamame in two blanching methods. Hardness is defined as the maximum force required for rupturing the sample. The figure shows that the non-blanched samples exhibited significantly higher hardness values than those after blanching treatment ($p< 0.05$). The duration of blanching also significantly affects the hardness value ($p < 0.05$). A previous study revealed that blanching pre-treatment leads to some soluble-solid loss in tissue and reduces the firmness of the cell wall [11]. The increase of blanching time will longer the starch gelatinization and pectin solubilization in edamame seeds, hence lowering the dried products' hardness [24].

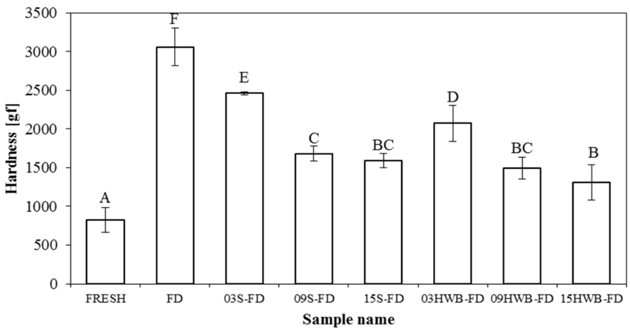


Fig. 4 The hardness of fresh and freeze-dried edamame Different letters indicate significant differences at $p < 0.05$

The hardness value is said to be one of the principal textural properties of dried food products. When the surfaces of the sample get hardened, the moisture movement inside the sample will be limited, thus decreasing its drying rate [20]. Therefore, the lowest moisture content in 15HWB-FD (Table 1) was reasonably expected, considering the influence of water blanching treatment to lower hardness and increase the drying rate.

C. Shrinkage Ratio

In food technology, shrinkage and rehydration capacity has a significant role in determining the quality of the dried product [25]. Shrinkage happens when the moisture is removed during convective drying, food polymers are not able to support their weight, and disrupt the structure of food cells. Especially for snack production, the higher values of shrinkage ratio (SR) exhibit better quality. The sample with a high SR value demonstrates the porous and crispy texture, two desired properties in snack products. The level of shrinkage in convective drying is higher than that in freeze-drying due to the higher air temperatures used during drying process [26]. As shown in Fig. 5, the SR of freeze-dried edamame with hot water blanching was significantly higher than that in steam blanching ($p < 0.05$). SR in FD control sample was lower than the others significantly, suggested more shrinkage occurred. These results correspond to that in sample hardness result (Fig. 3).

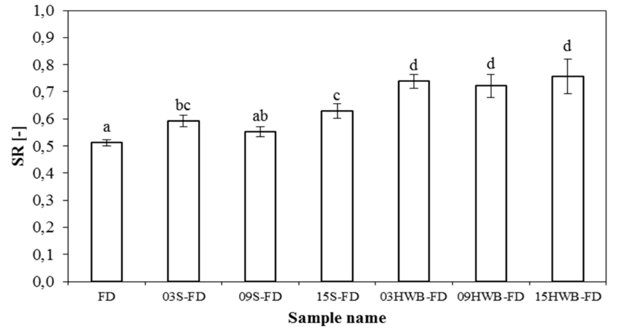


Fig. 5 Shrinkage ratio (SR) of fresh and freeze-dried edamame Different letters indicate significant differences at $p < 0.05$

D. Protein and Chlorophyll Contents

Protein is a main nutritional index for soybean, such as edamame. Table 2 shows the retention of protein and chlorophyll of edamame. As shown in Table 2, the freeze-drying resulted in a significant decrease of edamame protein ($p < 0.05$), probably due to the thermal degradation during secondary drying. Proteins have low thermal stability and can collapse at a temperature higher than their stability [25]. The blanching treatment resulted in higher protein retention after drying than the control, with the highest protein retention given by 9 minutes of water blanching treatment ($p < 0.05$). Since chlorophyll is vulnerable to factors such as oxygen, heat, and light, its preservation after the drying process can be an index to determine the success of the freeze-drying process.

TABLE II
PROTEIN AND CHLOROPHYLL RETENTION OF FRESH AND FREEZE-DRIED EDAMAME

Blanching method	Protein retention (%)	Chlorophyll retention (%)
FD	35.00 ± 0.06^{a}	0.59 ± 0.00^{a}
03S-FD	35.67 ± 0.03^{b}	0.97 ± 0.01^{d}
09S-FD	36.87 ± 0.04^{d}	0.97 ± 0.00^{d}
15S-FD	37.87 ± 0.03^{f}	0.83 ± 0.01^{c}
03HWB-FD	36.62 ± 0.38^{c}	0.78 ± 0.00^{b}
09HWB-FD	38.21 ± 0.03^{g}	1.01 ± 0.01^{e}
15HWB-FD	37.32 ± 0.03^{e}	1.20 ± 0.01^{f}
Fresh sample	49.10 ± 0.08^{h}	1.25 ± 0.02^{g}

Different letters on the same columns indicate significant differences at $p < 0.05$

From Table 2, we can see that the pre-treatment of blanching gave significantly higher chlorophyll retention compared to that with no blanching treatment, with the highest retention resulted from the drying with 15 minutes hot water blanching treatment ($p < 0.05$). A similar result was also reported by Kaewsuksaeng *et al.* [27], who reported that hot water-treated Thai lime at 50ºC delayed the chlorophyll decrease during storage than the one without hot water treatment. Another study reviewed that dehydration during vegetable drying prior to the storage could retain the chlorophyll better than the control, giving no significant chlorophyll loss in the product [28].

E. Scanning Electron Microscopy (SEM)

One of the advantages of FD products was retaining the original shape of materials after the drying process. Fig. 6 shows the SEM micrographs of freeze-dried samples in three different blanching methods. The micrographs are presented in two different magnifications: 500 and 3,000 times. From the figure, it can be found that the honeycomb network was formed in tissues of all samples. Blanching treatments (both hot water and steam) exhibits larger pores compared to those in control. According to Wang et al., smaller tissue pores can be associated with the smaller ice crystal formed, marked the faster freezing rate during the freeze-drying process [11]. This phenomenon confirms previous results, reported that samples with blanching pre-treatment resulted in a higher drying rate and smaller final moisture content (Table 1). In a closer look, blanching treatment exhibits different surfaces of the matrix compared to that in control. The control treatment resulted in a microstructure that appeared to be more rigid. Meanwhile, for blanching treatment, the surface appeared to be soft and melted. This texture can happen as a result of leaching and heating during the blanching process.

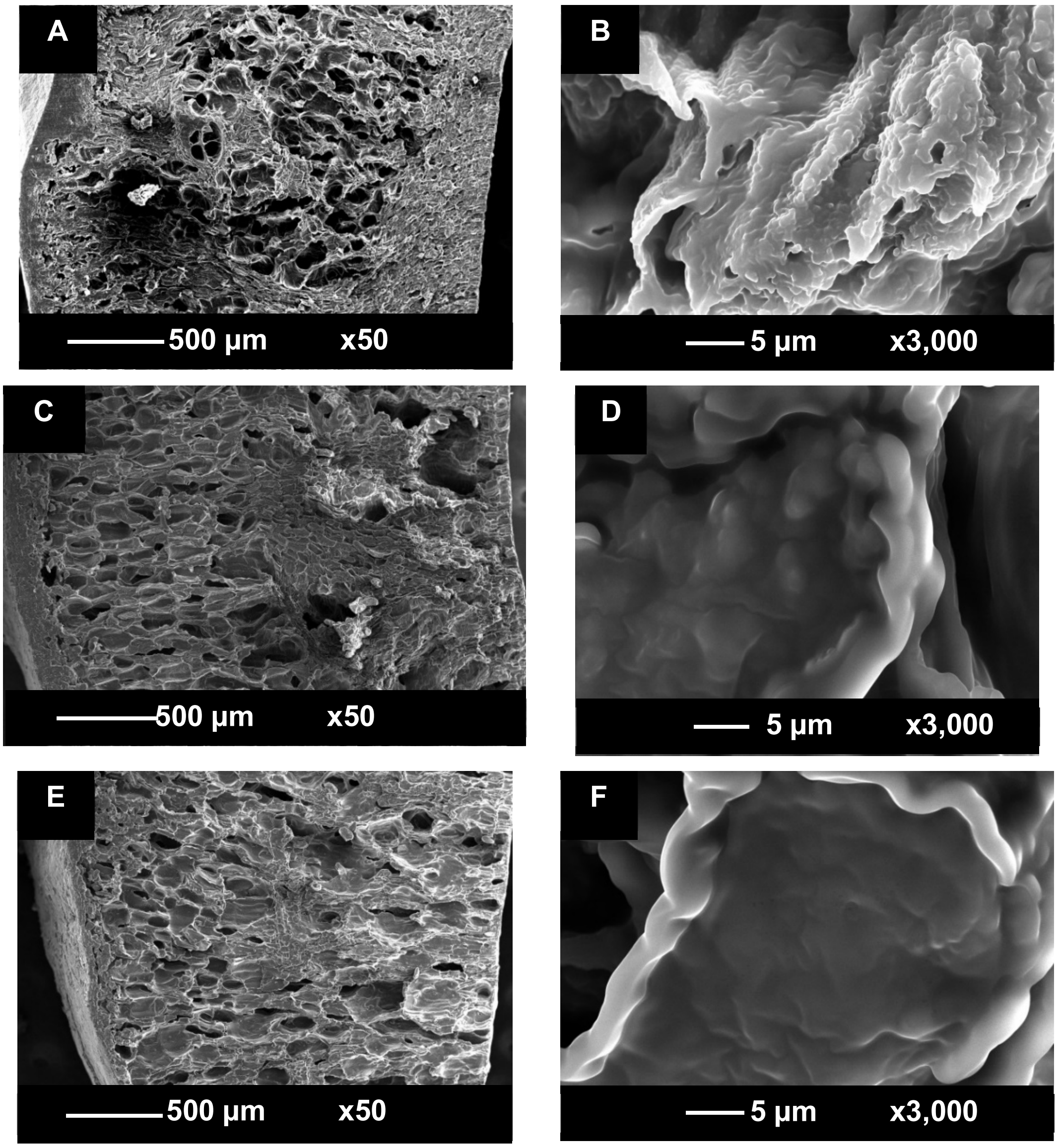
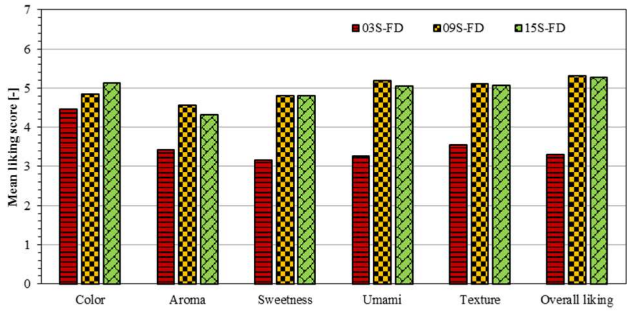


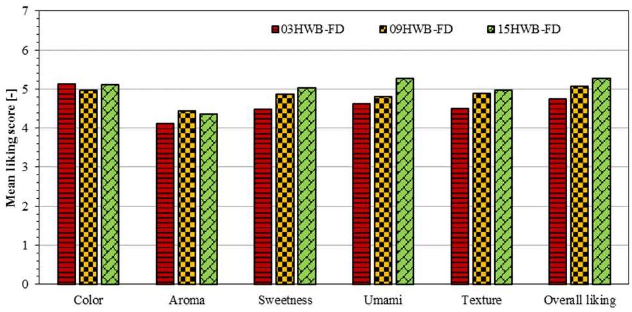
Fig. 6 Morphology of freeze-dried edamame at three different pre-treatments: control (A-B); steam blanching (C-D); hot water blanching (E-F)

F. Survey Test of Consumers

Consumers' survey test was conducted to evaluate and compare the sensory test between hot water blanching and steam blanching samples. Fig. 7 shows the mean liking scores of consumers, in which the liking values include: Color, aroma, sweetness, umami, texture, and overall liking. From Fig. 7, edamame with water blanching treatment on average is more likable than edamame with steam blanching treatment. Hot-water blanching and its duration gave relatively constant scores for all liking categories, ranging from 4 to 5 (Fig. 6b).



(a)



(b)

Fig. 7 Mean liking scores of the freeze-dried edamame with different pre-treatment: steam blanching (a) and hot water blanching (b)

Meanwhile, steam blanching treatment for 3 minutes gave a relatively lower mean liking score (Fig. 6a). Edamame was put into the blanching process before consumption to inactivate enzymes, reducing microbial load and protein stability. Moreover, since edamame is usually consumed fresh as a healthy snack, blanching is essential to remove unacceptable aroma and improve color and texture. Based on the sensory test we conducted, it can be concluded that the consumers can generally accept hot-water blanching treatment better than with steam blanching treatment.

IV. Conclusion

The impact of blanching treatment on the properties of edamame after the freeze-drying process was evaluated. The blanching treatment was proven to help improve the drying quality, such as a higher shrinkage ratio and retain protein and chlorophyll content during the drying process. Hot-water was justified to be more recommended than steam in case of blanching pre-treatment, especially in terms of textural analysis and consumers' preference.

Nomenclature

M	moisture content at the pre-determined time	% d.b.
M_0	initial moisture content	% d.b.
M_e	equilibrium moisture content	% d.b.
W_0	mass sample at the pre-determined time	g
W_1	mass sample after 24 hours oven drying	g
MR	moisture ratio	-
K	drying rate constant	h^{-1}
t	time	h
ΔE	color changes	-
D_g	geometric mean diameter	m
V	sample volume	m^3
L	length	m
W	width	m
T	thickness	m
SR	shrinkage ratio	%
V_0	sample volume before the drying	m^3
V_1	sample volume after the drying	m^3

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