

RESEARCH ARTICLE

Hot Water Blanching Pre-Treatments: Enhancing Drying of Seaweeds (*Kappaphycus alvarezii* S.)

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Abstract:

It is really important to dry seaweeds in a shorter drying time without affecting its quality. Blanching enhance drying rate, thus it could decrease drying time. However, study on hot water blanching temperature and time on the drying rate of seaweeds (*Kappaphycus alvarezii* sp.) has not yet been reported. Thus, this research aimed to investigate the effect of the application of hot water blanching pre-treatments on the drying rate, sensory, and nutritional attributes of seaweed (*Kappaphycus Alvarezii*, S.). Seaweed samples were blanched (88oC) at 5, 15 and 30 seconds duration and dried using solar glass dryer and heated air mechanical dryer. All samples were replicated three times. Complete Randomized Design (CRD) was used in both dryers and T-Test in comparing between dryers. Simple cost analysis was also performed to assess the annual cost and custom rate of using two methods of drying.

It revealed that in heated air mechanical dryer, samples blanched for 5 and 15 seconds dry faster (8 hours). In solar glass dryer, seaweed samples blanched at 5 seconds dry earlier (32.67 hours). Results imply that hot water blanching affects drying time in drying seaweeds and hot water blanching pre-treatments increased drying rate at the initial hour of drying. It verified that models fitted shows good predicting capacity and reveals good correlation coefficient. Hot water blanching pre-treatments and types of dryers did not significantly affect the total ash contents of the seaweed powder, while in crude protein levels, it revealed that hot water blanching pre-treatment were not significant within the dryers but significantly different between drving methods.

Moreover, pre-treatments undergone within the dryer were significantly different in crude fiber levels but insignificant in comparison between dryers. It also implied that color of the seaweed powder dried in solar glass dryer was preferred by panels and all seaweed samples dried using heated air mechanical dryer turned to dark color. Results revealed that hot water blanching pre-treatments and types of dryer do not affect the texture and odor preference of the panels and general acceptability scores of the seaweed powder were insignificantly different within dryers. It also showed that using solar glass dryer and heated air mechanical dryer, it is profitable to blanch the seaweeds before drying.

Keywords: Seaweeds, Pretreatments, Blanching, Drying Characteristics

Introduction

Seaweed farming is now emerging to be a vital source of income of the locality nearby coastal areas. Philippines is one of the top producers of seaweeds in the world and seaweed production reached 1.57 million metric tons with around 12,000 farmers engaged in seaweed farming as estimated by the Bureau of Fisheries and Aquatic Resources (BFAR, 2010). The Bureau of Fisheries and Aquatic Resources aims to increase seaweed production by at least 5% annually from 2017-2022. Seaweeds are exported either in raw forms (fresh or dried seaweeds) or processed forms (semirefined chips/carrageenan and refined carrageenan).

Kappaphycus alvarezii specie is a common variety of seaweed used to make carrageenan. Carrageenan is an emulsifier, stabilizer and used for binding, thickening and dispersion (Bartosikova, 2013). Being marine in nature seaweeds contain a large amount of water. Fresh seaweeds contain 75 - 85% water and 15 - 25% organic components and minerals. Seaweeds are dried before they can be used in industrial processing. Drying of seaweeds retards microbial growth, helps conserve desirable qualities and reduces storage volume (Xin Jin, 2013). Prior to drying, pre-treatments may be desirable such as blanching. A significant benefit of blanching with respect to drying is softening of the internal tissue results to increased drying rate, thus shorter drying time, less degradation of components and less energy consumption (Xin Jin, 2013).

Several drying methods for seaweeds were developed including heated air-mechanical dryer (HMD) and solar glass dryer (SGD). Solar glass dryer is similar to sun drying, where sunlight is the main source of drying except, that products to be dried are enclosed by a tunnelled glass; while heated air mechanical dryer use nichrome plate and LPG stove to raise the air temperature to be fed in the drying chamber of the dryer. Even if solar glass drying method was preferred by local farmers for the reason that it is more economical, heated air-mechanical dryer is all season dryer that can be used anytime compared to conventional dryer. Moreover, seaweed farmers prefer to use drying method which can produce dried seaweeds in shorter period, in economical way.

It is really important to dry seaweeds in a shorter drying time without affecting its quality. Blanching enhances drying rate, thus it can decrease drying time. However, study on hot water blanching temperature and time on the drying rate of seaweeds (*Kappaphycus alvarezii* S.) has not yet been reported. Furthermore, this study focused on investigation of the application of hot water blanching pre-treatments in drying seaweeds using solar glass dryer and heated air mechanical dryer. Therefore, hot water blanching pre-treatments may enhance drying rate and shorten drying time using solar glass dryer and heated air mechanical dryer.

Objectives of the Study

General objective of the study was to investigate the application of hot water blanching pre-treatments in drying of seaweeds. Specifically, it aimed to:

1. determine drying characteristics of hot water blanched seaweed dried using solar glass dryer and heated air mechanical dryer;
2. analyze proximate analysis of hot water blanched seaweed dried using solar glass dryer and heated air mechanical dryer;
3. evaluate sensory characteristics of seaweed as affected by hot water blanching pre-treatment; and,
4. perform simple cost analysis

Materials and Methods

Samples

All samples were washed, cleaned, and checked from epiphytes and other foreign materials. Seaweed samples were chopped into smaller pieces (1-2 inches), placed inside a net and laid for 5 minutes allowing excess water to drip-off. There were total fresh seaweeds samples of 96 kilograms with 12 kilograms on each treatment and 4 kilograms on each sample.

Hot Water Blanching

Materials used were prepared prior to blanching process. Water was heated until it reaches the desired temperature of 88°C (Yamanaka & Akiyama ,1993). Seaweed samples were blanched for 5 seconds, 15 seconds, and 30 seconds. After blanching, seaweed samples were suspended for 5 minutes before the drying process.

Drying

Heated-Air Mechanical Dryer

Heated-air mechanical dryer (HMD) is a mechanical and continuous dryer that used nichrome plate and LPG stove to raise air temperature to be fed in the drying chamber. The dryer was pre-heated to 50 degree Celsius. Moisture

content was monitored by weighing the samples at hourly interval. Air temperature and relative humidity inside the dryer were recorded. Drying process continued until seaweed samples reached the desired moisture content (14-15%). The raw dried seaweeds were ground for proximate nutrient analysis and sensory evaluation. After grinding, each sample was packed using zip lock to maintain moisture while stored in the cooler for laboratory analysis.

Solar Glass Dryer

Solar Glass Dryer (SGD) is a sun dependent dryer primarily made up of a tunneled glass. The solar glass dryer was placed in open field where there was no obstruction from the sun. Moisture content, air temperature and relative humidity were monitored by at hourly interval. Drying process continued until seaweed samples reached the desired moisture content (14-15%). Raw dried seaweeds were ground and packed using zip lock to maintain the moisture while stored in the cooler for proximate nutrient analysis and sensory evaluation.

Drying Characteristics

Weight of seaweed samples was determined before and after drying using the weighing scale. The initial moisture content in percentage (wet basis) was determined using the equation,

$$MC_1 = \frac{W_i - W_f}{W_f} \times 100\% \quad (1)$$

Where:

MC_1 = Initial moisture content of seaweed (%)

W_i = Initial weight of the seaweed (kg)

W_f = Final weight of the seaweed at any drying time interval (kg)

The final moisture content of test material was computed using the formula (PAES 202:2000),

$$MC_2 = \left(100 - \frac{W_1(100 - MC_1)}{W_2}\right) \times 100\% \quad (2)$$

Where:

MC_1 = Initial moisture content of seaweed (%)

MC_2 = Final moisture content of seaweed (%)

W_1 = Initial weight of the seaweed (kg)

W_2 = Final weight of the seaweed at any drying time interval (kg)

Regression Analysis

Curves were represented in two different types of plots, namely: moisture content versus time, and drying rate versus time. Seaweed samples that underwent hot water blanching pre-treatments and dried were subjected to regression analysis using Microsoft Excel 2010 and mathematical models were obtained and fitted with moisture reduction and drying curves.

Proximate Nutrient Analysis

Two hundred fifty (250) grams of dried seaweeds from each sample was analysed for ash content, crude protein and crude fiber. Analysis was done for 14 days.

Statistical Analysis

A Completely Randomized Design (CRD) at 1% and 5 % levels of significance was used in each drying method and the significance of differences among means was carried out using Duncan's multiple range test thru Assisat 7.7. Effects of hot water blanching pre-treatments on dried seaweeds using solar glass dryer and heated air mechanical dryer were compared using t-Test. Data were subjected to regression analysis using Microsoft Excel 2010 and mathematical models were obtained and fitted with moisture reduction and drying curves.

Simple Cost Analysis

The following equations were used in the conduct of simple cost analysis of solar glass dryer and heated-air mechanical dryer.

Annual Cost Equation

$$AC = AFC + \frac{W}{C}(VC) \quad (1)$$

$$CR = \frac{AFC}{W} + \frac{VC}{c} \quad (2)$$

where:

AC= Annual Cost, P/yr

AFC = Annual Fixed Cost, P/yr

W= Weight of dried seaweeds, Kg/yr

C= capacity of the machine, kg/hr

VC= Variable Cost, P/hr

CR= Custom Rate, P/Kg

Break-even Point

Break-even point indicates that at certain point, the investment has neither profit nor loss. It was calculated using the equation 3.

$$BEP = \frac{AFC}{CR - \frac{VC}{c}} \quad (3)$$

Net Income

Net income was calculated using equation 4.

$$NI = (CR - OC) \times C \times OP \quad (4)$$

where:

NI = net income, P/yr

CR= Custom Rate, P/kg

OC= Operating cost, P/Kg

C= Capacity, Kg/day
 OP= operating period, days/yr

Operating Cost

Operating cost was calculated using the equation 5.

$$OC = \frac{TC}{C} \quad (5)$$

where:

OC = Operating cost, P/kg
 TC = total cost, P/day
 C = capacity, Kg/day

Payback Period

Payback period is the time wherein the cost invested is recovered. It was calculated using the equation 6.

$$PBP = \frac{InvC}{NI} \quad (6)$$

where:

PBP = Payback Period
 InvC = Investment Cost, P
 NI = Net Income, P/yr

Results and discussions

Drying Characteristics

Initial weight of the samples was 4,000 grams with initial moisture content of 91 % (w.b). It was observed that after water blanching, the weights of the samples decreased from 4,000 grams to averages of 2860.83 grams (blanched at 5 seconds), 3,302.33 grams (blanched at 15 seconds) and 3593.67 grams (blanched at 30 seconds). Blanching softens the internal tissue of the seaweed (Jin et al., 2012), and releases water after it was blanched. Even if seaweeds are subjected to longer duration of blanching, decrease of water content was favorable to samples blanched at 5 seconds duration compared to 15 and 30 seconds duration.

Drying Time

Heated Air Mechanical dryer

Drying time in drying seaweeds as affected by blanching time and drying using heated air mechanical dryer is presented in Table 1. Samples that were blanched in 5 and 15 seconds dry faster (8hours) than samples that were not blanched (9 hours) and those blanched at 30 seconds (9 hours).

Analysis of variance shows that drying time of seaweeds varied significantly. Results imply that hot water blanching pre-treatments affect drying time of seaweeds using heated air mechanical dryer.

Solar Glass Dryer

In solar glass dryer, seaweed samples that were blanched at 5 seconds dried earlier (32.67 hours), followed by no blanched (40.33 hours), 15 seconds (40.33 hours) and 30 seconds (40.67 hours) blanching duration (Table 1). Analysis of variance shows that drying time of seaweeds varied significantly. Results imply that hot water blanching pre-treatments affect drying time of seaweeds using solar glass dryer. Sudden change in weather condition results to varying data on relative humidity and temperature that were recorded. Highest and lowest temperatures recorded on the solar glass dryer were 61.2°C and 36.8°C, respectively.

It was observed that drying process in solar glass dryer took longer time compared to heated air mechanical dryer, because solar glass dryer requires sunlight to dry at limited number of hours per day, while heated air mechanical dryer has continuous drying operation.

Table 1. Drying time of seaweeds as affected by different blanching times and dried using solar glass dryer and heated air mechanical dryer

Treatments	Drying Time, hr	
	Solar Glass dryer	Heated air Mechanical Dryer
Not Blanched	40.33 ^b	9 ^a
5 Seconds	32.67 ^a	8 ^b
15 Seconds	40.33 ^b	8 ^b
30 Seconds	40.66 ^b	9 ^a

means not followed by same superscripts differ significantly ($P < 0.01$)



Figure 1. Drying of seaweeds using solar glass dryer



Figure 2. Drying of seaweeds using heated air mechanical dryer.

Moisture Reduction Curves

Heated Air Mechanical Dryer

Moisture reduction curves show the profile change in moisture content (w.b.%) versus drying time (hr) as shown in Figures 1 to 4. As observed, moisture content decreases continuously with drying time. Rate of moisture loss was higher in the seaweed samples blanched at 5 and 15 seconds. Results imply that hot water blanching pre-treatments affect moisture reduction of samples that were blanched at 5 and 15 seconds but not the samples that were not blanched and blanched at 30 seconds. It was observed that blanching seaweeds at 30 seconds resulted to softening of the seaweeds and made barriers between limbs which prevent entry of drying air. However, seaweeds that were not blanched had longer drying period for they have more moisture to remove compared to blanched samples that partially released moisture after blanching.

All moisture reduction curves typically demonstrated smooth diffusion-controlled drying. Same observation was made by Guiné & Fernandes (2006), as temperature increases it allows greater diffusion coefficients, since the process of diffusion was favored in products with higher proportions of water and lower proportions of solids.

Solar Glass Dryer

Moisture reduction curves of seaweed samples that were dried using solar glass dryer are presented in Figures 1 to 4. A minor curve was observed during the initial hours of drying operation. This period was due to the effect of evaporative cooling, wherein temperature is reduced resulting from the evaporation of liquid, which removes latent heat from the surface from which evaporation takes place. As drying process continuous, temperature starts to increase more rapidly because effect of evaporative cooling is reduced (Traub, 2002).

Results imply that hot water blanching affects moisture reduction and drying time of seaweeds. Pre-treatments increased drying rate at the initial hour of

drying. Same observation was made by Dandamrongrak et al. (2003), that drying rate of treatments was high in the initial hour of drying due to free moisture of the outer surface of the commodity being dried that will be easily removed early in the process.

Moreover, it was observed that samples blanched at 15 and 30 seconds had longer drying time. This was probably due to effect of longer blanching that weakened seaweed limbs to soft flexible particles, so that when placed in tray, it caused compression and closing of spaces between limbs, preventing free access of the drying air through the samples. Drying process observed is mainly controlled by rate of internal movement of moisture to the surface of the commodity being dried (Mitchell and Potts, 1955).

A different condition of drying was observed on samples that were not blanched which took longer drying time to dry compared to samples blanched at 15 and 30 seconds. Because samples were not blanched, textures of the seaweed are still firm thus, internal tissues were not susceptible to immediate removal of moisture. Drying was largely governed by the amount of water which the drying air can take up and water capacity depends on the degree of saturation of air. Thus, drying requires more time to remove water for no moisture was initially removed before drying compared to the samples that were blanched.

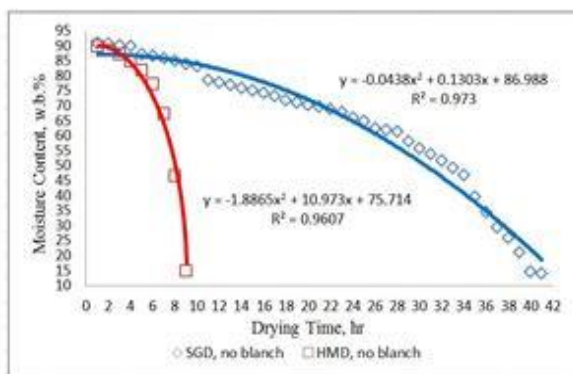


Figure 1. Moisture reduction curve: moisture content (w.b.%) vs drying time of seaweeds not blanched and dried using solar glass dryer and heated air mechanical dryer

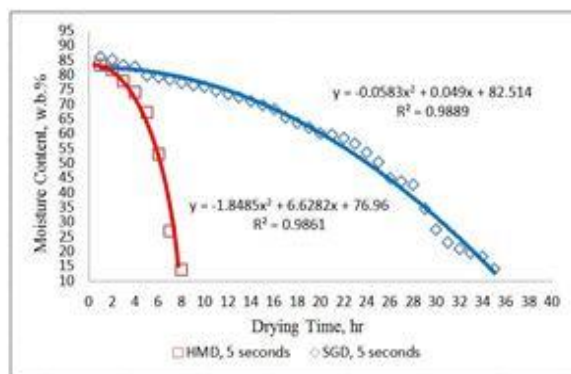


Figure 2. Moisture reduction curve: moisture content (w.b.%) vs drying time of seaweeds blanched at 5 seconds and dried using solar glass dryer and heated air mechanical dryer

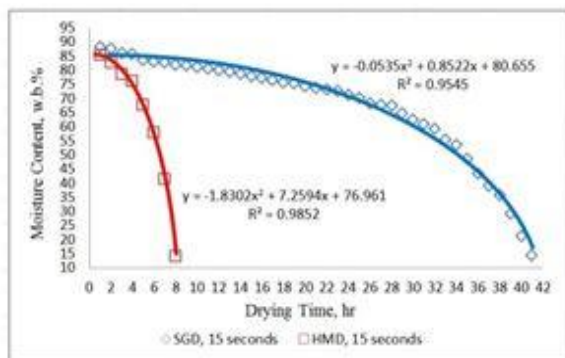


Figure 3. Moisture reduction curve: moisture content (w.b.%) vs drying time of seaweeds blanched at 15 seconds and dried using solar glass dryer and heated air mechanical dryer

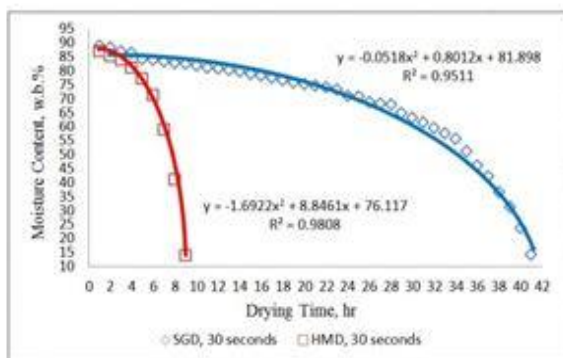


Figure 4. Moisture reduction curve: moisture content (w.b.%) vs drying time of seaweeds blanched at 30 seconds and dried using solar glass dryer and heated air mechanical dryer

Regression Analysis

All moisture reduction curves were subjected to regression analysis and mathematical models were fitted in the curves (Figure 1 to 4). Quality of fit was expressed by the coefficient of regression, R^2 . R^2 values measure variability between experimental and predicted values, and higher R^2 values indicate that the model is best fitted. All model fitted were in second-order polynomial equations. Results show high quality fitting with R^2 values ranging from 0.9511 to 0.9889 (Figure 3 to 6). From the results obtained it can be verified that the models fitted show good predicting capacity.

Drying Curve

Heated Air Mechanical Dryer

Drying rates of all treatments subjected to blanching were initially high when moisture was highest, then decreased rapidly as moisture decreased (Figures 5 to 8). Eventually, drying rate was observed to have constant rate before it dried.

Different drying curves were observed on samples that were not subjected to blanching. Drying rate decreased on the first 4 hours of operation and suddenly increased on the 7-8 hours of the drying, and then decreased on the last period. Increase on drying rate was happened when the drying rate of the samples that were blanched decreased, and it was noted that at 8 hours of drying, blanched samples at 5 and 15 seconds were dried. When the blanched samples were close to its desired dryness it resulted to increase of drying rate of the unblanched samples, for they have more moisture to remove than samples that were blanched that was noted earlier when samples released water after blanching.

Solar Glass Dryer

All drying curves were on the same pattern except samples that were not blanched (Figures 5 to 8). As observed, drying rate of the samples not blanched started at low drying rate and increased eventually. As the moisture decreased, the drying rate also decreased, until constant rate period is reached. Initially, low drying rate was probably due to evaporative cooling effect. Samples that were not blanched have more moisture than other samples. As they release more moisture; evaporative cooling effect occurs and breaks eventually as the moisture decreases and air temperature increases.

It was observed that heated air mechanical dryer has higher drying rate compared to solar glass dryer. Basically, heated air mechanical dryer is a controlled and a continuous dryer, while solar glass dryer is dependent on the heat supplied by the sun.

It was observed that drying rate increases significantly with increase in drying temperatures. Consequently, higher drying temperature results to a higher drying rate and thus the moisture content decreased subsequently. These results were in agreement with the observations of earlier researchers (Lahsasni et al., 2003; Hassan and Hobani, 2000) and results implied that hot water blanching pre-treatments consequently affect drying rate.

Regression Analysis

All drying curves were subjected to regression analysis and mathematical models that fitted the curves are presented in Figures 5 to 8. Higher R^2 values indicate that the model is best fitted. Results show high quality fitting with R^2 values ranging from 0.8631 to 0.9873. From the results obtained it can be verified that the models fitted shows good predicting capacity and reveals good correlation coefficient between the fitted model and experimental data.

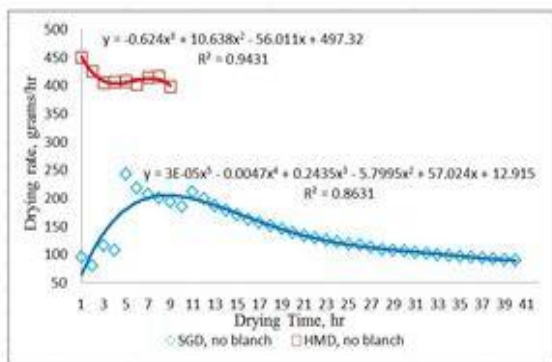


Figure 5. Drying curve: Drying rate, grams/hr vs drying time of seaweeds not blanched and dried using solar glass dryer and heated air mechanical dryer

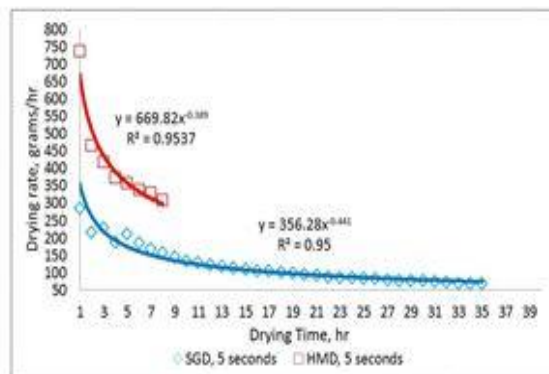


Figure 6. Drying curve: Drying rate, grams/hr vs drying time of seaweeds blanched at 5 seconds and dried using solar glass dryer and heated air mechanical dryer

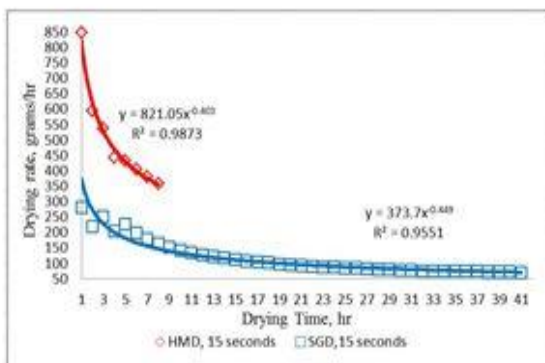


Figure 7. Drying curve: Drying rate, grams/hr vs drying time of seaweeds blanched at 15 seconds and dried using solar glass dryer and heated air mechanical dryer

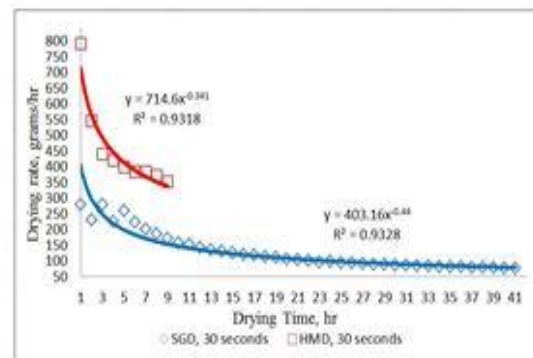


Figure 8. Drying curve: Drying rate, grams/hr vs drying time of seaweeds blanched at 30 seconds and dried using solar glass dryer and heated air mechanical dryer

Proximate Analysis of Seaweed Powder

Ash Content

Solar Glass Dryer

The level of ash ranged from 20.40% (5 sec) to 25.83% (30sec). Ash content of the seaweed powder that underwent 30 seconds hot water blanching was the highest (25.83%) and the lowest ash content (20.40%) was recorded from the seaweed subjected to 5 seconds blanching (Table 2). Ash content of samples not blanched and blanched in 15 seconds duration were 20.63% and 21.77%, respectively.

Results imply that levels of ash contents on each treatment were insignificant in variations. Thus, water blanching pre-treatments do not affect levels of ash contents in the seaweed powder. Moreover, Abu-Ghanman and Jaiswal (2015) added that sensory and quality attributes of the product being blanched depends on time-temperature combinations. Based on results, hot water blanching temperature and time combinations did not affect ash content levels of seaweeds.

Heated Air Mechanical Dryer

The levels of ash contents of the seaweed dried under heated air mechanical dryer ranged from 17.80% (30 sec) to 22.83% (no blanch) was presented in Table 2. The highest ash content level (22.83%) was observed in unblanched seaweed samples and the least ash content (17.8%) was noted for the seaweed samples blanched at 30 seconds.

Results reveal that different blanching durations did not significantly affect the total ash contents levels of the seaweed powder. Results signify that hot water blanching temperature and blanching time combinations did not affect vividly the ash content levels of seaweeds.

Crude Protein

Solar Glass Dryer

. The highest value of crude protein (3.367%) was recorded from the seaweed blanched in 15 and 30 seconds and the lowest value (3.13%) corresponded to the unblanched samples (Table 2).

Results show that minor differences of crude protein levels were not statistically significant from each other. Results reveal that water blanching of the seaweed and dried under solar glass dryer do not affect levels of crude protein in the seaweed powder. It indicates no appreciable change in crude protein contents as result of water blanching pre-treatments. Moreover, hot water blanching temperature and time combinations did not affect crude protein contents of seaweeds.

Heated Air Mechanical Dryer

Crude protein levels of the seaweed powder dried under heated air mechanical dryer varied from 3.567% to 4.067% (Table 2). Highest value (4.067%) was observed in the sample blanched at 15 seconds and least amount of crude protein (3.567%) was observed in the sample blanched at 30 seconds.

Even if there were variations of crude protein levels, there were no significant differences among treatments. Results imply that blanching temperature and time combinations in seaweeds, dried under heated air mechanical dryer do not affect levels of crude protein. This finding indicates that slight differences in crude protein levels in all treatments have no considerable change in crude protein contents as a result of hot water blanching pre-treatments.

Crude Fiber

Solar Glass Dryer

The highest value of crude fiber (12.303%) was obtained from the seaweed samples blanched at 15 seconds and the lowest value of crude fiber (4.370%) was obtained from the unblanched seaweed samples (Table 2).

Results shows that levels of crude fiber content were highly significant, wherein seaweed samples blanched at 15 and 30 seconds differ significantly from samples that were not blanched and those blanched at 5 seconds. Results reveal that hot water blanching pre-treatments affect increasing levels of crude fiber in the dried seaweeds. Results imply that water blanching enhances retention of crude fiber in the dried seaweed.

Heated Air Mechanical Dryer

Highest value (11.853%) was observed in samples blanched at 15 seconds and the lowest value (4.397%) was observed in samples blanched at 30 seconds (Table 2).

The levels of crude fiber of seaweed samples blanched at 5 seconds (12.057%) and 15 seconds (11.853%) were significantly different from samples that were not blanched (4.54%) and samples blanched at 30 seconds (4.3967%).

It was observed that levels of crude fiber increased when blanched at 5 seconds and decreased eventually when blanching duration increased. The trend was observed in both dryers, except that decrease on crude fiber of samples dried under heated air mechanical dryer started at 15 seconds, followed by 30 seconds blanching while in seaweed samples dried under solar glass dryer, crude fiber decreased only at 30 seconds blanching. Nevertheless, both dryers were on the same pattern.

Results imply that blanching (5 seconds duration) helps in retaining crude fiber but increasing blanching temperature results to percentage reduction of crude fiber level.

Table 2. Ash content(%), crude protein(%) and crude fiber (%) levels of the seaweed powder dried using heated air mechanical dryer (HMD) and solar glass dryer (SGD).

SENSORY CHARACTERISTICS						
Treatments	Ash Contents (%)		Crude Protein (%)		Crude Fiber (%)	
	SGD ^a	HMD	SGD	HMD	SGD	HMD
Not Blanched	20.63 ^a	22.83 ^a	3.13 ^a	3.97 ^a	4.37 ^b	4.54 ^b
5 Seconds	20.4 ^a	20.27 ^a	3.27 ^a	4.03 ^a	7.45 ^b	12.06 ^a
15 Seconds	21.77 ^a	19.63 ^a	3.37 ^a	4.07 ^a	12.3 ^a	11.85 ^a
30 Seconds	25.83 ^a	17.8 ^a	3.37 ^a	3.57 ^a	12.12 ^a	4.39 ^b



Figure 3. Seaweed powder dried in heated air mechanical dryer.



Figure 4. Seaweed powder dried in solar glass dryer

Comparison on Proximate Composition between Heated Air Mechanical Dryer and Solar Glass dryer

It was observed that variations of ash contents of seaweed samples dried between heated air mechanical dryer and solar glass dryer were insignificant in all blanching durations (Table 3). Results reveal that methods of drying do not affect level of ash contents. Similar observation was made by Kramer and Smith (1947), that even if there were variations of ash contents on the product

subjected to water blanching, results did not influence materially general proximate compositions.

It was observed that results on crude protein samples dried between heated air mechanical dryer and solar glass dryer were highly significant on seaweeds that were not blanched and significantly different in the samples blanched at 5 seconds and 15 seconds. Even if levels of crude protein on the samples blanched at 30 seconds had insignificant differences between heated air mechanical dryer and solar glass dryer, samples under solar glass dryer which constitute longer exposure to heat reduce levels of crude protein. Increase in temperature causes severe protein damage in food ranging from destruction of amino acids to complete racemisation (Rahma & Mustapha, 1988). Heat causes breakage in the myofibrillar protein bonds. As heat increases, moisture in protein evaporates and the protein loses flexibility and mass. Reduction in solubility accompanied by coagulation affects level or availability of crude protein (Alais & Linden, 1999).

Furthermore, mean differences on the crude fiber of seaweed dried under heated air mechanical dryer and solar glass dryer were insignificant, except for seaweed samples blanched at 30 seconds that were significantly different. Results reveal that drying methods do not affect levels of crude fiber on samples not blanched, and those blanched at 5 and 15 seconds.

Table 3. Summary of statistical analyses using paired t-test for comparison of mean values of ash contents, crude protein, and crude fiber levels of the seaweed powder.

PROXIMATE ANALYSIS PARAMETER	MEAN DIFFERENCE (HMD - SGD)	DEGREES OF FREEDOM	t - VALUE
Ash Content			
Not blanched	2.20	2	0.176 ^{ns}
5 seconds	-0.13	2	-0.030 ^{ns}
15 seconds	-2.13	2	-0.626 ^{ns}
30 seconds	-8.03	2	-1.363 ^{ns}
Crude Protein			
Not blanched	0.83	2	25.00 ^{**}
5 seconds	0.77	2	5.277 [*]
15 seconds	0.70	2	3.363 [*]
30 seconds	0.20	2	1.732 ^{ns}
Crude Fiber			
Not blanched	0.17	2	0.078 ^{ns}
5 seconds	1.27	2	0.958 ^{ns}
15 seconds	-0.45	2	-0.253 ^{ns}
30 seconds	-7.71	2	-3.5060 [*]

ns – not significant, * - significant, ** - highly significant

Moreover, Abu-Ghanman and Jaiswal (2015) emphasized significance of time-temperature combinations and blanching methods on effects of the product. Nutrient losses are more pronounced within initial phase of blanching, and factors

influencing such losses are blanching methodology, variety and blanching time. Blanching temperature effect is not of significant influence particularly if temperature applied is within the range of 80-100°C. From food safety perspective and quality retention requirements, higher blanching temperatures are recommended in order to eliminate surface microflora, and to inactivate enzymes associated with quality deteriorations during storage.

Sensory Evaluation

Color

Color acceptance scores of the seaweed powder dried under solar glass dryer were not significantly ($P > 0.05$) different. Best score (6.78) was given to samples that were blanched at 30 seconds and the least score (5.90) was given to samples blanched at 15 seconds. Insignificant result on difference of color scores implies that water blanching does not affect the color preferences of the panels. However, according to Sabah (2000) undesirable changes in sensory characteristics and nutritional properties of the food that have not undergone blanching pretreatments will occur during storage or later period.

For color acceptance scores of the seaweed powder dried under solar glass dryer, although given scores were not statistically significant, highest score (4.07) was given to seaweed samples blanched at 15 seconds and least score (3.10) was given to seaweed samples blanched at 30 seconds. Because results were not statistically significant, table indicates that water blanching pre-treatment does not affect color of the seaweed based on the sensory evaluation conducted.

Results reveal that color scores of all seaweed samples were significantly different between dryers (Table 4). Results also imply that color of the seaweed powder dried in solar glass dryer and heated air mechanical dryer were different, and based on the result on every dryer, seaweeds dried on solar dryer were preferred by the panels.

It was observed that all seaweed samples dried using heated air mechanical dryer turned to dark color. Moreover, earlier studies of drying seaweeds result in color darkening within 2 hours drying period under controlled conditions at temperatures above 50°C due to a complete damage of its antioxidant properties (Gupta et al., 2011). Moreover, Ahmed et al. (2002) stated, heat induces modifications on carotenoid pigment, resulting in significant vegetable color changes.

Odor

Highest odor score (5.94) was given to samples that were blanched at 30 seconds and the least score (4.83) was given to samples blanched at 5 seconds. Minor variation of odor scores result to insignificant difference. Same results were found in the seaweed powder dried under heated air mechanical dryer, wherein variations of odor scores were found insignificant. However, highest odor score (4.93) was given to samples blanched at 5 seconds and least scores (4.37) were given to samples not blanched and those blanched at 30 seconds. According to Sabah (2000), no significant changes of flavor or aroma of most foods when it is correctly blanched.

Based on the sensory evaluation conducted, water blanching does not affect odor preference of the seaweed powder on both dryers as assessed by panels

(Table 4). However, comparing results from solar glass dryer to heated air mechanical dryer, odor of seaweed samples blanched at 15 and 30 seconds were significantly different and insignificant results were observed on samples not blanched and those blanched at 5 seconds.

Texture

Highest odor score (5.40) was given to samples not blanched and least score (4.83) was given to samples blanched at 5 seconds (Table 4). On seaweed samples dried in heated air mechanical dryer, highest texture score (5.73) was given to seaweed samples blanched at 5 seconds and lowest score (4.70) was given to seaweed samples blanched at 30 seconds.

It was noted that odor scores given by panels varied insignificantly within and between dryers. Results reveal that water blanching pre-treatment and type of dryer do not affect texture preference of panels.

General Acceptability

Highest general acceptability score (6.0) was given to samples blanched at 30 seconds and least score (5.20) was given to the samples blanched at 5 seconds. On the seaweed samples dried in heated air mechanical dryer, highest general acceptability score (5.20) was given to seaweed samples blanched at 5 seconds and lowest score (4.06) was given to seaweed samples blanched at 30 seconds. Web chart of sensory evaluation results on sensory characteristics of seaweed powder, specifically on color, odor, texture and general acceptability dried under solar glass dryer and heated air mechanical dryer is presented in Figures 9 and 10, respectively.

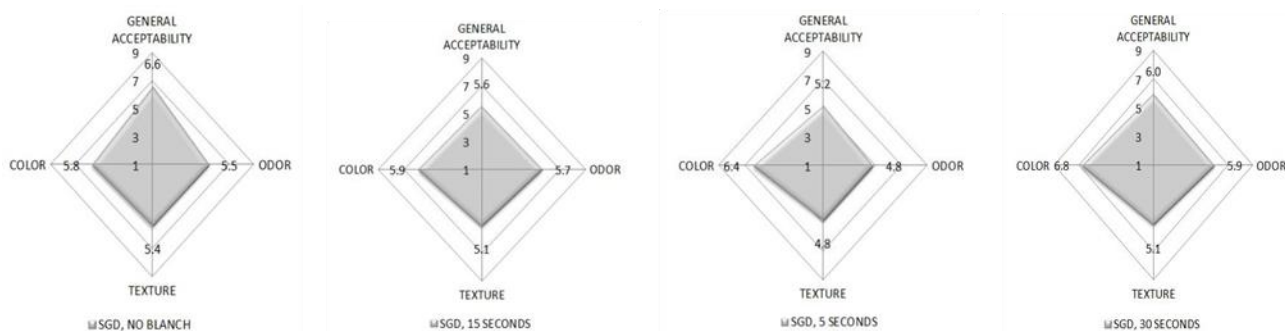


Figure 9. Web chart: Sensory evaluation results on sensory characteristics of seaweed powder dried under solar glass dryer

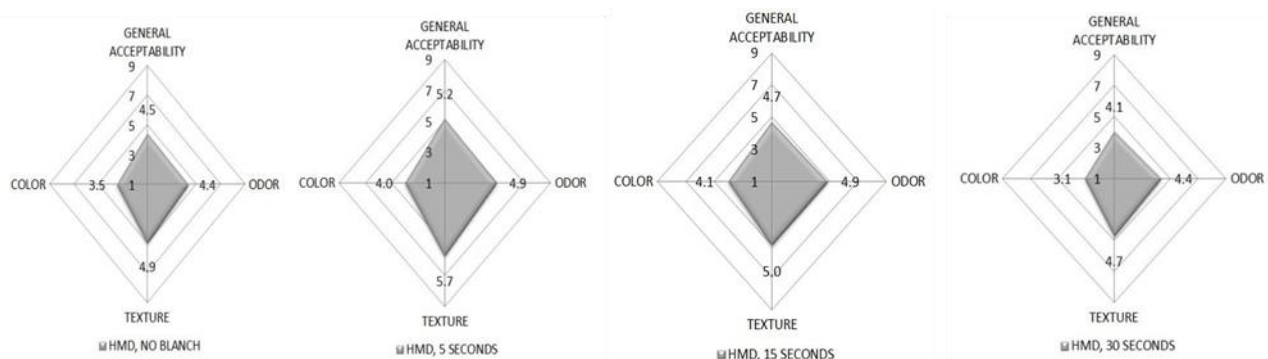


Figure 10. Web chart: Sensory evaluation results on sensory characteristics of seaweed powder dried under heated air mechanical dryer

Table 4. Summary of statistical analyses using paired t-test for comparison of mean scores of color, odor, texture, and overall acceptability of seaweed powder.

PROXIMATE ANALYSIS PARAMETER	MEAN DIFFERENCE (HMD - SGD)	DEGREES OF FREEDOM	t - VALUE
Color			
Not blanched	-3.11	2	129.5**
5 seconds	-2.39	2	4.797*
15 seconds	-1.84	2	4.248*
30 seconds	-3.69	2	6.537*
Odor			
Not blanched	-1.10	2	2.721 ^{ns}
5 seconds	0.10	2	-0.655 ^{ns}
15 seconds	-0.80	2	8.00**
30 seconds	-1.57	2	4.221*
Texture			
Not blanched	-0.47	2	0.482 ^{ns}
5 seconds	0.90	2	-1.352 ^{ns}
15 seconds	-0.07	2	0.062 ^{ns}
30 seconds	-0.43	2	0.623 ^{ns}
General Acceptability			
Not blanched	-1.30	2	2.982*
5 seconds	0.00	2	0.00 ^{ns}
15 seconds	-0.87	2	2.335 ^{ns}
30 seconds	-1.93	2	4.384*

As rated by panels, general acceptability scores of the seaweed powder were insignificantly different within dryers (Table 4). General acceptability scores given to seaweed samples not blanched and blanched at 30 seconds were

significantly different between dryer, while scores on seaweed samples that were blanched at 5 and 15 seconds were not significant between dryers.

Simple Cost Analysis

Simple cost analysis was performed to differentiate two methods of drying seaweeds namely, solar glass dryer (SGD) and heated air mechanical dryer (HMD). From 110 kilograms of harvested fresh seaweeds, recover of 98 kilograms of clean and chopped samples was noted and with cleaning recovery of 89.1%.

It was assumed that the prevailing fresh seaweed farm gate price was Php 12 / kilo. The operational cost includes cost of fresh products, salary for the worker, and the electricity costs. A straight line method was used for depreciation cost assumed to have 16% interest rate for investment cost. Blanching operation cost was assumed at Php 30.00 per operation.

Summary of simple cost analysis is presented in Table 5. In the table presented, cost analysis of not blanched and to the pretreatment that dries faster (5 seconds blanched) were compared. It shows that when using solar glass dryer, it is profitable to blanch seaweeds before drying with custom rate of Php 67.23 per kg., payback period 0.54 year, and annual net income of Php 12,951.21. while when using heated air mechanical dryer, it is cost-effective to blanch also seaweeds before drying with custom rate of Php 162.32, payback period 0.27 year, and annual net income of Php 551,204.81. Increase in annual net income was due to the increase in drying operations because of the shorter drying time with the aid of hot water blanching pretreatments and tends to increase production and income.

Table 5. Simple cost analysis of solar glass dryer and heated air mechanical dryer

	SOLAR GLASS DRYER		HEATED AIR MECHANICAL DRYER	
	Not blanched	With 5 seconds blanched	Not blanched	With 5 seconds blanched
Annual Cost (Php)	2,773.40	2,826.01	34,313.60	34,883.08
Annual Fixed Cost	1,321.25	1,321.25	23,812.50	23,812.50
Depreciation Cost	630.00	630.00	9,000.00	9,000.00
Interest on Investment	481.25	481.25	10,312.50	10,312.50
Tax and Insurance	210.00	210.00	4,500.00	4,500.00
Variable Cost (Php)	458.85	573.46	4,664.00	5,592.75
Repair and Maintenance	350.00	350.00	9,000.00	9,000.00
Labor Cost	17,500.00	19,250.00	25,200.00	28,800.00
Electricity	504.00	441.00	7,776.00	6,912.00
Fuel Cost	0.00	1,050.00	0.00	2,160.00
Custom Rate, Php/Kg	55.34	67.23	162.32	182.45
Operating Cost, Php/Kg	23.92	28.68	21.54	22.96
Break-even Point, Kg/yr	175.14	176.40	365.47	361.15
Net Income, Php/yr	10,558.52	12,951.21	486,537.30	551,204.81
Payback Period (yr.)	0.66	0.54	0.31	0.27

Summary, conclusion and recommendation

Summary

The study was conducted at Southern Philippines Agri-Business and Marine and Aquatic School of Technology (SPAMAST), Matti, Digos City from April 2017 to July 2017. The study was done to mainly investigate application of hot water blanching pretreatments to enhance drying for seaweed (*Kappaphycus alvarezii* S.). Specific objectives of the study were: to determine drying characteristics, proximate analysis, and sensory characteristics of hot water blanched seaweed dried using solar glass dryer and heated air mechanical dryer. Simple cost analysis was performed to assess annual cost and custom rate of solar glass dryer and heated air mechanical dryer.

Harvested fresh seaweeds were cleaned and weighed. After which, blanching operations were done. Initial weight of the samples was 4,000 grams with initial moisture content of 91 % (w.b). It was observed that after water blanching, weights of samples decreased from 4,000 grams to an average of 2860.83 grams (blanched at 5 seconds), 3,302.33 grams (blanched at 15 seconds) and 3593.67 grams (blanched at 30 seconds). In heated air mechanical dryer, samples blanched in 5 and 15 seconds dry faster (8 hours). In solar glass dryer, seaweed samples blanched at 5 seconds dry earlier (32.67 hours). It was observed that drying rate was high in the initial hour of drying due to free moisture of the outer surface of the commodity being dried that will be easily removed early in the process.

Moreover, it was observed, samples that were blanched at 15 and 30 seconds longer drying time. This was probably due to the effect of longer blanching duration that weakened seaweed limbs to soft flexible particles so that when placed in tray there was compression and close spaces between limbs, preventing free access of the drying air through the samples. A different condition of drying was observed on samples not blanched which took longer drying time to dry seaweed compared to those samples blanched at 15 and 30 seconds. Drying was largely governed by amount of water which the drying air can take and water capacity depends on the degree of saturation of air.

In addition, it was observed that drying process in solar glass dryer took longer time compared to heated air mechanical dryer, because solar glass dryer requires sunlight to dry at limited number of hours per day, while heated air mechanical dryer has continuous drying operation.

All moisture reduction curves were subjected to regression analysis and mathematical models that fitted the curves had higher R² values indicating that the model is best fitted. All models fitted were in second-order polynomial equations. Drying rates of all samples subjected to hot water blanching pretreatments were initially high, then decreased rapidly as moisture decreased. Eventually, drying rate was observed to reach constant rate period before it dried. In the case of solar glass dryer, drying rate of samples not blanched started at low drying rate and increased eventually. Initially, low drying rate was probably due to evaporative cooling effect. Moreover, drying rate increased considerably with increase in drying air temperatures. Thus, higher drying air temperature produced higher drying rate and consequently moisture content decreased. Results imply that water blanching pretreatments consequently affect drying rate. All drying rate curves were subjected to regression analysis and results show high quality fitting with R² values ranging from 0.8631 to 0.9873.

From the results obtained, it can be verified that the models fitted shows good predicting capacity.

It was observed that drying rate increases significantly with increase in drying temperatures. Consequently, higher drying temperature results to a higher drying rate and thus the moisture content decreased subsequently. These results were in agreement with the observations of earlier researchers (Lahsasni et al., 2003; Hassan and Hobani, 2000) and results implied that hot water blanching pre-treatments consequently affect drying rate.

In solar glass dryer, ash content of the seaweed powder that underwent 30 seconds water blanching was the highest (25.83%). For seaweed powder dried in heated air mechanical dryer, highest ash content (22.83%) was recorder from seaweed samples that were not blanched. In general, water blanching pre-treatments and type of dryers insignificantly affect total ash contents levels of the seaweed dried and powder. Results signify that hot water blanching temperature and blanching time combinations did not affect vividly the ash content levels of seaweeds. Moreover, Abu-Ghanman and Jaiswal (2015) added that sensory and quality attributes of the product being blanched depends on time-temperature combinations. Based on results, hot water blanching temperature and time combinations did not affect ash content levels of seaweeds.

In solar glass dryer, highest value of crude protein (3.367%) was recorded from seaweed powder blanched in 15 and 30 seconds. In heated air mechanical dryer, highest value was observed in the sample blanched at 15 seconds. Results revealed that hot water blanching of the seaweed and dried under solar glass dryer and heated air mechanical dryer did not affect levels of crude protein in the seaweed powder. This finding indicates that slight differences in crude protein levels in all treatments have no considerable change in crude protein contents as a result of hot water blanching pre-treatments.

In solar glass dryer, highest value of crude fiber (12.303%) was obtained from seaweed samples that were blanched at 15 seconds. Levels of crude fiber content were highly significant. Results revealed that water blanching pre-treatments affect by increasing levels of crude fiber in the dried seaweeds. In heated air mechanical dryer, Highest value (11.853%) was observed in samples blanched at 15 seconds. Levels of crude fiber recorded were significant in variations. It was observed that levels of crude fiber increased when blanched at 5 seconds and decreased eventually when blanching duration increased. The trend was observed in both dryers, except that decrease on crude fiber of samples dried under heated air mechanical dryer started at 15 seconds, followed by 30 seconds blanching while in seaweed samples dried under solar glass dryer, crude fiber decreased only at 30 seconds blanching. Nevertheless, both dryers were on the same pattern. Results imply that blanching (5 seconds duration) helps in retaining crude fiber but increasing blanching temperature results to percentage reduction of crude fiber level.

In comparing the proximate nutrient composition between solar glass dryer and heated air mechanical dryer, results revealed that methods of drying do not affect levels of ash contents. Similar observation was made by Kramer and Smith (1947), that even if there were variations of ash contents on the product subjected to water blanching, results did not influence materially general proximate compositions. It was observed that results on the crude protein samples dried between heated air mechanical dryer and solar glass dryer were highly significant on seaweeds that were not blanched and significantly different on the samples blanched at 5 seconds and 15 seconds. Even if levels of crude protein on the samples blanched at 30 seconds had insignificant differences

between heated air mechanical dryer and solar glass dryer, samples under solar glass dryer which constitute longer exposure to heat reduce levels of crude protein. Increase in temperature causes severe protein damage in food ranging from destruction of amino acids to complete racemisation (Rahma & Mustapha, 1988). Heat causes breakage in the myofibrillar protein bonds. As heat increases, moisture in protein evaporates and the protein loses flexibility and mass. Reduction in solubility accompanied by coagulation affects level or availability of crude protein (Alais & Linden, 1999).

Moreover, mean differences on crude fiber of seaweed that was dried under heated air mechanical dryer and solar glass dryer were insignificant except those seaweed samples blanched at 30 seconds which were significantly different. Moreover, Abu-Ghanman and Jaiswal (2015) emphasized significance of time-temperature combinations and blanching methods on effects of the product. Nutrient losses are more pronounced within initial phase of blanching, and factors influencing such losses are blanching methodology, variety and blanching time.

It was observed that color of the seaweed powder dried in solar glass was preferred by panels and all seaweed samples dried using heated air mechanical dryer turned to dark color. Moreover, earlier studies of drying seaweeds result in color darkening within 2 hours drying period under controlled conditions at temperatures above 50°C due to a complete damage of its antioxidant properties (Gupta et al., 2011). Moreover, Ahmed et al. (2002) stated, heat induces modifications on carotenoid pigment, resulting in significant vegetable color changes. Minor variation of odor scores result to insignificant difference. Same results were found in the seaweed powder dried under heated air mechanical dryer, wherein variations of odor scores were found insignificant. According to Sabah (2000), no significant changes of flavor or aroma of most foods when it is correctly blanched. It was revealed that hot water blanching pre-treatments and type of dryer did not affect the texture preference of panels. As rated by the panels, general acceptability scores of the seaweed powder were insignificantly different within dryers. Highest general acceptability score (6.0) was given to samples blanched at 30 seconds and least score (5.20) was given to the samples blanched at 5 seconds. On the seaweed samples dried in heated air mechanical dryer, highest general acceptability score (5.20) was given to seaweed samples blanched at 5 seconds and lowest score (4.06) was given to seaweed samples blanched at 30 seconds.

It was shown that using solar glass dryer is profitable to blanch the seaweeds before drying with custom rate of Php 67.23 per kg., payback period 0.54 year, and annual net income of Php 12,951.21, while using heated air mechanical dryer is cost effective to blanch also the seaweeds before drying to attain custom rate of Php 162.32, payback period 0.27 year, and annual net income of Php 551,204.81. Increase in annual net income was due to the increase in operation periods because based on the results presented hot water blanching results to shorter drying time and shorter drying time leads to increase production and income.

Conclusions

It was concluded that using heated air mechanical dryer, samples blanched in 5 and 15 seconds dry faster (8 hours) and in using solar glass dryer, seaweed samples blanched at 5 seconds dry earlier (35 hours). In addition, it was concluded that drying process in solar glass dryer (sunlight dependent) took longer time compared to heated air mechanical dryer (continuous drying). It

confirmed that hot water blanching pretreatment enhances the drying time in drying seaweeds.

Hot water blanching of seaweeds and dried under solar glass dryer and heated air mechanical dryer do not affect levels of ash content and crude protein but affect levels of crude fiber contents in the seaweed powder with significant result. It was concluded that hot water blanching pretreatment favors in the retention of crude fiber content in the seaweed powder.

Seaweed that were dried on solar dryer was preferred by the panels; seaweed powder that underwent hot water blanching pre-treatments, dried under solar glass dryer and heated air mechanical dryer, do not affect the texture and odor preference of the panels. All seaweed samples dried using heated air mechanical dryer turned to dark color. Simple cost analysis showed that it is profitable to blanch the seaweeds before drying.

Recommendation

In using solar glass dryer and heated air mechanical dryer with respect to shorter drying period, the researcher recommends that seaweeds should be blanched with temperature of 88°C at 5 seconds blanching duration to maximize usage of dryer at higher net income.

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