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Design, Development and Evaluation of Seaweed Drying Technology for Village Level Operation

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ABSTRACT

A solar-type seaweed dryer was designed and developed to answer the needs of Filipino seaweed farmers for efficient and reliable drying technology. Through extensive baseline community surveys and field tests, the study was able to design a dryer prototype that is capable of drying high-grade quality seaweeds in a short amount of time. Moreover, geographical factors, natural hazard vulnerability, and farmers' preference gave way for the development of two types of dryer: permanent and floating type. Both dryers were found to have positive effects in regards to drying time, product quality, streamlined operation, and overall economic benefits. Traditional drying practices takes around three (3) days to dry the seaweeds on good sunny days, but due to the varying weather conditions, the drying process can reach up to 7 days. The prolonged drying time, exposure to sudden downpours and contaminants greatly affects the quality of the seaweeds which in turn, compromises the market value of the dried seaweeds. The use of the drying technology remedied these problems inherent to traditional drying practices. To take full advantage on the use of the developed seaweed dryer, optimization experiments were conducted to determine the ideal settings of the dryer during daytime and nighttime conditions by varying the siding openings and operation of the exhaust fans. The optimization study resulted in a continuous and efficient drying operation under different weather conditions. Furthermore, field performance tests paved the way for the construction of a sturdier compact dryer design. Moreover, the incorporation of a solar-powered ventilation system and lighting system allowed continuous and efficient drying operation even during night time. Lastly, simple economic analysis also supported the profitability of drying technology in the long run.

Keywords: *seaweeds, solar, dryer, carrageenan, floating-type dryer, permanent-type dryer*

INTRODUCTION

The Philippines is one of the world's largest producers of seaweeds and the majority of its products are exported in either raw form (fresh or dried) or processed form (semi-refined and refined carrageenan (Buschmann *et al*., 2017). With around 50% of total aquacultural assets coming from seaweed cultivation, the industry provides jobs to more than 200,000 fisherfolks and 30,000 traders, making it one of the most profitable sectors of agriculture (Pedrosa, 2017). However, existing challenges and constraints in pollution control, disease proliferation, natural hazards, post-production losses, inconsistent quality, and quantity of dried seaweeds and financial constraints have taken a heavy toll on the sustainability of the seaweed industry (Southeast Asian Fisheries Development Center, 2018). To address these challenges, rigorous research and development intervention programs must be formulated and implemented in conjunction with favorable economic policies and active promotion of the seaweed industry.

Seaweed farming is a good income source especially for the people living in coastal barangays. However, seaweed grown by the farmers must undergo partial drying before being sold to the processors (for carrageenan production). This drying process is crucial for them to command a better price. The usual drying practice employed by the farmers is to sun dry the harvested seaweeds in open areas either by hanging, in makeshift platforms or in the ground that are vulnerable to varying climatic conditions particularly rain. Although there are many existing dryer designs, majority of these dryers are used in drying grains like rice and corn which are not appropriate for drying seaweeds. The Maligaya Flatbed dryer for example, it was designed to dry different grains and other commodities like coffee, legume and other crops (PhilRice, 2014). Although this dryer can be used for drying seaweeds, its drying bin was designed to hold mostly grains in bulk unlike seaweeds, due to its soft nature, must be spread thinly in the drying bin to avoid compaction thus lowering the capacity of the flatbed dryer. The solar dryer for seaweeds that was designed and tested in Malaysia on the other hand is a forced convection drying system wherein the the main components are double-pass solar collector with finned absorber, the blower, the auxiliary heater and the drying chamber (Fudholi, et. al., 2011). However, the developed dryer have small drying chamber area thus having a limited capacity of only 150 to 200 kg. Other drying structures used by the seaweed farmers at the moment are open platforms wherein the seaweeds are just scattered on the floor and are exposed to sudden downpours. In the event of rains and during nighttime, farmers collect the seaweeds and store inside their houses and just bring the seaweeds out when the weather permits. Other farmers used plastic coverings or canvass instead to protect their seaweeds from the elements. It takes around three (3) days to dry the seaweeds on good sunny days, but due to the varying weather conditions, the drying process can reach up to 7 days. The prolonged drying time, exposure to sudden downpours and contaminants greatly affects the quality of the seaweeds which in turn, compromises the market value of the dried seaweeds. The reduction in the buying price for poorly dried products or low quality products can reach as high as PhP10 per kilo from 2020 data gathered in Palawan. Thus, there is an urgent need for the development of a reliable and appropriate dryer that would hasten the drying time and renders high-grade dried seaweeds for a higher market price. Aside from developing the drying technology, field performance tests are essential parameters in improving the efficiency and suitability of the seaweed dryer for the use of local seaweed farmers.

OBJECTIVES

The general objective of this study was to develop an appropriate drying technology for more efficient and fast drying of seaweeds to help seaweed farmers in their drying activities. Specifically, the study aimed to:

1. design and fabricate a seaweed drying equipment in consideration of the information provided by farmers~~;~~

2. conduct actual testing of the fabricated drying technology to determine its optimum operating parameters; and

3. incorporate all identified improvements to the initial seaweed dryer design, evaluate the performance and perform simple economic analysis of the improved seaweed drying equipment.

METHODOLOGY

Site visits to selected seaweed growing areas in the Philippines were conducted to gather information regarding the farmers' existing production and post-production practices. The survey centered on their existing drying practices and the volume of seaweeds produced. Key Informant Interviews (KII) and Focus Group Discussions (FGD) were done to gather basic information.

Five (5) seaweed growing provinces with established farmers' associations were visited which include the town of Calatagan in Batangas which is one of the project sites of the UP Marine Science Institute, seaweed areas around Honda Bay, Barangay San Rafael and Anilawan of Puerto Princesa and Roxas, Palawan, island barangays of San Jose, Occidental Mindoro, Masinloc, Zambales and Digos, Davao del Sur. Individuals or groups interviewed include local fishery technicians and farmer-leaders of the different associations with an average membership of 95 farmers. Basic information regarding the seaweed production in the area, volume of production, existing practices especially in the drying activities and other relevant information were gathered. *Kappaphycus alvarezii,* being the most common seaweed species cultivated in the Philippines, served as the representative sample for the determination of physical and drying characteristics of seaweeds which were critical inputs to the dryer design.

The drying characteristic of seaweeds (*Kappaphycus alvarezii*) was determined by conducting a series of laboratory drying trials using different drying temperatures. Only three drying temperatures of 40, 50 and 60 ^{o}C were used in the experiment since it is not expected that a higher temperature of more than 60 ^{o}C will be achieved in the drying system that will be developed. Furthermore, based from the study conducted by de Faria et. al. (2013), using three drying temperatures of 40, 60 and 90 ^{o}C, they found out that 60 ^{o}C was the best drying temperature that will result to a higher carrageenan yield as well as with better quality. However, in the study conducted by the Universiti Malaysia Sabah, they found out that the drying temperature should not exceed 50 ^{o}C using *Kappaphycus striatum* as test materials (Khan, M., personal communication, June 10, 2016). *Kappaphycus alvarezii* was dried using a laboratory oven because oven drying can easily be set to the desired drying temperature and an infra-red dryer for faster moisture content determination. The laboratory drying experiments were continued until the samples were bone dry or the final weight has stabilized although, in actual field conditions, only partial drying is done wherein, drying activity is stopped when the seaweeds' moisture content is within the 38-40% range. In a study conducted by Kariduraganavar et. al. (2014), it was stated that carrageenan is mainly composed of dietary fiber which balances the nutrition better (Distantina et. al. 2011) and that technically, carrageenan is considered a dietary fiber (Southgate, 1990). From these studies, it can be surmised that using drying temperatures of 40-50 ^{o}C, was the optimal range for carrageenan extraction.

Based on the information gathered, a seaweed drying technology was initially designed and fabricated which was foreseen to be suitable in the selected areas. Major factors considered in the development include a) simple and low-cost technology suitable for a village-level application, b) input volume, c) availability of local fabrication materials, d) ensure high-grade semi-dried seaweeds that will command higher selling price; and e) versatility against natural hazards. Through these considerations, two main types of seaweed dryers were developed: permanent and floating type.

Permanent type seaweed dryer features a structurally sturdier foundation and thus it is more suitable in coastal areas prone to strong waves and wind. On the other hand, floating seaweed dryer is fitted with drum floatation device so that it can be easily towed from seaweed growing farms to processing areas. After fabricating the first two dryer models, the dryers were assessed based on their structural soundness due to their exposure to water and other weather elements such as heat, strong tides, wind, and others. Secondly, the dryers were evaluated on their drying performance based on pre-drying to post-drying activities, and finally, the dryers were assessed based on the farmers'/users' response. Based from the data gathered, the modifications and improvements needed in the design were integrated on the design/fabrication drawings.

The first permanent type dryer which was constructed in Anilawan, Puerto Princesa, Palawan, was rebuilt to cater the design improvements and to make the foundations more stable against storm surges since it is built near the shore and the foundation is submerged during high tides. On the other hand, the design improvements for the floating type dryer was incorporated during the construction of new seaweed dryers in Romblon, Occidental

Mindoro and Marinduque with the funding of DOST PSTC. Some of the notable design improvements made include the following: a) installation of drying racks inside the drying chamber to streamline the drying operations and avoid congestion, b) use of clear polycarbonate sheets as roofing materials instead of greenhouse plastics for durability, c) foundations were reinforced to add more stability, and d) installation of a solar power system comprising of solar panels, charge controller and batteries to run the exhaust fans and lighting system. The newly constructed dryers were reevaluated through optimization, field performance tests, financial viability and farmers' assessment.

Table 1. Designed experimental matrix of the seaweed dryer optimization.

TIME PERIOD		NIGHTTIME		DAYTIME	
Usage of Exhaust Fans		With running Exhaust Fan	Without running Exhaust Fan	With running Exhaust Fan	Without running Exhaust Fan
Height level of sidings opened	Fully Closed	x	x	x	x
	1/4 Open			x	x
	1/2 Open			x	x
	Fully Open	x	x		

Note: The character "x" corresponds to the treatment combinations that were tested on a single trial.

An optimization study was conducted in the province of Romblon where a floating type seaweed dryer was already installed and used by farmers. The study utilized the 2 x 2 and the 3 x 3 factorial design for the nighttime and daytime conditions, respectively. The experimental design used was to reduce the number of trial runs which are not critical in the dryer operations and concentrate on the significant parameters. An example of which, was that during nighttime operations, since air drying will be done in the absence of solar heat, the crucial factors considered was only either the sidings were fully closed or fully opened and the effect of operating the exhaust fans. Drying experiments were carried out in the daytime and nighttime period, with the intent to simulate sunny and rainy conditions, respectively. The independent variables are the adjusted height of the greenhouse sidings opened that will serve as the air inlet and the operation of the exhaust fans. On an eight-hour drying duration with a 30-minute reading interval, the moisture reduction of the seaweeds was recorded. Table 1 shows the design matrix conducted in the experiment.

The dryer's performance in different setting combinations was evaluated through the percent moisture removed or the amount of water removed with respect to the initial weight of samples (Equation 1). Analysis of Variance and Pairwise Mean Comparison were used in determining the variables interaction and the overall performance of the settings, respectively.

$$MR = \frac{W_i - W_f}{W_i} \; x \; 100\%$$

Equation 1

where,

MR = moisture removed (%)
W_i = initial weight of the sample (g)
W_f = final weight of the sample (g)

A follow-up field validation test based on the optimized setup and design improvements was conducted to determine the actual effects of the improved dryer design on the actual operation. At 835 kilograms of fresh seaweeds, the dryer was fully utilized with the inclusion of wooden flooring. Moisture reduction, temperatures, and relative humidity were all monitored and recorded.

RESULTS AND DISCUSSION

Baseline Information Gathering

From the areas surveyed, seaweed farmers can be categorized into small growers having an average harvest of 1 to 2 tons per cropping citing the lack of capital as one of the hindrances in expanding their areas. Although these farmers have small areas, they have an active seaweed farmers' association. Thru the association, sometimes farmers get support from the Local Government Units and other government and non-government agencies especially on the supply of planting materials, ropes, twines and floaters. Results from the surveys provided important input in the design and development of the drying system. Table 2 summarized the results of the survey.

Table 2. Summary results of the surveys conducted in the selected seaweed growing areas.

ITEM	PARTICULARS
Major species cultivated	cottonii (*Kappaphycus spp.*) and spinosum
Method of planting	Floating longline method
Number of cropping per year	From 3 cropping to year round planting
Harvesting period	45-60 days after planting
Average yield (fresh) per individual farmer	1-2 tons
Drying method/practice	Solar drying either by hanging, on platforms or on the ground lain with nets, plastic cover or canvas
Drying time	3 to 7 days
Final moisture content	38 – 40 %
Established Seaweed Farmers' Association in the sites visited	• Batangas Seaweed Farmers' Association, Calatagan, Batangas (35 members) • Anilawan Seaweed Farmers' Association, Puerto Princesa, Palawan (38 farmers) • San Rafael Seaweed Farmers' Association, Puerto Princesa, Palawan (106 members) • Ambulong Seaweed Farmers' Association (200 members) and Iling Seaweed Farmers' Association (185 members), San Jose, Occidental Mindoro • Bato Seaweed Grower' Association Digos, Davao del Sur (67 members) • Masinloc, Zambales (5 existing Seaweed Farmers' Association with 35 average memberships)
Problems inherent to drying of seaweeds	• Lack or no access to drying facilities/platforms • Tendency of sand and other impurities to be mixed with the seaweeds if dried on the ground • Need to cover or haul indoors to avoid contact with rains • Longer drying time • Need to haul during nighttime and spread or hang again the following day • Poor quality – lower selling price

Design Parameters and Drying Characteristic of Seaweeds

Physical characteristics such as weight, length, thickness, diameter and moisture content were determined using *Kappaphycus alvarezii* seaweed species since the majority of the seaweeds grown in the Philippines were of the *Kappaphycus spp.* used for carrageenan production. These parameters were valuable inputs into the development of an appropriate dryer design for the dryer size, spacing, thickness of drying platform and the frequency of turning operation. The values collected were summarized in Table 3.

Figure 1 shows the drying characteristics of *Kappaphycus alvarezii* at different temperature settings while Table 4 shows the proximate analysis of the seaweed samples dried at different drying temperatures and dried samples collected from a farmer-cooperator for comparison.

Results from the laboratory drying tests showed that at a higher drying

Table 3. Physical characteristic of a typical *Kappahycus spp.* grown in the Philippines.

PARAMETER	AVERAGE VALUE
Weight	1.5 kg
Thickness	15.24 cm
Length	25.4 cm
Diameter	45.72 cm
Moisture Content	91.68%

temperature, seaweeds tend to dry much faster which is expected. At a constant drying temperature of 60 and 50 ^{o}C, it will only take around 5.83 and 8.76 hours to reach the desired moisture content of 40% respectively, while at a constant drying temperature of 40 ^{o}C, it will take around 30.58 hours of drying. In actual field conditions, temperature varies especially during nighttime when the temperature falls below 30^{o}C thus requiring much longer time to dry. Although the drying temperature is important in the drying process, other factors must likewise be considered like the amount of moisture in the air (relative humidity or RH). The higher the RH, the longer it will take to dry the seaweeds since it will be more difficult to evaporate the water present in the seaweeds. This implies the importance of active air circulation between the dryer and the environment especially during nighttime (Tiwari *et al*., 2016). This is the main reason why farmers take a longer time to dry their seaweeds which can last up to seven days.

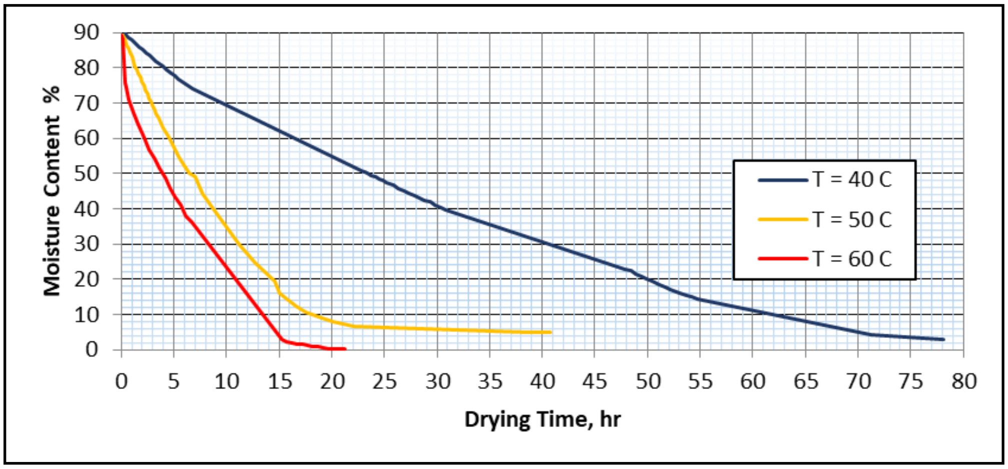

Figure 1. Drying characteristic of *Kappaphycus alvarezii* at different drying temperatures.

Table 4. Proximate analysis of seaweeds dried at different drying temperatures.

DRYING TEMPERATURE	ASH (%)	CRUDE FAT (%)	CRUDE PROTEIN (%)	CRUDE FIBER (%)
60^{o}C	47.15 ± 0.17	0.39 ± 0.00	2.46 ± 0.01	1.85 ± 0.16
50^{o}C	48.82 ± 0.41	0.43 ± 0.01	3.12 ± 0.18	2.20 ± 0.15
40^{o}C	41.36 ± 0.08	0.99 ± 0.02	5.27 ± 0.02	2.34 ± 0.22
Control*	45.09 ± 0.71	0.44 ± 0.00	3.69 ± 0.08	1.98 ± 0.04

*Samples collected from farmer-cooperator

The results of the laboratory drying tests were an important input to the development of the drying technology since the most favorable drying temperature was determined. Dryer features were added in order to maintain the temperature inside the drying chamber to hasten the drying process while preserving the high-quality of the dried products. On the other hand, the dryer sidings were designed in such a way that it can be rolled up when the temperature inside the drying chamber becomes very hot or unfavorable.

Design and Fabrication of the Dryer

Based from the results of the survey and other information gathered, an initial drying technology design for seaweeds was conceptualized. Two main dryer designs were identified namely, the floating-type and the permanent-type dryer for fabrication. The permanent-type dryer design was later sub-divided further to an inland-class and submerged-class dryer. The dryer configuration specifically the drying chamber were all the same. The main difference of the dryers was on the type of foundations used like for the floating-type dryer, drum floatation devices were used where the dryer will be used off-shore and towed near the seaweed farms to save on transport cost, bamboo or wooden stilts for the partially submerged-class dryer which will be constructed near tidal areas or close to the shoreline wherein, the dryer is partially submerged just below the platform during high tides and finally, cement footings and foundation posts for the inland-class dryer. A total of three (3) seaweed dryers were initially constructed in three seaweed growing areas namely, Calatagan, Batangas, were the floating-type dryer was installed (Figure 2), while the inland-class dryer type using concrete footings and foundation posts were installed in both Anilawan, Puerto Princesa, Palawan (Figure 3) and Ambulong, San Jose, Occidental Mindoro (Figure 4). Although the sites in Palawan and Mindoro, where the dryers were constructed, were partially submerged during high tide, the concrete footings and foundation posts combination was selected due to its sturdiness.

The need for a floating-type dryer came about during the initial survey conducted in Calatagan, Batangas. During the discussion, farmers suggested the floating-type design similar to those seen in resorts (floating huts or restaurants) so that the dryer can be easily towed to their production areas which are quite far. Data gathered showed that the time to haul 500 kilos of fresh seaweeds, which is the capacity of the banca used for one load, from the production site will take around one hour (back and forth) since the boats used do not have engines. The farmers just use poles to propel their boats due to the shallow depths of the water navigated.

The developed technology can be used either for solar drying or air drying. The sidings were designed in such a way that it can be rolled up or down depending on the weather conditions. The developed dryers have footpaths for easy access to the sidings for the rolling of the sidings. The dryers were constructed in such a way that pre-drying activities can likewise be accomplished. There is a porch were the newly harvested seaweeds are cleaned and/or removed from the lines prior to hanging or laying on the platform inside the drying chamber. Based from the field tests conducted and comments from farmer-users of the technology, modifications were incorporated on the initial design which includes the installation of drying racks, solar -powered exhaust fans for better circulation of the drying air and a lighting system to aid farmers during nighttime air-drying activities as well as added security.

Figure 2. The floating-type seaweed dryer constructed in Calatagan, Batangas (initial design).

Figure 3. The permanent-type seaweed dryer constructed in Anilawan, Puerto Princesa, Palawan.

Figure 4. The permanent-type seaweed dryer constructed in Ambulong, San Jose, Occidental Mindoro.

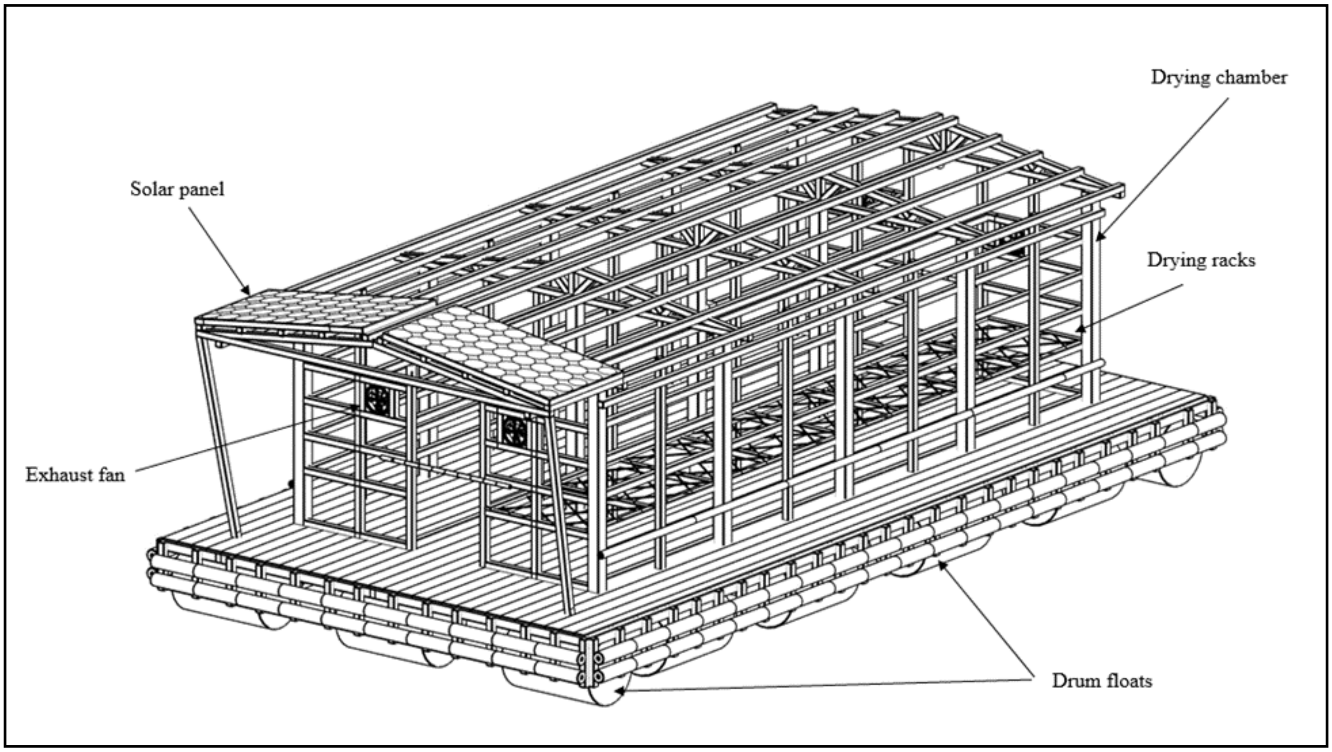

Figure 5. Isometric view of the improved seaweed dryer design indicating the major components

Figure 5 is an isometric view of the improved floating - type seaweed dryer design showing the major components. Figure 6 is the improved floating -type seaweed dryer funded for construction by DOST-PSTC Romblon while for the reinforced permanent-type dryer (Figure 7), a retaining wall (rip rap) was the more appropriate foundation for the dryer- a protection against strong waves or storm surges.

Figure 6. The improved floating-type seaweed dryer constructed in Looc, Romblon.

Field Test Results

The developed technology was field tested and evaluated. During the tests, the condition was mostly cloudy with minimal solar heating and the dryer sidings were raised or open 1/4 (25%) from the bottom. Results showed that even a slight chance of solar heating, the temperature (T) inside was higher than the ambient T and the relative humidity (RH) inside was lower than the RH outside of the dryer which is the desired condition to facilitate drying. However, during cloudy days and nighttime, to prevent the inside RH to increase, the sidings must be fully open to facilitate air drying. It took almost four days to dry the seaweeds since it was mostly cloudy and raining during the testing proper but still the drying was completed. This only showed that even during this kind of weather, drying can still be accomplished. Figure 8 shows the performance of the dryer installed in Calatagan, Batangas (floating-type dryer) based on temperature and relative humidity difference.

In the test conducted in Anilawan, Puerto Princesa, Palawan (permanent-type dryer), since solar heat was partially available on the first day, the sidings were fully closed to determine the inside temperature that the drying chamber can be reached. Based from the data, the highest temperature recorded was 46.49 ^oC with a relative humidity of 38.50% as compared to the ambient temperature and relative humidity of 34.85^oC and 63.75% respectively. This condition is favorable for faster drying of seaweeds although this is not yet the ideal condition, the optimum parameters or settings of the system must still be determined to attain the full potential of the system. In the initial trial run of the dryer, it only took 48 hours (2 days) to dry 600 kilos of seaweeds to 40% MC using a combination of solar drying during daytime and air-drying during nighttime. Figure 9 shows the plotted graph for the temperature and relative humidity of the dryer during the experiment.

The optimum operating parameters of the developed dryer were determined based from the results of the studies conducted in Looc, Romblon (Pangan, Ampo & Barredo, 2020). The study found out that the adjustment of sidings opened and the operation of exhaust fans have statistically significant effects on the moisture reduction of seaweeds. Combinations of the said settings were studied in order to come up with the optimum operating parameters of the seaweed dryer. Percent of moisture removed from the seaweed samples was used as the parameter in the experiment; higher percentage of moisture removed at a fixed time frame means that the setting combination removes the moisture from the seaweeds faster. Two separate analyses were done in order to come up with optimal settings for daytime/sunny and nighttime/ rainy conditions.

Analysis of Variance (ANOVA) results revealed that either the height opening level or the exhaust fan operation contributed to the general effect in moisture reduction (MR). For nighttime conditions,

Figure 7. The reinforced permanent-type seaweed dryer constructed in Anilawan, Puerto Princesa, Palawan with retaining walls (rip rap).

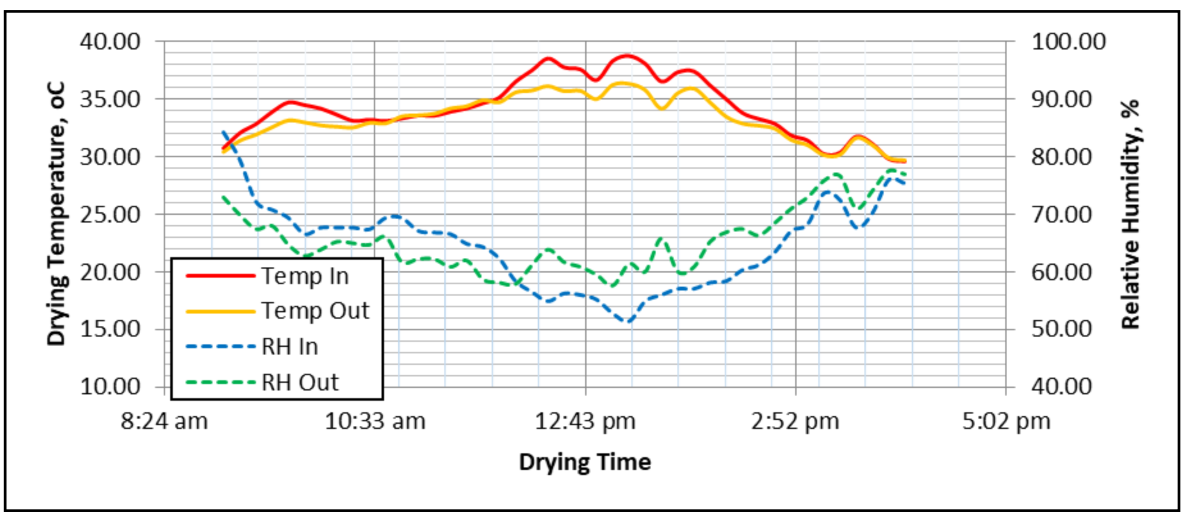

Figure 8. Comparison of Temperature and Relative Humidity data with sidings 25% open.

Pairwise Comparison of Means (Figure 10) showed that fully opened sidings without running exhaust fan contributed to the highest MR mean of 35.73%. For daytime conditions, on the other hand, Pairwise Comparison of Means (Figure 11) showed that quarter-opened sidings without running exhaust and half-opened sidings with running exhaust had the highest MR with no significant difference. This means that on average, both combinations will yield optimal MR.

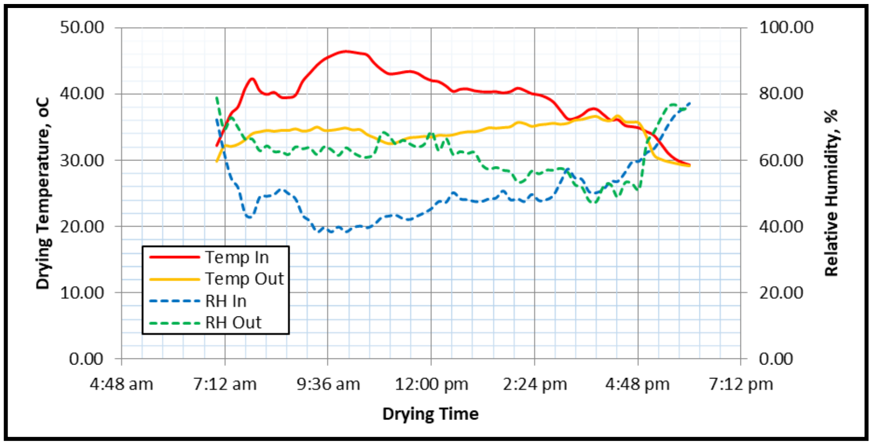

Figure 9. Drying temperature and relative humidity data with sidings fully closed

Based on these results, the following were the recommended dryer settings for a faster moisture removal: a) Daytime or sunny day: Open the sidings of the drying chamber up to a quarter (1/4) of the height from the bottom and turn on the exhaust fans when the inside temperature of the chamber is already high, b) Cloudy day or nighttime: Fully open both sidings of the drying chamber to allow the passage of air and c) Rainy day: Fully close both sidings of the drying chamber and turn on the exhaust fans.

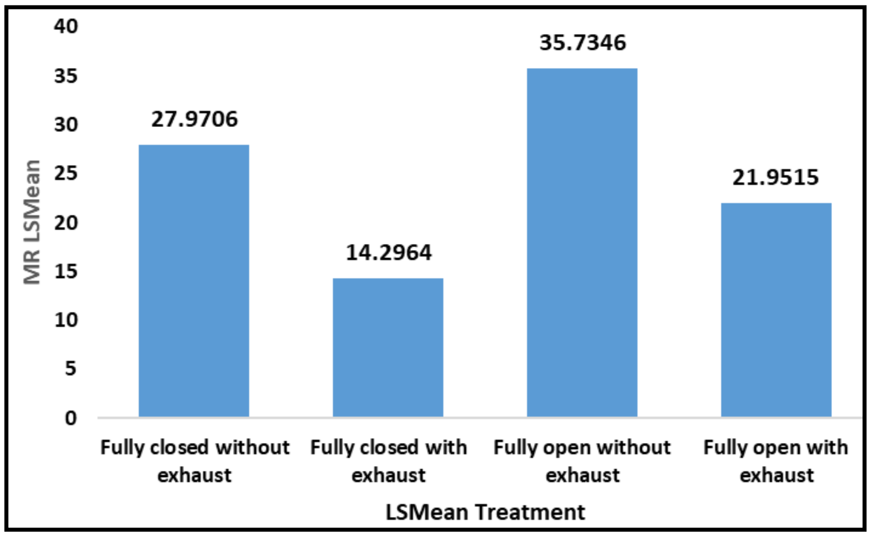

Figure 10. Pairwise comparison of means for nighttime condition.

After the field tests, seaweed farmers were asked to evaluate the performance of the dryers. The following were some of the assessment made: a) the developed dryer has bigger capacity, 2 tons of fresh seaweeds as compared to their drying platforms which can only accommodate from 200-500 kg depending on the dimensions of the platforms, b) drying is much faster and there is no need to cover or haul the seaweeds to a covered place due to rains, c) better quality of dried products having whitish to purplish color which are competitively priced by the traders. Dried seaweeds using traditional drying methods usually have dark or black color due to longer drying time which does not conform with the set quality standard for

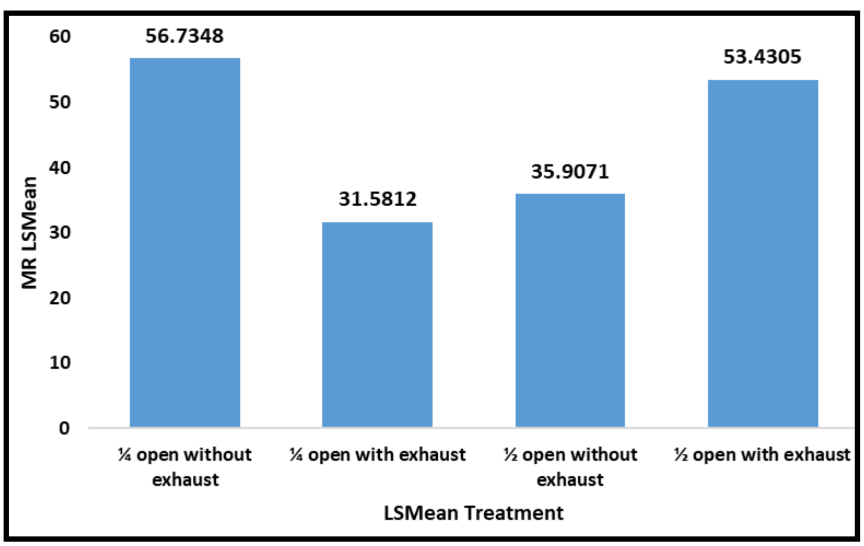

Figure 11. Pairwise comparison of means for daytime condition.

raw dried seaweeds, and d) allows continuous drying even during nighttime.

Simple Economic Analysis

A simple profitability analysis was conducted based from the data gathered during the survey and the drying tests made on the developed drying system. Assuming an individual farmer plant four times a year, an addition of PhP13,600.00 in annual income can be realized if the drying system will be utilized but there are certain instances that farmers are hesitant to plant due to poor weather or during rainy months. Farmers sometimes will not plant seaweeds due to foreseen drying problems thus reducing his cropping intensity. A reduction in cropping intensity will mean a loss of potential income for the farmer of PhP19,000.00 per cropping. On the other hand, with the introduction of the seaweed drying system, a potential income of PhP22,400.00 can be realized for an additional cropping done by the farmer. Table 5 shows the gross income comparison between traditional drying method used by farmers and the developed drying technology.

Table 5. Comparison of annual income using the developed drying system with the traditional drying method

PARAMETERS	WITHOUT PROJECT	WITH PROJECT
1. Production/cropping of		
fresh seaweeds[1]	2 tons	2 tons
2. Number of cropping/year	4	4
3. Total harvest/year	8 tons	8 tons
4. Raw dried seaweeds (RDS)		
at 40% MC[2]	1,120 kg	1,120 kg
5. Price per kilo of RDS[3]	PhP80.00	PhP80.00
6. Less		
a. Poor quality RDS[4]	less PhP10/kilo	-
b. additional labor cost[5]	PhP2,400	-
7. Income/year	PhP76,000.00	PhP89,600.00

[1]Based on farmers' average production and harvesting time of 60 days after planting
[2]100 kg of fresh seaweeds will yield approximately 14 kg of RDS (Palawan data)
[3]Prevailing buying price in Palawan (November 2020)
[4]Price reduction due to poor quality (presence of dirt, sand, straws and other contaminants, poorly dried with dark color and with signs of deterioration) (Palawan data)
[5]An addition of 2 drying days (on the average) including hauling to temporary storage area during night time and spread or hang the seaweeds again the following day (1 person @PhP300/day)

With an estimated initial investment of PhP350,000.00 for a unit of the seaweed dryer to be constructed near production sites, results of the cost and return analysis conducted showed that it was profitable to invest. With the current situation of the seaweed farmers, it is not possible for individual farmers to invest on the dryer. This is the reason why the technology is being promoted to different institutions to finance the construction of the dryers. As a result, many dryer units were funded for construction by both government and non-government institutions and were turned over to the different seaweed farmers' associations who will handle the operation of these dryers. To determine the financial viability of farmers' associations managing the operations of the dryers, two situations were considered in the analysis. The first situation was that the Farmers' association will buy fresh seaweeds from farmers and will be the one to dry and sell the dried products. With an adjusted buying price of PhP9/kilo (from the existing PhP5/ kilo) of fresh seaweeds, farmers will have immediate cash right away just like in Palawan, wherein farmers detach their harvest from the lines so that they can re-plant right away using the same nylon ropes and twines since they have no extra lines and additionally, having extra cash in their pockets when they go home. This situation was found to be profitable with an income of P145,000.00, a payback period of just 2.41 years and an ROI of 41.4%. The second situation assumed was that farmers will rent the drying system for a fee of P0.50/kg or a total of PhP1,000.00 per batch of 2,000 kilos of fresh seaweeds. The farmers themselves including family members will provide the required labor during the drying of their harvest to eliminate labor cost. The total income that can be realized from this set-up was PhP80,000.00 which is sufficient for the regular repair and maintenance cost of the dryer. Table 6 and Table 7 shows the summary of the two situations.

Table 6. Basic cost and return analysis when farmers' association will buy fresh seaweeds, dry and market the dried products.

ITEM	VALUE (PhP)
Initial Investment	350,000.00
Fixed Costs/year	
Depreciation	31,500.00
Interest on Investment	21,000.00
Repair and maintenance	10,500.00
Total Fixed Cost/year	63,000.00
Variable Costs/year	
Wages	
2 persons x P300/person-day x 3 days/ batch x 80 batches/year	144,000.00
Fresh seaweeds, 2,000 kg x 80 batches @PhP9/kg	1,440,000.00
Total (Fixed + Variable Costs)	1,647,000.00
Return	
Raw dried seaweed product @PhP80/ kg	22,400 kg
Total sales	1,792,000.00

Table 7. Basic cost and return analysis when the developed drying system will be rented by the farmers.

ITEM	VALUE (PhP)
Initial Investment	350,000.00
Fixed Costs/year	
Depreciation	31,500.00
Interest on Investment	21,000.00
Repair and maintenance	10,500.00
Total Fixed Cost/year	63,000.00
Variable Costs/year	
Wages	Family labor - no additional labor cost
Total (Fixed + Variable Costs)	63,000.00
Returns	
From rental fee of PhP0.50/kg	
2 tons/batch x 80 batches/year	160 tons fresh seaweeds
Total Income from rentals	80,000.00

SUMMARY AND CONCLUSION

A seaweed drying technology was initially designed and fabricated based from the initial survey conducted on the different seaweed growing areas of the Philippines. There were two types developed namely, the floating-type which uses drum floatation device and can be towed near the farmers' production areas and the permanent-type seaweed drying technology constructed using concrete footings and foundation posts. Design improvements and modifications were incorporated into the original design to further enhance its performance as well as its structural soundness. Results of the field testing which includes the optimization study, showed that the developed drying technology was capable of drying newly harvested seaweeds at a much faster rate as compared to the existing drying practices of the farmers and that the technology can be used even in the absence of solar heat and can continually dry even during rainy or cloudy days by using air-drying technique and the operation of the fans. Responses gathered from the seaweed farmers disclosed that the developed dryer has bigger capacity as compared to their existing drying platforms, drying is much faster and there is no need to cover or haul the seaweeds. The dried products have better quality and permits continuous drying even during nighttime since, the sidings of the drying chamber can be rolled-up or down depending on the weather conditions as well as the presence of the fans. The resulting partially dried seaweeds which is the requirement of the buyers were of good quality commanding prices at a premium. Result of the financial studies showed that investing in the technology is very profitable.

RECOMMENDATIONS

The UPLB developed drying technology have shown that it can help seaweed farmers in their drying activities which is much better than their existing drying practices. With the positive reactions from the seaweed farmers who have assessed the performance of the developed drying technology, it is recommended that the technology be promoted to different seaweed growing areas in the Philippines. It is likewise recommended to conduct impact assessment of the technology since there are already several dryer units that were constructed and being used by the famers in different seaweed growing areas in the Philippines.

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