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Effect of Dried *Eucheuma cottonii* Stored in Seaweed Storage Device on Its Quality

Iwan Malhani Al Wazzan, Putri Wullandari & Ahmat Fauzi
Indonesian Research Institute for Fisheries Postharvest Mechanization, Ministry of Marine and Fisheries,
Bantul Regency, Yogyakarta, Indonesia
*Corresponding author, email: iwan.malhani@gmail.com

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ABSTRACT A seaweed storage device in the form of a bunker has been developed by the Indonesian Research Institute for Fisheries Postharvest Mechanization. This study aimed to compare the quality of dried *E. cottonii* stored in the seaweed storage device and stored in the sacks placed in the room. Based on SNI 2690:2015, dried *E. cottonii* quality can be determined from its moisture content, impurities, Clean Anhydrous Weed (CAW), and Total Yeast and Mold Counts (TYMC). Moisture content was measured according to CAW, and contaminants were measured respectively according to SNI 01-2354.2-2-2006, SNI 8168:2015, and SNI 8169:2015. The results showed that moisture content of the seaweed stored in the bunker decreased by 27.17%, and that stored in the sacks decreased by 14.77%, signing a more significant weight loss during storage in the bunker. However, seaweed stored in the bunker has lower impurities (1.70±0.13 vs 1.84±0.13%), higher CAW (40.42±2.45 vs 38.75±2.45%), and TYMC (450±70 vs 2500±115.33 cfu/g).

Keywords: Bunker; CAW; dried *E. cottonii*; moisture content; impurities

INTRODUCTION

Indonesia seaweed production in 2018 reached 10.4 million tons, most of them are *Eucheuma* sp. and *Gracilaria* sp. This amount was almost 40% of seaweed production worldwide (FAO, 2018). Seaweed can be used as a mixture in animal feed and soil fertilizer or by extracting it into additional materials for the food, pharmaceutical, cosmetic, textile, paper, paint, and bioethanol industries (Kadi, 2004). Seaweed preservation can be ensured by drying, salting, freezing, or fermenting immediately after harvested (Liot *et al*., 1993). This treatment determined the quality of the seaweed include washing and storing. But most of these treatments were done by farmers improperly, i.e., the seaweed was stored in a humid environment, poor air circulation, etc. Based on SNI 2690:2015, good grade dried seaweed has a clean appearance, bright color, fresh odor, large thallus with stiff texture and must be harvested after 45 days old. In particular, dried *Eucheuma* sp. has 30% moisture content, at least 50% clean anhydrous weed (CAW), and 3% impurities content.

Depending on the storage method, a qualified dried seaweed with 20-30% moisture content can be stored for 2-3 years. Poor storage without enough air circulation could increase the moisture content up to 50-55%. It will be made the seaweed rotten easily so that it cannot be stored for a long time. Proper storage must not be humid, dry and has enough air circulation with support boards given at the base (above the floor) to protect from soil or floor moisture. The storage space volume required was 18 m^3 for every 1000 kilograms of dried seaweed (Wortel *et al*., 2014). Properly dried seaweed storage requirements, according to DJPB (2015), have enough air circulation but avoid using large circulation holes, easy to maintain and also cleaned away from dirt/foreign objects that could contaminate the seaweed, dried seaweed must be stored and arranged neatly on wooden pallets 20 cm above the floor and labeled with lot code, seaweed enters and leaves the storage recorded properly (number and lot code) and follows the first in first out (FIFO) rule, maximum pile height is five sacks.

Most of those requirements were not fulfilled by farmers. The dried seaweed was just packed into sacks then stacked in the room without enough air circulation, support boards, and a dirty environment. These conditions make the seaweed moist easily and contaminated by foreign objects or insects.

A bunker-shaped storage device has been developed as an alternative to store dried seaweed. The device specification meets all requirements as mentioned above. The bunker was made from 304 stainless steel food grade, dimension 3500x1700x2400 mm^3 (max. capacity 500 kg dried seaweed). The bunker is connected to a chiller box equipped with a dehumidifier and air conditioner. The air from the chiller box was ducted into the bunker through ½ HP electric blower and then ducted out again into the chiller box, creating closed-loop air circulation. The dehumidifier, air conditioner, and blower are controlled with an Arduino microcontroller creating the desired environment. The microcontroller works based on temperature and relative humidity sensors installed inside the bunker, storing dried seaweed under controlled conditions. This study aims to determine the effect of dried seaweed *E. cottonii* stored in a storage device to its quality observed based on moisture content, clean anhydrous weed (CAW), impurities, and total yeast mold count (TYMC) compared to conventional storage in sacks.

MATERIALS AND METHODS

Material

The material used was *Eucheuma cottonii* bought from Jepara, Central Java, Indonesia. The seaweed has been dried until the moisture content is in a range of 40-50%. Tools used were the seaweed storage device that LRMPHP has developed in the form of a bunker, ven (Memmert UN55), rotary siever (# 3 mm), hand siever (# 1mm), analytical scales (Fujitsu HTR 220E), digital scales (Krisbow KW06-551 (ACS-SC71)), porcelain cup (30 ml), spatula, beaker glass (IWAKI vol. 2L, 100ml, 50 ml), aluminum foil, scissors, sacks (capacity 30 kg).

Method

The study was conducted at the Indonesian Research Institute for Fisheries Postharvest Mechanization (LRMPHP), Bantul, Special Region of Jogjakarta Province, Indonesia, in November 2019 for 30 days. The parameters observed were moisture content, CAW, impurities, TYMC, temperature, and relative humidity (RH). Each parameter was measured following SNI 01-2354.2-2-2006 (moisture content), SNI 8168:2015 (CAW), and SNI 8169:2015 (impurities) with three replications respectively. TYMC was analyzed at Food and Nutrition Laboratory, PAU, Gadjah Mada University. CAW, impurities, and TYMC were diagnosed before the seaweed was placed inside the bunker 30 days later. Temperature and RH inside the bunker were measured through 9 sensors and collected as microcontroller input. The microcontroller used the data to regulate the air circulation, temperature, and humidity inside the bunker. The temperature and RH of the bunker were seated at 25-27 °C and 60-70% to reduce molds and yeasts contamination during storage. As a comparison, dried seaweed was stored in sacks and placed outside the bunker. The same parameters as the seaweed stored in the bunker were also measured. Temperature and RH seaweed stored in the sacks were measured and collected as microcontroller data.

RESULTS AND DISCUSSION

The moisture content must be below 40% before being stored because it tends to absorb air from the storage process (Blakemore, 1990). Therefore, *E. cottoni* was dried under direct sunlight for 2-3 hours as initial treatment because the moisture content was 41.59%. After 2 hours of drying under direct sunlight, it has been reduced to 38.75% and is ready to store. The seaweed entered the bunker (Figure 1) through the upper door with the help of a conveyor belt. The belt was driven by a ½ HP electric motor and operated separately with the bunker microcontroller control panel (Figure 2. As a comparison, the seaweed was stored in the sacks and placed outside the bunker in the same room (Figure 3).

The effect of additional storage on dried *E. cottonii* moisture content showed in Figure 4. The seaweed moisture content stored in the bunker reduced rapidly in the first 12 days and became slower afterward. The lowest moisture content stored in the bunker is 11.58% at day 30. This rapid decrease happened because the free water content was high. The mass of the material moves into the air in the form of water vapor, causing the water vapor pressure on the surface to decrease, which causes the further water transfer from the material to the surface to occur by diffusion so that the decrease in water mass becomes slower. The water transfer from the material to the surface will continue until the material water decreases, and there is a balance with the surrounding air (Chen & Mujumdar, 2009).

Figure 1. Dried seaweed storage device (bunker) developed by LRMPHP.

Figure 2. Bunker microcontroller control panel.

Figure 3. Sacks are used for seaweed storage.

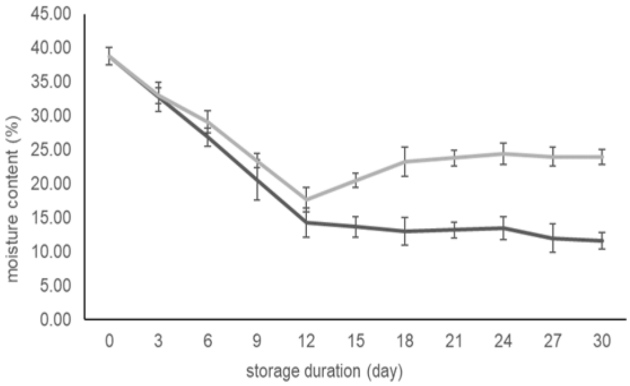

Figure 4. Moisture content comparison of *E. cottonii* stored in bunker and sacks (——— : sacks; ——— : bunker).

Seaweed moisture content stored in the sacks also reduced rapidly in the first 12 days compared with the seaweed stored in the bunker. The moisture content increased again after reaching the lowest level, 17.71%, on day 12. The moisture content of the seaweed was decreased during early storage because it still has a higher water activity than the surrounding air, and it makes the water inside the seaweed vaporized to the air to achieve balance with air relative humidity surrounding it. Figure 5 shows daily temperature and RH fluctuation around bunker during storage. It represents the environmental condition where the sacks were stored. The daily RH is very fluctuative, but the trendline (showed with arrow sign) is slightly increased, resulting in increased seaweed moisture content stored in the sacks. In grain storage, if air contact with grain has lower relative humidity than the equilibrium value then water is removed from the grain by air, reducing grain moisture content and increasing relative humidity on the air. Conversely, if the air contact with the grain has relayive humidity higher than the equilibrium value, the grain moisture content will be increased by the transfer of water from the air to the grain (Caddick, 2020). The same thing is supposed happen to seaweed storage.

The bunker relative humidity almost remained constant at 60-70%, resulting in seaweed moisture content decreasing during storage due to achieving balance with internal bunker relative humidity. The seaweed stored in the bunker will try to balance with the bunker inside relative humidity, and the other stored in the sacks will try to balance with the environment relative humidity around it.

Low relative humidity also reduces moisture content than high temperature (Fithriani *et al*. 2016). Since it influences the physical properties, including weight, density, viscosity, conductivity, and others, it is generally determined by weight loss upon drying. Unfortunately, lower moisture content also means more significant weight loss during storage, which means seaweed stored in bunkers experienced more significant weight loss than the seaweed stored in sacks.

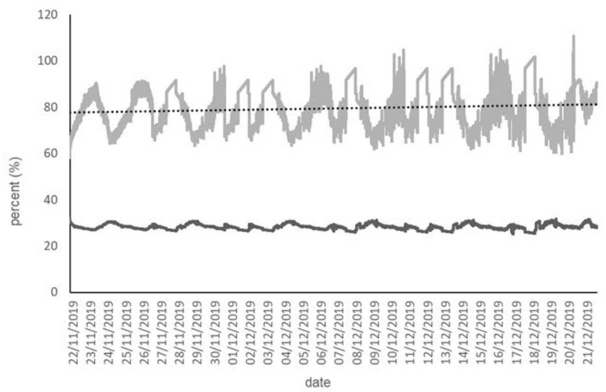

Figure 5. Temperature (▬▬) and RH (▬▬) of environtment outside bunker where the sacks placed.

CAW value can describe the total dry weight and total carrageenan content. A higher value means higher dry weight and carrageenan content, and vice versa (Subaryono & Kusumawati, 2019). Seaweed CAW stored in the bunker decreased to 40.42% from 50.83%, and those were stored in the sacks decreased to 38.75% from the same level. Both storage methods resulted in lower CAW levels than the standard quality requirements of dried Eucheuma sp. according to SNI 2690:2015 (Table 1). The occurrence of weight loss can indicate decreased CAW levels during storage. Statistical analysis showed that both treatments are insignificantly different, but according to SNI 2690:2015, a higher CAW level is better, so bunker storage is better than sacks in terms of CAW level.

The low moisture content of seaweed stored in the bunker is also closely related to bacterial growth, including yeasts and molds. Molds and yeasts are contaminants that can overgrow during storage due to humid conditions. Bacteria and molds have been identified as significant hazards in dried foods because they can produce toxins such as aflatoxin, ochratoxin, and other mycotoxins in dried foods (Hyun *et al*., 2018). Therefore, Total Yeast Mold Count (TYMC) is one of the crucial parameters in food safety.

Table 1. showed TYMC of dried *E. cottonii* stored in the bunker was lower than seaweed stored in sacks. Dried foods are advantageous in controlling microbial growth due to low water activity (aω), but they also tend to absorb water as the RH of the surrounding air is increased. Maintaining the recommended storage temperatures and RH is crucial to ensure optimal product quality and safety (Hyun, 2018). Bunker temperature and RH were always controlled within 25-27DC and RH 60-70% so that the molds and yeasts growth could be inhibited.

Molds and yeasts growth in foods was influenced by moisture content. The higher, mold and yeast will be easier to grow (Teurupun *et al*., 2013). Seaweed TYMC stored in the sacks was highly affected by temperatures and RH. The temperature around the sacks ranged at 25.4-31.9°C, and RH ranged at 58.1-110.86%. RH above 75% could increase moisture content and lead to yeast mold growth at 92% RH (Senthil *et al*., 2010). Microbials growth in foods is also closely related to water activity. Higher water activity will provide sufficient moisture to support bacteria, yeasts, and molds growth. Many foods have a water activity above 0.95, which will provide it. The water activity of some common foods is presented in Table 2. The amount of available moisture can be reduced to the point that will inhibit the organisms' growth (FDA, 2004). These results showed that the bunker could inhibit fungal growth. Statistical analysis also showed a significant difference between treatments means bunker is better storage than sacks in inhibiting microbial growth.

Table 2. Water activity (aω) of some common foods (FAO, 2014).

Foods	aω
Liverwurst	0.96
Cheese Spread	0.95
Red Bean Paste	0.93
Caviar	0.92

Table 1. Quality parameters value each storage method compared with standard.

Parameters	SNI 2690:2015	Bunker	Sacks
Moisture content (%)	max. 30%	11.58±1.10^a	23.98±1.25^b
Impurities (%)	max. 3%	1.70±0.13^a	1.84±0.10^a
Clean anhydrous weed (caw) (%)	min. 50%	40.42±2.45^a	38.75±1.91^a
Total yeast mould count (tymc) (cfu/g)	N/A	450±70^a	2.500±115.36^b

Impurities include salt, sand, other seaweed spesies, plastic, shellfish, and other foreign objects. Dried *E. cottonii* was sieved with rotary siever to separate seaweed from impurities until the impurity level reached 1.2% before being stored in bunker and sacks. Impurities then being analyzed again after 30 days stored, resulting in higher impurity levels in seaweed that stored in sacks (Table 1). After storage, the identification of impurities showed that most were salt and a small portion of broken or fallen seaweed. The bunker has an air duct system that allows undersized particles like salt and sand to fall into the chamber below. This chamber was designed to collect small particles that seaweed might release during storage. Seaweed is mostly water, salt, polysaccharides, and other metabolites, so when it loses a lot of moisture content, it will get dried, and salt will be released. Salt appears as an impurity due to loss ofmoisture content during storage. Salt and broken seaweed were collected in a special chamber not to contaminate other seaweed below in the bunker. In sacks, these impurities didn't have a particular container to contaminate the other. Both storage method impurities levels didn't exceed the maximum level described in SNI 2690:2015, so both storage methods still met the standard quality requirements. Statistical analysis showed that both treatments are insignificantly different, but lower impurities mean cleaner seaweed, so bunker storage is better than sacks.

CONCLUSION

E. cottoni stored in the bunker is better in caw, impurities, moisture content stability, and TYMC. It's cleaner and less contaminant but lighter because the water content of the seaweed stored in the bunker is lower than in the sacks, so its experienced more significant weight loss. This finding showed that the temperature and RH settings in the bunker are not yet optimum to store seaweed, so it required further study.

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