Data integration of humidity sensor and image texture for water content prediction of *Gracilaria* sp. during sun drying

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Abstract. Water content on site-measurement of dried seaweed required method with a minimum time of sample preparation time, less destructive effect to the sample, and could be validated. This research aimed to evaluate the potency of some features consist of image texture, resistance, and capacitance data of humidity sensor to predict water content changing of seaweed *Gracilaria* sp. during sun-drying. Dried *Gracilaria* sp. was rehydrated before being used in sun-drying for 4 hours. Gravimetrically-based water content evaluation, digital image taking, and measurement of resistance and capacitance value were conducted every 30 minutes interval during the drying. Images captured and collected by webcam in a conditioned lighting chamber were used subsequently for extraction of image texture features while a humidity sensor array contained 2 resistive sensors and 1 capacitive sensor respectively were applied to collect resistance and capacitance data. Collected data were used to create 4 datasets i.e. (1) 54 image texture features; (2) 3 resistance and capacitance features; (3) 57 features combination of dataset 1 and 2; and (4) 11 Features selected from dataset 3. Correlation coefficient and Root Mean Square Error of 4 datasets were applied for model evaluation utilized Multiple Linear Regression (MLR) and Multiple Layer Perceptron-based Neural Network (MLPNN). Investigation with cross-validation 10 folds test showed that MLPNN was the best model applied for dataset 1 with correlation coefficient and RMSE reached 0.89 and 9.11 respectively. Data integration of humidity sensor and image texture showed substantial potency to be used for the prediction of water content during sun drying.

1. Introduction

Indonesia has a large variety of seaweed species in its water. Not less than 782 seaweed species have been found. From the number of species, 18 species from 5 genera have new market potency. Among the 5 genera, *Eucheuma* and *Gracilaria* were recently cultured [1].

The utilization of *Gracilaria* sp. in Indonesia is mainly used as a source of gelatin polysaccharide. *Gracilaria* sp. market in Indonesia has some significant issues i.e. low selling price, the competition level of other seaweed products, heterogeneity of its quality, and its environmental changing-related growth. *Gracilaria* sp. foreign market has strict quality requirements related to its growth rate and water content [2]. One method that can be applied to meet the food industrial standard of seaweed as an ingredient is a dehydration process [3]. Drying not only retard decay but also will prolong shelf life and helps to extract some chemical constituents [4].
Water content measurement of dried food ingredients is usually based on the oven drying method during a certain period to evaporate some water contained inside the food ingredient. The method was continued with a gravimetric method to measure the weight difference of food ingredients before and after oven drying. Despite the gravimetric method that has become reference was regulated in Indonesia National Standard [5] about dried seaweed but it needs sample preparation and drying time [6].

Seaweed farmers and distributors usually applied traditional inspection and handpicking during on-site dried seaweed water content measurement which requires extra time and labor[7]. Some researchers have developed a method to measure water content in food with faster, less or non-destructive, accurate, and more objective. Application of soil moisture sensor connected to microcontroller and internet of things to measure water content in fruit and grain with accuracy reached 86.7% has been investigated [6] while the utilization of image texture parameters altogether with shape and color to classify different phase of drying of apple slices was studied with accuracy reached 95% [8].

A capacitance type measuring device was designed and developed to estimate the water content of seaweed during sun drying. It was observed that there was a linear correlation between gravimetric and capacitance value with a correlation coefficient of 17.6% [9]. A resistance type measuring device was developed for measuring the water content of paddy rice, guinea corn, and millet with a negative coefficient of correlation -0.95, -0.99, and -0.99, respectively [10]. Capacitive and the resistive sensor were included as a semi-quantitative method for water content estimation which has an easiness to operate and maintain, good accuracy and response time, and easiness of power supply accessibility [11].

The determination method of water content in algae was conducted by applying thermogravimetric analysis to perform precision results [12]. An obstacle with the method is the balance precision has a positive correlation with its price [11].

The non-destructively estimation method of seaweed water content during drying is still limited to be studied. The humidity sensor and image texture features can be used as a quality indicator of food ingredients during drying because the data collection relatively easy, fast, and non-destructive. This research aimed to investigate the potency of the humidity sensor and image texture features to be used solely and or together in water content measurement of dried *Gracilaria* sp. during solar drying.

2. Materials and Methods

2.1. Sample preparation

Dried *Gracilaria* sp. were collected and bought from traders and distributors in the northern shore of Central Java and brought to the fish product processing laboratory of Indonesia Research Institute for Fisheries Postharvest Mechanization.

That seaweed was rehydrated by dipping it in fresh water for 30 minutes with seaweed water and the water ratio is 1:3(w/v). After being drained for 5 minutes that rehydrated seaweed was divided into three replications of 300 grams each. Those samples were ready to be used for solar drying with a time interval of 30 minutes for 4 hours.

2.2. Image acquisition and capacitance and resistance value measurement with humidity sensor

Image acquisition and capacitance and resistance value measurement with a humidity sensor for *Gracilaria* sp. were conducted with a time interval of 30 minutes during 4 hours of sun drying. Images were captured and collected with a webcam in the lighting chamber (Figure 1 and Figure 2) and stored in .jpeg format with a resolution size 800x600 pixel. For image texture extraction, that .jpeg were converted and resized into .bmp format with size 400x300 pixel.

Mazda v 4.6 software was studied for image texture extraction [13]. The dried *Gracilaria* sp. image texture extraction process was depicted in Figure 3. Capacitance and resistance value measurement with a humidity sensor was conducted by tapping the sensor tip over *Gracilaria* sp. until the read of
value was stable on the instrument screen as shown in Figure 4. The instrument was supported for logging data into Micro SD Card and reset every time a new measurement was carried out.

Figure 1. Lighting chamber for dried seaweed image acquisition (1=Lighting box; 2=dried seaweed bin; 3=Lighting; 4=Webcam; 5=Webcam and lighting holder).

Figure 2. The image capturing with a webcam. Figure 3. Image texture features extraction.

Figure 4. Resistive sensor (x1 and x2) and capacitive sensor (x3) for water content measurement.
2.3. Water content measurement based on SNI-01-2354-2-2006
Water content measurement was conducted as a validation method to data generated by image texture features and capacitive-resistive humidity sensors based on SNI-01-2354-2-2006 [14].

2.4. Water content prediction with Weka v 3.8 software
Collected data from the image capturing and humidity sensor were used to create 4 datasets i.e. (1) 54 image texture features; (2) 3 resistance and capacitance features; (3) 57 features combination of dataset 1 and 2; and (4) 11 Features selected from dataset 3.
Correlation coefficient and Root Mean Square Error of 4 datasets were applied for model evaluation utilized Multiple Linear Regression (MLR) and Multiple Layer Perceptron-based Neural Network (MLPNN) in Weka. Multi-Layer Perceptron (MLP) was a perceptron based non-linear machine earning algorithm. It has a structure with 3 layers namely: (1) network input layer combined with bias as additional input; (2) hidden later; (3) output layer [15]. Model evaluation was tested with 10 folds cross-validation. The 10 folds CV split all data into 2 parts i.e. 10% as testing data while 90% remaining would be used as training data. The splitting process repeated to all data 10 times randomly. Correlation coefficient and Root Mean Square Error measured as average numbers from the repeated 10 times data split process [16].

3. Results and Discussion

3.1. Water content and drying rate changing during sun-drying
Changing water content during 240 minutes of sun drying showed a decreasing trend from 473.39 % dry basis (d.b) to 18.46 % d.b as showed in Figure 5. The main factor that contributes to this trend was solar irradiation as observed by [17].
Archive of climate data on 09th June 2020 in the Bantul region showed average temperature and humidity, 26.5°C, and 85%, respectively [18]. The instability of the drying rate as depicted in Figure 6 is very affected by the environmental climate during drying. It was observed that the drying rate could increase if the drying temperature was high while the relative humidity measured was low [19]. This phenomenon could happen when the partial pressure of water vapor and vapor pressure had a substantial difference.

![Figure 5. Water content changes during drying.](image)

![Figure 6. Drying rate changes during drying.](image)

3.2. Datasets
Datasets produced from image texture extraction had 54 features as mentioned in Table 1. Image texture features extracted with Mazda software could reach a high number and variability of parameters. To use the large features so conclusions could be formulated or ease to interpret analysis result number of features needed to be reduced or selected [20].
The humidity sensor used to collect resistance and capacitance value during *Gracilaria* sp. solar drying shows the results in Figures 7, 8, and 9. The resistance value of sensor X2 less sensitive than sensor X1 and X3 which performed zero values read after 180 minutes of drying. The use of 2 resistance value-based soil humidity sensors to predict the water content of fruit and grain was investigated and was able to reach an accuracy level of 86.7% [6].

Dataset 4 was generated by applying correlation-based feature selection (Cfs) in Weka v 3.8 Software. This method evaluated the feasibility of features subset by taking into account 2 parts i.e. predictive ability of each feature and redundancy level among those features [21].

### Table 1. 54 image texture features used in datasets 1 and 3.

| Image Texture Feature | Image Texture Feature | Image Texture Feature |
|-----------------------|-----------------------|-----------------------|
| Mean                  | Horzl_LngREmp          | 45dgr_ShrtREmp        |
| Variance             | Horzl_ShrtREmp         | 45dgr_Fraction        |
| Skewness             | Horzl_Fraction         | 135dr_RLNonUni        |
| Kurtosis             | Vertl_RLNonUni         | 135dr_GLevNonU        |
| Perc.01%             | Vertl_GLevNonU         | 135dr_LngREmp         |
| Perc.10%             | Vertl_ShrtREmp         | 135dr_ShrtREmp        |
| Perc.50%             | Vertl_ShrtREmp         | 135dr_ShrtREmp        |
| Perc.90%             | Vertl_ShrtREmp         | 135dr_ShrtREmp        |
| Perc.99%             | 45dgr_RLNonUni         | Teta1                 |
| Horzl_RLNonUni       | 45dgr_GLevNonU         | Teta2                 |
| Horzl_GLevNonU       | 45dgr_LngREmp          | Teta3                 |
|                      |                       | Teta4                 |
|                      |                       | WavEnLL_s-1           |
|                      |                       | WavEnHH_s-3           |
|                      |                       | WavEnLL_s-4           |
|                      |                       | WavEnLL_s-5           |
|                      |                       | WavEnHH_s-4           |
|                      |                       | WavEnHH_s-5           |
|                      |                       | WavEnHH_s-5           |
|                      |                       | WavEnHH_s-5           |
|                      |                       | WavEnHH_s-5           |
|                      |                       | WavEnHH_s-5           |
|                      |                       | WavEnHH_s-5           |

![Figure 7. Resistance measurement of x1 sensor.](image1)

![Figure 8. Resistance measurement of x2 sensor.](image2)

![Figure 9. Capacitance measurement of x3 sensor.](image3)
3.3. Water content prediction model evaluation
The model evaluation showed in Table 2 performed that 54 image texture features had the biggest potency to be used as a predictor in the water content predictive model of *Gracilaria* sp. during sun drying based on the highest correlation rate and lowest RMSE. It was investigated that variables easy to measure (color, texture, and spectral distribution) can be used to evaluate variables difficult to measure, such as chemical composition [21]. Furthermore, texture features were calculated based on pixel brightness information and mutual interaction between them. MLPNN showed a higher correlation for three datasets compared to MLR. MLPNN more represented non-linear boundary decisions [15].

| Dataset | Feature number | Correlation | RMSE |
|---------|----------------|-------------|------|
| 1       | 54             | 0.5733      | 22.7766 | 9.1136 |
| 2       | 3              | 0.8617      | 11.4165 | 12.5154 |
| 3       | 57             | 0.7099      | 17.3399 | 12.1585 |
| 4       | 11             | 0.8685      | 11.4092 | 16.143  |

4. Conclusions
It is observed from the experiment that dataset 1(image texture features) performed the best prediction of dried *Gracilaria* sp. water content using MLPNN modeling with a coefficient of correlation reached above 87% and RMSE 9.1136. Data integration followed by feature selection and MLR modeling (Dataset 4) performed promising results for the prediction of dried *Gracilaria* sp. water content. It has fewer features but its estimation ability almost equal to those of image texture features. Image texture features and humidity sensor can be used as a non-destructive method to predict *Gracilaria* sp. during drying. Future works for this research requires attempts to increase robustness in the model and to compare model effectiveness for other high-demanded seaweed species.

References
[1] Alamsjah M A 2010 Producing a new variety of *Gracilaria* sp. through cross-breeding research *J. Fish. Hydrobiol.* **5** 2 159-167
[2] Nurdjana M L 2001 Prospek sea farming di Indonesia (Prospect of sea farming in Indonesia) in: Sudrajat A, Heruwati E S, Poernomo A, Rukyani A, Widodo J, Danakusumah E (Eds.) Teknologi budidaya laut dan pengembangan sea farming di Indonesia (Marine cultivation technology and development of sea farming in Indonesia) (Jakarta:Departemen Kelautan dan Perikanan dan JICA) [In Indonesian]
[3] Gupta S, Cox S, Abu-Ghannam N 2011 Effect of different drying temperatures on the moisture and phytochemical constituents of edible Irish brown seaweed *LWT - Food Sci. Technol.* **44** 1266-1272
[4] Ito K, Hori K 1989 Seaweed: chemical composition and potential food uses *Food Rev. Int.* **5** 1-144
[5] BSN [Badan Standarisasi Nasional] 2015 SNI 2690:2015 Rumput laut kering (2015 SNI 2690: 2015 Dried seaweed) [In Indonesian]
[6] Prasetyo T F, Isdiana A F, Sujadi H 2019Implementasi alat pendeteksi kadar air pada bahan pangan berbasis internet of things *SMARTICS Journal* **5** 2 81-96 [In Indonesian]
[7] Eissa A H A, Khalik A A A 2012Understanding color image processing by machine vision for biological materials *In Tech.* 227-274
[8] Fernandez L, Castillero C, Aguiler J M 2004 An application of image analysis to dehydration of apple discs *J. Food Eng.* **67** 185–193
[9] Hakim A R 2011 Rancang Bangun Instrumen Pendeteksi Kadar Air Rumpu Laut Berbasis Mikrokontroler IPB (Bogor Agricultural University) (Design of IPB Microcontroller-Based Seaweed Detection Instruments (Bogor Agricultural University)). MiniThesis. Departemen Ilmu dan Teknologi Kelautan Fakultas Perikanan dan Ilmu Kelautan Institut Pertanian Bogor [In Indonesian]

[10] Lawal S, Bala K, Adeyemi M 2017 Development of resistance type moisture measuring device for grains Leonardo El. J.Prac. Technol. 255–268

[11] Vera M, Dutta B, Mercer D G, Maclean H L, Touchie M F 2019 Trends in food science & technology assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: a review Trends Food Sci. Technol. 88 484–496

[12] Silva V M da, Andrade L A S e J B de, Cunha Veloso M C da, Santos G V 2008 Determination of moisture content and water activity in algae and fish by thermoanalytical techniques Quim. Nova 31 4 901–905

[13] Materka A, Hajek H, Dezortova M, Lerski R 2006 Texture analysis for magnetic resonance imaging Prague (Germany: Med4publishing 7–41; 79–103

[14] BSN [Badan Standarisasi Nasional] 2006 SNI-01-2354-2-2006 Pengujian Kadar Air (SNI-01-2354-2-2006 Water Content Testing) [In Indonesian]

[15] Witten I H, Frank E 2005 Data Mining: Practical Machine Learning Tools and Techniques Second Edition Morgan Kaufmann Publishers San Francisco pp 423-425

[16] Dzeroski S, DrummD 2003 Using regression trees to identify the habitat preference of the sea cucumber (Holothuria leucospilota) on Rarotonga Cook Islands Ecol. Modell. 170 219–226.

[17] Phang Hooi-Kim, Chu Chi-Ming, Kumaresan S, Rahman M M, Yasir S M 2015 Preliminary study of seaweed drying under a shade and in a natural draft solar dryer Int. J. Sci. Eng 8 1 10-14

[18] BMKG 2020 Data online Pusat Database-BMKG (Online Data Database Center-BMKG)

[19] Fudholi A, Othman M Y, Ruslan M H, Yahya M, Zaharim A, Sopian K 2011 The effects of drying air temperature and humidity on the drying kinetics of seaweed Recent Researches in Geography, Geology, Energy, Environment, and Biomedicine 129-133

[20] Zapotoczny P, Kozera W, Karpiesiuk K, Pawlowski R 2014 The use of computer-assisted image analysis in the evaluation of the effect of management systems on in the color, chemical composition, and texture of m. longissimus dorsi in pigs Meat Science 97 518–528

[21] Karegowda A G, Manjunath A S, Jayara M A 2010 Comparative study of attribute selection using gain ratio and correlation based feature selection Int. J. Info. Technol. Knowl. Man. 2 271-277