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Advancing Paddy Rice Classification and Grading Employing Infrared Thermography (IRT) and Neural Network Techniques

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ABSTRACT: A crucial aspect of marketing and process controls is the Paddy Rice Grading, which consists of a collection of standardized techniques and procedures for assessing quality. To identify the heat that has been released, IR thermography makes use of the infrared wavelengths of the electromagnetic spectrum. To capture images of the sample, a FLIR ONE thermal camera was used. The average value of the thermal image's pixels was used to create a thermal index that served as a representation of each sample. Infrared thermography and image processing techniques were used in this study to evaluate the grading of Paddy rice. The results of the study showed that infrared thermography was 89.01% accurate at detecting moisture content and 95.04% accurate at recogniz- ing foreign objects. The findings showed that Paddy rice's moisture content could be precisely de- termined using infrared thermography evaluation using spectrum analysis. The use of non-contact, non-destructive methods for determining about the purity and moisture content of Paddy rice can be very helpful for farmers, rice millers, and other connected government agencies.

KEYWORDS: Infrared Thermography, Moisture Content, CNN, Image Processing, Paddy Rice, Confusion Matrix, FLIR Thermal Studio, Matlab.

INTRODUCTION

Rice is one of the agricultural crops produced in the Philippines, which has a long history of being recognized as an agricultural country. Most Filipinos rely on agriculture to provide for their everyday needs. They have a particular interest in farming because it enables them to generate income as well as get food. Paddy or unhusked rice has a set of distinctive character- istics that may be evaluated to help prevent losses from occurring or continuing, therefore it is important to understand the several quality aspects and how they vary in order to achieve max- imum returns from rice harvests. In Philippines, the Paddy rice has been graded based on the moisture content, purity and foreign matters of Paddy rice, based from Philippine National Standard PNS/BAFS 290:2019 Grains – Grading and classification – Paddy rice and milled rice. It was used by National Food Authority (NFA) and rice millers to give price to the farmer when purchasing Paddy rice.

The optimum amount of water remaining in the paddy, or the moisture content, should be in accordance with the set value of 14% and must satisfy the grade specifications given by the PNS, which are Premium Grade, Grade No. 1, Grade No. 2, and Grade No. 3. Depending on the purity and foreign material of the Paddy rice [1]. High moisture grains are too vulnerable to withstand shrieking pressure without incurring serious breakage, which means they also lose their quality quickly while stored. When processed, grain that is excessively dry becomes brit- tle and more likely to crack. If you sell too dry grain, the weight loss will reduce your profit. A new level of technology that will reduce costs, increase efficiency, and offer insights for de- velopment will be introduced by precision agriculture with the use of ICT in particular farm areas. Although there hasn't been much usage of it, it is captivating interest, especially among young farmers, who are discovering that rice farming isn't just grubby job but can be made smarter with the use of cutting-edge technology [2]. Based on the shape, color, and moisture content of the rice grain, rice quality can be classified [3].According to research, sorting rice and assigning it to groups or grades represents the process of rice grading. The grading of rice plays an important role for identifying the method used to evaluate rice quality in the rice producing field and its subsequent price on the market. The quality, genetic, agronomic, and commercial value of rice play a significant role in determining its grade and price [4]. Regardless of its distinctive properties, rice can be graded in many of ways. Examples include the use of a color approach filter, an edge detection template, decision tree analysis, and numerous others. Depending on the classification objective the user seeks to achieve. For instance, attributes like color and length might be exploited to achieve an objective like the originality of the rice. The advancement of machine vision systems has made it possible to classify rice into kernels that are chalky, cracked, broken, and internally injured. These are some methods that can be applied and are beneficial in the grading and classification of rice [5].

It's significant when determining Paddy rice's moisture content (MC) in the agricultural sec- tor. The need for a non-destructive method of measuring MC is Paddy on by the escalating cost of rice products. Furthermore, we can quickly ascertain the MC

distribution of the rice samples by measuring a single rice kernel. When rice has a high moisture content (MC), usually be- tween 25 and 40% dry basis (db) or 25 and 32% wet basis (wb), it is frequently harvested. Rice has a high respiration rate and is particularly susceptible to attack from microbes, insects, and pests at this moisture level. In marketing, it's crucial to know the grain bulk's average MC. [6]. Most mechanical properties of wood are significantly affected by moisture content (MC). The amount of water mass present in the material divided by oven-dry mass is the definition of oven-dry base MC, which is frequently used in the timber industry. The most common way to represent MC is as a share of oven-dry mass. However, measuring MC is not just done using the oven-dry method. Using the relative humidity and temperature of the environment, we may calculate the MC of the specimen. Depending on the temperature and relative humidity of the surroundings, wood specimens will eventually attain a moisture equilibrium. Equilibrium moisture content (EMC) at this point can be calculated using temperature and relative humidity [7].However, contrary to some study, assessment and evaluation of quality is done by a human sensory panel, which is time-consuming, expensive, and results-dependent. This can be re- placed with Computer vision and Neural network [8]. The most important parameters needed should be measured for quality analysis using image processing techniques. The objective of this study could be to develop a system that can classify rice grains in accordance to each characteristic that can be employed to improve the rice's quality. A solution like this should be less expensive and need less time for quality analysis [9]. Paying attention on different sam- pling techniques, sample sizes, preparation of samples methods, features, and neural network models to meet the demands of the rice industry [10]. To improve accuracy, color and texture features can be extracted. Additionally, it is possible to explore the classification of different rice kernel flaws, such as fissures [11]. In agriculture, industry, rice storage, trading, and pro- cessing, quick and easy non-destructive, accurate MC measurements are essential. It would be more beneficial for processing and pricing [6] if the device could provide both the mean and variation of MC samples.According to the aforementioned studies, the Philippines need a reliable system for classify- ing Paddy rice that benefits the government, farmers, rice millers, and consumers. Using infra- red thermography to assess Paddy rice could result in increased sales for both the customer and the seller. This is what the current study aims to do.

Review of Literature Rice Classification

The assessment of milled rice grains for the Philippines is still manually done. More so, local consumers have no reference to ensure that the milled rice they purchase is what they wish to have (David, D. et al.,2019).The grain shape of rice is the most visual index to identify rice type, variety, and grade. At present, the rice grain shape is mainly detected by artificial naked-eye recognition, so the effi- ciency is low and the error is large (Hu, Y.,2019).Classification can be a really tedious task when it comes to doing it manually instead of automatically. This would consume a lot of effort as well as a lot of time would be wasted (Arora, B. 2020).

Rice Quality Assessment

Since manual testing is time-consuming, costly, and inaccurate, machine vision-based qual- ity analysis of rice grains is preferred (Devi et. al., 2017).Rice quality is determined by different parameters including width, length, area, and num- ber of large, medium, small, and broken rice. In recent years, there has been an increasing trend in the automation of rice quality parameters. Satake RSQI10A Grain Scanner. This soft- ware is attached to a scanner and it measures the morphological parameters of rice including area, width, length, and number of rice (broken, medium, small) (Ali, S. et. al., 2017).Classification and quality analysis are done by comparing the sample image with the data- base image (Asif et al. 2018).Manual assessment of parameters such as the number of grains per ear and grain size is laborious. One solution to this problem is an image-based analysis that can be performed using a desktop PC. Furthermore, the effectiveness of analysis performed in the field can be improved through the use of mobile devices. Modern mobile devices (smartphones and Internet tablets) contain digital cameras with high resolution. Mobile devices have multicore processors with sufficient computational power for image processing and analysis. These features allow users to capture and process images wherever necessary. A number of applications for mobile de- vices have been developed for the morphometry of plant organs. (Komyshev et at.,2017).Rice quality is judged based on attributes, which could be classified ed several ways. Prod- uct characteristics could either be intrinsic, such as taste, texture, or color; or extrinsic to the product, such as packaging, brand, or label. Another attribute classification distinguishes be- tween search, experience, and credence attributes (Cuevas, R. et al., 2016).Identified five rice cultivars by means of developing an image processing algorithm. After preprocessing operations, 36 colour features in RGB, HSI, and HSV spaces were extracted from the images. These 36 colour features were used as inputs in the back propagation neural network (Golpour, I. et al., 2014).Hence it is important to stabilize rice prices. It further assumed that the amount of government procurement directly affects the behavior of the price of palay in the market (San- tos, M. et al. ,2018).

Advancing Paddy Rice Classification and Grading Employing Infrared Thermography (IRT) and Neural Network Techniques

Conceptual Framework

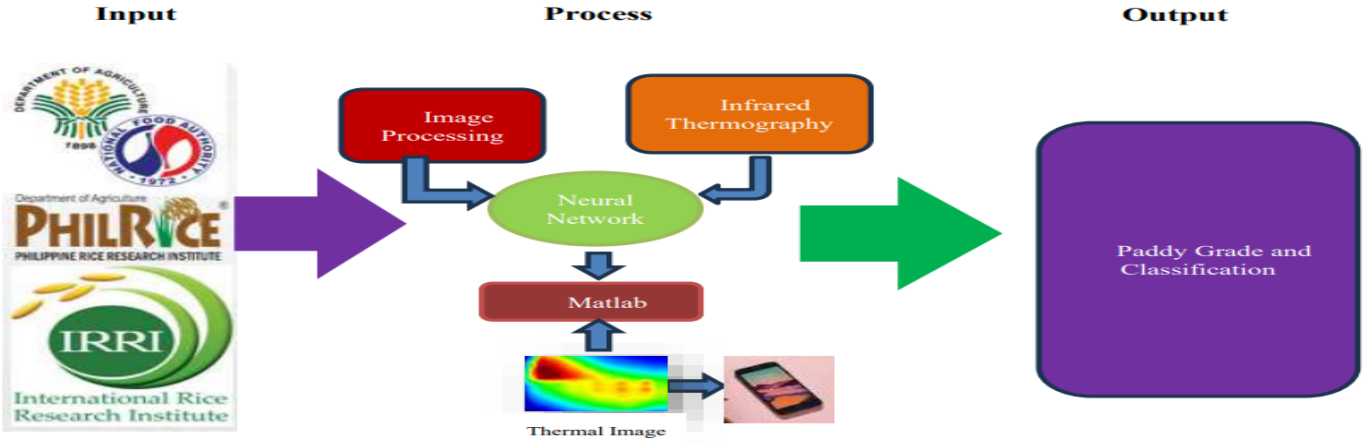


Figure 1. The conceptual framework of Advancing Paddy Rice Classification and Grading Employing Infrared Thermography (IRT) and Neural Network Techniques

Figure 1 shows the conceptual framework of the study, wherein the first step is to capture an image of a paddy provided by Philrice under the Department of Agriculture using a thermal camera that is attached to a mobile phone. After the acquisition of the thermal image, it will be uploaded to the computer and processed using the Matlab application.

Using the Matlab application, there will be three algorithms to be applied to get the grade and classification of a paddy. The image processing algorithm of this algorithm is to convert the image into a digital image for classifying the size of the paddy, detecting foreign matter, and determining the purity of the paddy. Infrared thermography is used to determine the moisture content of the paddy based on its temperature. Lastly, the neural network, using this technique, will grade and classify the paddy based on image processing and infrared thermography.

MATERIALS AND METHODS

2.1. Paddy Rice Sample

The Paddy rice samples that were used in the present study came from a Philippines rice granary. The samples were also taken during the harvest season and just before drying to obtain samples of real Paddy rice. In this study, three (3) different cultivars of Paddy rice were used, all of which are widely farmed in the Philippines. Paddy rice is typically harvested when the moisture content is between 20% and 25%. The moisture content of the Paddy rice was deter- mined using a Smart Sensor AR991 Grain Moisture Meter. A grain moisture meter can check Paddy rice with moisture levels between 11% and 55%. Three measurements of Paddy rice were taken, and an average moisture content was discovered. The information was used to show how precisely the moisture content of the Paddy rice could be determined.

The actual moisture content of the samples had been determined using a sun-drying method similar to that used by Filipino farmers. Paddy rice samples were prepared for each of these two functions in order to determine the purity and moisture content of the Paddy rice. In this study, 2,238 samples were graded and systematically categorized.



Figure 2. (A) Paddy rice sample ready for harvest; (B) AR991 grain moisture meter

The process for taking samples from a rice field and measuring the moisture level of the dried paddy is shown in Figure 2. The procedure involves arranging the harvest when the grains are mature, using techniques like their hands or mechanical harvesting, and then threshing thereafter. To remove extra moisture, the rice is dried after harvest. The most important stage is measuring the moisture content with the Smart Sensor AR991 Grain Moisture Meter.

2.2. Image Acquisition

Images of Paddy rice samples were captured using a thermal imaging camera (FLIR ONE Gen 3) with an 80 x 60 thermal resolution and a visual resolution of 1440 x 1080, which were attached to a mobile phone device and saved in FLIR ignite cloud storage. FLIR ONE utilizes Multi Spectral Dynamic Technology (MSX) to combine the regular and thermal im- ages. This will be done to provide the raw thermal image with additional raw data, resulting in a better vision as RGB scaled images. At least 1500 images for each Paddy rice sample were captured. The samples are obtained with a sampling distance of around 16 inches. A 300-watt LED flood light is a powerful tool for the illumination of the Paddy rice samples to eliminate harsh shadows. The angle between the thermal imaging camera and the axis of the illumination source is kept at about 45 degrees. The thermal imaging camera is mounted on a modified tripod as illustrated in Figure 3 to provide rigid and stable support as well as simple vertical mobility.

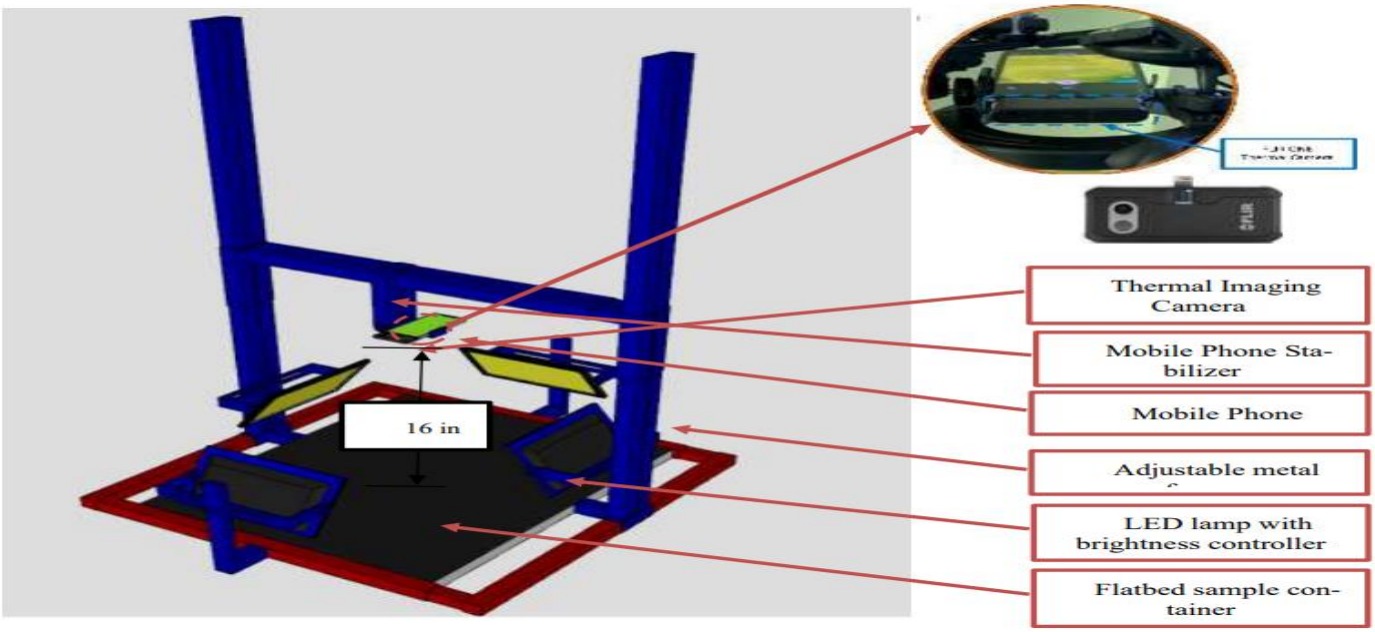


Figure 3. Thermal imaging setup

An infrared (IR) image and a digital color (DC) image can both be produced by the FLIR ONE camera in a single shot. Researchers may benefit greatly from the special capabilities of the FLIR ONE camera. FLIR Thermal Studio was used to process the infrared image in order to ascertain the moisture content (MC) of the Paddy rice. The DC image was processed using Matlab in the meantime in order to measure and identify the Paddy rice and foreign mater.

2.2.1. Pre-processing



Figure 4. Converted DC image to Grayscale image.

The conversion of an infrared image from a DC to a grayscale representation is shown in this figure. Filtering eliminated the noise and background from the DC image. Raw images must regularly have noise reduced. Smoothing, offset, and normalizing are all included. Next, gray- scale images should be created from the infrared images.

2.2.2. Segmentation is the splitting of an IR image into distinct elements. In IR images, this technique is widely used to identify the object and other significant characteristics. It is quite challenging to segment and extract the Region Of Interest (ROI) from a grayscale image. In order to recognize items in the grayscale images, the IR image is split into many segments as a collection of pixels or super-pixels. A threshold can be used to convert a greyscale image into a binary image.

The histogram shape thresholding requires finding the best threshold to distinguish the fore- ground from the background. Two regions that indicate the existence of two distinct regions are dark and bright areas. The ideal threshold was determined using semantic image segmen- tation. The identified threshold was used to assign labels to the pixels in the background and foreground.

Semantic Segmentation is a crucial step in the image's object detection process. It involves comprehending an image down to the pixel level. The majority of semantic segmentation tech- niques demand that each image pixel contains an item label. Every pixel is where the forecast is made. The prediction covers both the class and the limitations of each kind of item [14].

2.2.3. Edge detection

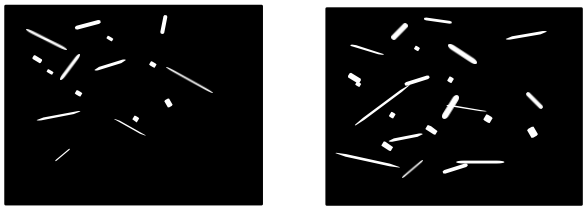


Figure 5. Segmented foreign matter from the binary image.

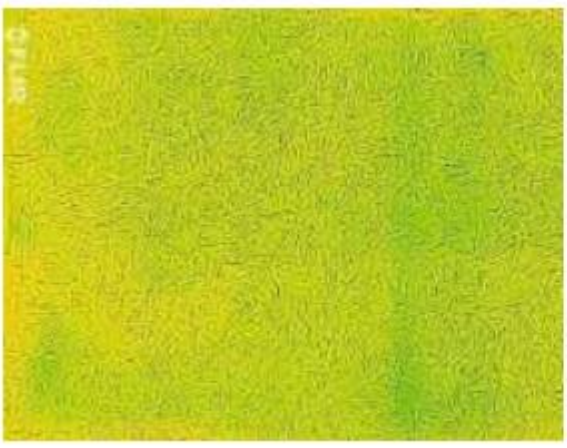
Figure 5 shows the binary image's segmented foreign matter along with the corresponding per- centage of foreign matter. The foundation for edge detection using different edge operators is edge detection. Edge operators are able to recognize differences in texture, color, and other characteristics. The greatest detector for creating the best-filtered image is canny edge detec- tion. The borders of the grey scale image are discovered using this optimum detecting method.

2.2.4. Features extraction

Features extraction is the process of identifying the important characteristics and quantifiable attributes of a binary image. The extracted features from a picture can help identify different areas in the image. These qualities could have both low-level and high-level properties. The low-level characteristics are immediately extracted using the image intensity values.

2.3. Purity and Foreign Matter

Purity refers to how much Paddy rice is free of impurities. Contrarily, anything that is not Paddy rice is referred to as foreign matter, such as chaff, straw, other crop seeds, gravel, dirt, stones, clay, and mud. The purity of the Paddy rice will be evaluated in this study using a frequency and percentage distribution approach, and the foreign material was converted into binary pictures using segmentation and thresholding and processed in MATLAB.





```
% %Read image
img = imread('S1.jpg');
```

```
%view original image
figure,
imshow(img);
%=========================================================================
% First crop out the image.
%-------------------------------------------------------------------------
imageRow1 = 50; %top
imageRow2 = 2000; %Buttom
imageCol1 = 200; %Left
imageCol2 = 1400; %Right
% Crop off the surrounding clutter to get the RGB image.
rgbImage = img(imageRow1 : imageRow2, imageCol1 : imageCol2, :);
%view cropted image
figure,
imshow(rgbImage);
%convert into grayscale image
ms=rgb2gray(rgbImage);
figure,
imshow(ms);
[BW,maskedImage] = segmentImage(ms); % copied from segmentImage function
figure,
imshow(BW);
%remove small holes
fillta = bwareaopen(BW,200);
figure,
imshow(fillta);
%=========================================================================
% count the foreign matters
%-------------------------------------------------------------------------
[a b]=bwlabel(BW,8);
measurements=regionprops(a,'BoundingBox');
%first show cropted image
figure;
imshow(rgbImage);
hold on;
for k=1:length(measurements)
 thisBB=measurements(k).BoundingBox;
 rectangle('Position',[thisBB(1),thisBB(2),thisBB(3),thisBB(4)] ,...
 'EdgeColor','r','LineWidth',2);
end
%title (b);
hold off;
%-------------------------------------------------------------------------
%Frequency and percentage distribution
numWhite = sum(fillta(:));
numBlack = numel(fillta) - numWhite;
numberOfPixels = numel(fillta);
% ROI as a percentage of Total Image
WpercentageROI = (numWhite / numberOfPixels) * 100;
BpercentageROI = (numBlack / numberOfPixels) * 100;
title({
 ['Purity: ',num2str(BpercentageROI),'% ']
 ['Foreign Matter: ',num2str(WpercentageROI),'% ' ]
 ['Grade = 1']
```

['Moisture Content = 13.9%']
});

Figure 6. Shows the finding of foreign matters and Paddy rice. As shown in the left-hand corner of Figure 6, the system will first use Matlab to recognize the foreign matter before computing the total pixel of the foreign matter (White pixels). The dark pixel region will be used to indicate the Paddy amount of rice.

2.4. Moisture Content

Moisture content (MC) has a significant impact on a number of characteristics of Paddy rice. The term "oven- dry basis MC," which is frequently used in the agricultural sector, is defined as the amount of water in the Paddy rice divided by the oven-dry mass. However, in addition to the oven-dry method, there are additional ways to measure MC.

We can determine the MC of the sample by combining the relative humidity and temperature along with the data we were able to obtain from an IR image of the Paddy rice. The experiment's Paddy rice sample will eventu- ally achieve moisture equilibrium based on the temperature and relative humidity. Temperature and relative hu- midity were measured using FLIR Thermal Studio Software.

The following equation can be used to compute equilibrium moisture content (EMC). In the equation below, relative humidity (h) is given in decimals, e.g., 0.70 instead of 70%, and temperature (T) is expressed in degrees Fahrenheit.

$$W = 330 + 0.452T + 0.00415T^2 \quad (1)$$

$$K = 0.791 + 0.000463T - 0.000000844T^2 \quad (2)$$

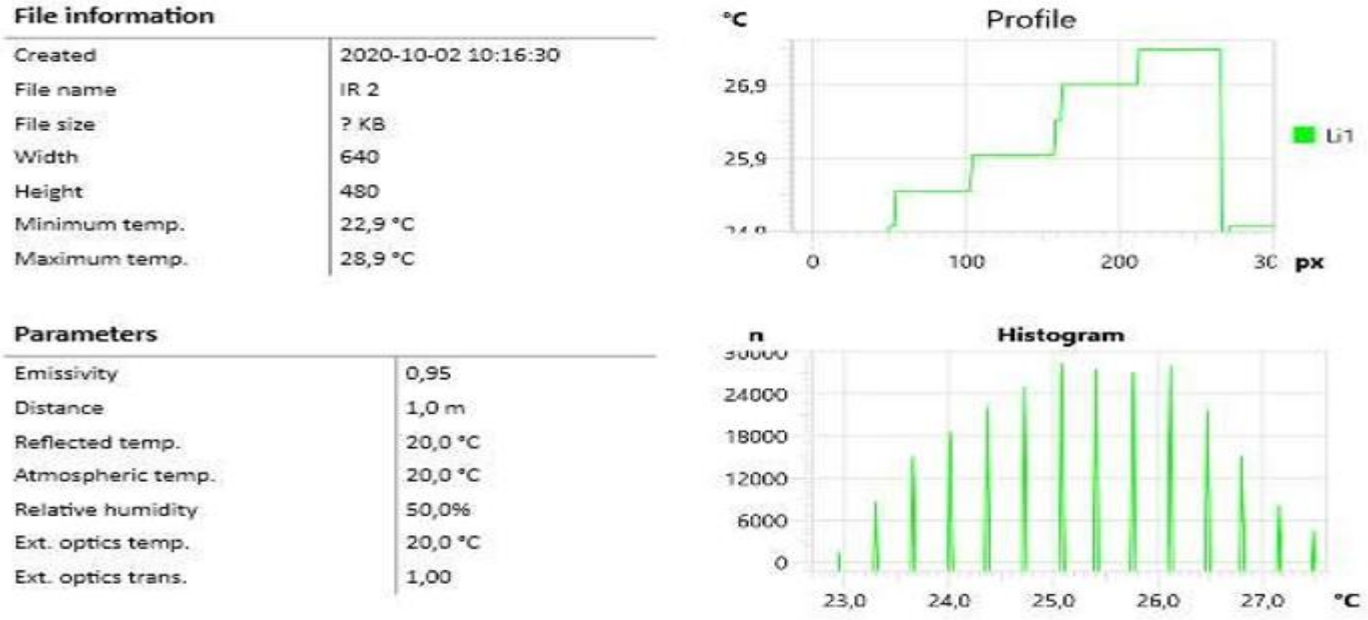
$$K_1 = 6.34 + 0.000775T - 0.0000935T^2 \quad (3)$$

$$K_2 = 1.09 + 0.084T - 0.0000904T^2 \quad (4)$$

Where T is the dry-bulb temperature (°F). Thus, given two pieces of information, dry-bulb (or ambient) temperature and the RH, the EMC can be readily calculated.

$$EMC(\%) = \frac{1800}{W}\left[\frac{Kh}{1-Kh} + \frac{K_1Kh + 2K_1K_2K^2h^2}{1+K_1Kh+K_1K_2K^2h^2}\right] \quad (5)$$

Where *EMC* is the equilibrium moisture content (%), *h* is the relative humidity expressed in decimal form (% / 100), and *W*, *K*, *K1*, and *K2* are coefficients defined by Eqs. 1 thPaddy 4, respectively [15]

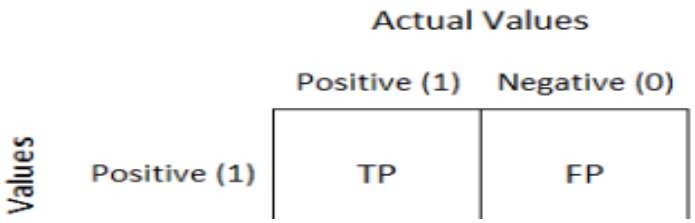


2.5. Evaluation using Confusion matrix

After confirming the Paddy rice's purity and moisture level, the process ends with evaluation. A table known as a confusion matrix is frequently used to illustrate how well a classification model (also known as a "classifier") performs on a set of test data for which the true values are known.

It allows the visualization of the performance of an algorithm. It allows easy identification of confusion between classes [16]. The *Confusionmat* function, one of the useful Matlab functions, was utilized by the researcher [17],[18]. The accuracy of the model can be easily calculated using the confusion matrix. The formula for calcu- lating accuracy is:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$$



RESULTS AND DISCUSSION FOREIGN MATTER

The confusion matrix that was created after a classifier was trained and its performance eval- uated using this test set is displayed below.

LEGEND:
A = 2% Foreign Matter,
B = 5% Foreign Matter,
C = 10% Foreign Matter,
D = 15% Foreign Matter,
E = 100% Foreign Matter,
F = 100% Rough Rice

CONFUSION MATRIX

PREDICTED CLASS \ ACTUAL CLASS	A	B	C	D	E	F
A	96.6	3.3	0.1	0	0	0
B	2.3	96.7	1	0	0	0
C	0	5.0	91.7	3.3	0	0
D	0	0.5	4.4	95.1	0	0
E	4	0	0	0	96.0	0
F	6	0	0	0	0	94.0

Figure 7. The Confusion matrix for the determination of foreign matters and Paddy rice with an accuracy rate of 95.04%.

Figure 6 shows the classification confusion matrix for each class produced by the discriminant analysis approach. Three classes with high accuracy rates for foreign matter are shown in Fig- ure 6: Class B (5% foreign matter), Class A (2% foreign matter), and Class E (100%) with accuracy rates of 96.60% and 96.00%, respectively. With accuracy rates of 95.10% for Class D and 94.00% for Class F, respectively, Class D came in second with (15% foreign matter) while Class F came in third with (100% Paddy rice). The Class C with 10% foreign materials, on the other hand, had the lowest classification accuracy rate. The overall classification accu- racy rate is, in fact, 95.04%. The lighting situation was cited for confusion and misclassifica- tions [19].

Moisture content

LEGEND:
A = 20.09%,
B = 18.32%,
C = 17.10%,
D = 15.23%,
E = 14.57%,
F = 13.91%,
G = 12.63%

ACTUAL CLASS

PREDICTED CLASS \ ACTUAL CLASS	A	B	C	D	E	F	G
A	91.95	4.2	3.8	0.0	0.0	0.0	0.0
B	0.0	84.9	7.8	3.5	3.9	0.0	0.0
C	0.0	4.4	77.9	13.3	0.0	4.4	0.0
D	0.0	4.6	1.8	87.2	1.8	4.6	0.0
E	0.0	0.0	0.0	0.0	94.6	5.4	0.0
F	0.0	0.0	0.0	0.0	5.0	95.0	0.0
G	0.0	0.0	0.0	0.0	4.2	4.2	91.6

Figure 8. The confusion matrix table for moisture content detection with accuracy rate of 89.01%.

Figure 8. Shows that the diagonal elements correspond to the expected observations. A total of 2,860 observations out of 3,220 were predicted correctly. Therefore, the overall accuracy is 89.01%. The accuracy rate for classification for Class F – 13.91%MC was highest (95.0%), followed by Class E – 14.57%MC (94.6%), Class A – 20.09%MC (91.95%), Class G – 12.63%MC (91.95%), Class D – 15.23%MC and Class B – 18.32% (87.2% and 84.88%, re-
spectively).

Nevertheless, with a classification accuracy rate of 77.9%, Class C-17.10%MC appeared to have the lowest rate. Keeping the Class C-17.10% expected outcomes in mind will help the model perform better. With the probable exception of the sample, the classifier misclassified 100 samples (22.1%) in total from Class C-17.10%, which is the greatest misclassification rate of any class. This suggests that 77.9% of predictions for Class C-17.10%were correct.

Impedance and near-infrared spectroscopy's effectiveness at determining out the moisture con- tent of Paddy rice was evaluated in one study. The findings showed the great accuracy of both approaches, with near-infrared spectroscopy having a little better accuracy (0.55% error) than impedance (0.79% error) [19] [20].

SUMMARY AND CONCLUSION

Based on the results of this study, a technique for image processing that calculates the average pixel of foreign matter and Paddy rice can be used to identify the purity of Paddy rice. It is possible to determine the moisture content measurement using equilibrium moisture content to predict the moisture content of the Paddy rice by using FLIR Thermal Studio to analyze the presence of relative humidity and temperature from the IR image and process.

Hyper-spectral spectroscopy can be used to compare the temperatures of foreign items and Paddy rice. The average accuracy rate for detecting moisture content is 89.01%, while the av- erage success rate for obtaining foreign matter using the thermal imaging technique is 95.04%. The findings of this study suggest that the identification of foreign materials and the moisture content of Paddy rice may be possible using infrared thermography.

So overall, technology in all aspects is very important in everyday life, especially for farmers and all concerned agencies in terms of farming, agriculture, etc. This study will serve as one of the instruments for helping farmers earn income while at the same time sustaining the quality of their foods, as indicated in this paper.

IMPLICATIONS AND RECOMMENDATIONS

The findings showed that Paddy rice's moisture content could be precisely determined using infrared thermography evaluation using spectrum analysis. The use of non-contact, non-de- structive methods for determining about the purity and moisture content of Paddy rice can be very helpful for farmers, rice millers, and other connected government agencies.

However, future research on the application of this technology is nevertheless possible, and it is strongly advised to create new methods for image enhancement, feature extraction, machine learning, data set creation, and real-time Paddy rice classification system that can classify rice in real-time during production can help guarantee that the quality of rice complies with the necessary standards. To fulfill the rising demand for high-quality rice and to ensure food secu- rity, researchers can enhance the classification of rice's accuracy and effectiveness.

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