The Imaging Methods for Classifying Crispiness of Freeze-Dried Durian using Fuzzy Logic

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Abstract—In quality control of freeze-dried durian, crispiness is a key quality index of the product. Generally, crispy testing has to be done by a destructive method. A nondestructive testing of the crispiness is required because the samples can be reused for other kinds of testing. This paper proposed a crispiness classification method of freeze-dried durians using fuzzy logic for decision making. The physical changes of a freeze-dried durian include the pores appearing in the images. Three physical features including (1) the diameters of pores, (2) the ratio of the pore area and the remaining area, and (3) the distribution of the pores are considered to contribute to the crispiness. The fuzzy logic is applied for making the decision. The experimental results comparing with food expert opinion showed that the accuracy of the proposed classification method is 83.33 percent.

Keywords—Durian, crispiness, freeze drying, pore, fuzzy logic.

I. INTRODUCTION

ALONG with Mangosteen, Durian is a famous fruit of Thailand, which is the first county that exports durians. Thailand exports both fresh and processed durians for more than 10,000 million baht per year [1]. One of the popular processed durians is the freeze-dried durian. It had been shown by a research result [1], and by its popularity that freeze-dried durian is preferable in the market comparing to other dried durian products. As a result, in order to keep high quality freeze-dried durian, it is very important to control the quality of the product.

On the quality control issue, recent research works in [2]-[6] investigated the quality of the freeze dried products. These researches studied the effects of the freeze-drying process to the products. Moreover, image analysis is a tool to support the above investigations [7]-[9]. However, these previous works did not address a quality of freeze-dried durian in term of crispiness, which is a key quality parameter for the processed durians.

We had introduced a classification of freeze-dried durian crispiness based on image processing and fuzzy logic in [10]. However, our previous method had some drawbacks on the feature extraction and the fuzzy rules. Therefore, in this paper, we propose its improvement. The remainder of the paper is organized as follows. The basic concept of our proposal is described in section 2. Then, the detail method is explained in section 3. Section 4 describes the experiments and results. Section 5 and 6 give the discussion and conclusion respectively.

II. BASIC CONCEPTS

Our proposed method is based on the analysis of freeze-durian images taken from a Scanning Electron Microscope (SEM). In the analysis, we start by trying to find features of the images that will represent the crispiness of the durians. According to the study of the freeze dry process, the texture of durian has changed because the water molecular flow through and damage the texture of durian [11], [12]. Due to the effect pores as illustrated in Fig. 1 are created. According to the study in [1], the characteristic of these pores indicates the crispiness of the freeze-dried durian. In our previous work, we propose to use 3 features of the pores as the input to fuzzy interference system for the classification.
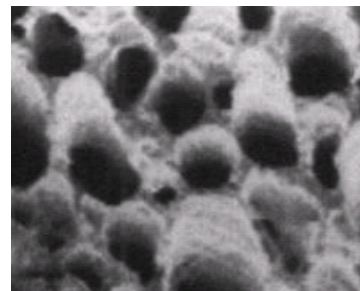

Fig. 1 Freeze-dried Durian Image

The three features include (1) the average diameter of the pores, (2) the ratio between the areas with and without pores, and (3) the distribution of the pores. However, in our previous work, we assume that all pores have the same size. As a result, the ratio of the areas and the distribution of the pores are identical. Although it gave a good result, we propose to improve these features as follows.

For the first feature, if the diameter of the pore is large, it means the freeze-dried durian is crispier. This first case is shown in Fig. 2 (a) and (b). Therefore, we propose to use the average diameter of the pores as the first feature. However, observing only the average diameter of pores is not enough to consider the crispiness since freeze-dried durians with too few large-size pores mean less crispiness than those with more small-size pores as shown in Fig. 2 (c) and (d). This feature can be represented by the ratio between the total pore area and the remaining area. For the third feature, although the average size and the ratio of the areas are large, the freeze-dried durians might not be crispy if all the pores are not distributed well as shown in Fig. 2 (e) and (f). Therefore, we measure the

mean distance between a pore to all of it neighbors. Then, we use the average of these mean values as the representation of the distribution.

Since these three features of the pores that indicate the crispiness are against each others, we propose to use the fuzzy logic principle to decide the level of crispiness.

Case I Diameter of pore

(a) Crispy   (b) No-crispy

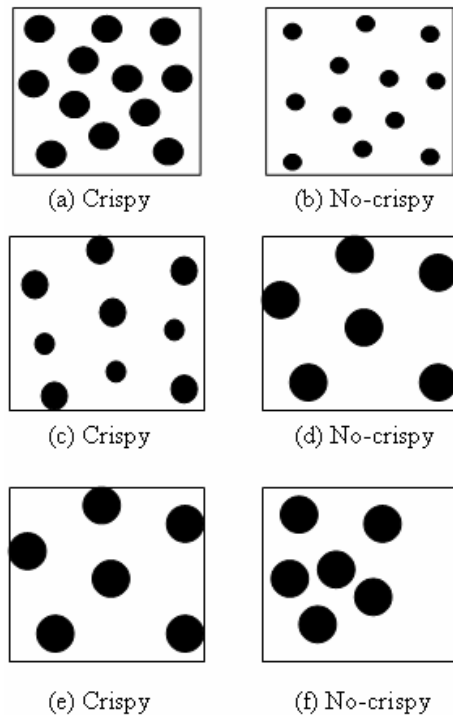(c) Crispy   (d) No-crispy

(e) Crispy   (f) No-crispy

Fig. 2 Crispiness based on feature of the pores

III. PROPOSED METHOD

Based on the basic concept, the proposed classification of freeze-dried durian crispiness is concluded in Fig. 3. The following subsections describe the steps in the proposed method.
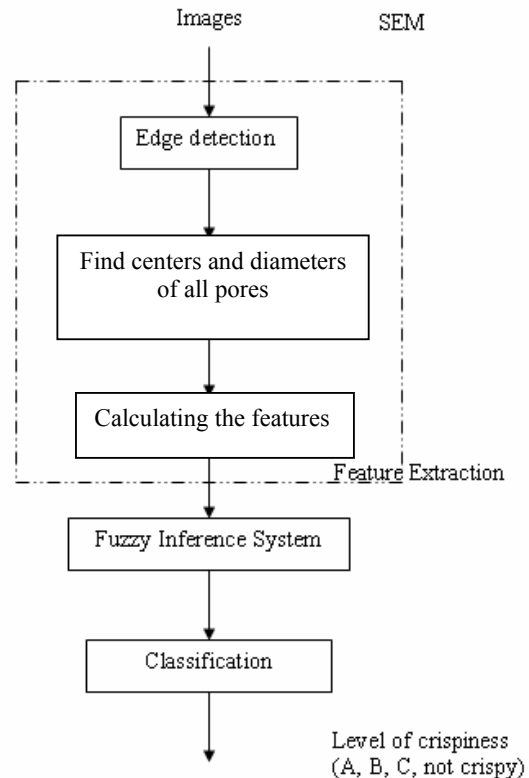

Fig. 3 Flow chat of proposed method

A. Freeze-Dried Durian Image

The images of the freeze-dried durians under consideration are taken from an SEM. All images are taken under the same conditions such as same image size.

B. Feature Extraction

This step is for feature detection. First, an edge detection method is applied to find all edges in the images. Then, the Hough transform is used to find the centers and corresponding diameters of all circles, which are considered to be the images of the pores. Finally, all 3 features are calculated as follows. The first feature is the average of the diameters. Then, the ratio between the areas of pores and space is computed by computing the sum of all circle's areas first. Finally, the third feature is computed by (1) computing the distances between a pore to its neighbors, (2) computing the mean of the distance and (3) computing the average of the mean distances.

C. Fuzzy Logic System

Fuzzy Logic (FL) is a step of decision process. The three features computed in previous step are the inputs of if-then rules of the FL. The AND operator is used for making the decision. The detail of the fuzzy logic system is as follows.

1. Membership functions

Each feature is considered to be a member of the FL, wherein each member must have a membership function for making the decision. Fig. 4 shows each input membership function of the 3 features. In these functions, the value of each feature is divided into 3 levels, Low, Medium, and High. The inputs and output can be classified in linguistic variables and fuzzy sets as follows. The appropriate values for defining the membership functions are come from the study in [1].

1. Feature 1 denoted by d: $d \in \{Low, Medium, High\}$

2. Feature 2 denoted by R: $R \in \{Low, Medium, High\}$

3. Feature 3 denoted by σ: $\sigma \in \{Low, Medium, High\}$

(a) Diameter of pore

(b) Ratio between pore and space
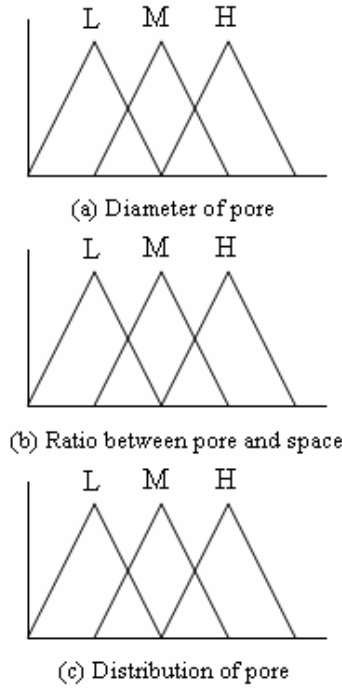
(c) Distribution of pore

Fig. 4 Inputs membership function

To set output membership function, we consider 4 classes of crispiness including crispy with grade A, B, C and not-crispy. Fig. 5 shows the output membership function.
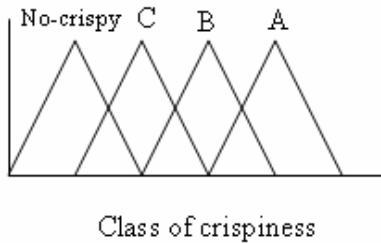

Class of crispiness

Fig. 5 Output membership function

2. IF-THEN rules

The fuzzy knowledge base contains IF-THEN rules describing the system behaviours. The AND operation is used to construct the set of rules. Since there are 3 inputs and each have 3 possible values, there are totally 27 rules.

D. Classification

The output of FL is a probability value ranging from 0.0 to 1.0. Therefore, the values are converted to linguistic variables. In our case, crispy-A, crispy-B, crispy-C, and not-crispy are classified by using the equal interval of output value between 0.0 and 1.0; i.e. the output intervals for the not-crispy, crispy-A, crispy-B, crispy-C are 0.0-0.25, 0.25-0.5, 0.5-0.75, and 0.75-1.0, respectively.

IV. EXPERIMENTAL RESULTS

We tested the proposed method with 12 freeze-dried durian samples, which were taken the images using an SEM. The Matlab 7.0 running on a PC with Pentium IV processor 3.0 GHz, 256 RAM MB was used for all image processing steps. The results of fuzzy logic decision are shown as Table I.

TABLE I
FUZZY LOGIC CLASSIFICATION

No. Image	output	Class
1	0.153	not-crispy
2	0.387	crispy-C
3	0.250	not-crispy
4	0.618	crispy-B
5	0.836	crispy-A
6	0.550	crispy-B
7	0.174	not-crispy
8	0.471	crispy-C
9	0.651	crispy-B
10	0.797	crispy-A
11	0.752	crispy-A
12	0.370	crispy-C

We compare the results from our proposed method with results from the subjective opinions of food experts using same images. The results are shown in Table II.

TABLE II
COMPARISON BETWEEN PROPOSED AND EXPERT DECISION

No. Image	Proposed	Expert	Result
1	not-crispy	not-crispy	Correct
2	crispy-C	crispy-C	Correct
3	not-crispy	not-crispy	Correct
4	crispy-B	crispy-B	Correct
5	crispy-A	crispy-A	Correct
6	crispy-B	crispy-B	Correct
7	not-crispy	not-crispy	Correct
8	crispy-C	crispy-C	Correct
9	crispy-B	crispy-B	Correct
10	crispy-A	crispy-B	Incorrect
11	crispy-A	crispy-A	Correct
12	crispy-C	not-crispy	Incorrect

V. DISCUSSIONS

The experiment result shows that the proposed method can classify crispiness of freeze-dried durian. However, some images are wrongly classified comparing to the expert opinions. Fig. 6 shows an example of the incorrect images. In this image, some pores have the twist shape or non circle, so these pores are not detected. As a result it is wrongly classified.
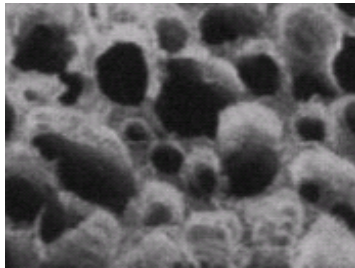

Fig. 6 Image with non circle pores

VI. CONCLUSION

A method for no-expert classification of freeze-dried durians based on its crispiness is proposed. The method is based on the analysis of SEM images of freeze-dried durians. Three features of circular pores are used as the inputs to the fuzzy system. The experiments on samples of freeze-dried durians showed that the method can classify crispiness with 83.33 % accuracy comparing with the expert options.

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