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"Application of image analysis techniques for quality assessment of Swiss-type of cheese"

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I. Introduction

The aim of this paper is to present an application of techniques for images analysis in order to assess quality of Emmental cheese. The software ImageJ is used for processing the images of cheese samples. A statistical analysis is performed in order to evaluate how even is distribution of areas with gas holes on the cut surface of Emmental cheese. The factor of even gas holes distribution is defined. Experts' estimation is used for comparison with results of images analysis and the results are encouraging.

II. Materials and methods

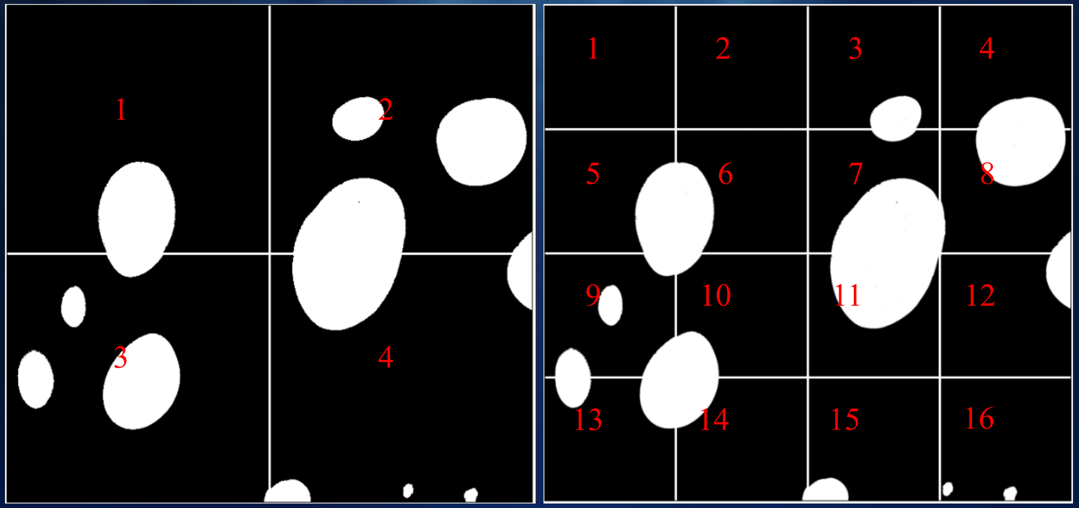
II.1 Cheese samples and the experimental setting

For the purpose of this research, four samples of Swiss-type of cheese are bought from the marketplace. The cheese samples were factory cut into several slices with an average thickness of about 2 to 4 millimeters and stored in a transparent commercial package.

A group of four cheese slices from each brand is selected and each of the slices is captured at bought sides with a digital camera Canon EOS 2000D. The raw images are saved in a Bitmap format locally in a computer for further processing. It is used a tripod for mounting the camera and holding it in a stable position. The images are obtained in a laboratory environment with daylight condition. An expert evaluation of the cheese samples is performed under the same laboratory conditions and the gas holes are analyzed under daylight lightening. The cheese slices are with close to rectangular or square shape and a region of interest (ROI) is manually cut from the bitmap images.

II.2 Digital image segmentation

All the ROI images are thresholded with the Otsu thresholding algorithm. In order to analyze the thresholded images and measure the ratio between pixels representing gas holes, an open source software ImageJ is used for digital image processing. A plugin for processing the images and measuring the area of the gas holes is developed and implemented in ImageJ. The plugin provides an ability for choosing dimension of a grid by which the images will be cut and a stack of images will be created. Two different sizes of the grid are tested: 2x2 and 4x4 (Fig. 1).



a) b)

Figure 1: Used grid dimensions – 2x2 a) and 4x4 b)

II.3 Software tool for gas holes evaluation

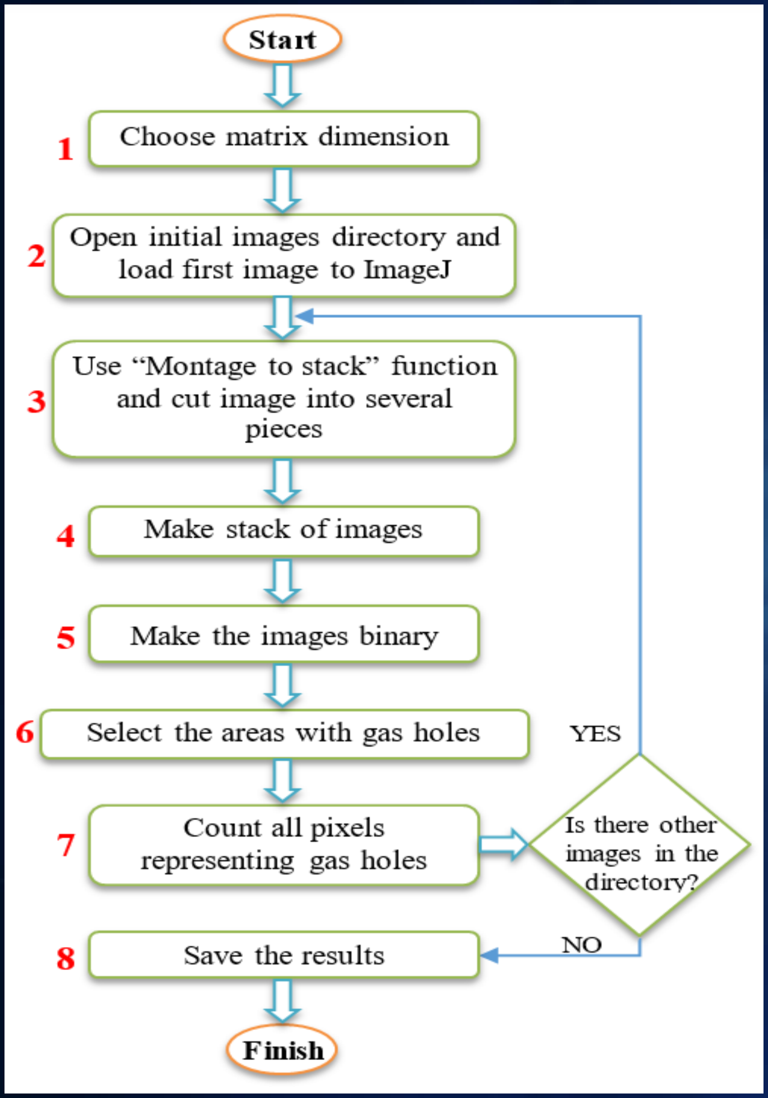


Figure 2: Workflow of the plugin

A plugin for processing the images of cheese samples is developed using the functionalities of the open-source software ImageJ. Figure 2 shows the workflow of the plugin. Figure 3 shows a simple GUI for selecting an option for the grid – 2x2 or 4x4.

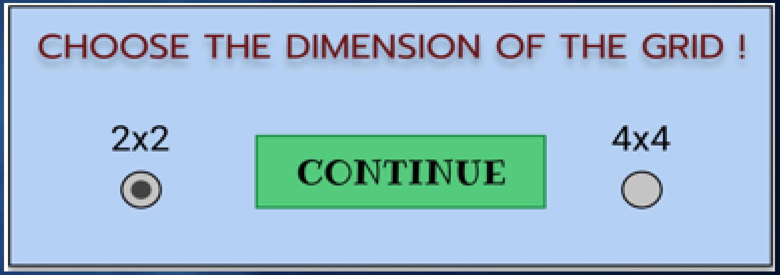
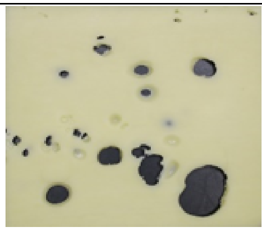
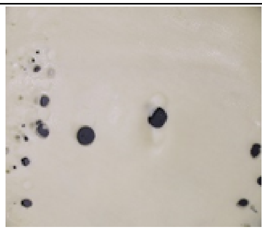
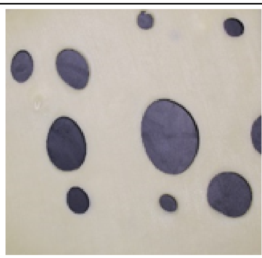
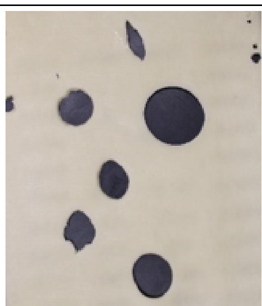


Figure 3: GUI for choosing the grid dimension

The obtained results for amount of white pixels are used for calculation of the ratio (Cgh – coefficient of gas holes area) between white pixels and the area of whole slice of a stack.

II.4 Expert evaluation of gas holes distribution

Table 1. Expert evaluation

Brand 1	
	Moderate distribution of gas holes. Presence of small pores and single with irregular shape.
Brand 2	
	Weak formation and distribution of small gas holes on the cut surface.
Brand 3	
	Presence of uniform distribution of gas holes on the entire cut surface. The gas holes have a regular oval shape.
Brand 4	
	Presence of gas holes on the entire cut surface. Single pores with an irregular shape are found.

An expert evaluation about the distribution of the gas holes on the surface of the cheese samples is made, by experts in dairy products. Table 1 shows example images (one for each brand) and comment about the distribution of gas holes and their shape. As a good example of even distribution of gas holes can be considered the image of the Brand 3, and as an example for weak formation and distribution can be considered the image of the Brand 2. Disadvantages in structure of samples Brand 1 and Brand 2 are related to non-optimal parameters of fermentation process. In this context, a computer based approach for fast and accurate evaluation of distribution of gas holes in Swiss-type of cheese could be applied for optimization of production process.

II.5 Statistical analysis

After obtaining the results for Cgh by using the developed ImageJ plugin, the data is summarized and processed in Excel. A statistical analysis is made in order to evaluate the distribution of the gas holes on the cut surface of the analyzed Swiss-cheese samples. The data for coefficient of gas holes areas (Cgh) for all ROIs of every trademark are used for analysis of holes distribution on the cut surface of the samples. Mathematical expectation of Cgh is defined as average for all samples of examined trademark:

$$\overline{C_{gh}} = \frac{C_{gh1} + C_{gh2} + \cdots + C_{ghN}}{\mathrm{N}} = \sum \frac{C_{gh}}{N} \qquad (1)$$

where N is the number of the ROIs for every cheese sample and it is equal to 16 or 4 depends on grid size. The dispersion and the standard deviation σ are determined by Eq. 2.

$$\sigma^2 = \frac{\left[(C_{\mathrm{gh}1} - \overline{C_{gh}})^2 + \cdots + \left(C_{ghN} - \overline{C_{gh}}\right)^2\right]^2}{N-1} = [\sum (C_{ghk} - \overline{C_{gh}})^2]/(N-1) \qquad (2)$$

For each trademark of analyzed Swiss- cheese, the upper LMAX and the lower LMIN limits of Cgh are calculated by Eq. (3).

$$L_{MIN,MAX} = \bar{X} \mp \frac{\sigma}{\sqrt{N}} t_{\frac{1+\varphi}{2}, N-1} \qquad (3)$$

$$t_{\frac{1+\varphi}{2}, N-1} = t_{1-\frac{\alpha}{2}, N-1}$$

where t is Student's t-distribution, φ – likelihood, α– level of confidence.

It is calculated a factor of gas holes even distribution (Fdist) as a ratio of Cgh values which fall in confidence interval (between LMIN and LMAX) to the number of all Cgh values for every trademark.

$$F_{dist} = \frac{n_{Ci}}{N} . 100 \qquad (4)$$

where nCi is the number of Cgh values which are between LMIN and LMAX limits and with N it is noted number of Cgh values.

III. Results and discussions

An analysis of experimental data is performed and results are summarized in tables 2 and 3. The lowest values of dispersion are 0,988 (using grid 2x2) and 3,128 (using grid 4x4) and they are calculated for samples of Brand 2 that are evaluated as “Weak formation and distribution of small gas holes on the cut surface.” For samples of all other brands it is observed that dispersion has high values which could be explained with moderate distribution of areas with gas holes on the cut surface.

Brand	X	б	$\alpha = 0.01$		$\alpha = 0.05$		$\alpha = 0.1$	
			Lmin	Lmax	Lmin	Lmax	Lmin	Lmax
Brand 1	8,504	6,285	-7,973	24,981	-0,036	17,044	2,561	14,447
Brand 2	2,358	0,988	-0,231	4,948	1,016	3,700	1,424	3,292
Brand 3	14,305	6,235	-2,041	30,651	5,833	22,777	8,409	20,200
Brand 4	8,134	5,201	-5,502	21,769	1,067	15,201	3,216	13,052

Table 2

Brand	X	б	$\alpha = 0.01$		$\alpha = 0.05$		$\alpha = 0.1$	
			Lmin	Lmax	Lmin	Lmax	Lmin	Lmax
Brand 1	8,508	9,054	2,424	14,591	4,410	12,606	5,374	11,642
Brand 2	2,360	3,128	0,258	4,462	0,944	3,776	1,277	3,443
Brand 3	15,010	12,739	6,450	23,570	9,244	20,776	10,601	19,419
Brand 4	8,002	12,539	-0,423	16,428	2,327	13,678	3,662	12,342

Table 3

Figure 4 presents factor of gas holes even distribution calculated using grid 2x2 and three different levels of confidence. It is observed that only for level of confidence α=0,1 the factor of gas holes even distribution has lowest value for samples of Brand 2 which corresponds with experts' estimation.

Figure 5 presents factor of gas holes even distribution calculated using grid 4x4 and three different levels of confidence. It is observed that for all level of confidence the factor of gas holes even distribution has lowest value for samples of Brand 2 which corresponds with experts' estimation. For level of confidence α=0,05 and α=0,01 the factor of gas holes even distribution has highest values for samples of Brand 3 and 4.

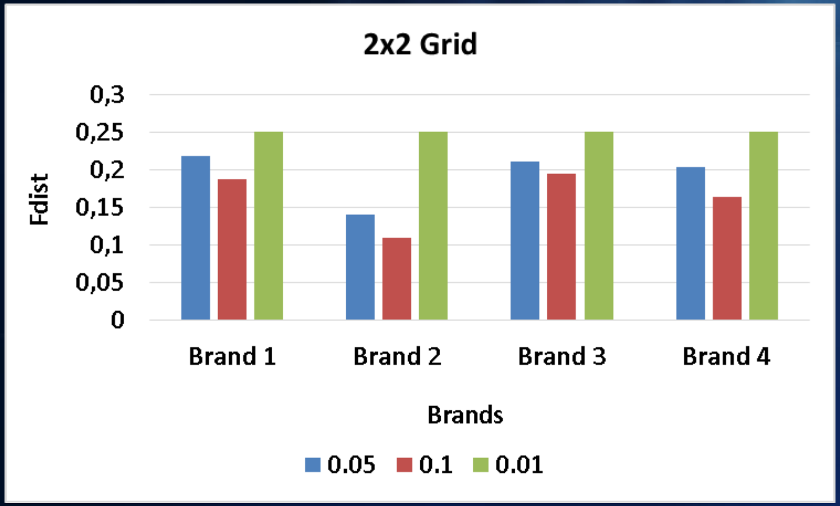


Figure 4

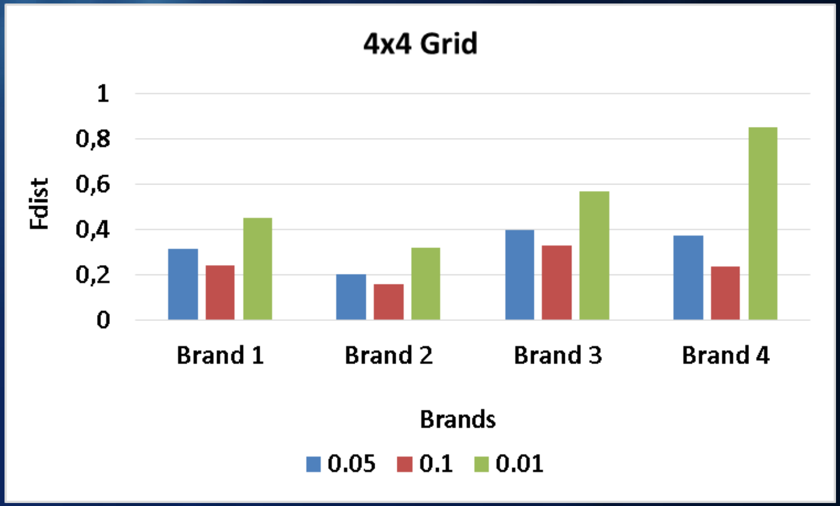
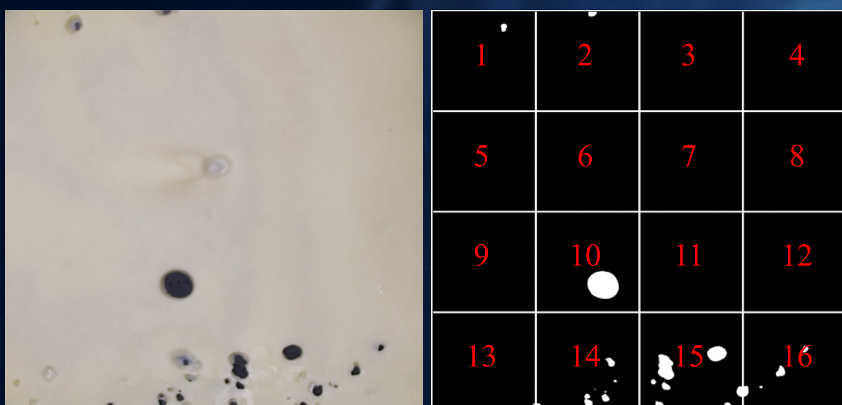


Figure 5:

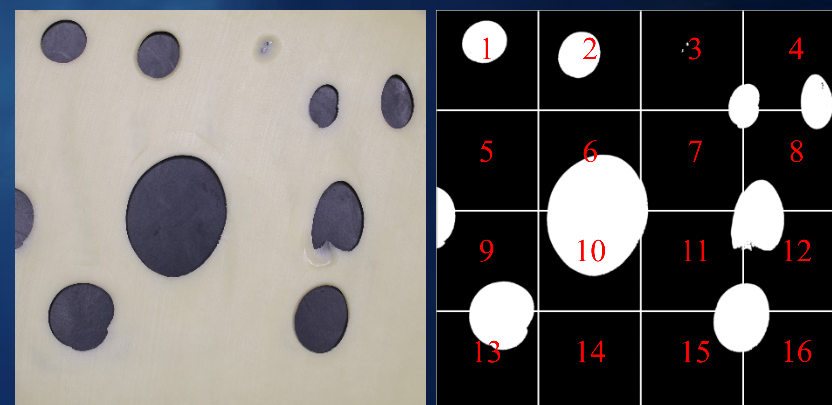
Figure 6 presents one image of sample of Brand 2 and its binary image divided into 16 ROIs. It is observed that small number of ROIs have areas with gas holes.

Figure 7 presents one image of sample of Brand 2 and its binary image divided into 16 ROIs. It is observed that almost all of ROIs have areas with gas holes.



a) b)

Figure 6



a) b)

Figure 7

Figures 8 and 9 presents graphics of Cgh values for samples which are presented on figures 6 and 7 respectively. It is observed that Fdist has low value (0,25) for sample of Brand 2 and high value for sample of Brand 3 (0,625).

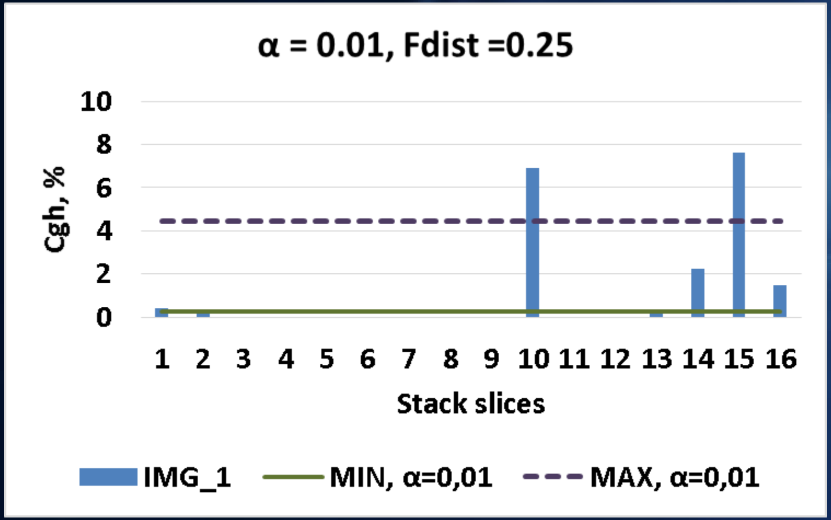


Figure 8

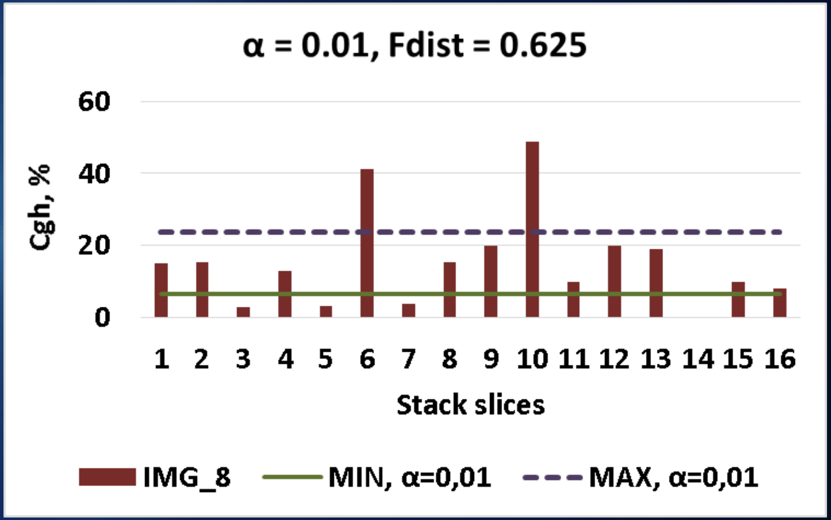


Figure 9

IV. Conclusion

A statistical analysis of data obtained by image processing of Swiss-type cheese samples have been performed and the results could be summarized as follow:

- distribution of gas holes on the cut surface of Swiss-type of cheese could be analyzed trough images processing;
- when the number of Cgh values which falls into the confidence interval is high (Fdist has high value) then the gas holes have moderate to uniform distribution on the examined cheese surface;
- usage of grid sized 4x4 leads to more precisely separation of cheese samples according to gas holes distribution;

In the future the research could continue with an analysis of gas holes according to their shape and distribution. The processing of every image could be accelerated using parallel execution of threads for every slice in stack.

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Thank you for your attention !