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**APPLICATION OF IMAGE PROCESSING WITH MULTILEVEL THRESHOLDING FOR MOULD DETECTION ON BLUE CHEESE CUT SURFACE**

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**Abstract.** *The techniques used by computer vision are based on signals which carry information about objects and their processing using wide range of methods. There are variety of types of signals according to their frequency or wave length. The visual range of spectrum is defined for wave with length between 380 nm and 750 nm. The waves with such length are registered by humans' receptors and they form sensitivity for colors. The human accepts the biggest portion of information about environment through its vision. Because of this there are developed a lot of methods for storing and processing the visual information. In the last years digital information processing and especially computer based such, is widely used in every area of human activity. By this way the computer vision and especially image processing became to be very important for human life. As a part of quality of human's life, the quality of food is also controlled by methods of computer vision. The subject of this research is one of popular dairy products – blue cheese. The characteristics taste and smell of this cheese are formed thanks to growth of mould *Penicillium roqueforti*. The growth of this moulds is detected by images processing with multilevel thresholding based on Otsu's method. Samples of eight trademarks of blue cheese are used for experiments. The results show that multilevel thresholding with two levels is appropriate for mould detection but multilevel thresholding with four levels support detection of areas with high concentration of moulds *Penicillium roqueforti* and areas with weak growth of moulds. Based on these results, in the future a software which would be helpful in reaching a high-quality control in the dairy industry could be developed.*

**Keywords:** *image processing, multilevel thresholding, blue cheese, quality, *Penicillium roqueforti**

## **I. INTRODUCTION**

Every living organism needs sustainable energy levels and nutritional support in order to perform daily tasks, be alive and grow and remain healthy. Main source of nourishment is food and its various forms. It contains vital nutrients such as fats, proteins, carbohydrates, which are part of the group of the macronutrients, and minerals and vitamins, classified as micronutrients. Those two categories allow human's body to function properly.

Today's constantly increasing population requires major food supplies, which have been provided by the food industry. It presents a complex system, which is accountable for the food from its production to its distribution including the processes

of supply, processing, consumption and disposal. The food industry main components are: agriculture, food processing and distribution, regulation, financial services, research and development, and marketing [1].

The food quality has been under significant strain due to the ever-increasing requirements for superior standard of living and the consumers' demands for a lower likeability of causing adverse health consequences to them. Consequently, every year the food system is pressured to include modern computerized or digital automation in order to enhance the food health control. With the rapid growth of technology this obstacle could be seamlessly overcome. The pros of implementing software-based gadgets and devices (sensors, programmable logic controllers, microcomputers, etc.) would be beneficial in providing various mediums of control. Without any doubt, computer vision and image processing methods ensure objective food quality evaluation because they could not be manipulated as simple as the human's statements. Moreover, computer (machine) vision systems have tendency to be developed as an inseparable part of the food processing plants for real-time quality evaluation and quality control.

Despite the perceptions of image processing as a tool only for digital image manipulations, it has been proved to be a successful technique applied in the natural sciences and technical disciplines, especially in the observation of food. Studies have stated that the food industry has significantly been using image processing methods and algorithms, which makes it one of the few industries seeking such approaches [2].

The current purpose of this research is to complement information to the science matter of observations through the obtained results by analysing one of the most popular dairy products - blue cheese, with the application of image processing algorithm (*Multi Otsu Threshold*). Cheese in general has vital nutritional value to people because it is rich in protein, fats, calcium, NaCl and low levels of iron [3]. Dairy products naturally are a high-fat and calorie dense food, but low-fat options could also be found. For instance, brands like Cheddar, Gouda and Mozzarella are with low percentage in fats. Cheese could be consumed by people who are sensitive or intolerant to lactose, as well. As a cheese ages, the lactose converts to lactic acid. Lactose-free examples are the soft cheeses such as Cheddar, Swiss, and Parmesan, which makes it the "perfect" food for every well-balanced diet.

Blue cheese's origin is related with the infestation of the mould *Penicillium roqueforti*, which is the reason for its appearance and flavour. In order the cheese to become "blue", oxygen must reach the inside of it. The mould (*P. roqueforti*) is injected into the cheese curd in the early stages of the aging process. In the past, the mould occurred naturally in the milk spontaneously with spores from the environment (from caves, naturally-rotten bread). Then the fungus matures inside the air tunnels of the cheese. The whole process happens from the inside out and it takes about three to six months for the cheese to mature. The ripening temperature is typically 8–15 °C, depending on the variety [4,5].

Today, blue cheese is one of the most preferable foods of all time and its consumption ranges worldwide. Varieties of blue cheeses are French Roquefort,

English Stilton, Spanish Cabrales, Danish Danablu or Italian Gorgonzola.

The appearance of the ripped blue cheese is usually white-off or yellowish, depending on the used animal milk (cow's, goat's, sheep', etc.), with bluish/greenish channels and veins due to the growth of the mould. The produced fresh cheeses have a high amount of moisture, soft texture and a strong flavour. The sharp flavour is due to the free short-chained fatty acids (C4:0±C12:0) and n-methyl ketones, produced by the mould from fatty acids during the lipolysis. Esters and lactones have role in determining the typical flavour of blue cheese, as well [4].

The microenvironment of the blue cheese consists of pronounced gradients of pH and NaCl, salt, water activity, etc, which results in diversity of habitats on the surface and inside of the cheese. During the production and fermentation, when cheese has been dry-salted or brine-salted, salt is added as a preservative. Moreover, the structural differences of blue cheeses determine the level and distribution of O<sub>2</sub> and CO<sub>2</sub>. Hence, it influences the growth and biochemical activity of the microorganisms. The quality of the final product is influenced by those parameters [5].

## **II. LITERATURE ANALYSIS**

The potential of image analysis has been noticed by the food industry in recent years due to the importance of maintaining food quality and safety principles. Moreover, the ever-increasing life standard and the high expectations of the consumer pressure manufactories to constantly observe new methods of food evaluation assessments and classifications.

The application of computer vision and image processing covers different product groups such as dairy products, fruit and vegetables, meat, bakery products and more. Its purposes could be classified as defects detection, structure evaluation, size and shape determination, colour recognition, mould detection, feature extraction, etc.

Nevertheless, modern computer vision and image analysis methods have proposed abundance advantages and feasibilities when observing the features of digital images in the urge of achieving higher levels of safety and quality. Moreover, technology is preferred when examine food products because it provides an objective and reliable inspection which could not be simply changed.

### **2.1. Application of Computer Vision and Image Processing in Cheese Evaluation**

Computer vision and image processing have a wide range of applications and offer plenty of algorithms which applied in different ways results in interesting researches. Both of them represents an efficient technique in investigating cheese features and provide information about the composition, the structure and the texture of this dairy product.

Cheese is a kind of food which overgoes multitude inspections from experts before it is offered to the consumers as a result of its dynamically changing quality attributes. When examined, the cheese is determined by its appearance

characteristics, classified as following [6]:

- sensory – taste, smell, texture, appearance, colour;
- physical – size, smoothness of the structure, level of curd fines, hardness, mechanical openings;
- nutritional – macro and micro elements;
- chemical – free fatty acids, free amino acids;
- safety – presence of foreign bodies, absence of pathogens.

For the ordinary consumer most of the quality criteria might be obscure. He relies on his primitive sensory abilities to determine whether the food is good or not. Hence, cheese colour is one of the major indicators, used in image analysis. The colour of the dairy product could vary from white to yellow or even orange due to the affection of different factors. For instance, the kind of milk (from cow, goat, sheep) and its microflora content, preservatives, food additives, presence of mould (especially in blue cheeses) and others. Manufactories could also influence the colour of the final product. For example, a study using image processing and colour diagnosis for determining the presence of diseases in yellow cheese is one excellent application of modern technology [7].

Another quality indicator is the mechanical openings which are often related to defects in the cheese structure. Normally, they are associated with rennet coagulated pressed cheeses, however in some types like Emmental, Gouda, Edam the evenly spaced round openings (eyes) are a desirable characteristic. The potential of computer vision has been noticed in this sphere, as well, as a useful tool for evaluation. X-ray computed tomography and image analysis have been applied in relation to eye formation in cheese and eventually those techniques resulted as a non-destructive medium to monitor the size of every eye hole [8]. Another study also examines the mechanical openings and the structural quality of Swiss-type cheese based on magnetic resonance imaging [9].

Digital image analysis represents a method which could evaluate the texture of the dairy product by detecting the quantity of ingredients added to the food. These are different herbs (parsley, garlic, onion, etc.) and spices (chili, black/red pepper, lavender, etc.) which contributes to the flavor of the cheese. Computer vision method and thresholding algorithm have been implemented in the interest of localizing and distinguishing the additional ingredients in the surface of the food [10]. Therefore, the amount of herbs and spices was successfully determined with 88% (with garlic and parsley) and 81% (with pepper and parsley) accuracy.

An algorithm has been implemented in order to ascertain the length of shreds of Mozzarella cheese which are usually visually determined after the product has been torn into tiny pieces [11]. The X-Y sweep method is applied also to evaluate the cheese shreds [12]. It is based on image segmentation where a visual scene is swept in X- and Y-direction. Therefore, a joint (ambiguous segment) is formed from the intersection of the shared interiors of the two segments. This means that the ambiguous segment consists of pixels which could not be swept through in X-direction or Y-direction. After that, a topology sorting method is applied in order to select the best match. The final results were with 95% accuracy of evaluating the

shred lengths.

Application of image processing and machine vision could be found in analyzing the rest of the quality criteria. Cheese quality indicators are determined by image processing algorithms and techniques which are applied for different kinds of cheese:

- Cheddar, Emmental, Ragusano – cheese meltability, browning and oiling-off [13,14,15,16];
- Mozzarella – cheese meltability [14,15,17];
- White cheese – mould growth on the surface [18] and analysis of cut surface structure [20,21,22,23,24];
- Yellow cheese – mould growth on the surface [18,24];

### **2.2. Application of Computer Vision and Image Processing in Blue Cheese Evaluation**

Despite the various applications of computer vision methods in the food industry and in particular estimating the quality of products, there are a few which provide fast and accurate determination of blue cheese quality parameters. One blue cheese in order to be estimated with excellent expert score, the amount and the distribution of mould on its surface is vital when examining it. There is a study where it is used multispectral digital image processing for a complex analysis and classification of blue cheese [25]. Another one proposes a method for evaluating the blue cheese by the distribution of mould on its surface with image analysis [26]. The images of the samples are divided into nine regions of interest and thereby the ration percent of areas with mould versus the total area size is calculated. The obtained results present information about the statistical distribution of areas with mould by their size. Additionally, a computer vision method for determining the distribution of cavities with presence or lack of mould on the blue cheese surface is implemented [27]. The research establishes a relation between the final conclusions and the experts' evaluation, hence the algorithm could be used for production process optimization and automatic evaluation of the cheese.

## **III. OBJECT, SUBJECT, AND METHODS OF RESEARCH /Ибо/**

Otsu's method is a means of automatically finding an optimal threshold based on the observed distribution of pixel values [28]. The Otsu's method is named after its inventor Nobuyuki Otsu. The idea of Otsu's method is to find threshold that would maximize the between-class variance of levels and minimize the intraclass variance of the threshold black and white pixels. The Otsu's method can be applied also for the multiple thresholds segmentation [29].

The images which have been used are a 2D (two-dimensional) function of the gray scale intensity and contains N pixels with gray levels  $(0,1,\dots, L - 1)$ . Probability of gray level i in an image is denoted  $p_i$ :

$$p_i = f_i/N \quad (1)$$

where  $f_i$  is the number of pixels with gray level  $i$  and  $N$  is the number of all pixels in the image.

The pixels of image are divided into two classes:  $C_1$  with gray levels, pixels in  $[1, \dots, t]$  and  $C_2$  with gray levels, pixels in  $[t + 1, \dots, L]$ . Using  $t$  as threshold. Therefore the gray level probability distributions for the two classes are:

$$C_1: p_1/\omega_1(t), \dots, p_t/\omega_1(t), \quad (2)$$

$$\text{and } C_2: p_{t+1}/\omega_2(t), p_{t+2}/\omega_2(t), \dots, p_L/\omega_2(t), \quad (3)$$

where means global intensity  $\omega_1(t)$  and  $\omega_2(t)$  are:

$$\omega_1(t) = \sum_{i=1}^t p_i \quad (4)$$

$$\omega_2(t) = \sum_{i=t+1}^L p_i \quad (5)$$

The means intensity of the pixels in  $C_1$  ( $\mu_1$ ) and  $C_2$  ( $\mu_2$ ) are:

$$\mu_1 = \sum_{i=1}^t i p_i / \omega_1(t) \quad (6)$$

$$\mu_2 = \sum_{i=t+1}^L i p_i / \omega_2(t) \quad (7)$$

The dispersion  $\sigma_B$  are determined as the between-class variance of the thresholded image by formula:

$$\sigma_B^2 = \omega_1(\mu_1 - \mu_T)^2 + \omega_2(\mu_2 - \mu_T)^2 \quad (8)$$

Otsu verified that the optimal threshold  $t^*$  is chosen so that the between-class variance  $\sigma_B^2$  is maximized. The optimal threshold value,  $t^*$  is:

$$t^* = \text{Arg Max} \{ \sigma_B^2(t) \} \quad (9)$$

$$1 \leq t < L$$

Multilevel thresholding is a process that segments a gray level image into several distinct regions [30]. Although applying multi-level thresholding to an image is a straightforward operation, computation of the threshold levels with Otsu criterion is a computationally expensive process [31]. Finding a modified between-class variance  $\sigma_B^2(t)$  necessarily requires pre-computing the zeroth-order moment  $\omega(k)$  and the first-order moment  $\mu(k)$  of the  $k$ th class [32]. If an image is segmented into  $K$  clusters/classes ( $C_0, C_1, \dots, C_{K-1}$ ),  $K-1$  thresholds ( $t_0, t_1, \dots, t_{K-2}$ ) must be selected [33]. The u-v interval zeroth-order moment  $P(u, v)$  and the u-v interval first-order

moment  $S(u, v)$  of a class with gray levels from  $u$  to  $v$  are defined as:

$$P(u, v) = \sum_{i=1}^v P_i, \quad (10)$$

and

$$S(u, v) = \sum_{i=1}^v P_i, \quad (11)$$

The cumulative probability  $\omega_k$  is computed as

$$\omega_k = \sum_{i \in C_k} p_i = \sum_{t_{k+1}}^{t_k} p_i = \sum_1^{t_k} p_i - \sum_1^{t_{k-1}} p_i \quad (12)$$

Therefore  $\omega_k$  and  $\mu_k$  are respectively determined by:

$$\omega_k = P(1, t_k) - P(1, t_{k-1}) = P(t_{k-1} + 1, t_k) \quad (13)$$

$$\mu_k = S(1, t_k) - S(1, t_{k-1}) = S(t_{k-1} + 1, t_k) \quad (14)$$

Also, the optimal thresholds can be determined by:

$$\{t_0^*, t_1^*, \dots, t_{k-2}^*\} = \text{Arg Max} \{\sigma_B^2(t_0^*, t_1^*, \dots, t_{k-2}^*)\} \quad (15)$$

A macro has been developed that uses the plugin with the multi-step Otsu threshold algorithm to segment images. This algorithm is used to divide the pixels of an input image into several different classes and allows the selection of the threshold value. Multi Otsu Thresholding for image segmentation is a variant of the basic Otsu's method. Adjustments in the plugin Multi Otsu Threshold have been made. Pixels that have values equal to the threshold values do not enter any of the regions, therefore it has been changed and these values could be included.

Figure 1 presents the steps of launching macro. First step is to launch ImageJ program (step 1). Then it is necessary to open an image for processing (step 2). Next step is to start macro which is located on the "Plugins" menu of ImageJ's menu bar (step 3).

It is presented an algorithm for image segmentation, coded using the ImageJ macro language. Figure 2 presents block diagram for developed macro (MOT\_Segmentation). It processes greyscale images. If the original RGB input image is not 8-bit type, the macro will convert it to a matrix with values can be anything from 0 to 255. The output image will be of the same file format as the input. Then the macro calculates the image width and height using methods getWidth() and getHeight(). The multiplication of height and width gives the number of all pixels in the image. After that the macro prompts user to select a numLevels, the possible values for selection are from 2 to 5. Therefore, if the condition  $i < \text{numLevel}$  is true, the next step of the algorithm is to run the Multi Otsu Threshold, where the variable  $i$  is used as the number of the regions.

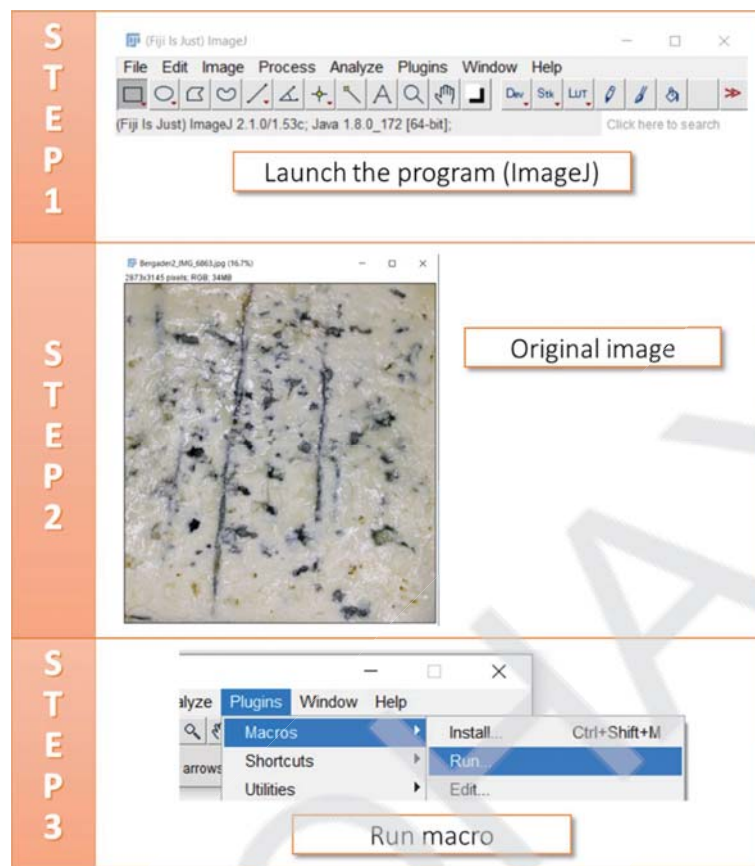


Figure 1. Steps of launching macro

The macro generates a 256 bin histogram for every region and displays the values in the "Results" window. MOT Segmentation counts the pixels with black color of the image. The percentage of pixel for  $i$  region is determined by the following formula:

$$C_{ri} = ((N - C_b) / N) * 100\%, \quad (16)$$

where  $C_b$  is the number of pixels with black color of the image and  $N$  is the number of all pixels in the image. Then the value of  $C_{ri}$  will be add to the "Results" window. Then these actions for finding the percentage of pixels will be repeated for the next region. Finally, all calculated  $C_{ri}$  values are displayed in the "Results" window.

The research objects which have been analyzed are different trademarks of blue cheese. The tested cheeses were bought from different marketplaces in Bulgaria thanks to financial support of University of Food Technologies. Two pieces of eight trademarks of blue cheese are used for experiments. The selected ones are: Bergader, Steffel Gran Bavarese, DorBlue 50%, DorBlue 55%, Emborg Uhrenholt, Paladin Regina Blue, Ramberber and DorBlue. These cheeses are known for their specific color and taste.

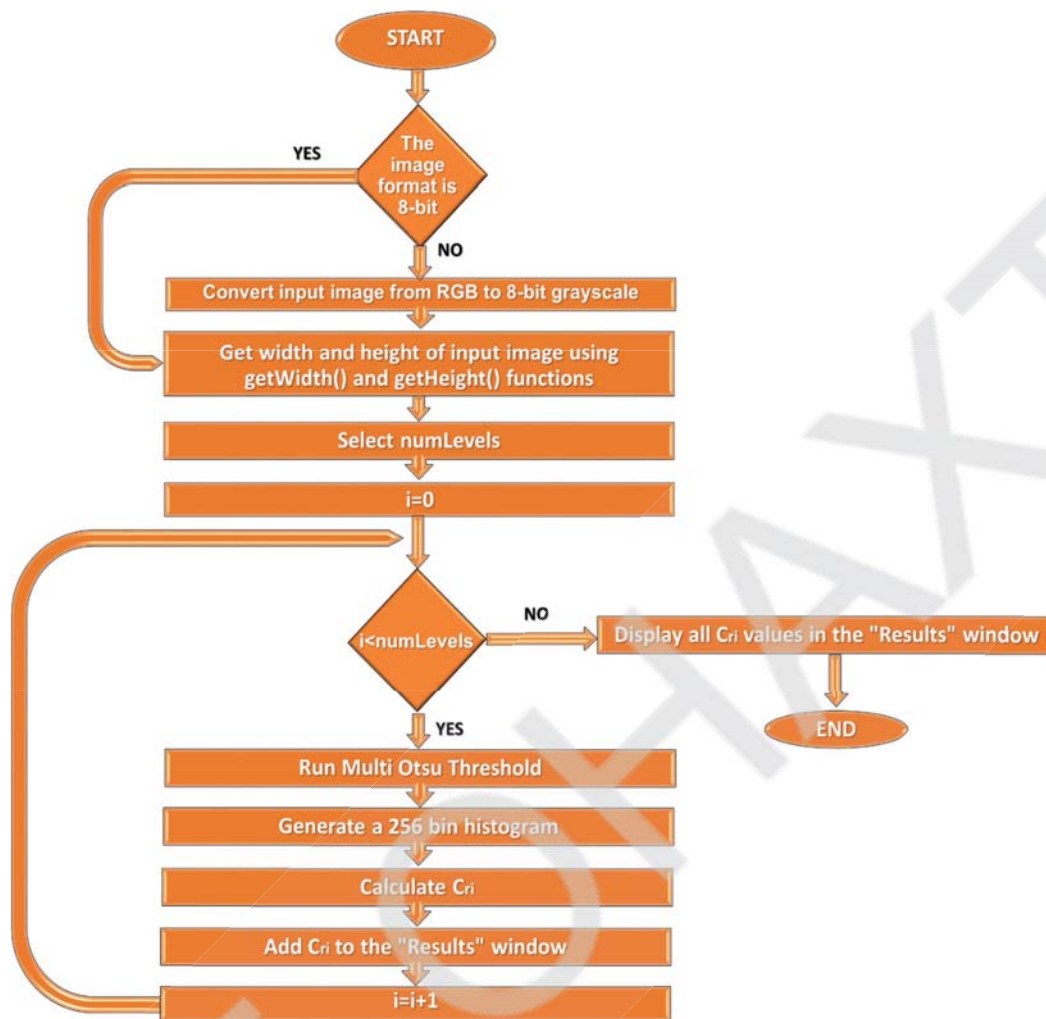


Figure 2. Block diagram for the macro

The system used for images acquisition is located in department of “Computer Systems and Technologies” at University of Food Technologies Plovdiv. The system consists of camera for images capturing, lighting module (ring, 500 lux), tripod and digital camera. The camera was mounted on a tripod so that the distance from the camera to the sample is the same for all experiments. To avoid external light conditions, the camera for images capturing is a cube with sizes 600 mm and it is covered with dark enclosure white-colored inside and the lighting module is positioned in the center of the upper side of camera. The distance between lighting ring and the base of the digital camera is 400 mm. Each of the pieces of blue cheeses were cut with cheese slicer. The all samples of blue cheese cut surfaces are captured by modern Canon EOS 2000D CMOS digital camera with 24.1 megapixel resolution.

Every captured original image is stored in a JPEG format. It is used the rectangular selection tool to select and crop region of interest (ROI) for every image. The ROI images are used for processing with developed macro in ImageJ.

#### IV. RESULTS /Владимир/

Figure 3 shows the result of using the MOT Segmentation macro for NumLevel3. There are shown Cri values for three regions, where Region 0 represents the pixels of mould.

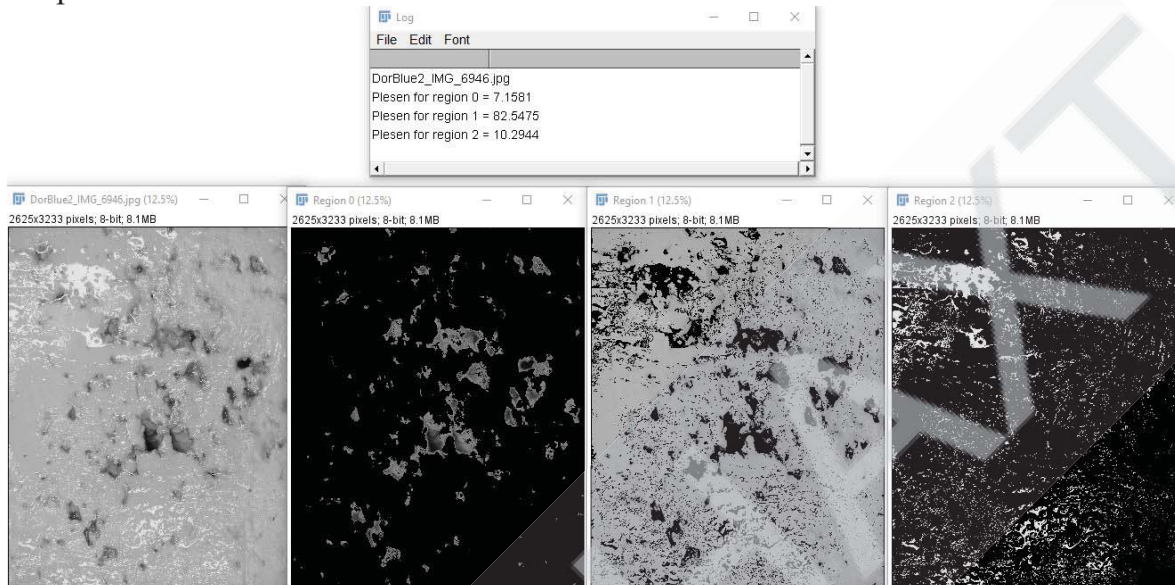


Figure 3. The result of image processing with MOT Segmentation macro

Figure 4 and figure 5 present original ROI images of samples of trademarks Bergader and EmborgUrenholt and segmented images for NumLevel 2. It is observed that Region 0 contains pixels of mould whereas Region 1 – the pixels of cheese. The sample of Bergader has  $C_{r0} = 10,3444$  and  $C_{r1} = 89,6556$ . The sample of EmborgUrenholt has  $C_{r0} = 17,4830$  and  $C_{r1} = 82,5169$ . As it could be seen, the second trademark has more mould on its surface.

Figure 6 and figure 7 present original ROI images of samples of trademarks Bergader and EmborgUrenholt and segmented images for NumLevel 4. It is observed that Region 0 and Region 1 contain pixels of mould, where Region 0 – the pixels of areas with high concentration of mould and Region 1 – the pixels of areas with weak growth of mould. Region 2 and Region 3 contain the pixels of cheese. The sample of Bergader has  $C_{r0} = 5,0846$ ,  $C_{r1} = 15,3716$ ,  $C_{r2} = 58,8308$  and  $C_{r3} = 20,7130$ . The sample of EmborgUrenholt has  $C_{r0} = 5,3744$ ,  $C_{r1} = 11,6416$ ,  $C_{r2} = 23,6171$  and  $C_{r3} = 59,3669$ . The summary of Region 0 and Region 1 provide more quantity of the detected mould in comparison with quantity of mould detected in NumLevel 2.

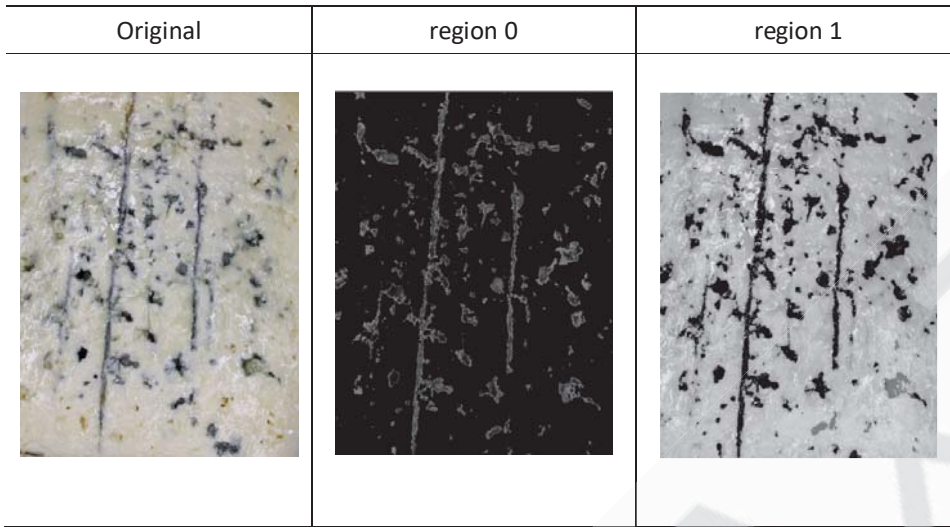


Figure 4. Images of sample of Bergader

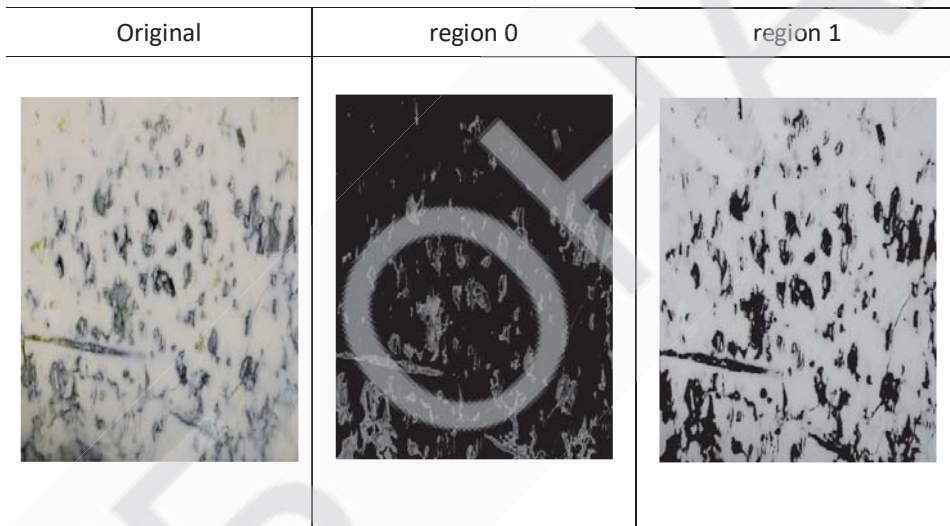


Figure 5. Images of sample of EmborgUrenholt

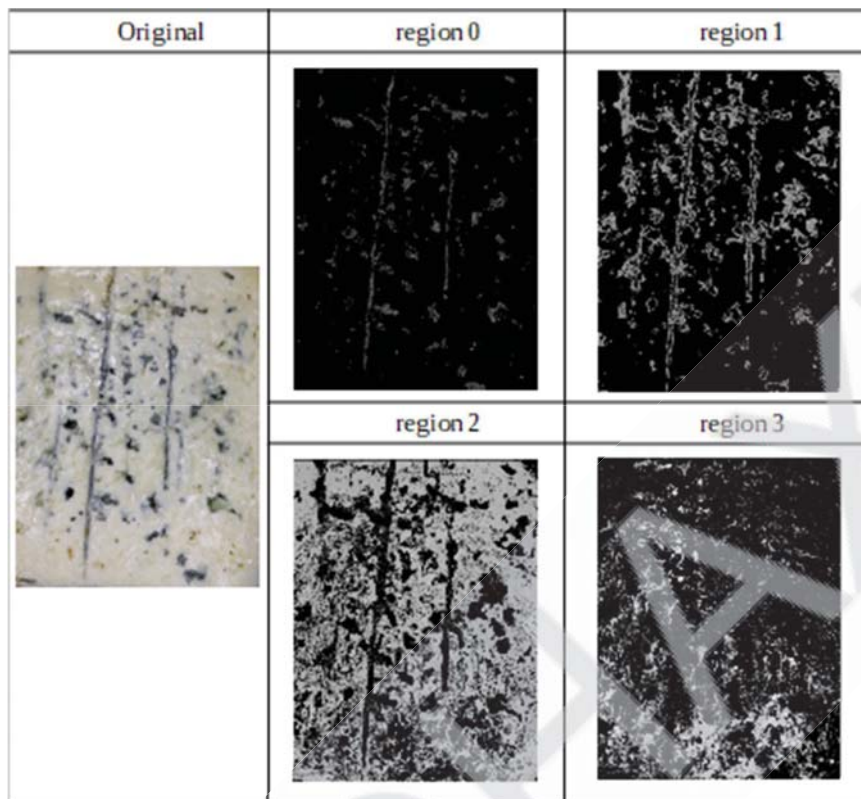


Figure 6. Images of sample of Bergader

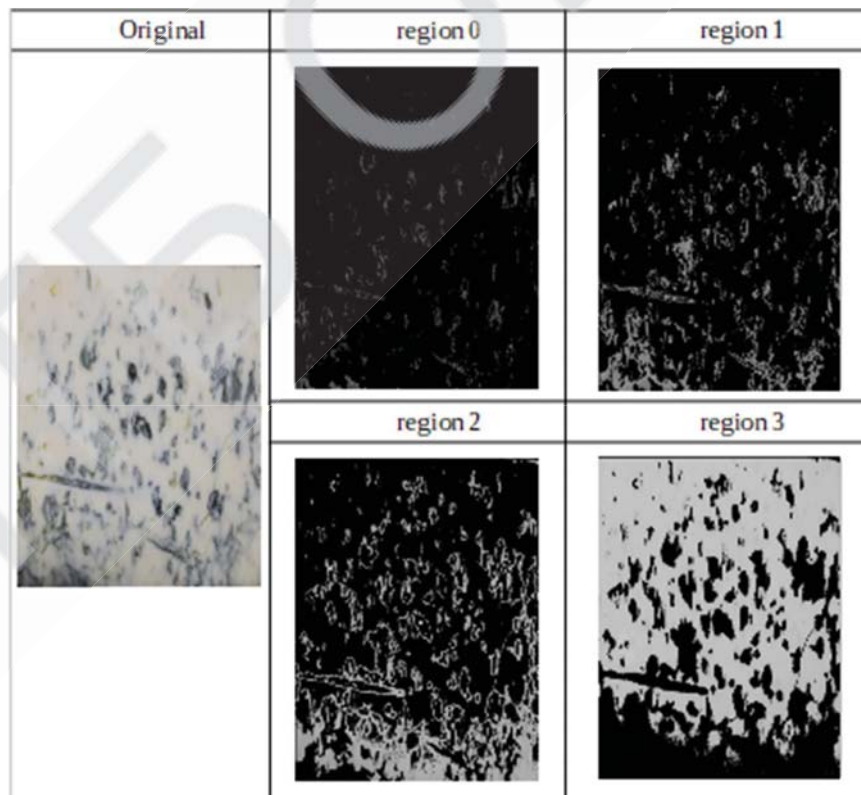


Figure 7. Images of sample of EmborgUrenholt.

Table 1 shows the results of the collected average values for the different NumLevels from 2 to 5 of the examined samples. It is observed that samples of Paladin ReginaBlue have the lowest values for regions with mould.

Table 1. Average values for  $C_{ri}$

	Bergader	Stefel Granbavarese	Dor Blue50%	Dor Blue55%	Emborg Urenholt	Paladin ReginaBlue	Ramberter	Dor Blue
Num Level 2	10,3892	12,4432	11,9790	8,2183	17,5186	6,6220	12,8912	11,6382
	89,6108	87,5653	88,0211	91,7817	82,4814	93,3780	87,1088	88,3618
Num Level 3	5,7883	7,0308	6,1462	4,7073	6,7440	2,8733	7,2868	7,2416
	24,1051	26,3342	26,4947	15,1670	24,3830	21,0053	29,0072	38,7117
Num Level 4	70,1065	66,6349	67,3591	80,1257	68,8728	76,1233	63,7060	56,8001
	4,0580	4,5142	3,1382	2,6825	3,8515	1,4549	4,4141	2,4064
	10,4091	12,0321	9,4648	6,3655	12,2251	6,2892	13,1222	11,9278
Num Level 5	37,9342	43,3369	31,7900	21,8918	26,6360	29,0076	39,7287	43,1751
	47,5988	40,1168	55,6070	69,0603	57,2874	63,2483	42,7352	42,4907
Num Level 5	3,0324	3,1798	2,2047	1,8885	2,7002	0,9637	2,7291	1,7021
	6,0966	7,2862	6,4901	4,6103	7,3730	3,3620	8,4635	6,8753
	16,4198	17,7926	17,5117	10,1401	14,6831	11,8184	19,1943	24,2655
	37,3478	38,4824	32,0568	29,9634	26,4067	32,9528	39,6876	33,4287
	37,1034	33,2590	41,7367	53,3977	48,8369	50,9030	29,9257	33,7285

Figure 8 presents the values of  $C_{ri}$  for areas with mould for all samples of trademarks Bergader and Emborg Urenholt. It is observed that samples of trademark Bergader have more areas with high quantity of mould but samples of trademark Emborg Urenholt have more areas with weak growth of mould. It could be seen on figure 8 a) that samples of Emborg Urenholt have more quantity of mould than samples of Bergader thanks to more areas with weak growth of mould (figure 8 b)).

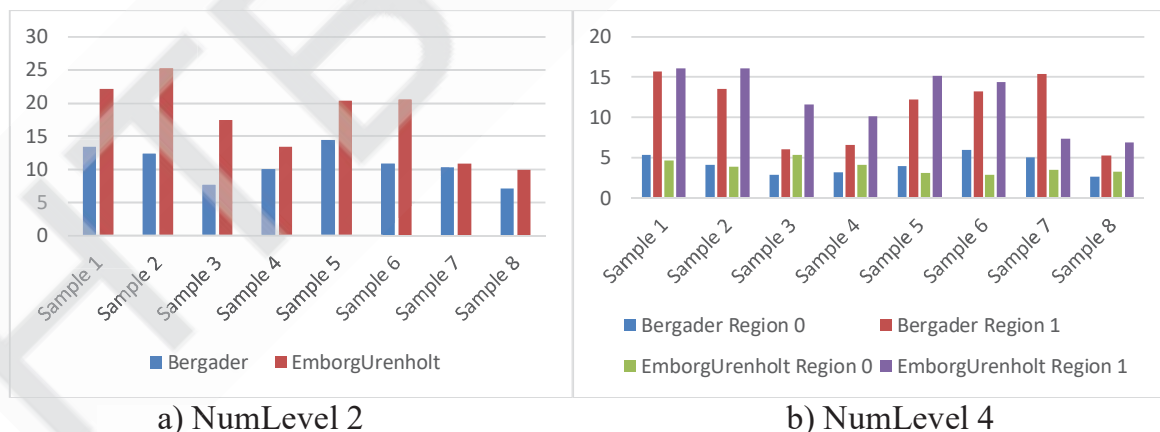


Figure 8.  $C_{ri}$  values for areas with mould

## V. CONCLUSIONS

The purpose of this research is to present the application of the Multi\_Otsu\_Threshold by developing a macro (MOT\_Segmentation) which could be applied in evaluating the presence of mould on the surface of blue cheese. Depending on the level of segmentation it could be detected mould in different stages of growth. Based on the obtained results, in the future a software could be developed which would be helpful in detecting the mould on the surface of different dairy products. As part of the future work, it could be examined the influence of the quantity of detected mould on the sensory characteristics of the blue cheese (taste, smell, flavour, etc.).

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