Possibilities for computer-based assessment the quality indicators of Kashkaval cheese using image processing

Alexandar Balabanov[1], *Hristina* Andreeva[2*], *Angel* Danev[2], *Atanaska* Bosakova-Ardenska[2], *Galin* Ivanov[1], and *Tatyana* Balabanova[1]

[1]Department of Technology of Milk and Milk Products, Faculty of Technology, University of Food Technologies, 26 Maritza Blvd., 4002, Plovdiv, Bulgaria
[2]Department of Computer Systems and Technologies, Technical Faculty, University of Food Technologies, 26 Maritza Blvd., 4002, Plovdiv, Bulgaria

Abstract. As a popular type of cheese in the Balkan Peninsula, Kashkaval cheese is an object of various researches related to its quality and safety. Many studies are performed to provide more objective techniques for sensory evaluation variety of cheese using computer-based technologies. Thus, the current study supports this trend by evaluating the potential for quality assessment of Kashkaval cheese using image processing. The current study presents two open-source software products – ImageJ and Scilab and their functionalities that are applied for image analysis of three samples of Kashkaval cheese, which are produced using different sodium chloride content. The cheese samples are also evaluated using a traditional procedure for sensory evaluation and these results are compared with results received by image processing. Specific structural elements with color, which is very similar to the color of the main cheese matter are effectively detected using different methods for edge detection in Scilab, and using analysis of luminance in ImageJ. Another observation indicates that the color of cheese samples could be effectively evaluated using ImageJ or Scilab. In conclusion, it could be noticed that open-source software products for image processing Scilab and ImageJ could be utilized for the quality evaluation of Kashkaval cheese to support the assessment of the visual quality characteristics.

1 Introduction

Cheese is a preferred dairy product in Bulgaria due to its positive effect on human health. Thus, a variety of cheeses are produced in this region, and the most popular are white brined cheese and Kashkaval cheese [1]. A set of government standards and manufacturing regulations are developed to ensure the production of quality and safety cheese. Specialized instruments and equipment are developed to control a wide range of parameters related to cheese quality. Advancement of techniques and technologies induct improvements in measuring and control devices, which are used in dairy industry and computer-based technologies also became crucial for quality control of manufacturing. In the last decade, many researches have been performed to utilize computer vision methods for cheese quality evaluation [2, 3, 4]. Non-destructive and contactless computer-based technologies, based on image processing, are effective tools for monitoring the fundamental processes during cheese production such as ripening [4]. Since digital image processing uses information, that is extracted from the visible part of the electromagnetic spectrum, specific structural elements of cheese that could be examined visually by experts became the subject of researches related to the application of computer vision methods [2]. As examples in this direction are results reported by Caccamo et al. [5] about measurement of gas holes in Swiss type of cheese using image processing (trough Matlab software); analyses about distribution of vegetables and herbs in cheese reported by Jeliński et al. [6] (using Matlab software); color measurement of Mozzarella cheese presented by Minz and Saini [7] (using Scilab software); monitoring the evolution of gas holes in a traditional Portuguese cheese during its ripening by image processing, reported by Dias et al. [8] (using ImageJ software); analysis of rind thickness of Trentingrana cheese based on image processing is reported by Caraffa et al. [9] (using Iris, AlphaMos, Tolouse France); assessment the presence of specific structures like parts of broken porcelain bowl (known as "Porcelanov lom") in Bulgarian white brined cheese, is reported by Danev et al. [10] based on image processing trough tailor-made application written on Java; identification of areas occupied by molds on surface of Bulgarian yellow cheese is reported by Mladenov et al. [11] using image processing in HSI (Hue, Saturation, Intensity) and RGB (Red, Green, Blue) color models.

Current research aims to propose an effective analysis of the cut surface and its color for Kashkaval cheese, produced using different sodium chloride content, through image processing based on open-source applications. The application of computer vision

* Corresponding author: h_andreeva@uft-plovdiv.bg

methods for laboratory experiments related to the development of Kashkaval cheese with reduced sodium chloride content correlates to modern concepts based on the utilization of computer-based technologies. Thus, the current study has become actual, especially in the context of the popularization of the utilization of open-source software for image analysis of cheese.

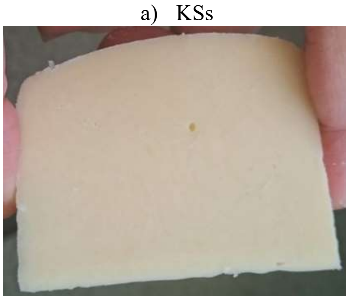
2 Materials and methods

2.1 Kashkaval cheese samples

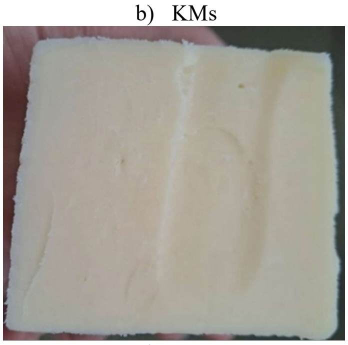
For this experimental work, three lots of Kashkaval cheese with content of NaCl in the final product – 3.1%, 1.5% and 0.7% were manufactured. In this way, the influence of the reduced salt content on the quality characteristics of Kashkaval cheese produced from cow milk is evaluated. The main organoleptic changes occurring during the storage period of the samples with different NaCl content are compared. The encoding of the experimental samples is as follows (their pictures are presented in Figure 1):

- KSs is Kashkaval cheese with a content of NaCl (3.1%);
- KMs is Kashkaval cheese with reduced content of NaCl (1.5%);
- KLs is Kashkaval cheese with a low content of NaCl (0.7%);

a) KSs



b) KMs



c) KLs

Fig. 1. Original images of Kashkaval cheese.

2.2 Sensory evaluation

The organoleptic assessment of studied samples of Kashkaval cheese produced from cow milk is conducted by a 50-points system, developed by specialists from the department of "Technology of milk and milk products" at UFT – Plovdiv, Bulgaria. During the assessment of each indicator, a certain number of points are deducted in the presence of deficiencies according to the description in Table 1. In the presence of two or more deficiencies for the same indicator, the deduction of the points has to be performed according to the most depreciating indicator.

Table 1. 50-points grading system of Kashkaval cheese.

Indicators and characteristics	**Minimal and maximal deduct**	**Assessment**
1. ***Appearance of the samples – 5 points***		
Smooth, clean, with a well-shaped surface, without technical deformations	0	**5**
Light dents (damage or deformation) and small creases on the outer surface	1 - 2	4 - 3
Deformed and softened surface with the visible presence of slime (ropiness)	3 - 4	2 - 1
2. ***Cut surface, structure – 10 points***		
Smooth, with uniform structure and uniform creamy yellow color, without highlighting the individual layers	0	**10**
Unevenly distributed creamy yellow color	1 - 2	9 - 8
Uneven structure, presence of separate layers	3 - 5	7 - 5
Presence of bacterial or technical holes	6 - 8	4 - 2
3. ***Color of the cut surface – 5 points***		
Uniform amber-yellow color, specific to the type of the cheese	0	**5**
Uneven color of the cut surface	1 - 2	4 - 3
Non-specific color with different color shades (pale yellow, greenish, bluish-gray, etc.)	3 - 4	2 - 1
4. ***Consistency – 10 points***		
Dense and elastic at 18 – 20 °C.	0	**10**
Poorly elastic	1 - 2	9 - 8
Soft, noticeably smearing	3 - 5	7 - 5
Soft, smearing	6 - 8	4 - 2
5. ***Taste and aroma – 20 points***		
A specific and well-expressed aroma of mature cheese, from moderately salty to salt-free taste, without aftertaste and smell	0	**20**
Poorly- expressed taste and aroma	1 - 3	19 -17
Unexpressed taste and aroma	4 - 6	16 - 14
Salty taste	7 - 10	13 - 10
Spicy taste	10 - 13	10 - 7
Presence of a slight, barely perceptible aftertaste and/or aroma.	14 - 17	7 - 3
Expressed bitter aftertaste	18 - 19	2 - 1

2.3 Computer-based color evaluation in La*b* color space

To perform computer-based color analysis of the cut surface of Kashkaval cheese three types of samples are captured using a digital built-in camera of a smartphone (Samsung A34). The device uses a Sony IMX582 – a Quad-Bayer sensor. It is a 1/2" sensor with 0.8µm pixels and it is based on a 26mm f/1.8 optically stabilized lens. Thus, one image of the control sample (KSs) is obtained, one for the reduced content of NaCl sample (KMs) and one for the low content of NaCl sample (KLs). Each image is precut in such a way to remove the background and to select a major region of interest without technical holes.

When dealing with color the preferred color model is La*b* because it is fundamental for instrumental color measurement devices. Thus, the La*b* color model is chosen for the current study. A mask sized with an odd number is used to analyze how even the color is in the whole cut surface of the sample. This mask is applied to define a set of squares (non-overlapping) that build the image, and a representative color extracted from each square as an average value, is used to accumulate in an array [12]. To analyze the evenness of the color all values of this array are used for statistical analysis. Every value in the array is calculated using the next formulae:

$$L_i = \frac{\sum_{j=1}^{mask*mask} L_{pix(k,l)}}{(mask*mask)} \quad (1)$$

$$a_i = \frac{\sum_{j=1}^{mask*mask} a_{pix(k,l)}}{(mask*mask)} \quad (2)$$

$$b_i = \frac{\sum_{j=1}^{mask*mask} b_{pix(k,l)}}{(mask*mask)} \quad (3)$$

where i has a value from 1 to (width of image/mask)*(height of image/mask), *pix(k,l)* is a pixel located in a square region defined by mask size. As a key assumption, it is expected that when a lot of colors, accumulated into the array are near to the mathematical expectation, then the color of the examined surface is even distributed and in opposite when a small number of colors are near to the mathematical expectation then the color of the examined surface is unevenly distributed. To prove this assumption an analysis based on confidence intervals is performed [13, 14].

A comparison between samples is also made based on difference between their colors, calculated as average values in La*b* color space. The difference between two colors (ΔE) is calculated using the following formula [15]:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (4)$$

where ΔL, Δa* and Δb* are components that define Euclidian distance between two points (colors).

The data for each color component of the cheese are analyzed. The mathematical expectation of every color component is determined by the next formula:

$$\bar{X} = \frac{X_1 + X_2 + \cdots + X_N}{N} = \sum \frac{X_k}{N} \quad (5)$$

where $X_1, X_2, \ldots, X_N$ are values determined for each color component for ROIs of all examined samples. The number of the obtained ROIs depends on the used mask size. The dispersion and the standard deviation σ are determined by formula (6).

$$\sigma^2 = \frac{[(X_1 - \bar{X})^2 + \cdots + (X_N - \bar{X})^2}{N-1} = \frac{\sum (X_k - \bar{X})^2}{N-1} \quad (6)$$

The upper L_{MAX} and the lower L_{MIN} limits, of the color values for each color component, are calculated using formulae (7) and (8).

$$L_{MIN,MAX} = \bar{X} \mp \frac{\sigma}{\sqrt{N}} t_{\frac{1+\varphi}{2}, N-1} \quad (7)$$

$$t_{\frac{1+\varphi}{2}, N-1} = t_{1-\frac{\alpha}{2}, N-1} \quad (8)$$

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

In this research, the color of Kashkaval cheese samples is evaluated using two different software products with public domains – ImageJ and Scilab. Both programs provide a wide range of possibilities for digital image processing and the implementation of additional data processing using built-in programming tools. Two different programs are developed according to the capabilities of the selected two software products, and their structure is described in the next two sub-sections.

2.3.1 Using the open-source software Scilab

Scilab is a powerful software for scientific computing. It is freely available and it is widely used in engineering, scientific, and mathematical communities as an alternative to commercial packages such as MATLAB. Scilab features such as high performance and flexibility, making it suitable for numerical analysis, statistics, image processing, and more tasks. It is completely free and distributed under a license that allows free modification and extension of the software, uses a matrix-based approach to calculations, and allows easy management of large data sets creating the graphs that are used to visualize data and results. Scilab supports a variety of modules and libraries that extend its functionality in areas such as optimization, signal processing, image processing, and more. It offers interfaces for integration with other languages such as C, C++, Fortran and Java, allowing easy extension of its functions. It can be used on various operating systems, including Windows, macOS, and Linux [16].

A program in Scilab 6.1.1 was developed to analyze the color of Kashkaval cheese using the La*b* color model. The workflow of the developed program is presented in Figure 2. The images are loaded automatically and then converted from RGB to La*b* color space by user-defined program code based on the theoretical formulas by passing through XYZ coordinates. The time required to perform this conversion is measured. It is set from which point to start measuring the time using the tic() function, and the measurement ends assigning elapsed time to a variable using function toc(). The measured time in seconds is stored in the variable Time_1. Then the mask size is set and the image traversal is started by summing the values of all the pixels falling in the mask for each component separately. The average value of the color components for the region of interest defined by the mask is calculated, the sequence number of the investigated region is increased and these values are saved in a text file. These actions are repeated until all the pixels in the image are traversed. The time required to obtain the averaged color values for all obtained areas is measured and saved in the Time_2 variable. After the algorithm is finished, the total processing time is calculated as the sum of the two measured times (Time_1 and Time_2), and all three values are written into a text file.

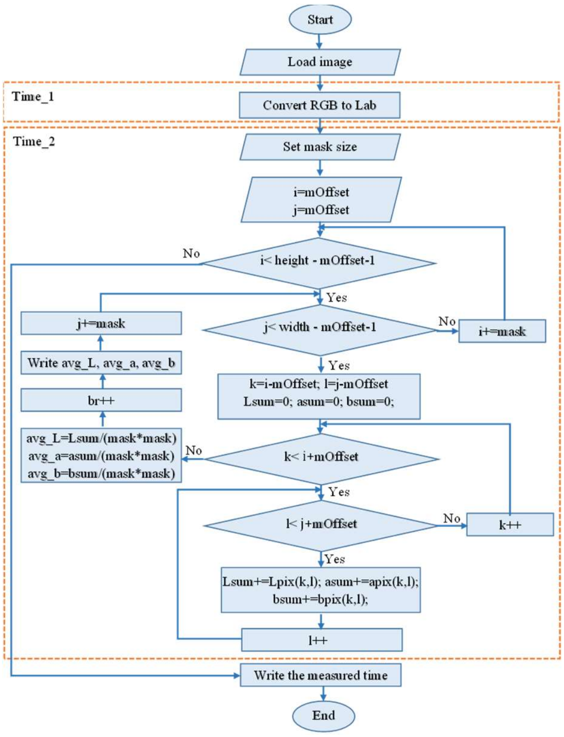


Fig. 2. Workflow of the program for Kashkaval cheese color evaluation implemented in Scilab software.

2.3.2 Using the open-source software ImageJ

ImageJ is a widely used open-source software for digital image processing. It is a Java language-based program that can be used as an online application or as a downloadable application, on any working station with Java virtual machine version 1.4 or later installed. As a downloadable application, ImageJ can be used with Windows, Mac OS, Mac OS X, or Linux. The program works with different image formats such as TIFF, GIF, JPEG, BMP, DICOM, FITS, and "raw". ImageJ provides a wide range of functions for digital image editing, analyzing, displaying, image segmentation, and much more. The program provides opportunities to work with stacks of images. It can perform different calculations over image pixels, such as area calculation of a user-defined region of interest, pixel value calculation and different statistics can be calculated too. The program can create histograms and supports standard image processing functions such as contrast manipulation, smoothing, sharpening, edge detection, and filtering using a variety of algorithms. It provides standard geometric transformations such as scaling, rotation and flips [17].

The open architecture of the program ImageJ provides extensibility to develop Java plugins or macros based on macro language. Developed plugins or macros can be successfully used in computer-based systems for quality control of food products by evaluation of different visual parameters.

In this research, ImageJ version 1.54g is used to develop a macro program for color evaluation of Kashkaval cheese using La*b* color space. Initially, input images are transformed from RGB to La*b*. The overall color evaluation of the Kashakaval cheese can be divided into two main steps (1) and (2) as shown in Figure 3. The process begins with starting the ImageJ program, and manually opening the initial image (KSs, KMs, KLs one at a time). Set the desired mask size and manually run the macro program from the ImageJ interface (1). The process continues with macro execution labeled as step (2) in Figure 3. In the developed macro program, a set of global variables is initialized at the beginning (2.1).

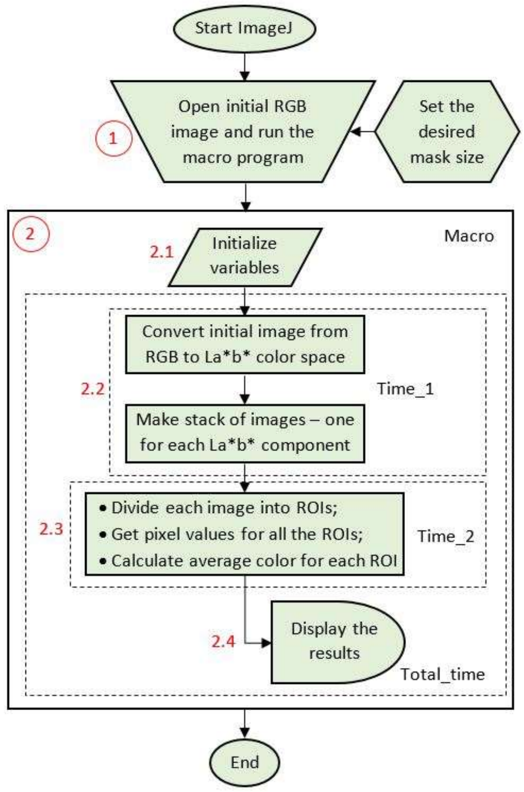


Fig. 3. Workflow of the process for Kashkaval cheese color evaluation implemented in ImageJ software.

After that, the program continues its execution by performing the sub-processes (2.2) where the program converts the currently loaded initial image from RGB to La*b* color space by using the build-in ImageJ function

"Lab Stack" and generates a stack of three images – one for each of the La*b* color space components. Using the getTime() function, it is measured the elapsed time for image conversion and for the stack of images creation (Time_1). In sub-process (2.3), the macro performs the main processing algorithm, in which each image from the stack is separately processed by dividing it into regions of interest (whose amount depends on the size of the mask set in the beginning), and for every ROI all pixel values are extracted and used for the calculation of the average color for each ROI. Time_2 is measured for sub-process (2.3). At the end of the macro execution, results for the average color of each ROI and the calculated times are displayed. Additionally, Total_time for the sub-processes (2.2), (2.3) and (2.4) is calculated and displayed too.

2.4 Structural elements evaluation

The structure of the Kashkaval cheese cut surface could have specific elements that are reasons to decrease the score for this quality characteristic, as described in Table 1. The presence of such elements is visually observed by experts, consequently it could be evaluated by image processing using appropriate algorithms. The next two sub-sections present opportunities to analyze the structure of the cut surface of Kashkaval cheese using algorithms implemented in Scilab and ImageJ software products.

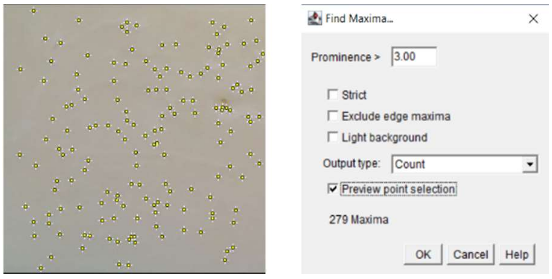
2.4.1 Using the open-source software Scilab

The sensitivity of edge detection methods to small differences in the gradient of color and grayscale images is widely used in image analysis to extract information about specific regions in images. Different methods for edge detection based on specific kernels, such as Prewitt and Canny are effective in distinguishing contours in inverted images [18]. Another research [19] highlights the utilization of a variety of methods for edge detection that are implemented in Matlab software for evaluation of agricultural and food products. Continuing work in this direction, our research presents opportunities for quality assessment of the specific type of cheese (Kashkaval) using edge detection methods implemented in Scilab to extract valuable information from images of cheese samples.

Scilab has a built-in function for edge detection that has the following syntax construction "BW = edge(I, method, threshold)", where I is the input image, which must be grayscale (MxN matrix). If the input is an RGB image, it is necessary to convert it to grayscale before using edge detection. The method is a string specifying the edge detection method. Available methods are: 'sobel', 'canny', 'prewitt', 'fftderiv' and 'log' (Laplacian of Gaussian). The threshold is an optional threshold value that controls the sensitivity of the edge detection method and varies between 0 and 1. Lower thresholds detect more edges, while higher thresholds focus on stronger edges. When setting a binarization threshold, default values can be used, or methods can be applied to automatically determine the threshold value to set for this parameter. In Scilab, only Otsu's method for automatically determining a threshold for binarization has been implemented. For the 'sobel' and 'prewitt' methods, the direction parameter can also be set, which specifies the direction to calculate the gradient of the image. The 'log' method also uses the sigma parameter, which is the standard deviation of the LoG filter, and the size of the LoG filter is nxn, where n = ceil(sigma*3)*2+1 (the ceil() function is used to round the calculation result). When choosing the 'canny' method, the threshold parameter can be a two-element vector, in which the first element is the low threshold and the second one is the high threshold. If the threshold is a scalar value, the low threshold is 0.4*threshold and the high one is the threshold value itself. The parameter sigma is the aperture parameter for canny operator, which must be 1, 3, 5 or 7 [16]. A binary image is a result of applying edge() function of Scilab and the next step of program is execution of imlabel() function to count located in the processed image objects (structural elements). The number of found objects is stored in a text file and the information about the values of edge() function parameters.

2.4.2 Using the open-source software ImageJ

In image analysis, the location of areas, that have high contrast in comparison with the background of the image, often corresponds to the identification of specific objects and features. As a useful tool for the implementation of such functionality, Find Maxima function of ImageJ is a popular instrument for image analysis in various scientific and practical areas. For example, counting birds to analyze their migration is successfully performed using Find maxima function of ImageJ to evaluate a dataset of videos captured during their flights [20]. Another research using ImageJ, especially its Find Maxima function, proposes an automated approach to counting wheat ears, thus supporting agricultural development [21]. The current research utilizes the Find Maxima function to locate specific structures on the cut surface of Kashkaval cheese that are formed during cheese maturation, mainly when the concentration of sodium chloride is reduced. These structures are visually highlighted on the examined surface, which motivates their localization through image analysis using a built-in function called "Find Maxima…". It is a part of the "Process" menu of ImageJ. The tool determines the local maxima in the currently loaded image and creates a binary image of the same size with the maxima, or one segmented particle per maximum, marked and labeled. The analysis can be performed on an existing rectangular selection (part of the original image) or the entire image if no selection is made. In this study, the "Find Maxima…" function is performed on images in RGB and HSB color spaces. Figure 4 shows an example of an RGB image analyzed with "Find Maxima…" function.



a b

Fig. 4. a) Detected and marked all maxima in a sample of Kashkaval cheese; b) "Find Maxima…" tool settings.

The process of analyzing images of Kashkaval cheese using "Find Maxima…" tool of ImageJ consists of several steps. It begins with starting the ImageJ program and manually opening an initial image. After that, the "Find Maxima…" tool is used and initial parameters are set. When the *"Output type"* parameter is set to be *"Count"* and a *"Preview point selection"* is checked, the amount of all detected maxima in the current image is shown on the screen immediately. For this research, seven different values for the parameter *"Prominence"* are used: 3, 5, 7, 9, 11, 13 and 15. Two additional analyses are made – when the initial image is transformed in grayscale format and when it is transformed in HSB color space. Thus, each channel (R, G, B and H, S, B) is separately analyzed using the "Find Maxima…" tool. The information for all counted elements is stored in an electronic table for additional analysis.

3 Results and discussion

3.1 Sensory evaluation

The organoleptic assessment of the studied samples is performed on the ninth month from the date of their storage and the results are presented in Figure 5. The specific taste-aroma characteristics of the different types of cheese are determined by the ratio of multiple components such as volatile fatty acids; esters and ketones of these acids; free amino acids; amines, peptides and peptones, which are formed as a result of complex biochemical transformations of the lactose, the proteins and the milk fat during the period of ripening and storage of the cheese. The amount of salt determines the taste, consistency and appearance of cheese and has important meaning for microbiological safety and quality of the ripened product [22, 23]. It is evident that at the end of the storage period with high organoleptic assessment are samples labeled KSs, followed by sample KMs and the lowest organoleptic assessment is for sample KLs. A maximum number of points is awarded for the appearance indicator because all three samples have a regular parallelepiped shape, with a flat top and bottom base. This is due to the circumstance that the storage process is conducted in a packaged state of the Kashkaval cheese, in which the indicator is preserved to the maximum extent.

Fig 5. Organoleptic assessment of Kashkaval cheese with different contents of sodium chloride, stored for nine months.

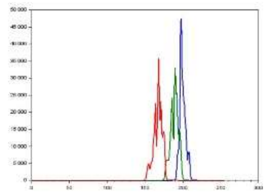
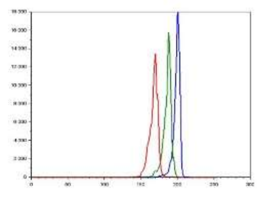
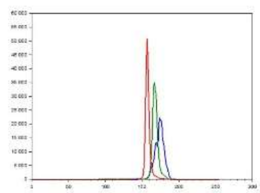
The sample KSs has good taste-aroma properties and it receives high assessment points on the indicators: consistency – dense and elastic; cut surface – smooth with well-expressed uniform structure and uniform yellow color onto the whole exterior and interior surface; taste and aroma – well-expressed slightly spicy and moderately salty. At the end of the storage period, the sample KMs emphasized the expressed aroma of ripened Kashkaval cheese, a slightly salty and spicy taste and barely perceptible aftertaste and odor. The consistency is soft, not elastic and noticeably greasy. For the cut surface indicator, it is established that there is an uncharacteristic slightly grainy structure and uneven distribution of light yellow color with the presence of formed small white crystals. The KLs sample is characterized by a highly expressed aroma, bitter taste and barely perceptible salt aftertaste, and regarding the consistency indicator – soft and greasy. The color of the sample is light yellow and uneven and the cut surface has non-uniform structure with the presence of visible white crystals. Similar results are obtained by Møller et al. [24], who analyze samples of Cheddar cheese with different content of salt – 0.9%, 1.3%, 1.7% and 2.3% for a storage period of nine months. The authors find an increase in bitterness and a decrease in the sensation of salty taste in cheeses with NaCl concentration of 2.3% to 0.9%. Rulikowska et al. [25] also found an increase in bitterness with decreasing NaCl content in Cheddar cheese. Several researchers have suggested that NaCl inhibits the hydrolysis of β-casein, which casein fraction is mainly responsible for the appearance of bitter taste in cheeses [26, 27]. Guinee и Sutherland [28] hypothesized that organoleptic defects in cheese correlate with the values of the salt indicator in the aqueous phase. According to the authors, each type of cheese has a precisely defined ratio between the indicators of salt and water content (S/M). Lowering the values of this ratio leads to a change in the quality characteristics of the cheese due to unwanted bacterial growth and uncontrollable enzyme activity. In Cheddar cheese, in addition to bitterness, an unpleasant aftertaste and an unexpressed aroma, another drawback was found, namely the formation of crystals during the ripening and storage of the cheese. According to Agarwal et al. [29] this process is more pronounced in cheese with low S/M values (less than 3.6%), compared to Cheddar cheese with an S/M ratio of 4.5%. Also, the formation of crystals is a result of the deep hydrolytic changes that occur during the ripening and storage process in semi-hard and hard cheeses [30]. The amino acid tyrosine is released and grouped in the cheese matrix forming hard crystals with a white color [31]. Although tyrosine makes a significant contribution to the organoleptic properties of cheese, it is actually tasteless. The formation of the tyrosine crystals also predetermines the pronounced sandy and non-uniform consistency in the cheese.

From the obtained results presented in Figure 5, it is evident that the indicators of taste and aroma, consistency, cut surface and color undergo significant changes in the storage period, compared to the indicator of appearance.

3.2 Computer-based evaluation

To test the capabilities of the open-source software, images of cheese with different amounts of sodium chloride were used. Table 2 presents the major ROIs of original images and their histograms.

Table 2. Images of tested samples and histograms.

Original image (ROI)	Histogram
KSs	
	
KMs	
	
KLs	
	

To analyze the color of the different cheese samples, tests were made with different mask sizes 3x3, 5x5, 7x7x, 9x9, 11x11, 13x13 and 15x15. Processing each image with a given mask results in the averaged color values for the multiple regions into which the image is divided. These values (averaged) of all regions are used to calculate color for the whole sample as average. Color differences between couples KLs/KSs, KMs/KSs and KLs/KMs are calculated using formula (4) and results are presented in Table 3. It is observed that the lowest color difference (about 2) is calculated for colors of samples KMs and KSs which could be explained with small visual differences registered for these samples (registered by sensory evaluation). The highest color difference (about 10) is calculated for colors of samples KLs and KSs that corresponds to significant differences for color of their cut surfaces (registered by sensory evaluation). As a conclusion, calculated color difference has very small fluctuations depending on mask size, which could be explained with uniformity of the color for all samples.

Table 3. Color difference ΔE

Mask size	KLs/KSs	KMs/KSs$	KLs/KMs$
3	10.13	1.97|1.98	8.85
5	10.12	2.00	8.82
7	10.11	1.95	8.89
9	10.08	1.98	8.83
11	10.08	1.98	8.83
13	10.11	1.96|2.04	8.83|8.85
15	10.09	2.01	8.87

$Scilab|ImageJ

The limits of the confidence intervals are calculated using formulae (7) and (8). It is checked how many obtained color averages fall within the confidence interval and it is calculated the percentage of areas that fall within that interval. The obtained results are presented in Table 4, where the hit rates in the confidence intervals at different alpha values for both software products are presented. About 75% of the values obtained by Scilab and ImageJ match exactly, so one number is given in the table. In the remaining cells, the value obtained with Scilab is shown on the left of the vertical line, and the value obtained with ImageJ is on the right. These differences are due to a different ways RGB images are converted to the La*b* color system. In ImageJ, a built-in function is used, and in Scilab a program to convert the images. Another reason for the observed differences in color components is related to the different implementation of floating point numbers into utilized software products, which is crucial when calculating color transformation. From the table, it can be seen that at α=0.05 and mask size 5x5, 9x9 and 15x15 and at α=0.1 and mask size 5x5 and 15x15 for the L color component, a decreasing trend is observed for the number of ROIs falling into the confidence interval which corresponds to decrease of sodium chloride content for examined samples, and to the decreasing quality of the cut surface consequently.

When examining the color of the cheese samples, the time required for the two software products to perform the image processing was also measured. For this purpose, a portable computer system with CPU Intel(R) Core (TM) i5-11320H CPU @ 3.20GHz 3.20 GHz, 8 cores, and 8 GB internal memory was used. The time needed for the image processing for each sample with different mask size is measured ten times and average values are calculated.

Table 4. Number of regions in the range of confidence intervals for all images processed with different mask sizes, in percentages.

		α =0.01			*α =0.05*			*α =0.1*		
Mask	**Sample**	**L $^{\$}$ (%)**	**a*$^{\$}$ (%)**	**b*$^{\$}$ (%)**	**L $^{\$}$ (%)**	**a*$^{\$}$ (%)**	**b*$^{\$}$ (%)**	**L $^{\$}$ (%)**	**a*$^{\$}$ (%)**	**b*$^{\$}$ (%)**
3x3	KSs	1.14|1.00	0.08|0.97	1.58|1.77	0.89|0.81	0.03	1.34|1.32	0.78|0.80	0.02|0.01	0.68|0.71
	KMs	1.48	0.97	0.34	1.08	0.25	0.23	1.00	0.08	0.17
	KLs	1.01	0.20	6.04|6.08	0.86	0.17	5.02	0.55	0.13	4.29
5x5	KSs	1.91	0.15|0.14	3.69|3.70	1.59	0.10	2.58	1.33	0.09	1.99
	KMs	2.02	2.13|2.11	0.53	1.46	1.55	0.35	1.16	1.07	0.30
	KLs	1.88	0.95	5.66|5.65	1.29	0.85	4.30	0.84	0.57	3.39
7x7	KSs	2.71|2.69	5.04|5.00	4.60|4.61	2.00	0.72|0.64	3.00	1.61	0.26|0.28	2.17|2.16
	KMs	3.16	7.30|7.33	1.65	2.42	3.44	0.70	1.93	3.16	0.32
	KLs	2.95	1.47	6.74	1.78	1.07	5.65	1.40	0.81	4.54
9x9	KSs	3.51	4.86|4.81	6.47	2.52	0.33	4.76|4.81	1.88	0.23	3.67
	KMs	3.15	7.28	2.80	2.33	5.30	1.81	1.69	3.90	1.17|1.22
	KLs	3.63	2.06|2.09	7.12	2.21|2.24	1.28	3.72	1.74	1.08|1.10	2.91|2.94
11x11	KSs	4.31	10.58	6.39	3.33	5.63|5.59	4.99	2.46	3.17|3.06	3.59
	KMs	4.08	10.33	4.08	2.95	5.03	2.17	2.43	3.99	1.48
	KLs	4.81	2.68	8.48|8.53	3.20	1.77	5.45	2.68|2.64	1.60	3.68
13x13	KSs	5.66	6.74|5.18	7.17|6.74	4.04	1.35|0.54	6.42|5.66	2.91	0.49	5.39|5.07
	KMs	4.66|4.57	12.19|12.72	3.35|4.08	2.99|3.95	8.84|8.27	1.08|3.70	2.27|2.84	7.77|5.43	1.08|2.59
	KLs	5.75	3.75	10.71	3.87	2.72	7.14	2.85	2.12	4.36
15x15	KSs	5.51	2.25	7.32	4.49	0.65|0.72	6.23	3.26	0.65	5.58
	KMs	6.19	15.72	5.52	4.18	10.03	4.52	3.18	7.86	4.01
	KLs	6.70	3.19	11.36	4.08	2.37	8.09	2.78	1.63	6.21

$^{\$}$Scilab|ImageJ

The average time needed for RGB to La*b* conversion is not related to the mask size. For the program in the Scilab environment, a value of 8.12 seconds is obtained, and for the macros in ImageJ – 0.12 seconds, which means that the second approach is significantly faster than the first. Additionally, another two times (Time_2 and Total_time) are studied and the average values are shown in Figure 6. It is observed that the measured processing time and the calculated total time for both programs depend on the mask size and with the increase of the mask size both times are decreasing.

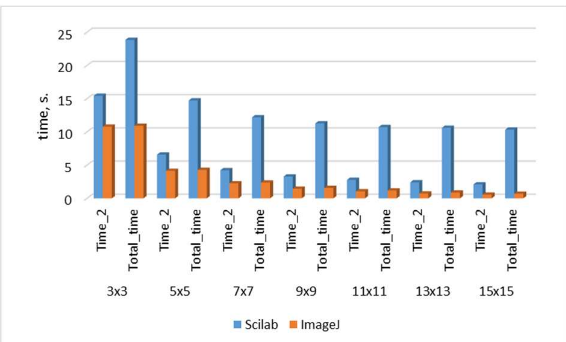
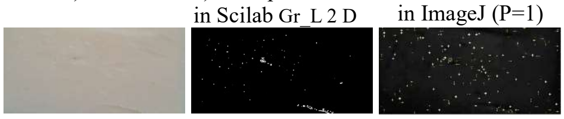


Fig. 6. Averaged times for image processing with different mask sizes.

Specific structural elements with a color close to the color of the main Kashkaval cheese matter are analyzed with both Scilab and ImageJ programs (Figure 7).

a) KSs | b) KSs processed in Scilab Gr_L 2 D | c) KSs processed in ImageJ (P=1)

d) KMs | e) KMs processed in Scilab Gr_L 2 D | f) KMs processed in ImageJ (P=1)



g) KLs | h) KLs processed in Scilab Gr_L 2 D | i) KLs processed in ImageJ (P=1)

Fig. 7. Examples for segmented images using Scilab and ImageJ environment.

For the approach based on image processing with Scilab environment, well-known edge detection algorithms with different parameters are tested. Several approaches are analyzed based on the color space that has been used. The first approach is based on edge detection algorithms applied directly to grayscale images obtained after performing the build-in Scilab function for RGB to Gray conversion (rgb2gray()). For the second approach, the RGB color components are extracted separately, then the edge detection algorithms are applied to the converted images. The third approach is based on HSV color space and the edge detection algorithms are applied individually to H, S and V color components. Additionally, edge detection algorithms implemented in Scilab have an important parameter such as the thresholding value. Two different thresholding values are tested – default and one calculated by Otsu's thresholding algorithm. A special encoding is composed based on the template **A_B C D** to present the results shown in Figure 7 and Figure 8, where **A** is a symbol for the color component that is used to extract information for the next processing steps, **B** is a method for edge detection (it could be one of Sobel (S), Canny (C), Prewitt (P), fftderiv (F) and Log (L)), **C** is the sigma parameter which applies to the 'log' (the standard deviation of the Log filter) and 'canny' (aperture parameter for canny operator) methods, **D** is a letter that indicates whether the default threshold value is used (D) or a value, which is calculated using Otsu's method is used (O).

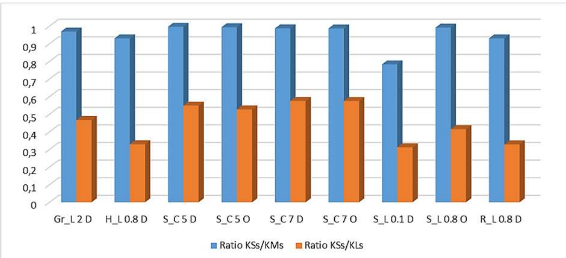


Fig. 8. Results for specific structural elements obtained using Scilab environment.

Based on a scored expert assessment a ratio between KMs (Kashkaval cheese with medium quantity of NaCl 8 of 10 points), KLs (Kashkaval cheese with low quantity of NaCl – 4 of 10 points) and KSs (Kashkaval cheese with standard sodium chloride content – 10 of 10 points) is determined. Thus, the ratio of KMs/KSs is about 0.8 % and the ratio of KLs/KSs is about 0.4 %. The ratios described above are used together with the data obtained after image processing and the final results are shown in Figure 8. From Figure 8, it can be seen that the closest results to the expert-scored assessment are obtained by applying Log edge detection algorithm with sigma values of 0.1, 0.8 and 2 by processing images with default or Otsu's thresholding value, as well as Canny edge detection algorithm with sigma value of 5 or 7 by processing HSV images with extracted saturation component only and applied default thresholding value or Otsu's one for segmentation. Mladenov et al. [11] and Mladenov [32] also found that saturation component is significant for identification of specific areas on the Bulgarian yellow cheese surface.

For the approach based on image processing with ImageJ application for specific structural elements evaluation on the cut surface of Kashkaval cheese, it is used Find maxima function. In this approach, RGB and HSB color spaces are used for processing the images and it has been found experimentally that the function Find Maxima with the parameter "*Prominence*" set to 1 or 6 gives satisfactory results only with images with extracted saturation component. The calculated ratios (KSs/KMs and KSs/KLs) are quite close to those established by the experts (Figure 9).

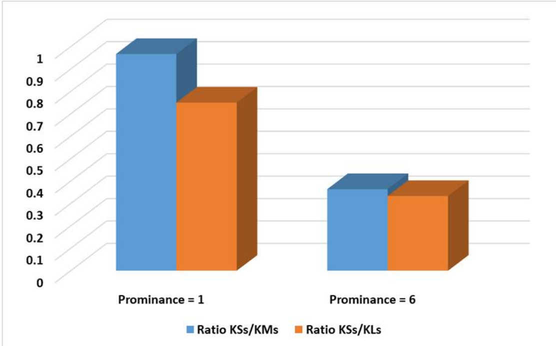


Fig. 9. Results for specific structural elements obtained using ImageJ application.

From the results, obtained using both software products, can be made a conclusion that edge detection algorithms implemented in Scilab environment provide more accurate results and the software can be used effectively for the detection and recognition of specific structural elements on the Kashkaval cheese cut surface.

4 Conclusion

The current research utilizes two popular in scientific practice software products to analyze visually evaluated quality characteristics of Kashkaval cheese. The examined quality characteristics are the quality of the cut surface and the color of the cut surface. Computer-based evaluation of the quality of the cut surface of the examined samples of Kashkaval cheese is based on the usage of built-in functions of both software products-Scilab and ImageJ whereas evaluation of uniformity of the color is based on user-defined programs implemented in Scilab and ImageJ environments. The experimental results could be summarized as follows:

- Regarding usage of the same model for information extraction to analyze uniformity of the color, experimental time complexity evaluation, that is performed for the execution of programs using Scilab and ImageJ, indicates faster work of ImageJ in comparison with the Scilab program.
- The luminance component of the La*b* color model is more informative for evaluation of the color of Kashkaval cheese in comparison with other two components of the same color model due to very small differences in the color hue of the smooth part of the samples and of the specific grains formed by tyrosine amino acid.
- Due to small differences in color for Kashkaval cheese and for light grains results of tyrosine grouping, edge detection methods are effective for localization of the specific grains of tyrosine.

As a benefit of the discussed research, it could be noticed that there are used images captured by smartphone device and open-source software, which is a cost-effective approach and thus it is more accessible to a wide range of potential users like small farms and dairies, but not only for big companies.

As a future work, accumulating images of Kashkaval cheese could allow the definition of exact quantitative relations between results of images processing and expert scores for the quality of the cut surface and its color, and thus the process for assessing the visual quality characteristics of Kashkaval cheese could be automated. Such automation could be integrated in production to support fast and robust quality control in dairy industry.

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