Cut surface of Bulgarian white brined cheese evaluation by image analysis in HSI color space

A Bosakova-Ardenska1, H Andreeva1, A Danev1, P Panayotov2, P Boyanova2
1University of Food Technologies, Technical Faculty, Department of Computer Systems and Technologies, Plovdiv blv. Maritza 26, Bulgaria
2University of Food Technologies, Technological Faculty, Department of Milk and Dairy Products, Plovdiv blv. Maritza 26, Bulgaria
e-mail: hristinaandreeva@abv.bg

Abstract. This paper presents a research over possibilities to evaluate a cut surface of white brined cheese by image analysis. Samples from seven trademarks of Bulgarian white cheese in brine are evaluated by experts and their cut surfaces are captured with digital camera. A Java application for color images processing in HSI color space is developed. The application executes multilevel thresholding and produces grayscale images with four colors – white, black, light gray and dark gray. The images of all tested cheese samples are processed with this application and there are calculated ratios of pixels with the same color to all pixels in the processed images (Kdiv for white, black, light gray and dark gray colors). The cut surfaces of cheese samples are evaluated by experts and it is performed a correlation analysis between experts’ estimation and the coefficients Kdiv. The results show that there is a significant correlation between experts’ estimation and the pixels with dark gray color (their coefficient Kdiv) in the processed images.

1. Introduction
Milk and milk products have a long history in a human diet. Many years ago (even during the ancient period) the human uses methods for long keeping the milk as milk products (cheese, curd and etc.). Milk and milk products contain essential protein, enzymes and microorganisms which are important part of healthy diet [1]. The milk is the most significant food for all mammals (including human). Important part of human growth (his baby period and infant period) is selection of similar to human milk foods like goat milk, quark with fruit and cheese [2]. The regions in the World have specific milk products and standards for their quality. In Bulgaria the most popular milk product is Bulgarian white cheese in brine [3]. The quality of Bulgarian white brined cheese is controlled by standards shortly described on Table 1.

All procedures for quality control of cheese characteristics are objective except one – the sensory evaluation according to standard BDS 15612-83. One of sensory parameters for cheese quality is the structure of cut surface. This surface contains two parts- first received by cutting and second received by fracture the cheese block. Previous researches show that images processing could be applied for computer evaluation of some specific elements on the cut surface of the cheese, such as smoothness, presence of technical holes [4,5], and presence of porcelain structures on the broken part of cut surface [6].

Many researchers last years have been working over application of HSI (Hue, Saturation, Intensity) color space in quality grading of fruits and vegetables [7, 8, 9, 10, 11, 12, 13, 14], meat [15, 16, 17] and other foods [14, 18, 19]. The reported results show that HSI color space is successfully applied for
evaluation some characteristics of quality of examined foods because this color model is designed to be very close to the human color perception.

### Table 1. Standards for quality control of Bulgarian white cheese in brine.

| Title | Description |
|-------|-------------|
| BDS 15:2010 | Bulgarian National Standard for Bulgarian white cheese in brine produced from cow, sheep, goat, buffalo milk or mixed milk. |
| BDS 15612-83 | Bulgarian National Standard for sensory evaluation of milk products. |
| BDS 1109-89 | Methods for determination the moisture and dry matter in milk products. |
| BDS 1111-80 | Determination of acidity in milk and milk products. |
| BDS 8274-82 | Methods for determination the NaCl in milk and milk products. |
| BDS EN ISO 8968-1 | Milk – determination the nitrogen content – Part 1 Kjeidahl method |
| BDS EN ISO 707 | Milk and milk products – Guidance of sampling |
| BDS EN ISO 6888-1 and BDS EN ISO 6888-2 | Microbiology of food and animal feeding stuffs- Horizontal method for the enumeration of coagulase-positive staphylococci: Part 1 and Part 2. |
| BDS EN ISO 11290-1 and BDS EN ISO 11290-2 | Microbiology of food and animal feeding stuffs- Horizontal method for detection and enumeration of Listeria monocytogenes: Part 1 and Part 2. |
| ISO 3433 | Cheese- determination the fat content – Van Gulik method. |
| ISO 16649-1 and ISO 16649-2 | Microbiology of food and animal feeding stuffs- Horizontal method for the enumeration of beta-glucuronidase-positive Escherichia colli: Part 1 and Part 2. |

The aim of this paper is to present an research of possibilities for application of images processing in HSI color space for evaluation of whole cut surface of the Bulgarian white cheese in brine including both parts – cut surface and broken surface.

### 2. Materials and methods

#### 2.1. Cheese samples

Samples from seven trademarks Bulgarian white cheese in brine are examined. The cheese is produced using classic technology from cow milk. Cut surface of examined cheese is evaluated by two ways: sensory way by experts using standard sensory evaluation and by images processing using developed application. The images of cut surfaces are acquired by digital camera SONY DSC-HX300 and they are stored in BMP format.

#### 2.2. Application for images processing

It is developed a Java application for images segmentation in HSI color space. The HSI color space is chosen because the specific areas and structures on cut surface of the cheese are presented with small changes in pixels intensity. The application calculates limits for every color component in three different modes (Mode 0, Mode 1 and Mode 2). On figure 1 is presented workflow of the application. The main steps in program workflow are:

1) Select experimental data and settings: this step consist of choosing a directory with experimental images (the folder must contain only images for experiment), setting the number of images for processing and choosing the algorithm mode.

2) Images processing: this step includes a multilevel thresholding (segmentation) of selected images in HSI color space and calculation of $K_{dev}$ by formulae 1 for every image. Image processing is implemented using Java class ImageIO.
According to selected processing mode five limits (L1 to L5) for the three components (Intensity, Saturation and Hue) in HSI color space are used. All pixels that have intensity between L1 and L2 are presented with black color in grayscale image; between L2 and L3 are presented with dark gray color; between L3 and L4 are presented with light gray color; between L4 and L5 are presented with white color. The limits are calculated using sorted information for Intensity, Saturation and Hue components. Formulae (2) present the values for limits in different modes for the color components.

\[
\begin{align*}
K_{div\text{w}} &= \frac{c_{\text{min}}}{c_{\text{all}}} \times 100; K_{div\text{lg}} &= \frac{c_{\text{light gray}}}{c_{\text{all}}} \times 100; \\
K_{div\text{dg}} &= \frac{c_{\text{dark gray}}}{c_{\text{all}}} \times 100; K_{div\text{bl}} &= \frac{c_{\text{black}}}{c_{\text{all}}} \times 100
\end{align*}
\]  

(1)

Formulae (2) present the values for limits in different modes for the color components.

\[
L_1 = \text{color}\_\text{component}[0]
\]

\[
L_2 = \begin{cases} 
\text{color}\_\text{component}[\text{pixel}\_\text{count}/4], & \text{mode} = 0 \\
\text{color}\_\text{component}[3 \times \text{pixel}\_\text{count}/8], & \text{mode} = 1 \\
\text{color}\_\text{component}[\text{pixel}\_\text{count}/8], & \text{mode} = 2
\end{cases}
\]

\[
L_3 = \text{color}\_\text{component}[\text{pixel}\_\text{count}/2]
\]

\[
L_4 = \begin{cases} 
\text{color}\_\text{component}[3 \times \text{pixel}\_\text{count}/4], & \text{mode} = 0 \\
\text{color}\_\text{component}[5 \times \text{pixel}\_\text{count}/8], & \text{mode} = 1 \\
\text{color}\_\text{component}[7 \times \text{pixel}\_\text{count}/8], & \text{mode} = 2
\end{cases}
\]

\[
L_5 = \text{color}\_\text{component}[\text{pixel}\_\text{count}]
\]

(2)

\[
\text{Select experimental data and settings}
\]

Choice a directory

Set the number of files for processing

Choice processing mode

\[
\text{Images processing}
\]

Multilevel thresholding of each of the selected files (images) in HSI color space

Calculation of \(K_{div}\) for black, white, light gray and dark gray pixels

\[
\text{Visualization of the results}
\]

Visualization of all \(K_{div}\) coefficients for each image of the sample

Visualization of average \(K_{div}\) coefficients for the sample

**Figure 1.** Workflow of the application.
3) Visualization of the results: in this step processing results of all experimental images are displayed. Displayed information contains:

- file name and coefficients by formulae (1) for every grayscale image;
- average $K_{\text{div}}$ of black pixels;
- average $K_{\text{div}}$ of dark gray pixels;
- average $K_{\text{div}}$ of light gray pixels;
- average $K_{\text{div}}$ of white pixels.

The application saves grayscale images into a sub-directory of the working directory with automatically generated name (this name is displayed into Results dialog). Figure 2 presents GUI (Graphical User Interface) of the application. The first window (left side of Figure 2) is for settings and second window (right side of Figure 2) is for results.

2.3. Correlation analysis

Correlation analysis is a method for processing statistical data used to determine the degree of relationship between two or more variables. According to the measuring scale in which the variables are expressed, different correlation coefficients are used. The most popular correlation coefficient is Pearson's correlation coefficient that requires both variables to be measured on a metric scale. The absolute value of this correlation coefficient is in the range from 0 to 1 [20]. This coefficient is used for the purpose of the current study.

3. Results

Table 2 presents images of cut surfaces of the cheese samples before and after processing with the developed application. Images of all samples are processed in Mode 0, Mode 1 and Mode 2. It is observed that smooth cut surface (up half of the image) is presented with dark gray color in the processed images. The broken part of cut surface has complex 3D structure and it contains four colors in the processed images.

Figure 3 presents average results of experts’ sensory evaluation for examined cheese. According to the standard this estimation is an integer between 2 and 15. It is observed that cheese samples of trademark “Mechkarevo” and “Dobrotica” have high estimation. Their cut surface is smooth with porcelain structures on the broken part of the surface (Table 2).

![Figure 2. Application for cheese cut surface evaluation in HSI color space – GUI.](image)

![Figure 3. Averaged experts’ evaluation.](image)
| Original | Mode 0 | Mode 1 | Mode 2 |
|----------|--------|--------|--------|
| Matand   | ![Matand Mode 0](image1) | ![Matand Mode 1](image2) | ![Matand Mode 2](image3) |
| Olimpus  | ![Olimpus Mode 0](image1) | ![Olimpus Mode 1](image2) | ![Olimpus Mode 2](image3) |
| Vakom    | ![Vakom Mode 0](image1) | ![Vakom Mode 1](image2) | ![Vakom Mode 2](image3) |
| Shipka   | ![Shipka Mode 0](image1) | ![Shipka Mode 1](image2) | ![Shipka Mode 2](image3) |
| Dobrotica| ![Dobrotica Mode 0](image1) | ![Dobrotica Mode 1](image2) | ![Dobrotica Mode 2](image3) |
| Mechkarevo| ![Mechkarevo Mode 0](image1) | ![Mechkarevo Mode 1](image2) | ![Mechkarevo Mode 2](image3) |
| Domashno | ![Domashno Mode 0](image1) | ![Domashno Mode 1](image2) | ![Domashno Mode 2](image3) |
Tables 3, 4 and 5 present $K_{div}$ black, $K_{div}$ dark gray, $K_{div}$ light gray and $K_{div}$ white for processed experimental data (images) in three modes. Figures 4, 5 and 6 present averaged coefficients for grayscale images of samples summarized by trademarks in different modes.

### Table 3. Coefficients of black, white, light gray and dark gray pixels in percentage for Mode 0.

| Cheese samples | $K_{div}$ Black | $K_{div}$ dark Gray | $K_{div}$ light Gray | $K_{div}$ White |
|----------------|-----------------|---------------------|----------------------|----------------|
| Matand         |                 |                      |                      |                |
| Sample 1       | 6.93            | 7.67                | 31.19                | 34.19          |
| Sample 2       | 2.36            | 7.02                | 30.13                | 40.47          |
| Olimpus        |                 |                      |                      |                |
| Sample 1       | 9.20            | 25.83               | 32.90                | 32.05          |
| Sample 2       | 8.84            | 29.35               | 30.57                | 31.23          |
| Vakom          |                 |                      |                      |                |
| Sample 1       | 17.06           | 27.86               | 26.92                | 28.13          |
| Sample 2       | 17.73           | 27.40               | 26.77                | 28.08          |
| Shipka         |                 |                      |                      |                |
| Sample 1       | 0.75            | 27.06               | 31.57                | 40.60          |
| Sample 2       | 0.56            | 27.88               | 29.85                | 41.69          |
| Dobrotica      |                 |                      |                      |                |
| Sample 1       | 8.22            | 27.34               | 31.99                | 32.43          |
| Sample 2       | 2.81            | 28.23               | 31.19                | 37.75          |
| Mechkarevo     |                 |                      |                      |                |
| Sample 1       | 10.45           | 28.35               | 28.75                | 32.43          |
| Sample 2       | 6.61            | 29.11               | 28.57                | 35.69          |
| Domashno       |                 |                      |                      |                |
| Sample 1       | 0.73            | 27.26               | 29.55                | 42.44          |
| Sample 2       | 3.98            | 26.71               | 30.15                | 39.13          |

![Graph](image)

**Figure 4.** Averaged coefficients of black, white, light gray and dark gray pixels for Mode 0.

### Table 4. Coefficients of black, white, light gray and dark gray pixels in percentage for Mode 1.

| Cheese samples | $K_{div}$ Black | $K_{div}$ dark Gray | $K_{div}$ light Gray | $K_{div}$ White |
|----------------|-----------------|---------------------|----------------------|----------------|
| Matand         |                 |                      |                      |                |
| Sample 1       | 8.03            | 15.17               | 19.49                | 57.29          |
| Sample 2       | 3.38            | 15.50               | 17.07                | 63.03          |
| Olimpus        |                 |                      |                      |                |
| Sample 1       | 10.65           | 14.30               | 19.07                | 55.96          |
| Sample 2       | 10.65           | 18.19               | 18.05                | 53.09          |
| Vakom          |                 |                      |                      |                |
| Sample 1       | 23.43           | 14.28               | 14.53                | 47.73          |
| Sample 2       | 23.09           | 13.90               | 14.72                | 48.27          |
| Shipka         |                 |                      |                      |                |
| Sample 1       | 1.41            | 16.38               | 16.44                | 65.75          |
| Sample 2       | 2.39            | 15.36               | 16.21                | 66.01          |
| Dobrotica      |                 |                      |                      |                |
| Sample 1       | 9.90            | 14.35               | 16.41                | 59.32          |
| Sample 2       | 3.37            | 16.27               | 18.02                | 62.33          |
| Mechkarevo     |                 |                      |                      |                |
| Sample 1       | 13.52           | 15.19               | 16.14                | 55.13          |
| Sample 2       | 8.05            | 17.40               | 14.21                | 60.33          |
| Domashno       |                 |                      |                      |                |
| Sample 1       | 2.11            | 15.66               | 18.17                | 64.04          |
| Sample 2       | 4.40            | 15.98               | 16.80                | 62.81          |
Figure 5. Averaged coefficients of black, white, light gray and dark gray pixels for Mode 1.

Table 5. Coefficients of black, white, light gray and dark gray pixels in percentage for Mode 2.

| Cheese samples | Sample 1 | Sample 2 | Sample 1 | Sample 2 | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
|----------------|----------|----------|----------|----------|----------|----------|----------|----------|
| Matand         | 5.37     | 1.88     | 6.36     | 6.13     | 7.42     | 7.79     | 6.00     | 0.48     |
| Olimpus        | 39.44    | 38.16    | 38.18    | 39.73    | 41.76    | 41.35    | 37.57    | 38.09    |
| Vakom          | 40.25    | 42.56    | 40.86    | 39.91    | 37.80    | 37.99    | 42.36    | 41.26    |
| Shipka         | 14.92    | 17.39    | 14.59    | 14.20    | 13.00    | 12.85    | 19.45    | 20.15    |
| Dobrotica      | 0.60     | 2.01     | 5.38     | 2.01     | 0.64     | 3.24     | 4.15     | 4.77     |
| Mechkarevo     | 39.43    | 38.51    | 39.43    | 38.51    | 37.86    | 38.87    | 41.56    | 43.77    |
| Domashno       | 40.75    | 40.20    | 38.04    | 38.77    | 40.39    | 40.27    | 15.03    | 16.04    |

Figure 6. Averaged coefficients of black, white, light gray and dark gray pixels for Mode 2.

The values of $K_{div}$ for colors in segmented images are averaged by trademarks and these summarized values are used for correlation analysis versus the experts’ estimation.

A statistical analysis for different modes is performed using MS Excel and the results (Pearson’s correlation coefficients) are shown in table 6, 7 and 8. The results show that $K_{div}$ dark gray for Mode 0 has significant correlation with organoleptic evaluation for structure of cut surface.
Table 6. Correlation coefficients for Mode 0.

|        | $K_{div}$ Black | $K_{div}$ dark Gray | $K_{div}$ light Gray | $K_{div}$ White | Expert evaluation |
|--------|------------------|---------------------|----------------------|-----------------|-------------------|
| $K_{div}$ Black | 1                |                     |                      |                 |                   |
| $K_{div}$ dark Gray | 0.34             | 1                   |                      |                 |                   |
| $K_{div}$ light Gray | -0.67          | -0.27               | 1                    |                 |                   |
| $K_{div}$ White | -0.96            | -0.41               | 0.45                 | 1               |                   |
| Expert evaluation | 0.12             | 0.81                | 0.01                 | -0.24          | 1                 |

Table 7. Correlation coefficients for Mode 1.

|        | $K_{div}$ Black | $K_{div}$ dark Gray | $K_{div}$ light Gray | $K_{div}$ White | Expert evaluation |
|--------|------------------|---------------------|----------------------|-----------------|-------------------|
| $K_{div}$ Black | 1                |                     |                      |                 |                   |
| $K_{div}$ dark Gray | -0.64         | 1                   |                      |                 |                   |
| $K_{div}$ light Gray | -0.58          | 0.41                | 1                    |                 |                   |
| $K_{div}$ White | -0.97            | 0.54                | 0.39                 | 1               |                   |
| Expert evaluation | 0.12             | 0.23                | -0.47                | -0.05          | 1                 |

Table 8. Correlation coefficients for Mode 2.

|        | $K_{div}$ Black | $K_{div}$ dark Gray | $K_{div}$ light Gray | $K_{div}$ White | Expert evaluation |
|--------|------------------|---------------------|----------------------|-----------------|-------------------|
| $K_{div}$ Black | 1                |                     |                      |                 |                   |
| $K_{div}$ dark Gray | 0.86             | 1                   |                      |                 |                   |
| $K_{div}$ light Gray | -0.69          | -0.83               | 1                    |                 |                   |
| $K_{div}$ White | -0.92            | -0.77               | 0.40                 | 1               |                   |
| Expert evaluation | 0.15             | 0.24                | -0.03                | -0.25          | 1                 |

4. Conclusion
In this paper there are presented results of a research of possibilities for evaluation of cut surface of white cow cheese in brine using images processing in HSI color space. A Java application is developed for images processing. The application calculates $K_{div}$ black, $K_{div}$ dark gray, $K_{div}$ light gray and $K_{div}$ white coefficients for images of cut surface processed with multilevel thresholding in HSI color space. Three different modes for multilevel thresholding in HSI color space are implemented. The results show that $K_{div}$ dark gray in Mode 0 has significant correlation (about 0.81) compared with experts’ organoleptic evaluation. This result is encouraging and the research will continue with accumulating images of cut surfaces of Bulgarian white cheese in brine produced of various milk (goat, buffalo and mixtures) and adapting the application to work with such cheese.

5. References
[1] Walther B A, Schmid R, Sieber and K. Wehrmuller 2008 Cheese in nutrition and health Dairy Sci. Technol. vol. 88 pp 389–405
[2] Sen P. A, Mardinogulu and J. Nielsen 2017 Selection of complementary foods based on optimal nutritional values Scientific Reports DOI:10.1038/s41598-017-05650-0
[3] Weichselbaum E B, Benelam and H. Costa 2009 Synthesis report No 6: Traditional Foods in Europe In EuroFIR Project Management Office/British Nutrition Foundation United Kingdom
[4] Bosakova-Ardenska A, Kostadinova-Georgieva L., Shopov N., Panayotov P., Andreeva H., Boyanova P., Ganchovska V., Danev A., Pashova E. and Iliev T. 2019 A comparative study of thresholding algorithms for cut surface evaluation of Bulgarian white cow cheese in brine Scientific Works of University of Food Technologies vol. 66 issue 1 pp 136-142 ISSN 1314-7102 CD version, E-ISSN 2535-1311 online version
[5] Bosakova-Ardenska A. Panayotov P. and Boyanova P. 2019 Application of Auto-Threshold plugin for cut surface evaluation of white cheese in brine IOP Conf. Series: Materials Science and Engineering 618 012002 DOI:10.1088/1757-899X/618/1/012002

[6] Danev A., Bosakova-Ardenska A., Boyanova P., Panayotov P., Kostadinova-Georgieva L. 2019 Cheese quality evaluation by image segmentation International conference CompSysTech ISBN: 978-1-4503-7149-0 pp 161-168 DOI: 10.1145/3345252.3345258

[7] Ahmad U 2017 The use of color distribution analysis for ripeness prediction of Golden Apollo melon Journal of Applied Horticulture vol. 19

[8] Bakar A. B. Hisham A. Ishak R. Shamsuddin W. Z. Wan Hassan 2013 Ripeness Level Classification for Pineapple using RGB and HSI Colour Maps Journal of Theoretical & Applied Information Technology vol. 57 (3)

[9] Chopra Sh. and R. Kadyan 2017 Machine Vision Based Automated Object Sorter Using Digital Image Processing MATLAB International Journal of Engineering Development and Research (IJEDR) ISSN:2321-9939 Vol.5 Iss. 3 pp.23-26

[10] Khojastehnazhand M. M. Omid and A. Tabatabaeefar 2010 Development of a lemon sorting system based on color and size African Journal of Plant Science Vol. 4 No 4 pp 122-127

[11] Moallem P. N. Razmjoooy B. Mousavi 2014 Robust Potato Color Image Segmentation using Adaptive Fuzzy Inference System Iranian journal of fuzzy systems vol. 11 pp 47-65

[12] Saldaña E. R. Siche M. Luján R. Quevedo 2013 Review: computer vision applied to the inspection and quality control of fruits and vegetables Brazilian Journal of Food Technology vol. 16 pp 254-272

[13] Seema A. G. Kumar S. Gill 2015 Computer vision based Model for fruit sorting using K- Nearest neighbour classifier Int. J. Electr. Electron. Eng. vol.2 pISSN 1694-2426

[14] Sun Da-Wen 2008 Computer Vision Technology for Food Quality Evaluation Academic Press Amsterdam ISBN: 978-0-12-373642-0

[15] Chiara V. Nai F. S. A. Saada M.F.Ibrahima S. Sudina A. Zakariaa and A.Y.M. Shakaffa 2014 Meat Color Recognition and Classification Based on Color using NIR/VIS Camera 8-th MUCET, Melaka, Malaysia

[16] Krastea Iv. Vl. Ganchovska 2015 Determining the changes modification of HSI color components of sheep meat in the process of ripening Proceedings of "Innovation technologies in food industry: science, education and production" pp 307-311

[17] Sun Xin 2016 Prediction of Pork Color Grade Using Image Two-Tone Color Ratio Features and Support Vector Machine Advance Journal of Food Science and Technology vol. 11 (9) ISSN: 2042-4868 pp 593-598

[18] Golpouri I. J. Parian R. Chayjan 2014 Identification and Classification of Bulk Paddy, Brown, and White Rice Cultivars with Colour Features Extraction using Image Analysis and Neural Network Czech J. Food Sci. vol. 32 No 3 pp 280-287

[19] Sun Da-Wen T. Brosnan 2003 Pizza Quality Evaluation Using Computer Vision Part 1 Pizza Base and Sauce Spread Journal of Food Engineering vol. 57 pp 81-89

[20] Sharma A K 2005 Text Book of Correlations and Regression Discovery Publishing House ISBN 81-7141-935-6