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White bread porosity evaluation by image processing with HisMedian algorithm

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Abstract. This paper presents an application of algorithm HisMedian in the field of white bread porosity evaluation. There are proposed two modifications of algorithm HisMedian. The algorithm HisMedian and its modifications are implemented on Java. The images of examined bread are processed with proposed thresholding algorithms and a ratio of white pixels to all pixels is used for correlation analysis versus bread porosity measured by standard physicochemical procedure. The highest correlation coefficient is 0,93. It is proposed an equation for bread porosity evaluation using ratio of white pixels to all pixels for binary images which are produced by algorithm HisMedian and its modifications. The lowest absolute error for bread porosity calculated with proposed equation, is 1,83. The results show that the algorithm HisMedian and its modifications could be used for computer evaluation of white bread porosity.

1. Introduction

Bread and bread products are essential food for Eastern Europe and thus their quality is very important and it is controlled with a lot of standards. There are a lot of methods for quality control of bread and bread products [1]. Some of these methods are effective but they have a high cost (like a computer tomography). Now computer vision methods come to be very popular because they are effective, non-destructive and not very expensive. In a research [2] the author propose computer vision system for automatic determination count of big pores on slice of white bread produced by approved standard "Bulgaria" 02/2011. Proposed system processes images in HSV color space. Five algorithms for global thresholding are used for image processing of white bread [3]. One of these algorithms (Vector Median Thresholding) gives ratio of black pixels to all which corresponds with physicochemical porosity of examined bread. The algorithm "Vector Median Thresholding" processes color images using size of kernel as a parameter and color vector norm. A bread made with fat replacer texture is studied by image processing with Otsu algorithm and ImageJ Default algorithm [4]. It is evaluated the texture of bread samples, prepared using different emulsifiers (i.e. SSL, DATEM and E471) in three concentrations (0.2, 0.4 and 0.6%) at three proofing times (25, 35 and 45min), using L*a*b* color space and thresholding algorithm IsoData [5]. It is evaluated the effect of soy protein isolate, Guar gum and Ocimum basilicum seed powder as replacers of fat on porosity, color and texture of Muffin cake trough image processing with ImageJ [6]. The aim of this research is to propose an approach for evaluation the physicochemical porosity of white bread by image processing with HisMedian algorithm and its modifications.

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2. Materials and methods

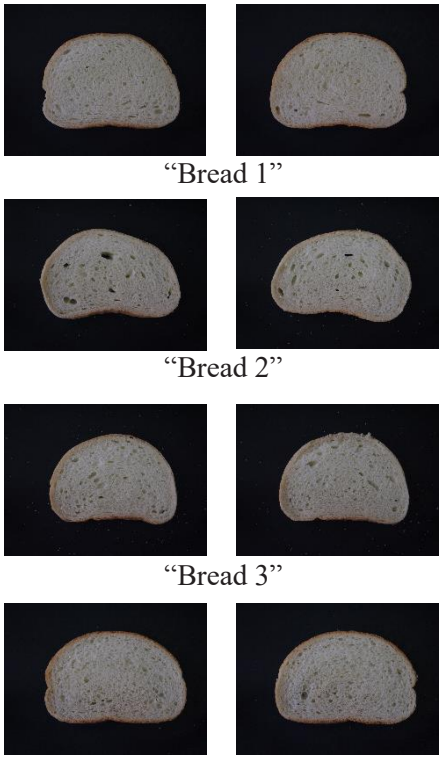
2.1. Materials

For the purpose of this research four trademarks of white bread are bought from the marketplace. The bread is produced according to the Approved Standard "BULGARIA" - №02/2011 [7].

Two methods for porosity evaluation are used – standard one, based on physicochemical processes (described in more details in [8, 9 and 10]) and objective one based on modern computer technologies using digital image processing techniques. According to Bulgarian National Standard (BDS 3412-79) [8] in Bulgaria there is only one method for bread porosity of the middle evaluation – a physicochemical one. This method is time consuming and difficult to implement in a large scale systems for quality evaluation, but most of all it is destructive. All the steps in this method are processed manually. Regarding to the Approved Standard "BULGARIA" the porosity of the middle for white bread should not be less than 67%.

In order to accomplish the analyzes of this research, ten slices of bread is taken from the middle part of each bread. Each of the slices is captured from both sides by a digital camera *Olympus Pen mini E-PM1* with 12.3Mp resolution and an optical sensor – Live MOS. An experimental setting is used for capturing the images of all the slices of the bread. The experimental setting is shown on Figure 1 and a samples of captured images for each trademark are shown on Figure 2.

Figure 1. Experimental setting for the images capturing: 1- digital camera; 2 – a tripod for holding the camera in a stable position; 3 – black pad for background unification; 4 – a bread slice.



"Bread 1"

"Bread 2"

"Bread 3"

"Bread 4"

Figure 2. Images of white bread slices

According to the previous researches [9 and 10] a rectangular region of interest (ROI) is chosen for cropping the images. The dimensions of the ROI are automatically calculated. A graphical illustration of ROI dimensions calculation is shown on Figure 3 a) and b). The cropped images are saved in Bitmap format and then they are loaded in a program for computer evaluation of bread porosity of the middle.

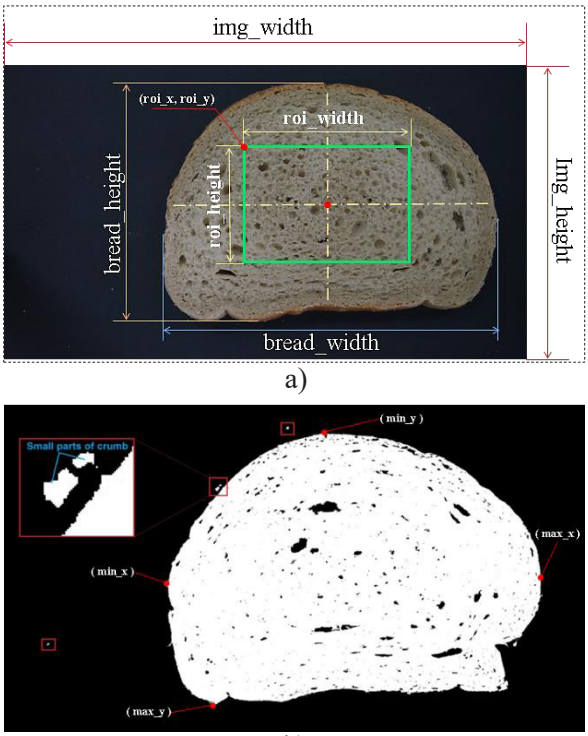


Figure 3. Calculation the dimensions of rectangular ROI

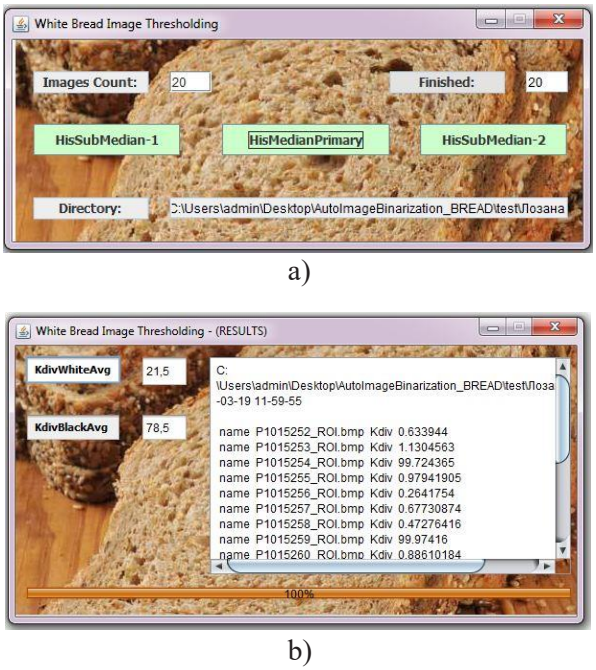


Figure 4. Graphical user interface of the program "*White Bread Image Thresholding*". a) main window of the program; b) result window of the program

The process of automatic calculation the dimensions of the rectangular ROI consists of several steps:

1) Determining the dimensions of the original image of the slice (*img_width* and *img_height*);

2) Determining the dimensions of the bread slice (*bread_width* and *bread_height*). The original image is segmented using the Otsu thresholding algorithm. These dimensions are calculated by the following formula: *bread_width = max_x - min_x* and *bread_height = max_y - min_y*;

3) Removing the small parts of crumbs laying next to the bread slice. This is performed by using a class called *BlobsFiltering{}* available from the AForge.NET library;

4) Determining the center of the bread slice. It is calculated using the following equations: *rectangle_center_x = min_x + bread_width/2* and *rectangle_center_y = min_y + bread_height/2;*

5) Determining the dimensions of the ROI. They are calculated by the following formula: *roi_width = bread_width/2* and *roi_height = bread_height/2;*

6) Drawing and positioning the rectangular ROI. Coordinates (*roi_x* and *roi_y*) of the starting point of the rectangle are defined. This is performed by using the following equations: *rectangularRoi_x=min_x+roi_widt/2* and *rectangularRoi_y=min_y+roi_height/2*;

7) Crop the ROI.

Using a modern computer technologies and algorithms for digital image processing, it is developed a special computer program called "*White Bread Image Thresholding*" for objective evaluation of the bread porosity of the middle. The program is implemented on Java and it is designed to operates with a cropped images defined by a specific region of interest (in this research a rectangular one). The graphical user interface of the main start window of the program is shown on Figure 4 a) and the result window is shown on Figure 4 b). From the main window of the program it can be chosen the amount of images for processing. The program provides three different ways for automatic calculation the median values

(*HisMedianPrimary*, *HisSubMedian-1*and *HisSubMedian-2*) from an image histogram and to threshold the images using these median values. The full path to the cropped images is shown in the "Directory" text field. On the right side of the result window it is presented the information for coefficient of diversity (*Kdiv*) for each of the images that have been processed and the average *Kdiv* values for white and black pixels are presented on the left side of the window. The values for *Kdiv* are calculated as ratio of white pixels to all pixels or black pixels to all.

2.2. Methods. Thresholding algorithms for bread porosity evaluation

An algorithm for thresholding grayscale images using histogram median [12] is modified and implemented in the computer program "*White Bread Image Thresholding*" for objective evaluation of white bread porosity of the middle. The conception of histogram median thresholding algorithm is based on two principles – statistical data processing using a histogram and nonlinear function for defining the threshold value [12]. The algorithm consists of the following steps:

1) building a histogram according to the data from the image;
2) building a sub-histogram which contains information for non-zero frequency of colors;
3) sorting the sub-histogram data by frequency values;
4) finding the (*primary*) median value by frequency from the sorted sub-histogram data;
5) set threshold to be equal to color of median by frequency in sorted sub-histogram (formula 1).

Two modifications of described algorithm are proposed:

1) HisSubMedian-1: the threshold value is calculated as median by frequency in first half of the sorted sub-histogram. The first half is defined by begin of the sub-histogram and primary median.

2) HisSubMedian-2: the threshold value is calculated as median by frequency in second half of the sorted sub-histogram. The second half is defined by primary median of the sorted sub-histogram and its end.

On Figure 5 are presented Primary Median, SubMedian-1 and SubMedian-2.

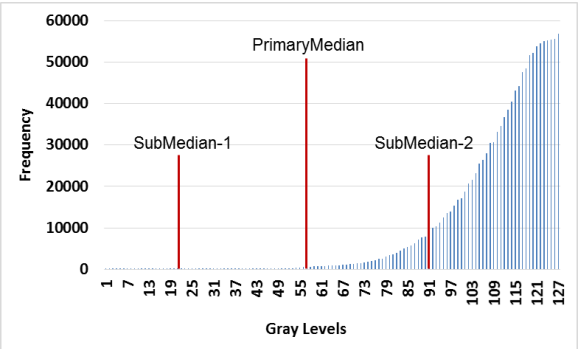


Figure 5. Sorted histogram data with defined three median values

$$\text{Threshold}_{\text{primary}} = \text{median}\left(\text{sub\_H}_{\text{f}}\right)_{color} \qquad (1)$$

where *sub-H* is a notation for *sub-histogram*, *f* is the color frequency in *sub-H*, $median()_{color}$ is the color of median by frequency value in the sorted sub-histogram.

All the images of the bread slices are segmented in three different ways according to the selected algorithm (HisMedian, HisSubMedian-1 or HisSubMedian-2). The porosity of the middle is evaluated by a calculation of a coefficient of diversity (*Kdiv*) which gives the ratio of the pixels representing the pores of the bread to all pixels in the image.

3. Results

The slices of examined bread are captured using the experimental setting (figure 1), then they are used for a physicochemical analysis. All images are processed with four thresholding algorithms: HisAnalysis [11], HisMedian, HisSubMedian-1 and HisSubMedian-2. On Table 1 are shown the results of physicochemical analysis, results of image processing with algorithm HisAnalysis and the results of image processing with proposed program- "*White Bread Image Thresholding*".

Table 1. Results for physicochemical porosity of the white bread, and results for *Kdiv* obtained using HisAnalysis algorithm and HisMedian algorithm with its modifications

	Physicochemical Porosity, [%]	*HisAnalysis, Kdiv*	*HisMedian, Kdiv*	*HisSubMedian-1, Kdiv*	*HisSubMedian-2, Kdiv*
Bread 1	87.15	58.62	20.43	40.02	39.61
Bread 2	81.55	62.50	10.77	15.31	31.35
Bread 3	85.95	62.70	10.92	25.09	40.39
Bread 4	85.78	63.77	25.48	15.07	36.63

A correlation analysis is performed to evaluate the accuracy of the *HisMedian* algorithm and its modifications. On Figure 6 are presented correlation coefficients for *Kdiv* and physicochemical porosity.

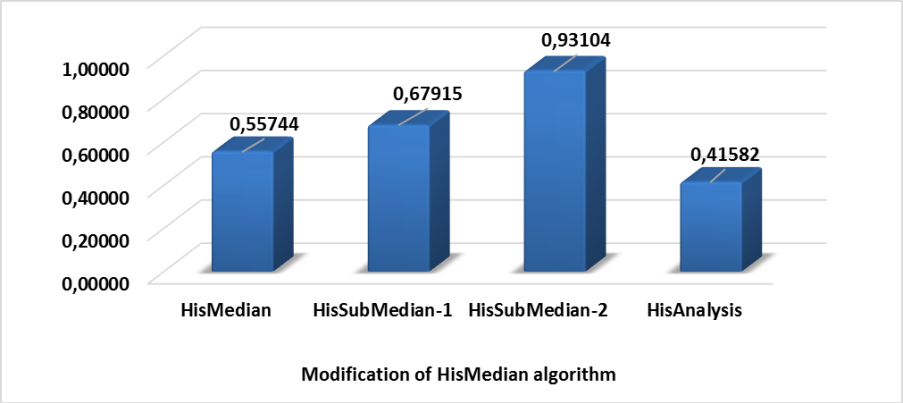


Figure 6. Correlation coefficients

The results of the correlation analyzes show that the coefficient of diversity (*Kdiv*) can be used for calculation the real porosity of the white bread (the preferred algorithm is SubHisMedian-2). The porosity of white bread could be calculated by the formulae (2).

$$P = \frac{\sum_{i=1}^{NP} Kdiv_i}{NP} + C, \quad (2)$$

where P is the porosity of the middle in percentages; NP (*Number of Pictures*) is the amount of all pictures processed from a single bread and C is a constant value. On Figure 7 and Figure 8 are shown the porosity of the white bread and the absolute error in comparison with porosity obtained by physicochemical method.

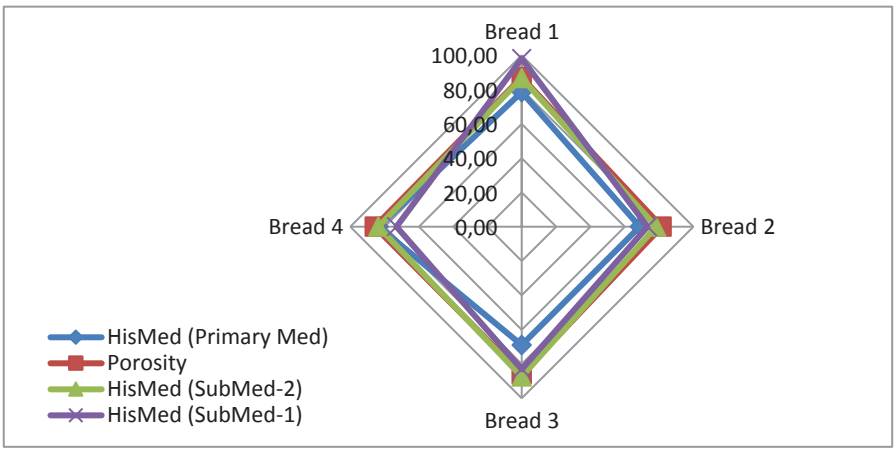


Figure 7. The white bread porosity calculated by formula 2

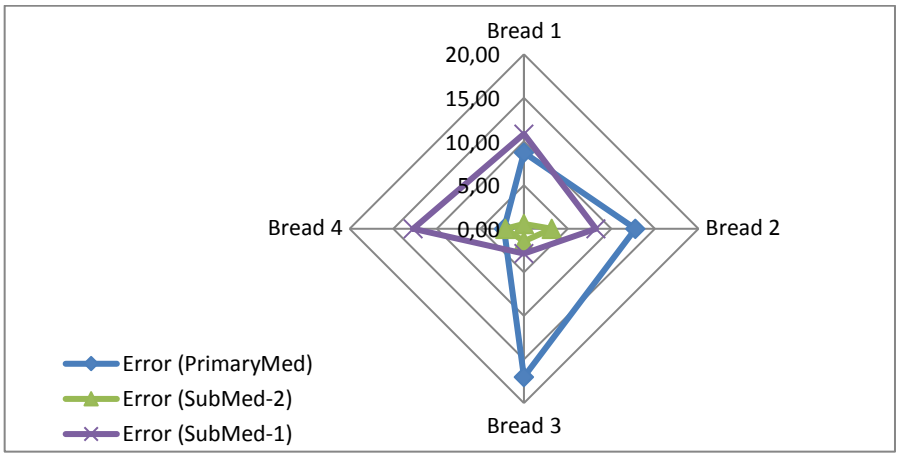


Figure 8. The absolute error for white bread porosity

4. Conclusion

This paper presents an application of modifications of HisMedian algorithm in the field of automatic bread porosity evaluation. The results could be summarized as follows:

- the algorithm HisAnalysis is not preferred for white bread porosity evaluation;
- the correlation coefficients for *Kdiv* by algorithm HisMedian and its modifications are above 0,5;
- the correlation analysis between physicochemical porosity and *Kdiv* by algorithm HisSubMedian-2 gives the highest correlation coefficient (0.93);
- the average error for white bread porosity calculated by the proposed formulae (2) with HisSubMedian-2 algorithm is below 5 %.

The results show that the algorithm HisMedian and its modifications could be used for computer evaluation of white bread porosity.

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