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Application of global thresholding in bread porosity evaluation

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Abstract:The white bread is one of most popular food in Bulgaria. Its quality is defined by standards and control is also standardized. The white bread has four groups of quality parameters - organoleptic, physicochemical, chemical contaminants and microbiological. This paper presents one research over white bread porosity which is one of physicochemicalparameters. By standard evaluation of bread porosity is time expensive procedure. Current research proposes one fast computer based approach for white bread porosity evaluation. In experiments are used three brands white breads. The images of breads are binarized with four known algorithms and coefficient of diversity (ratio of white pixels and all image pixels) for resulting binary images is calculated. This coefficient corresponds with bread porosity.Experimental results show that one of these algorithms – Vector Median Thresholding, is appropriate for bread porosity evaluation.

Keywords:*Global Thresholding, Vector Median Thresholding, White Bread, Porosity Evaluation.*

1. Introduction

The bread is one of essential foods in our menu. Most popular bread in Bulgaria is white bread which prepares by standard "Bulgaria" [1]. In this standard are defined four categories for quality parameters: organoleptic, physicochemical, chemical contaminants and microbiological. The organoleptic parameters are form, surface, color, taste, smell, status of middle and other. The physicochemical parameters are: weight, dry matter content, moisture content, porosity of middle, content of salt and other. The chemical contaminants are content of metals – lead and cadmium. The microbiological parameters are the presence of pathogenic microorganisms, signs of potato disease and visible mold. The standard defines rules for examination of all parameters of the quality.

By standard "Bulgaria" porosity of the middle of white bread must be least 67%. The standardized rules for examination of bread porosity are described in standard BDS 3412-79. The procedure for examination of bread porosity is as follows:

1) The bread is cut into two equal parts. Getting three samples of the middle of the half bread with specific instrument (metal cylinder processed with oil). The samples are getting near to bread crust (10mm) and must have sizes: diameter 30mm and length 40mm. The common volume of taken three samples is 850mm3. This volume are calculated by formula:

$$V = \frac{3{,}14.d^2.H.a}{4} \quad (1)$$

where V is volume, d is diameter of sample, H is length of cylindrical sample and a is number of samples.

2) The samples are weighted with technical weighing instrument (accuracy 0,01g);

3) Every sample must be cut on 16 or 18 parts. Every part of samples must be compressed manually to remove the pores. The compressed part must have shape of round ball.

4) All round balls (compressed parts of samples) must be introduced in a measuring cylinder which contains 500mm3 oil (temperature 18-20 C°).

5) The relative density of the bread was calculated using the formula:

$$RD = \frac{M}{V_1} \quad (2)$$

RD – relative density of bread; M – weight of samples; V1 – volume of compressed parts of samples (calculated as subtraction between oil volume and volume of oil and bread's balls).

6) The porosity of bread's middle (noted with X) are calculates by next formula:

$$X = \left[\frac{V-\frac{M}{RD}}{V}\right].100 \quad (3)$$

This procedure is time expensive and needs from special equipment. The main idea behind current research is to reduce time for examination of bread porosity using computer technics.

The thresholding is an image processing techniques which transform color or grayscale image to binary image (image containing only two colors, typically - black and white). Typical reason for thresholding is finding objects in image. By thresholding every pixel in image receive black or white color depends of some threshold value. When all pixels was compared with the same threshold value then procedure is global thresholding [2, 12]. Sometimes global thresholding is not appropriate because the image has areas with significant difference in brightness or the image has light spots and shadows. In this cases decision is local (adaptive) thresholding which change threshold value dynamically in image processing [2].

The aim of this research is to apply global thresholding technique in evaluation of white bread porosity. For this purpose are we need of: laboratory system for image acquisition (with appropriate software) and a computer program for image

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processing which will found coefficient of diversity for binary images of bread. The results will be interpreted as possibilities for automatic bread porosity evaluation.

2. Laboratory system for image acquisition

The system (fig. 1) is situated in University of Food Technologies, department of Computer Systems and Technologies and contains [11]:
- Interface for connection with PC in real-time mode: DAQ Signal Accessory;
- Basler digital CCD camera, type SCA 1390-17GC.
- Camera Link and GigE Vision interfaces;
- Illumination implemented with 9 fluorescent lamps with white light;
- Working surface;
- Software package LabVIEW.

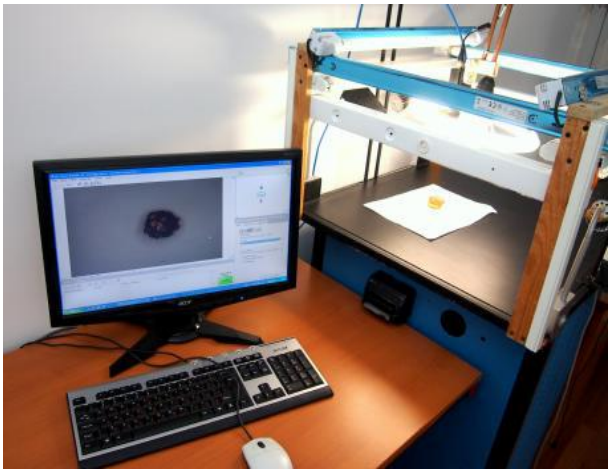
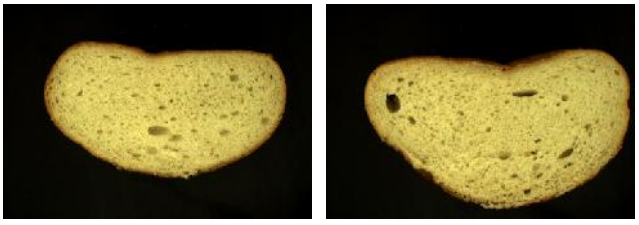
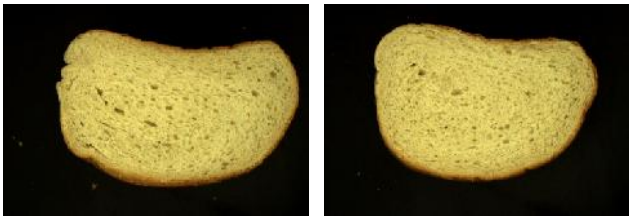


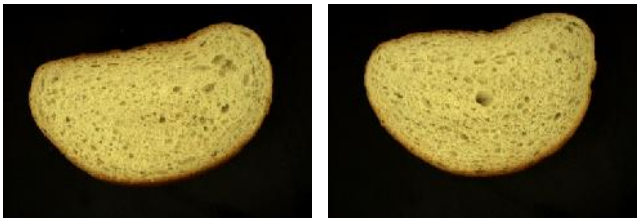
Figure 1. Laboratory system for image acquisition



"Bread 1", by standard



"Bread 2", by standard



"Bread 3", NOT by standard

Figure 2. Pictures of white breads

This system is used for capture of white bread slices. Three marks white bread are purchased from supermarket (we will name them "Bread 1", "Bread 2" and "Bread 3"). "Bread 1" and "Bread 2" are produced by Approved Standard "Bulgaria" [1] but "Bread 3" is not. On figure 2 are presented some images of slices of selected three breads.
For every bread are chosen (by random way) 10 slices and every slice is captured (image is in BMP format). It is taken only the middle of slice to avoid the influence of the color of the crust when determining the threshold for binarization. The images are binarized to select the pores of bread and to calculate their percentage ratio compared with the dense part.

3. Algorithms for global thresholding

In this research are used four known algorithms for global thresholding: Maximum entropy thresholding [3], Mixture Modelling Thresholding [4], Tsai Moment Preserving Thresholding [5] and Median value Thresholding [6, 8].
The Maximum Entropy algorithm is similar to Otsu method [7, 10] but rather than maximizing the inter-class variance (equivalently, minimizing the within-class variance) the inter-class entropy is maximized. The spatial gray-level distribution and the gray-level distribution are both used in defining this criterion. The gray level of each pixel and the average gray-level value of its neighbourhood are studied. The frequency of occurrence of each pair of gray levels is computed. This will draw a surface that, presumably, has two peaks and one valley. The peaks correspond to the foreground and the background. They can be separated by choosing the threshold which maximizes the entropy in the two groups (A and B). The entropy for group A is defined as H(A) and calculates by formulae:

$$H(A) = -\sum_{i=1}^{s}\sum_{j=1}^{t}\frac{p_{ij}}{P_{st}}\ln\frac{p_{ij}}{P_{st}} \quad (4)$$

wherep_{ij} is joint probability mass function which calculates as division occurrence frequency (for pair (i,j) which consists of the pixel gray level and the average of the neighbourhood) to total pixels number. P_{st} is calculated by formulae:

$$P_{st} = -\sum_{i=1}^{s}\sum_{j=1}^{t} p_{ij} \quad (5)$$

The Mixture Modelling Thresholding is algorithm which separates the histogram of an image into two classes using a Gaussian model. It then calculates the image threshold as the intersection of these two Gaussians. This thresholding technique has the advantage of finding a threshold that is in certain cases closer to real world data. The Gaussian parameters can also be used to characterize the obtained two regions.
Tsai Moment Preserving Thresholding algorithm consider image as a blurred version of an ideal bi-level image. The algorithm preserves first three moments in bi-level (binary) image. The moments are calculated by formulae:

$$m_i' = \sum_{j=0}^{1} p_j (z_j)^i, i = 1,2,3 \quad (6)$$

where p_0 and p_1 denote the fractions of the below-threshold pixels and the above-threshold pixels in image, z0 and z1 are black and white colors. Preserving of first three moments in bi-level image means that next equations are satisfied:

$$m_i' = m_{i,}, i = 1,2,3 \quad (7)$$

$$p_0 + p_1 = 1$$

The Tsai moment-preserving thresholding is to select a threshold value such that if all below-threshold gray values in image are

replaced by z0 and all above-threshold gray values replaced by z1, then the first three moments of image are preserved in the resulting bi-level image.

Median value thresholding is an algorithm which finds threshold as median. This algorithm produce binary (bi-level) image from color image. The image is divided in square parts and for every part local median is found. The all found medians are sorted to find global median (which is threshold). The vector median (local and global) is found as middle value in sorted row of pixels. To find vector median pixels are sorted as comparisons are made by color vector norm (formulae 8). To find scalar median red, blue and green components of color are sorted independently and three components of median are found. On figure 3 are presented scalar and vector determining of median color for part of image with sizes 3x3.

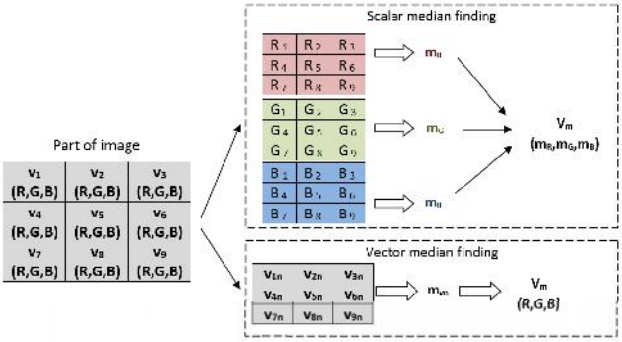


Figure 3. Scalar and vector determining the median value

$$V_{in} = \sqrt{R_i^2 + G_i^2 + B_i^2}, i - pixelnumber \qquad (8)$$

4. Results

We get three breads from different brands for testing of considered four thresholding algorithms. The breads are noted with titles “Bread 1”, “Bread 2” and “Bread 3”. “Bread 1” and “Bread 2” are produced by Approved Standard “Bulgaria” [1] but “Bread 3” is not. The selected breads contain different number of slices (between 14 and 17) and we choose 10 slices by random way. Selected slices are captured with our laboratory system for image acquisition (fig.1, fig. 2). The Median value thresholding algorithm process directly color image but other three algorithms works with grayscale image which is produced with Photoshop. In table 1 are presented pictures of breads before and after processing with discussed four algorithms. The pictures are cut from original images as rectangle which is near to bread crust like in standard technology. For experiments are used program implementations of algorithms “Maximum entropy thresholding”, “Mixture Modeling Thresholding” and “Tsai Moment Preserving Thresholding” from [9].

In table 2, 3 and 4 are presented values of Kdiv for processed with selected algorithms images. The values of Kdiv in percent are calculate like number of white pixels divide to number of all image pixels [6].

Table 1 Images of breads before and after thresholding with different algorithms

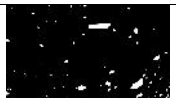
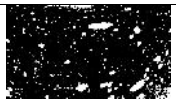
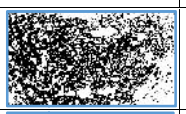
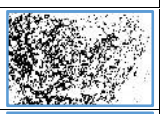
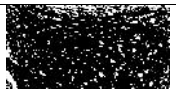
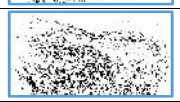
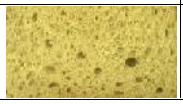
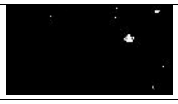
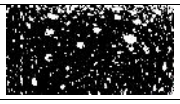
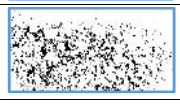
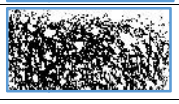
Algorithm Bread	Image	Max. entropy thresholding	Mixture Modeling Thresholding	Tsai Moment Preserving Thresholding	Median valueThresholding	
					Scalar	Vector
Bread 1						
Bread 2						
Bread 3						

Table 2 Kdiv for Bread 1

Slice num.	Max. Entropy Thresh.	Mixture Modeling Thresh.	Tsai Moment Preserving Thresh.	Median valueThresh.	
				Scalar	Vector
1	1,01	15,74	85,67	50,99	96,42
2	15,42	22,80	92,88	49,73	69,94
3	2,02	13,74	93,85	50,31	92,56
4	1,18	15,80	95,66	52,10	72,18
5	3,00	10,30	96,66	50,81	70,77
6	5,15	9,83	96,00	49,71	76,01
7	9,37	9,37	94,36	50,41	46,40
8	13,52	13,52	95,12	51,73	45,40
9	2,64	6,11	95,10	50,91	88,29
10	2,75	11,13	95,82	51,49	52,75
Avg.	5,606	12,834	94,112	50,819	71,072

Table 3 Kdiv for Bread 2

Slice num.	Max. Entropy Thresh.	Mixture Modeling Thresh.	Tsai Moment Preserving Thresh.	Median value Thresh.	
				Scalar	Vector
1	1,25	15,81	96,59	50,00	7,15
2	0,45	19,81	96,53	49,96	99,14
3	1,76	4,42	96,98	50,86	82,07
4	3,81	20,15	95,91	51,55	58,54
5	4,20	16,09	85,26	50,79	42,22
6	0,59	14,70	84,43	50,45	76,44
7	2,41	6,41	92,05	50,35	98,63
8	1,70	14,29	97,71	50,29	84,22
9	3,93	9,52	95,84	49,37	98,04
10	2,38	13,20	97,00	50,78	91,85
Avg.	2,248	13,44	93,83	50,44	73,83

Table 4 Kdiv for Bread 3

Slice num.	Max. Entropy Thresh.	Mixture Modeling Thresh.	Tsai Moment Preserving Thresh.	Median value Thresh.	
				Scalar	Vector
1	3,16	15,24	85,47	50,59	43,15
2	1,93	20,65	95,89	51,74	92,08
3	3,57	20,92	96,17	52,19	50,87
4	3,18	19,27	95,49	51,84	75,41
5	3,05	15,05	91,27	50,72	55,05
6	8,12	8,12	93,25	49,10	61,40
7	2,37	13,19	88,21	49,86	40,28
8	3,49	14,18	89,27	50,36	62,51
9	1,07	14,29	89,48	49,48	93,10
10	8,60	15,93	89,77	49,50	60,28
Avg.	3,854	15,684	91,427	50,538	63,413

On figure 4are presented thresholds calculated by discussed three algorithms (which process gray scale images). The results shows that Tsai Moment Preserving algorithm calculates thresholds which have near values for all slices. The algorithm Maximum Entropy calculates lowest thresholds in comparison with other two algorithms. On the other side algorithm Tsai Moment Preserving calculates highest thresholds in comparison with other two algorithms.

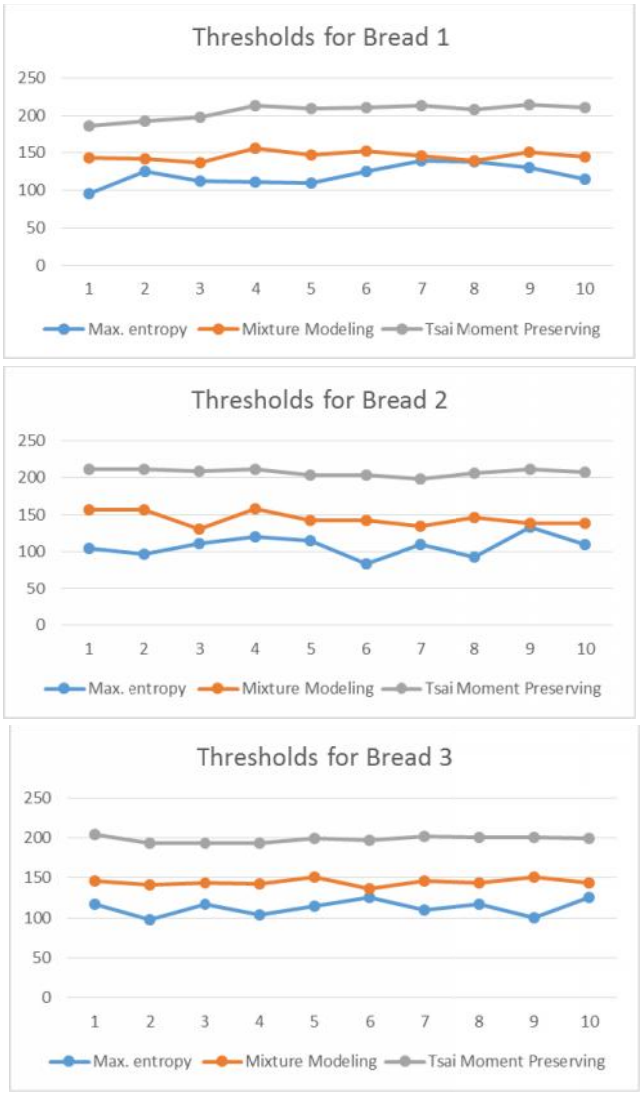


Figure 4. Threshold values for 10 images

Table 5, 6 and 7 presents color components (R,G,B) and color vector norm for 10 slices of "Bread 1", "Bread 2" and "Bread 3".

Calculated average Kdiv of "Bread 1" and "Bread 2" for binary images produced by Scalar Median thresholding algorithm is near to average Kdiv for "Bread 3" – about 50%. Calculated Kdiv of "Bread 1" and "Bread 2" for binary images produced by Vector Median thresholding algorithm is above 67% which satisfied standard [1]. For "Bread 3" average Kdiv for binary images produced by Vector Median thresholding algorithm is below 67%. The other three algorithms (Maximum Entropy, Tsai Moment Preserving and Mixture Modeling) produce binary images for which average Kdiv is near for captured three breads. It is obviously that only algorithm Vector Median thresholding is appropriate for bread porosity evaluation.

Table 5 Color values for "Bread 1"

Slice num.	Scalar Median				Vector Median			
	R	G	B	Vn	R	G	B	Vn
1	200	184	91	286	212	201	114	313
2	204	187	92	291	224	187	91	305
3	206	189	92	294	222	206	113	323
4	218	201	98	312	228	207	102	324
5	214	198	98	307	229	204	94	320
6	214	197	97	306	216	210	121	324
7	218	202	100	313	217	200	96	310
8	214	199	99	308	204	195	112	303
9	219	203	101	315	233	221	109	339
10	214	199	98	308	213	199	103	309
Avg.	212,1	195,9	96,6	304	219,8	203	105,5	317

Table 6 Color values for "Bread 2"

Slice num.	Scalar Median				Vector Median			
	R	G	B	Vn	R	G	B	Vn
1	219	201	100	313	192	163	66	260
2	216	199	99	309	245	226	123	355
3	213	195	97	304	227	212	108	328
4	217	200	100	311	221	204	98	316
5	210	191	93	298	209	185	84	291
6	210	193	96	300	225	206	96	319
7	206	188	91	293	227	223	122	340
8	213	195	96	304	238	205	98	329
9	215	198	98	308	243	225	124	353
10	212	193	94	301	231	220	110	337
Avg.	213,1	195,3	96,4	304,1	225,8	206,9	102,9	322,8

Table 7 Color values for "Bread 3"

Slice num.	Scalar Median				Vector Median			
	R	G	B	Vn	R	G	B	Vn
1	210	192	95	299	209	187	85	293
2	204	186	90	290	228	202	97	319
3	202	184	89	287	207	179	86	286
4	203	185	89	288	210	197	99	304
5	207	190	94	296	213	192	85	299
6	205	188	92	292	203	196	103	300
7	210	192	95	299	205	190	86	292
8	207	191	96	297	216	197	90	305
9	208	191	95	297	224	213	114	329
10	207	191	94	296	216	194	90	303
Avg.	206,3	189	92,9	294,1	213,1	194,7	93,5	303

5. Conclusion and future work

The bread is one of most popular and important foods. By Bulgarian standard white bread has four groups parameters – organoleptic, physicochemical, chemical contaminants and microbiological. One of physicochemical parameters is porosity of middle. Technical procedure for examination of white bread porosity is time expensive. This research proposes one fast computer based approach for porosity examination. The approach includes capturing of bread slices, images thresholding and calculation of coefficient of diversity for binary images. This coefficient corresponds with bread porosity. They was tested four algorithms for global thresholding and results show that only Vector Median Thresholding is suitable for purpose of white bread porosity evaluation (for breads by standard Kdiv has value above 67% and for bread which is not produced by standard coefficient has value below 67%). Future work will continue with examination of porosity of other brands white bread.

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