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RESEARCHES REGARDING THE IMAGE ANALYSIS IN WHEAT QUALITY EVALUATION

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Abstract

There have been analyzed the main quality parameters of 27 wheat samples from Romanian crops, of the years 2010 and 2011, namely: Humidity (%), Hectolitric mass (kg / hl), Falling number (sec), Protein content (%), Wet gluten content (%) and Gluten Index. Afterwards, the wheat samples were ground on the Chopen pilot-type mill and the alveografic parameters were determined from the resulting flour: Resistance (P, mm), Extensibility (L, mm), Mechanical Work (W, 10E-4J), Elasticity index (Ie,%), Gluten Extensibility index and the P/L report. The wheat samples taken for analysis were scanned using a commercial scanner, at a resolution of 200 dpi. The obtained results were examined with a specific software, used for the analysis of ImageJ image. For each image we determined the color histogram with the specific parameters: R, G, B, Brightness and Fractal Dimension. Our results have shown highly significant correlations between the color histogram parameters (Brightness, R, G, B) and the alveografic parameters, namely: Resistance (-0.64< r <– 0.72), Mechanical work (- .62 < r < -0.64) and the P/L ratio (-0.62 < r < -0.68). No significant correlations were found between color parameters of the image analysis and the physical and chemical parameters of the wheat. Models of multiple regression have been described for the prediction of alveografic parameters P, W and P/L, based on the color parameters. The results suggest an interesting potential for including the image analysis in a coherent assessment procedure of the wheat, but in order to validate this conclusion, there are necessary further experimental researches.

Key words: alveograph, image analysis, wheat crops quality

INTRODUCTION

Wheat grain color can vary from light yellow to brown red. The main factors which determine the color are some flavonoid pigments (tricine) and carotenoids (xanthophylls such as lutein).
The analysis of color based on digital images of wheat grains has been used in various studies. *Neuman et al*. (1989) have shown that the method can be used to distinguish certain varieties of Canadian wheat [1].
Klepacka et al. (2002) have shown the existence of a significant relationship between the wheat bran shades of gray of and ferulic acid content of these (r = -0.65). They also found a correlation between the level of gray color grains and the degree of extraction (r = 0.74) [2].
Manickavasagan et al. (2008) studied the potential of the wheat image analysis (using monochrome images based on the shades of gray) to provide information which allow the discrimination of different classes of wheat, to automation of industrial processes [3].
Newton's experiments and confirmed by the Young-Helmholtz theory, demonstrated that the human eye retina contains three types of cone receptors, each being sensitive to a certain range of light waves. These receptors are: Long or Red receptors (sensitive to red light with long wavelengths, in the range 500 nm-700nm), the Green or Middle receptors (sensitive to green light having medium wavelengths, 450nm-630nm) and Short or Blue receptors (sensitive to blue light with short wavelengths, in the range 400nm- 500 nm) [4,5].
In practice, the description of any color in the visible spectrum consists of its noting,

representation or specification, through three numerical color parameters, which define a set of tristimulus values. A tristimulus value expresses, directly or indirectly, the extent to which primary RGB colors combine to form a new color. Implicitly, it expresses the characteristics of color stimuli, which are sensitive to LMS wavelengths, corresponding to the primary color components (RGB).
The scanners read the amounts of light reflected by a RGB image and convert them in the tristimulus values (digital), and monitors receive tristimulus values (digital) and convert them in RGB light, visible on the fluorescent screen.
The RGB color model can be implemented in different ways. The range of colors which can be described using this model is determined, dimensionally, by the number of bits used to describe each color component. The most common mode of implementation, used since 2006 for computer monitors, uses 24-bit color and 8 bit color / pixel or 256 digital levels / channel (28 = 256), which is why the number of colors that can be represented based on this model is limited to 256R x 256G x256B = 16.7 million colors, about the number that can be distinguished by human eye [5].
Since several studies have shown significant correlations between the levels of certain compounds in wheat grain and its color, we decided to investigate the relationship between the color of wheat grains and their technological quality, in the Romanian wheat samples .

MATERIAL AND METHOD

27 Romanian wheat samples were analyzed to determine the physical and chemical parameters listed in Table 1.

Table 1. Methods of analysis used for analyzing the quality parameters of wheat

Quality parameter	Analysis method
Hectolitric mass (MH, kg/hl)	STAS 6123/2-73
Moisture (M, %)	SR ISO 712/1999
Protein content (P, %)	ICC 159-95 (NIR method, Perten Inframatic 8600)
Wet gluten (WG,%)	SR ISO 21415-2:2007
Gluten Index (GI)	ICC 155-94
Falling number (FN, s)	SR ISO 3093:2005

Wheat samples were scanned at a resolution of 200 dpi, using a commercial scanner, to obtain digital images. Digital images were analyzed using a specialized software, ImageJ, developed by the National Institutes of Health (U.S.).
We used the options of the program which assess the way the image colors are constructed, starting from the three primary colors, Red, Green and Blue. Basically, the program made for each image a specific histogram for each color. The x coordinate axis contains the possible values for each primary color (between 0 and 255), and the y coordinate axis contains the number of identified pixels. Thus, the program calculates average quantities of red, green and blue and the associated standard deviations (Photo 1).

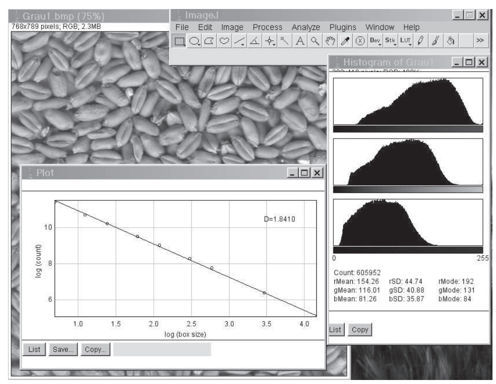

Photo 1. Image of a wheat sample, according to, Software Image J

Each sample was grounded in a Chopen type pilot mill, to obtain the corresponding flours. For each flour we determined alveografic parameters, according to ISO 27971:2008, Resistance (P, mm), Extensibility (L, mm), Extensibility Index (G), Mechanical work (W, 10E-4 J), P / L Ratio, and Elasticity index (Ie,%). Also, we used the options to assess the fractal dimensions of the analyzed images.
The results were interpreted statistically, using a specific software, StatSoft, Inc.. (2004),STATISTICS (Data Analysis Software System), version 7, www.statsoft.com).

RESULTS AND DISCUSSIONS

The results obtained by determining the quality parameters for the 27 wheat samples are shown in Table 2, using the estimates of variability:

the arithmetic average (X), the standard deviation (sx) and the coefficient of variation (CV).

Table 2. The estimates of variability for the quality parameters of wheat samples

Quality parameters	$X \pm s_x$	CV (%)
MH (kg/hl)	75.115 ± 1.680	2.236
U (%)	11.667 ± 0.850	7.285
P (%)	12.733 ± 1.160	9.133
GU (%)	27.000 ± 5.440	20.139
GI	71.604 ± 22.190	30.993
FN (s)	246.286 ± 90.420	36.715
P (mm)	65.632 ± 24.260	36.965
L (mm)	63.947 ± 24.280	37.964
G	17.575 ± 3.280	18.662
W (10^{-4} J)	137.895 ± 66.350	48.117
P/L	1.208 ± 0.730	60.460
Ie (%)	36.235 ± 21.350	58.912

Table 2 shows that the wheat samples were characterized by a high variability of the rheological parameters (P, L, G, W, G, P / L and Ie), and also of the physical and chemical parameters expressing the enzymatic activity (FN , GI). The parameter Wet gluten content (GU) was characterized by an average variability, while the parameters Hectolitric Mass (MH), Humidity (U) and Protein content (P) were characterized by low values of variability.

The results obtained by determining the color parameters and the fractal dimensions (D), for the 27 wheat samples are shown in Table 3. The analyzed color parameters were: Brightness (M), Average content of red (R), Average content of green (G) and Average content of blue (B).

Table 3. The estimates of variability for the color parameters and fractal dimension of the wheat samples

Quality parameters	$X \pm s_x$	CV (%)
M	112.506 ± 4.572	4.063
R	148.332 ± 5.207	3.510
G	111.381 ± 4.650	9.133
B	77.381 ± 4.448	5.748
D	1.836 ± 0.035	1.901

From Table 3 we can see that, unlike the variability of wheat quality parameters, the variability of wheat color parameters is several times lower.

This can be interpreted as the determinants of color of the wheat kernels (probably genetic factors, dependent on variety), are relatively little influenced by environmental factors. The highest variability affects shades of green of the images, and the lowest variability appears in the shades of red.

Table 4 presents the values of correlation coefficients between the physico-chemical and the image parameters of wheat samples. In Table 4 we can see that the only physico-chemical parameters which correlate with image parameters we used, are Hectolitric Mass and Protein content.

Hectolitric Mass increases distinct significantly, as luminosity (M) decreases, for the wheat sample analyzed.

Also, the parameter Hectolitric Mass decreases as the Content of red, green and blue images decreases in the analyzed images.

This fact allows us to model the parameter Hectolitric Mass due to the color parameters, according to the regression model below:

$$\mathbf{MH = 89.099 - (0.018 \cdot R) - (0.673 \cdot G) - (0.335 \cdot B) + (0.796 \cdot M)}$$

The regression model explains about 45% of the Hectolitric Mass variability (r = 0.673, r2=0453, F=4.22, p<0.008).

There was no significant correlation between the shape of grains, evaluated by fractal dimension, and the Hectolitric Mass. Table 4 shows that the sample of wheat, characterized (by image analysis) by a smaller amount of red, had a significantly higher protein content.

There have been no significant correlations between the image parameters and the other quality parameters of wheat, namely: Humidity, Wet gluten content, Gluten index and Falling number.

Table 5 presents the coefficients of correlation between the image parameters and the alveografic parameters for the wheat samples.

The table shows that the alveografic parameters Resistance (P) and Mechanical work (W) are significantly correlated with the image parameters.

The alveografic Resistance decreased distinct significantly, as the brightness of wheat was higher, respectively as the images that had a higher content of green and blue.

It is interesting the correlation of this parameter with the values of Fractal dimension. The Fractal dimension measures the complexity of shape of the analyzed structure, its value being higher as the structure has a more complex shape.

Table 4. The correlation coefficients between quality physico - chemical parameters and and image parameters, for the wheat samples

Perechi		**r**	**Perechi**		**r**
U	MH	-0,13	GI	P	-0,27
	GU	-0,28		FN	-0.08
	GI	0,27		M	-0,22
	P	-0,09		D	0,28
	FN	0.00		R	-0,00
	M	0,06		G	-0,22
	D	0,09		B	-0,35
	R	0,01	P	FN	-0.01
	G	0,06		M	-0,30
	B	0,07		D	0,30
MH	GU	0,29		R	**-0,44**
	GI	0,12		G	-0,31
	P	0,28		B	-0,14
	FN	0.15	FN	M	-0.10
	M	**-0,57**		D	-0.01
	D	-0,04		R	-0.04
	R	**-0,39**		G	-0.13
	G	**-0,59**		B	-0.15
	B	**-0,64**	M	D	**-0,60**
GU	GI	**-0,51**		R	**0,86**
	P	**0,90**		G	**1,00**
	FN	0.10		B	**0,95**
	M	-0,23	D	R	**-0,55**
	D	0,22		G	**-0,58**
	R	-0,34		B	**-0,48**
	G	-0,23	R	G	**0,85**
	B	-0,11		B	**0,68**
			G	B	**0.95**

(n = 27, where, if r = 0.38-0.48 when p <0.05, r = 0.49-0.60, when p <0.01, r = 0.61-1.00, then p <0.001)

Table 5. The coefficients of correlation between the alveografic parameters and the image parameters for the wheat samples

Pairs		r	Pairs		r
P	M	**-0.67**	W	M	**-0.69**
	D	**0.52**		D	**0.51**
	R	-0.43		R	**-0.56**
	G	**-0.65**		G	**-0.68**
	B	**-0.69**		B	**-0.61**
L	M	-0.03	P/L	M	-0.41
	D	0.10		D	0.21
	R	-0.09		R	-0.18
	G	-0.06		G	-0.40
	B	0.07		B	**-0.53**
G	M	-0.02	Ie	M	-0.24
	D	0.13		D	0.42
	R	-0.08		R	-0.27
	G	-0.04		G	-0.23
	B	0.09		B	-0.10

(n = 20, where, if r = 0.42-0.54 when p <0.05, r = 0.55-0.65, when p <0.01, r = 0.66-1.00, then p <0.001).

As the analyzed wheat kernels were deviated from a smooth aspect, the alveografic parameter Resistance increased. This may be partly the result of a higher presence of shrunken kernel grains, as shown by the images in photo 2. These images show grains that had the highest (1879, above) respectively the lowest Fractal dimension (1764, below).

We can find in the literature opinions that flours obtained from the shrunken kernel grains have higher quality characteristics. This might be because, at the beginning of ripening, grains accumulate a higher amount of proteins that generate gluten. Drought leads to shrunkening of kernels, hurry the postmaturation of these proteins and prevent migration in the grain of other non proteinaceous components [6]. However, increasing the quality of gluten in flours obtained from shrunken kernel grains is decompensated by a sharp decrease of the degree of extraction of flour.

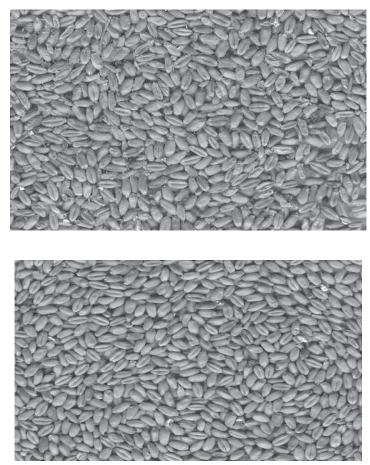

Photo 2. The image of wheat with the highest (down) and the smallest (up) fractal dimension

The best image predictors for the alveografic parameter Resistance, using the specific algorithm for the forward steepwise regression were Fractal dimension (D) and Content of blue (B).

Multiple regression model that includes these image parameters is shown in photo 3. It explains 52.5% of the variability of the parameter alveografic Resistance ($r = 0.725$, $r2 = 0.525$, $F = 9.39$, $p <0.018$):

Table 5 shows that all image parameters correlated with the alveografic parameter Mechanical work (W).

The alveografic Mechanical work had a very significantly lower value as the image brightness was higher. Also, its value decreased as the amount of red, green and blue were higher.

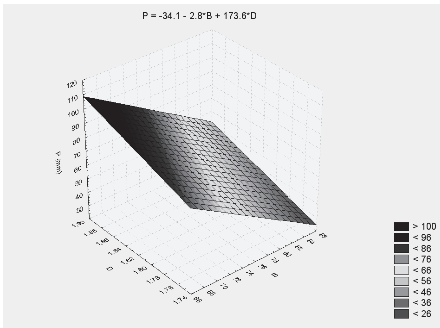

Photo 3. Multiple regression between the alveografic resistance (P) and the image parameters Fractal Dimension (D) and Blue content (B)

The best predictor for the alveografic parameter W was brightness, which explains about 48% of the variability in this parameter, as seen from the regression equation shown in Figure 1 ($r = 0.69$, $r2 = 0.48$, $F = 15.94$, $p < 0.0008$).

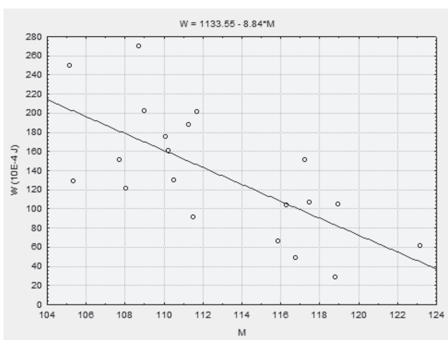

Fig. 1. Regression between alveografic Mechanical Work (W) and brightness (M) of wheat grains

Even in this case, we could notice the significant correlation of the Fractal dimension (D) with the value of the alveografic parameter W ($r = 0.51$). Perhaps the explanation is also offered throughout the shrunken kernels, which determined the increasing of the Fractal dimension of wheat. The increasing of the Fractal dimension of various biological structures (cells, cell organelles, etc.) has been associated in many studies with different deviations from their normal status. Thus, the correlation of Fractal dimension of the grains with the increasing of baking quality of wheat may suggest a similar phenomenon, of deviation from the variety normality, due to the action of certain environmental factors or plant growing factors.

The parameter P/L, which quantifies the relationship between Resistance and Extensibility of dough, had a significantly higher value as the content of Blue images was lower.

We notice that the alveografic parameters related to dough extensibility (Extensibility L, Gluten swelling index and Elasticity index of gluten G Ie) were not significantly correlated with image parameters.

CONCLUSIONS

Our results show that there are important prerequisites for the evaluation of wheat quality parameters such as Hectolitric mass, Resistance, and Work on behalf of the alveografic image parameters: Brightness, Fractal dimension and Contents in the primary colors (Red, Green, Blue).

We believe that our results can be an interesting research direction, in order to use optical methods for rapid assessment of wheat quality.

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