

Dielectric properties of wheat flour mixed with oat meal

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A b s t r a c t. Possibilities of using electric methods for determining admixtures of oat meal to wheat flour, type 650 are presented. In wheat flour, oat meal and mixtures containing 10, 20 and 30% of the oat meal, moisture, protein, starch and ash content, sedimentation value, yield and softening of wet gluten were determined. In samples containing 0, 5, 10, 15, 20, 25, 30 and 100% of oat meal, the dielectric loss factor and conductivity were determined using an impedance analyzer for electromagnetic field frequency ranging from 0.1-20 kHz. It was found that the dielectric loss factor varied for tested material. The best distinguishing between tested mixtures was obtained at the measuring electromagnetic field frequency of 20 kHz. The loss factor was significantly correlated with the yield of wet gluten and the sedimentation value, parameters indicating the amount and quality of gluten proteins in flour.

K e y w o r d s: wheat flour, oat middlings, electrical properties, dielectric loss factor

INTRODUCTION

The human diet is based on cereal products, in which bakery products have the largest share. The increasing awareness of producers and consumers resulted in an increase in the range of bakery products with additives improving their value. Such additives may include oat products, as oat protein is characterized by its high biological value (Peterson *et al.*, 2005). Exogenous amino acids form about 40% of it, while in wheat and rye protein their content reaches only 30% (Ralecewicz and Knapowski, 2006). In oat grain there are a lot of lipids with a significant content of unsaturated fatty acids (Czubaszek, 2008; Hampshire, 2004; Peterson *et al.*, 2005). Furthermore, in those lipids also present are tocopherols and tocotrienols, compounds with anti-cancer activity, additionally preventing cardiovascular diseases. A component, which had the largest contribution to the increase in

interest in oats, is dietary fibre containing about 50% of soluble fraction and β -glucans (Hampshire, 2004). Oats bran is particularly rich in fibre, with a 24% content of that component (Zarzycki and Rzedziecki, 2009). Compounds present in oat fibre absorb substances harmful to health *ie* heavy metals, residues of plant protection agents from food and prevent them being absorbed by the body. They also bind cholesterol in the human digestive system thus reducing its assimilation and reducing its levels in blood. This is of enormous significance for prophylactics of diseases such as arteriosclerosis or ischaemic heart disease (Peterson *et al.*, 2005; Weaver and Schneeman, 2005). It was demonstrated that bakery products with oat additives might have good physical and organoleptic properties (Czubaszek, 2008; Flander *et al.*, 2004; Meltzer, 2005; Salmenkallio-Marttila *et al.*, 2004).

So far, for determining the presence of admixtures in flour the microscopic evaluation of starch granules was used, as they are characterized by different sizes, shapes or surface structures, depending on their origin. Studies on determining dielectric and electric properties of flour obtained from various seeds have been conducted around the world for a long time (Guo *et al.*, 2008, 2010; Nelson, 2008). Electrical methods are also used by researchers to analyze the quality of bread (Liu *et al.*, 2009). Studies performed in recent years on electric properties of flour and their correlation with chemical properties (Łuczycka and Pentoś, 2010; Łuczycka and Romański, 2008) allow to assume that selected electrical properties of flour may be a quantitative indicators for the additives content in wheat flour.

The aim of this study was to determine the electrical properties of wheat flour, oat meal and their mixtures, and to assess the possibility of distinguishing those products on

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that basis. Also an attempt was made to determine correlation between selected chemical and technological parameters with electrical properties.

MATERIAL AND METHODS

The material studied was commercial wheat flour, type 650, 'Diamant', produced by Młyny Zbożowe Grygiera Sp. z o.o. and oat meal obtained by grinding in a laboratory mill WŻ-1 (ZBPP Bydgoszcz) whole grains of naked oats (commercial mixture from the Seed Headquarters in Głubczyce). Mixtures of wheat flour and oat meal were prepared, with meal content of 5, 10, 15, 20, 25 and 30% on mass basis. Wheat flour and oat meal were used as control samples.

For wheat flour, oat meal and selected mixtures (10, 20 and 30% of oat meal) the following were determined: moisture with the oven method (PN-EN ISO 712:2009), starch content with the polarimetric method (AOAC 1995), total ash (PN-EN ISO 2171:2010) and total protein with the Kjeldahl method, using the conversion rate of $N \times 5.7$ for wheat flour and mixtures, and $N \times 6.25$ for oat meal (PN-EN ISO 20483:2007). The quality parameters of flour were also determined, such as yield and softening of wet gluten using the method of manual washing in water (PN-EN ISO 21415-1:2007) and the sedimentation value in SDS solution (Axford *et al.*, 1979).

Measurements of electrical parameters of wheat flour, oat meal and their mixtures were performed using a FLUKE PM6304 impedance analyzer. The intermediate method used is based on measurements of capacitance and resistance of a sample placed in a capacitor, followed by calculating the dielectric loss factor, $\text{tg } \delta$, and permittivity, ϵ , on the basis of obtained electromagnetic field frequency and geometry of the measuring capacitor.

A cylindrical capacitor was connected to the measuring device, of height $h = 50$ mm, external $a = 38$ mm and internal $b = 10$ mm cylinder diameters; the tested material was placed in the space between electrodes. The frequency range of the electromagnetic field was from 100 Hz to 20 kHz. Weight of samples ranged from 16.28 to 17.64 g, and moisture was within 11.1-11.9%. Measurements were performed at the tem-

perature of 21°C (ambient and samples). In order to maintain a constant humidity (40%) and ambient temperature, the tests were conducted in air-conditioned room and were repeated 6 times. The obtained results were subjected to statistical analysis.

RESULTS AND DISCUSSION

Tests were performed to characterize the studied material for its chemical and technological parameters (Table 1). It was found that oat meal contained more total protein and ash and less starch than wheat flour. Due to that, an increase of oat meal in the mixture with wheat flour was accompanied by the increase in protein and ash content, and a decrease in starch content. When comparing obtained results to the literature data it can be said that the quantities of listed components were typical for oat meal and wheat flour, and their mixtures (Czubaszek, 2008; Konopka *et al.*, 2004; Sadowska *et al.*, 2001).

Parameters used to determine baking quality of flour are yield of wet gluten and softening of gluten, together with the sedimentation value (Popper *et al.*, 2006). Flour used for baking of bakery products has yield of wet gluten of 25% and softening no higher than 9 mm (PN-A-74022:2003). Tested wheat flour had good baking parameters, and replacing part of it with oat meal resulted in a significant decrease in yield and softening of wet gluten (Table 1). Similar changes were observed in earlier studies (Czubaszek and Karolini-Skaradzińska, 2005). Changes in the protein composition of wheat-oats mixtures, disadvantageous for technological reasons, are also confirmed by the sedimentation value, as the admixture of oat meal significantly decreased that parameter value.

The conducted studies of electrical properties showed that the dielectric loss factor, $\text{tg } \delta$ (Fig. 1) distinguished the tested material by the content of oat meal more effectively than permittivity, ϵ (Fig. 2). The dependence of the dielectric loss factor on electromagnetic field frequency for the whole tested range is shown in the Fig. 1. It can be seen that above 6 kHz the curves form a parallel bundle.

Table 1. Chemical composition and technological properties of tested samples

Sample	Total protein	Starch	Ash	Yield of wet gluten	Gluten softening (mm)	Sedimentation value (cm ³)
	(%)					
Wheat flour	12.0	50.4	0.72	33.5	6	80
Content of oat meal in blends (%)	10	13.2	50.6	0.86	28.1	5
	20	13.4	49.6	0.99	24.4	4
	30	13.5	49.4	1.14	16.1	3
Oat meal	13.9	42.9	2.13	–	–	–

For permittivity, ϵ , however, it was found that curves depicting its dependence on electromagnetic field frequency admittedly were parallel, but in no frequency range the dependence of permittivity on the amount of oat meal added was monotonic (Fig. 2). Thus further discussion concerns solely the dielectric loss factor, $\text{tg } \delta$.

To determine the correct measuring frequency (for which differences in the dielectric loss factor values are the highest between the samples), differences, expressed as percentage, between obtained values of the dielectric loss factor were determined for successive samples in tested electromagnetic field frequencies, and the following calculations were performed:

$$r = \sum_{i=2}^6 \frac{\text{tg } \delta_{(i-1)} - \text{tg } \delta_i}{\text{tg } \delta_i} 100\%,$$

where: i – sample number, $\text{tg } \delta_{(i-1)}$ – the dielectric loss factor of a sample with lower meal content, $\text{tg } \delta_i$ – the dielectric loss factor of a sample with higher meal content. Figure 3 contains r values for each measuring frequency.

Large differences were found both for low and high measuring frequencies. However, because the bundle of curves for the dielectric loss factor is parallel (Fig. 1) for frequencies exceeding 6 kHz, the low frequencies range should be discarded as inadequate for distinguishing compositions of wheat flour mixtures with oat meal. In the high frequencies range, the largest relative differences between the determined dielectric loss factor values of the tested material

occurred at the frequency of 20 kHz, thus this frequency can be indicated as the most adequate for studies of this type. Figure 4 presents values of the dielectric loss factor of tested mixtures (determined for the electromagnetic field frequency of 20 kHz). Statistical calculations performed showed a significant dependence of that parameter on the share of oat meal in oats ($R^2 = 0.9948$).

The next stage of the analysis of obtained results was to calculate coefficients of correlation between tested chemical and technological properties of flour and the dielectric loss factor determined at the electromagnetic field frequency of 20 kHz. A significant co-dependence between the dielectric loss factor and gluten efficiency and the sedimentation factor was found (Table 2). On that basis it may be assumed that the value of the dielectric loss factor, measured in wheat flour and its mixtures of oat meal, depends largely on the quantity and quality of gluten proteins. The loss factor dependence on gluten efficiency is described by an linear trend shown in the Fig. 5. The correlation factor, R^2 , was very high and exceeded 0.96 (gluten – Fig. 5) and 0.95 (sedimentation value – Fig. 6).

No description of the use of electric methods for determining admixtures of oat meal to wheat flour was found in the available specialist literature. Research on the electric and dielectric features of flour applies only to its conductivity or studies are conducted at very high frequencies, above 10MHz (Guo *et al.*, 2008, 2010), hence the available literature does not contain data that would permit a discussion of the results obtained during this study.

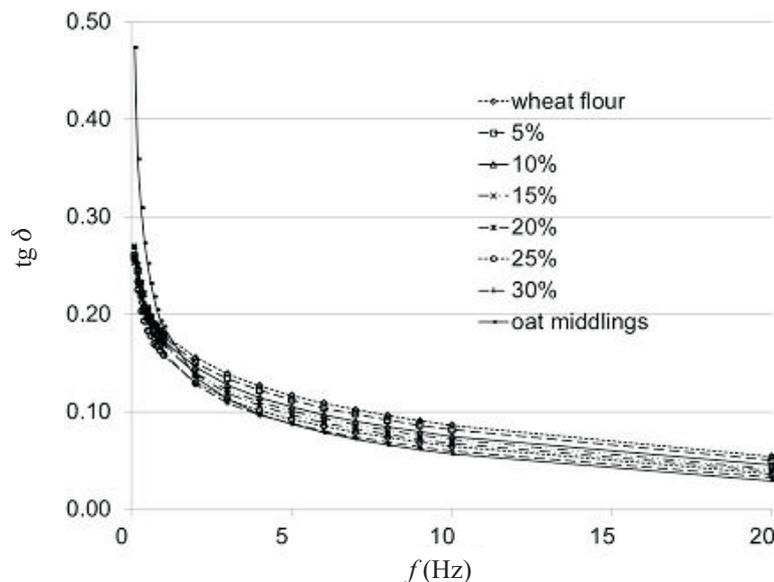


Fig. 1. Effect of electromagnetic field frequency, f , on the dielectric loss factor, $\text{tg } \delta$, of the tested mixtures of wheat flour and oat meal.

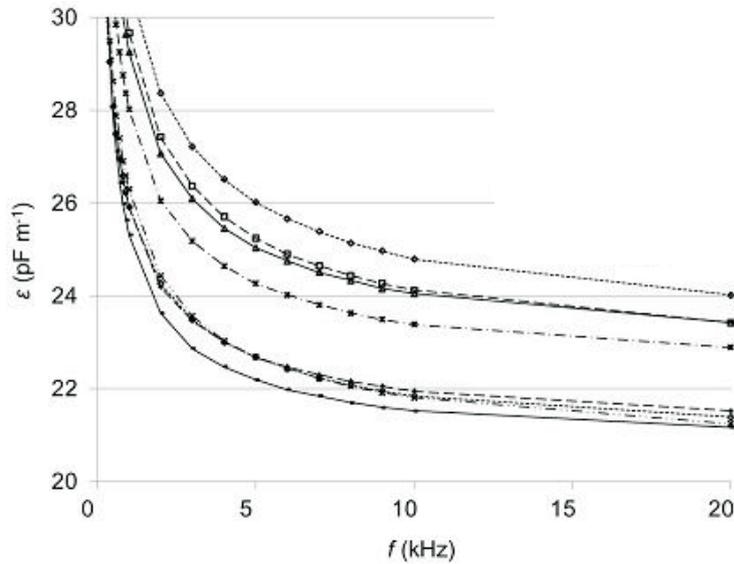


Fig. 2. Effect of electromagnetic field frequency, f , on the permittivity of the tested mixtures of wheat flour and oat meal. Explanations as in Fig. 1.

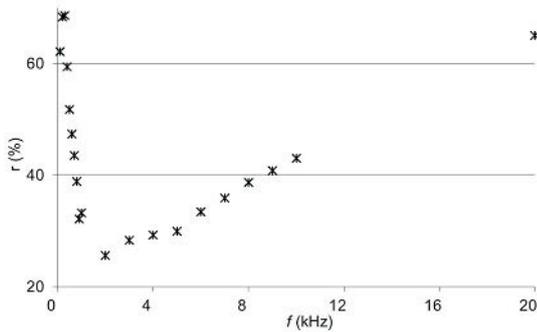


Fig. 3. Sums of relative differences in the dielectric loss factor between analyzed samples of tested material within the electromagnetic field frequency range of 100 Hz-20 kHz.

Table 2. Values of correlation coefficient value between chemical and technical properties of flour samples and their dielectric loss factor

Feature	$\text{tg } \delta$
Total protein content	-0.94
Starch content	0.70
Ash content	-0.80
Yield of wet gluten	0.98*
Gluten softening	0.86
Sedimentation value	0.97*

*Significant coefficient for a level of significance of 0.05.

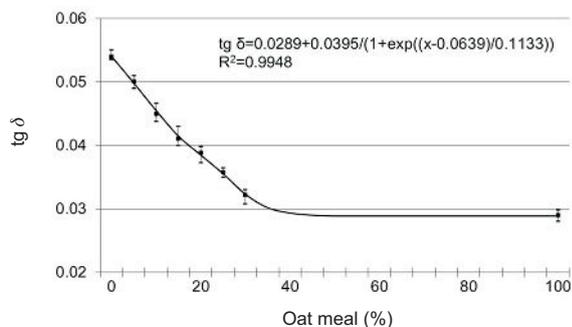


Fig. 4. Value of dielectric loss factor, $\text{tg } \delta$, for tested mixtures of wheat flour with oat meal ($f = 20$ kHz).

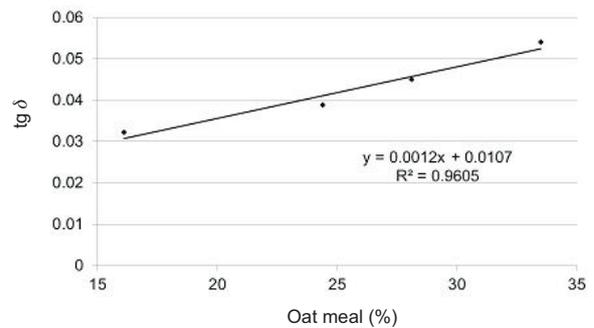


Fig. 5. Correlation between yield of wet gluten and the dielectric loss factor, $\text{tg } \delta$, of wheat flour and its mixtures with oat meal ($f = 20$ kHz).

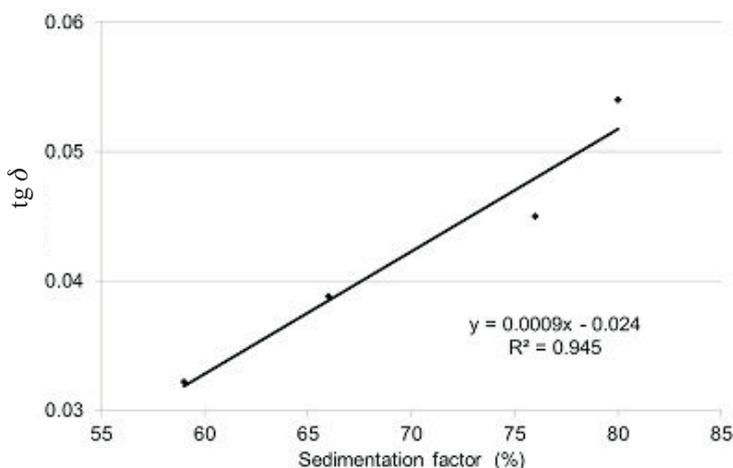


Fig. 6. Correlation between sedimentation factor and the dielectric loss factor, $\text{tg } \delta$, of wheat flour and its mixtures with oat meal ($f = 20$ kHz).

CONCLUSIONS

1. The dielectric loss factor is an electric value that can be used for quantitative determinations of oat meal admixture in wheat flour.
2. The best distinguishing of tested mixtures was seen at the measuring electromagnetic field frequency of 20 kHz (measurements were conducted in the frequency range of 100 Hz-20 kHz).
3. The loss factor is significantly (a level of significance 0.05) correlated with yield of wet gluten and the sedimentation value – parameters indicating the quantity and quality of flour proteins.
4. The loss factor dependence on gluten efficiency is an linear function (a regression factor of 0.96).

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