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THE EVALUATION OF WHEAT GRAIN ODOUR AND COLOUR AFTER GAMMA AND MICROWAVE IRRADIATION

Jerzy R. Warchalewski[1], Justyna Gralik[1], Renata Zawirska-Wojtasiak[2], Jan Zabielski[3], Romualda Kuśnierz[1]
[1]*Department of Biochemistry and Food Analysis*
[2]*Institute of Food Technology of Plant Origin*
[3]*Department of Nuclear Methods in Agriculture*
Agricultural University of Poznań, Poland

ABSTRACT

Wheat grain was exposed to gamma ionising irradiation at selected doses between 0.05-10 kGy and microwave radiation from 45 to 180 sec. The sensory evaluation of a grain odour proved that both applied treatments,

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gamma and microwave irradiation, did not cause significant changes in the grain odour in comparison to control samples of grain with the exclusion of maximum irradiation dose 10 kGy, and maximum microwave heating time 180 sec. The results obtained after measurement of the grain reflected-light showed that gamma ^{60}Co irradiation did not cause any changes in grain colour. The grain after microwave heating at 90, 120, 180 sec was characterised by significantly higher lightness (L^*) value. The total colour difference (ΔE) between microwave irradiated samples and the control ones was increasing gradually, with the increase in temperature. The yellowness (b^*) and the redness (a^*) values were statistically significantly higher in the case of 120 and 180 sec of irradiation time comparing to the control sample.

Key words: gamma irradiation, microwave radiation, sensory evaluation of wheat grain odour, colour measurement

INTRODUCTION

The term food quality includes three principal areas: nutritional value, acceptability and safety. Acceptability includes a large array of attributes, among them visual appeal, aroma, flavour, texture, mouthfeel, convenience, and cultural appropriateness [4]. Some of these desirable properties can be supported by gamma ionising irradiation and microwave radiation of a foodstuff. However, radiolytically induced chemical modifications of foodstuffs have the potential to generate unnatural chemical changes with undesirable or toxic properties including the formation of hydrogen peroxide, production of "end products" of the lipid peroxidation process, transformation of permitted synthetic antioxidants to reactive quinone species, production of breaks in DNA, chemical modifications of proteins and the conversion of ascorbate to oxalate [9].

Electromagnetic energy (EME)-based drying process may produce materials at acceptable expense, which rehydrate more readily than hot air dried products due to a less degraded (collapsed) structure [16]. Microwave energy is not a form of heat. Heat is a secondary effect of an electromagnetic field interacting with matter such as food. Thus, food is very well suited for heating and drying with microwave energy. Microwaves are able to penetrate the dry surface regions which promotes mass transport and increases drying rate. Controlling heating uniformity is important to ensure the microbial safety and high quality of microwave dried foods. There is a lack of general models for predicting the heating pattern, moisture and vapour distribution during the drying procedure based on the dielectric properties, water distribution, density, food composition. In addition, reliable data on microwave treated products are still missing. Also, more knowledge is needed about the influence of geometry, the size of the object being dried, and phenomena like shrinkage, puffing and stress-cracking. This certainly will lead to the drying process industry investing in modern technology [16].

Today microwave drying is used mainly for drying of pasta and post-baking of biscuits. However, several other industrial microwave drying applications exist. Microwave drying of grain is carried out on a pilot-plan in USA and Canada [16].

Also, more knowledge about nutritional value, colour, taste and aroma is required in order to control of the quality parameters of drying products. This work is a part of the complex investigations performed in order to compare changes induced by ionising and microwave irradiation of wheat grain. The study concerns the influence on biological activities [22], nutritional [23] and technological properties [12] as well as grain susceptibility to insects infestation and evaluation of colour and odour of wheat grain. Odour and colour makes an essential criterion in the evaluating of cereal grain both in commerce and technology [6, 8, 11, 13]. Frequently off-flavours in food are caused by microbial metabolites [24]; the same is true about grain [11, 26]. However, sometimes off-flavours can be produced by processing treatments.

This work concerns the evaluation of grain odour and colour after gamma and microwave irradiation of wheat grain.

MATERIALS AND METHODS

Winter wheat Begra variety used for a study was harvested in 1996 and 1997 from experimental field Plant Breeding Station DANKO in Choryń.

Gamma irradiation experiment was conducted in a RChM-gamma-20 irradiation apparatus made in USSR, packed with ^{60}Co. 5000g wheat grain divided into 5 portions. Each portion of 1000g was irradiated in an aluminium vessel with gamma rays at the following doses: 0.05; 0.1; 0.5; 1; 5; 10 kGy. The strength of the irradiation dose was determined by Fricke's dosimeter was 0.5 Gy/sec.

Microwave irradiation was carried out in a Samsung Electronics RE 1100 microwave oven. The unit operated on 220 V, 50 Hz alternating current and emitted radiation at frequency of 2450 MHz. Before the irradiation process microwave oven was calibrated according to the Standard Test Method for Calibration of Microwave Ovens [21]. 5000 g of wheat grain was placed in portions on Petrie dishes (a 20-cm diameter) and irradiated at different time from 15 to 180 sec with the high power of 1250 W and plate rotation. The grain depth measured in the centre of the dish was 2-3 cm. The temperature of the grain was recorded as an average of three readings taken immediately after radiation treatment. The grain samples were allowed to cool, then were stored in airtight containers at room temperature for futher analyses.

Moisture of wheat grain was determined using moisture-air-oven method, drying at 135 ^{o}C according to AACC methods [1].

The sensory characteristics of the grain odour were assessed by the panel of ten-members. The analysis involved a triangle difference test of smell. The samples of grain were presented to the panellists in 100 ml volume covered containers, preheated prior to the analysis in a thermostat of 40 ^{o}C. The results were read out from statistical tables [3] at significance level of $P = 0.05$.

Profile analysis was performed by 10 member panel, on the basis of arbitrarily elaborated vocabulary of odour descriptors. The descriptors were chosen from Basic Flavour Descriptive Language [20]. The vocabulary consisted of 4 descriptors in both cases: grain, hay, malty, and rotten for irradiated grain and grain, hay, malty, and brown for microwave radiation. The samples were presented in the same way as for the triangle test. Panellists were asked to estimate the intensity of every descriptor on the linear 10 cm scale anchored on both sides for the intensity of descriptors as "none" and "very strong". The mean values for assessor's notes are presented by graphs.

The colour measurements were made with a Minolta Chroma Meter CR-200 D calibrated to a standard white reflective plate [17]. The grain samples for colour measurement were placed in the light impervious vessels covered by a glass plate in order to obtain perfectly flat surface. Every colour measurement was made in six readings per sample. Lightness (L^*) and chromaticity dimensions: a^* (redness) and b^* (yellowness) were recorded. In the recommendation of the CIE (Commission Internationale de l'Eclairage) the uniform colour space is defined by (17):

$$L^* = 116\,(Y/Y_0)^{1/3}-16,$$

$$a^* = 500\,[(X/X_0)^{1/3}-(Y/Y_0)^{1/3}],$$

$$b^* = 200\,[(Y/Y_0)^{1/3}-(Z/Z_0)^{1/3}],$$

with the restriction: $Y, Y_0 > 0.01$.

X,Y,Z are the tristimulus values of a colour, and X_0, Y_0, Z_0 define the colour of the nominally--white-object-colour stimulus with Y_0 equal to 100. In this colour space, the total colour difference ΔE between two colours, each given in terms of L^*, a^*, b^* was calculated from:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

The above equation was used in order to estimate the objective differences between gamma and microwave irradiated samples of grain as compared to their respective control samples.

RESULTS

As it is shown in table 1, both applied treatments: gamma and microwave irradiation, did not cause significant changes in the grain odour in comparison to the control grain sample, with the exclusion of maximum irradiation dose 10 kGy and maximum microwave radiation time at 180 sec.

Table 1. Triangle difference test of grain odour. Results are read out at significance level of P=0.05.

Irradiated grain		Microwave heated grain	
Dose (kGy)	Result	Exposure time (sec)	Result
0.05	-	15	-
0.1	-	45	-
0.5	-	60	-
1	-	90	-
5	-	120	-
10	+	180	+

- no significant change of odour
+ significant change of odour

The odour profile was estimated both for the two samples and the reference samples of the grain. The data from the descriptive profile analysis are presented in figures 1 and 2. In both cases the reference samples have a typical grain odour (descriptor 1) with little participation of two other descriptors: 2 hay and 3 malty. The 10 kGy irradiation dose and 180 sec of microwave radiation, caused to form untypical odour, named according to Basic Flavour Descriptive Language, as "rotten" in the case of gamma irradiated sample and 'brown' after

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microwave treatment. The appearance of these off-flavours influenced the decrease in the intensity of a typical grain odour. The “rotten” off-flavour is described as unfresh or even decay, while “brown” is associated with burnt or roasted grain.

Figure 1. Odour profile of irradiated grain with 10 kGy dose in comparison to reference grain profile.
Descriptors: 1. grain, 2. hay, 3. malty, 4. rotten.

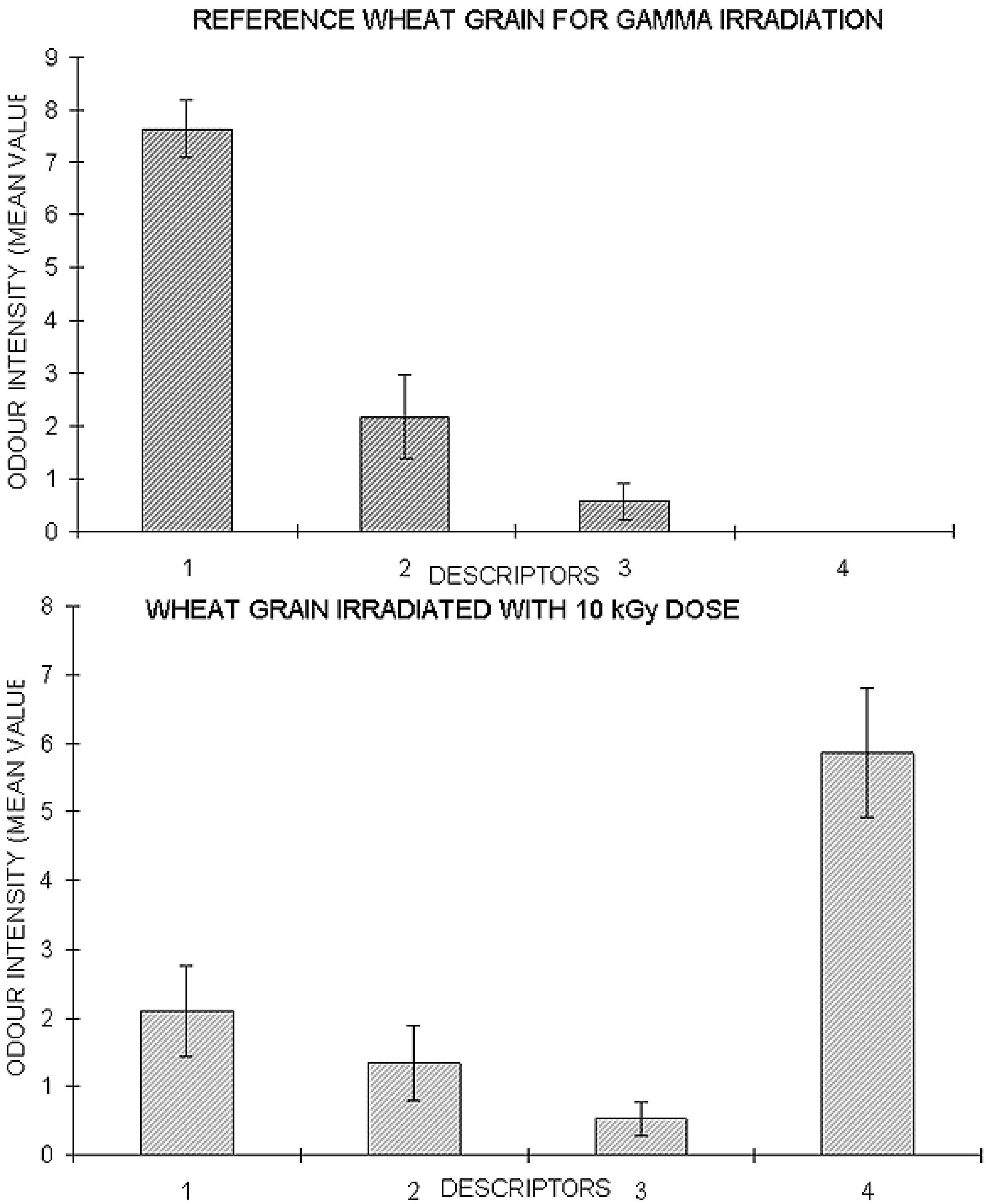
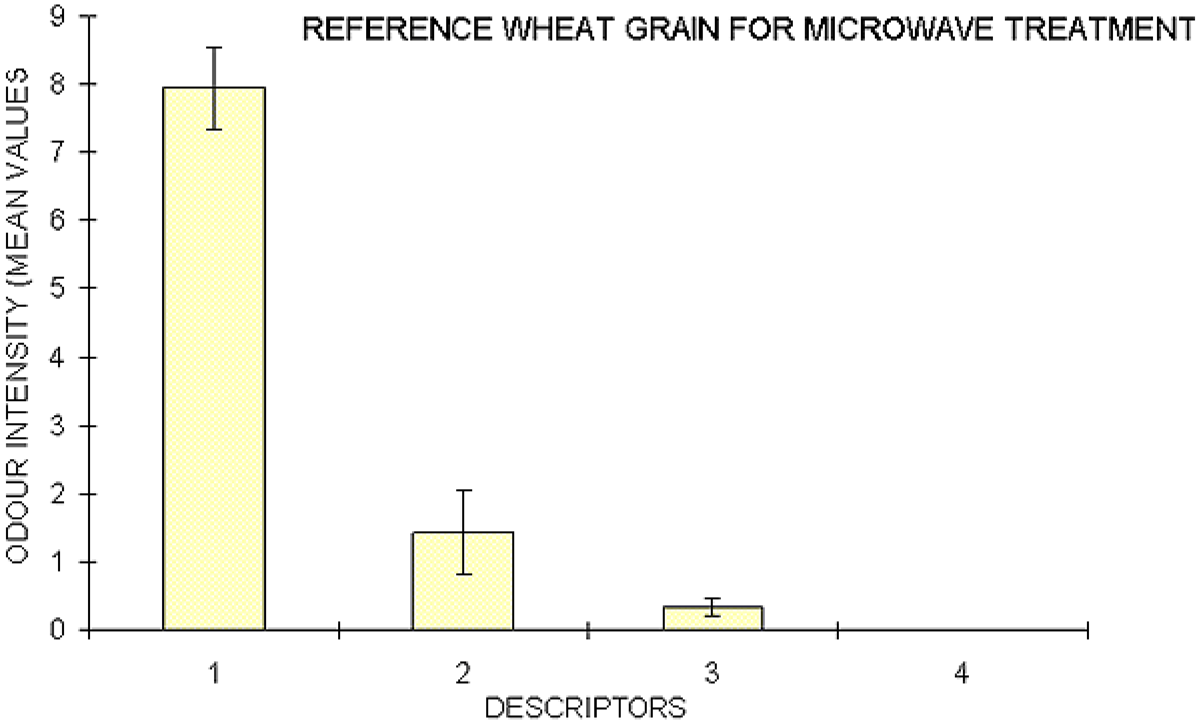
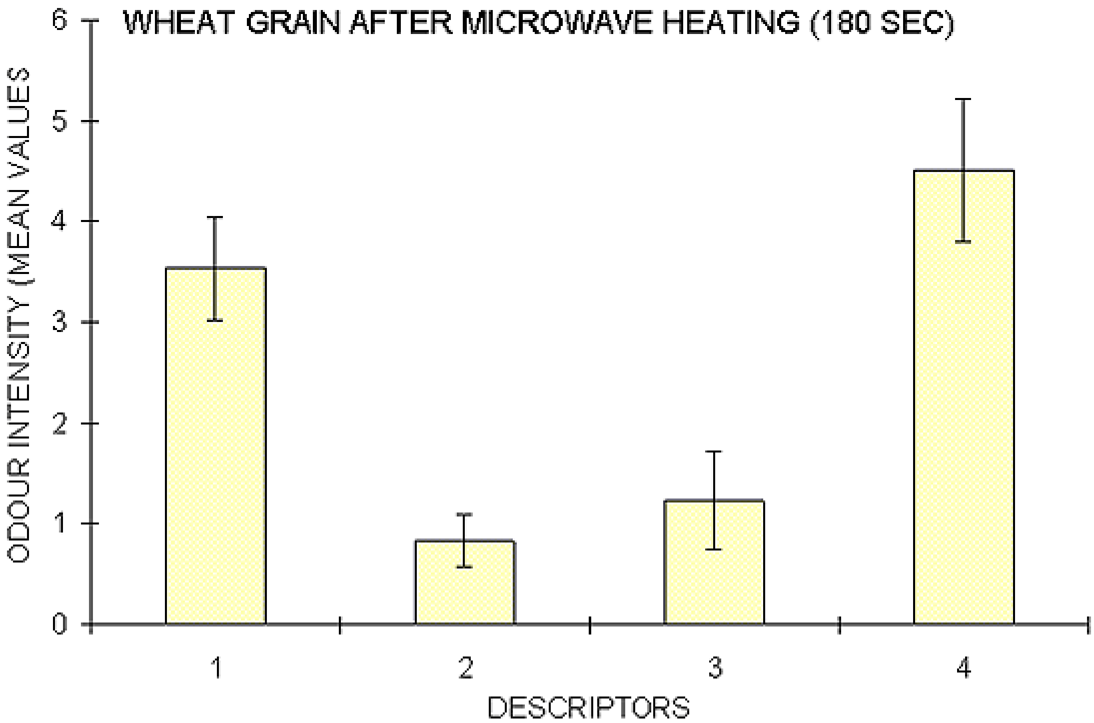


Figure 2. Odour profile of microwave heated grain for 180 sec in comparison to reference grain profile.
Descriptors: 1. grain, 2. hay, 3. malty, 4. brown.





Burnt-like flavour is usually observed in overheated food [2, 7]. Appearance and sensoric properties of the microwave treated plain starch and blended with some compounds pointed to the reactions occurring after treatment [19]. The development of the secondary food aromas was observed. In the case of plain, microwave treated starch 'intensive, caramel, smoked plums' aroma appeared, similar to "brown" observed in the present work. On the other hand, starch blended with glutamic acid was characterised, after microwave irradiation, as "pleasant, ginger bread"[19]. The descriptor (brown) used in the present work can express an intermediate aroma appeared as a consequence of a chemical complex of wheat grain.

Nijhuis et al. [16] presented advantages and disadvantages of alternative technologies of dry conservation process like: freeze drying, microwave and radio frequency. Microwave drying has positive ratings for: drying rate, flexibility, colour, flavour, nutritional value, microbial stability, enzyme inactivation, rehydration capacity, crispiness and fresh-like appearance. These qualities pointed out that microwave irradiation is a good technology for dry conservation process of fruits and vegetables on condition that the time of heating is properly chosen.

Characteristic unpleasant odour of the gamma irradiated samples occurred only at 10 kGy dose. Some changes in odour of irradiated food were also stated, e.g. in spices [10]; but like in this work at the doses higher than 5 kGy. The investigations concerning the effect of gamma irradiation on volatile flavour components of wheat and bread proved the increase in off-flavour intensity [18]. It was suggested that gamma irradiation can increase the formation of the volatile degradation products of amino acids and proteins, as well as their interaction with reducing sugars due to obtain the ultimate radiation-induced breakdown products of starch.

Obtained results of the determination of the grain colour by the measurement of reflected-light were summarised in tables 2 and 3. In order to estimate the significance of the differences between control and irradiated samples, the analysis of variance and standard deviations were performed. From the values obtained it can be concluded that at the level of P = 0.05 there were not any statistically significant changes in grain colour induced by gamma ^{60}Co irradiation (table 2). Wootton et al. [25] found that the milling yield of whole grain rice was not affected by increasing gamma radiation dosage up to 10 kGy, but the colour deteriorated towards yellowish. It was proved further, that a higher moisture content of grain rice underwent greater deterioration in colour. The moisture of wheat grain samples used in present work was at the level of 13.21%. This moisture shoud be low enough not to cause significant changes in grain colour during gamma irradiation process.

Table 2. The colour characteristics of wheat grain exposed to gamma irradiation ^{60}Co.

Irradiation dose [kGy]	Moisture[1] [%]	L^{*} [2] [%]	a^{*} [2]	b^{*} [2]
Control sample	13.21±0.10[3]	44.9±1.00	2.8±0.40	11.0±0.48
0.05	13.56±0.13	46.3±0.39	2.7±0.21	10.6±0.29
0.1	13.47±0.04	45.9±0.36	2.5±0.12	10.5±0.24
0.5	13.21±0.10	45.6±0.71	2.6±0.23	10.7±0.38
1	13.48±0.02	45.8±1.35	3.1±0.29	11.8±0.58
5	13.30±0.01	44.1±1.34	2.6±0.52	10.4±0.53
10	13.35±0.06	45.3±0.73	2.7±0.33	10.9±0.70

[1] **average of three readings per sample.**
[2] **average of six readings per sample.**
[3] **± standard deviation.**

On the other hand, it was shown that microwave irradiation significantly changed the colour of the grain (table 3). The analysis of variance and calculation of the smallest significant value proved that from 90 to 180 sec of microwave treatment, the values of L^{*} (lightness) were

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significantly higher in comparison to control sample which pointed out that these samples were surprisingly lighter than the control one. Also visual inspection of grain samples confirmed these results. Many unexplained aspects of cereal quality could be due to enzymes [13]. Unfortunately, our knowledge of the large number of enzyme systems in wheat is limited. Nicolas and Drapron [15] list effects of lipoxygenase in breadmaking; among them their role in modification of colour and odour.

Table 3. The colour characteristics of wheat grain exposed to microwave irradiation.

Exposure time [sec]	Microwave output [kJ]	Moisture[1] [%]	Temperature[1] [°C]	L^{*} [2] [%]	a^{*} [2]	b^{*} [2]	ΔE
control sample	-	12.24±0.03[3]	20.0	45.5±1.54	3.1±0.28	11.5±0.84	-
15	8.55	12.22±0.06	27.8	45.8±1.18	3.1±0.12	11.3±0.76	2.33
45	25.65	12.18±0.04	43.0	46.1±1.08	3.1±0.10	9.3±0.58	4.89
60	34.20	12.22±0.07	48.0	46.2±0.33	3.3±0.49	12.2±0.61	4.64
90	51.30	11.72±0.03	64.0	47.3±0.78	3.5±0.35	12.6±0.53	13.18
120	68.40	10.59±0.11	79.0	47.7±0.49	3.9±0.42	13.0±0.29	16.36
180	102.60	9.87±0.18	98.2	48.6±0.82	4.1±0.38	14.7±0.77	27.35
the smallest significant difference	-	-	-	1.74	0.60	1.16	-

[1] average of three readings per sample.
[2] average of six readings per sample.
[3] ± standard deviation

The total colour difference (ΔE) between microwave irradiated samples and control sample was increasing gradually with the rise of radiation time. The yellowness (b^{*}) and the redness (a^{*}) values were statistically significantly higher in the case of 120 and 180 sec of radiation time in relation to the control sample. However, the increase of these values was not significant enough due to equate the L^{*} value, which was visually confirmed. The significant increase of L^{*} value could be associated with some thermal decomposition and modification of grain components which was correlated with the increase of the grain temperature from 64 to 98 °C (table 3). The temperature at which damage of wheat starch begins is suggested at between 53-64 °C [5]. However, it depends on the initial moisture content of the grain. On the other hand, alpha-amylases like lipoxygenases of wheat grain are fairly heat-stable, since no inactivation occurred below 60 °C [13]. The colour of the flour, due to both its content of wheat and bran pigments, affects bread whiteness [13]. But other factors influence the colour of bread crumb greatly as well. Foremost among these is the fineness of the grain. The brightness of grain and flour is probably only a minor factor in the formation of bread crust colour. Data for the distribution of pigments in the components of the wheat kernel are scant. However, it had earlier been assumed that their concentration in whole wheat was as follows: carotene-0.18 µg/g, xanthophyll-0.99 µg/g, xanthophyll ester-0.63 µg/g and flavones as tricin-2.3 µg/g [13]. Native wheat lipoxygenases are known to have some bleaching action on grain carotenoid pigments [15].

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It was proved that gamma ionising irradiation did not change significantly the moisture of grain (table 2). In the case of microwave treatment the temperature of grain increased linearly with the irradiation time of wheat sample and microwave output (table 3). Moisture content decreased as irradiation time increased, particularly for those samples receiving higher radiation treatments. Similar results concerning temperature and moisture changes of the microwave treated flour were reported for 90 to 480 sec irradiation time [14].

Considering examined properties of the grain it can be concluded that both treatments will not change grain quality in terms of odour and colour when extreme doses and irradiation time used in this process are avoided.

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Jerzy R. Warchalewski, Justyna Gralik, Romualda Kuśnierz
Department of Biochemistry and Food Analysis
Renata Zawirska-Wojtasiak
Institute of Food Technology of Plant Origin
Jan Zabielski
Department of Nuclear Methods in Agriculture,
Agricultural University of Poznań
48 Mazowiecka St., 60-623 Poznań, Poland
tel. (+48 61) 8487346
fax (+48 61) 8487146
