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APPLICATION OF INSTRUMENTAL COLOUR MEASUREMENT AS AN INDICATOR OF CHANGES OCCURRING IN WHEAT BAKERY PRODUCTS DURING PRODUCTION PROCESS

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Key words: colour evaluation, L*a*b* system, wheat bakery products

The study covers an analysis of changes which occur in colour of wheat bakery products manufactured from two types of flour. For the purposes of the study, the researchers adopted different periods of dough mass kneading and thermal treatment in order to determine the influence of the said parameters on the colour of finished products. A range of L*a*b* factors variability was found out on the basis of test results, subject to the type of actual flour. The colour of finished products was a function of dough kneading period (in every case), thermal treatment period (depending on the examined parameter and type of flour) as well as of the interaction between these two parameters.

NOTATIONS

L* – lightness (%), a* – chromaticity parameter red/green (-), b* – chromaticity parameter yellow/blue (-).

INTRODUCTION

Consumer requirements and competition which keeps increasing on food products market oblige the manufacturers and researchers to carefully plan the production process in order to make the articles featuring the highest quality standards possible at a minimum cost. A food product is a perishable material; it is susceptible to multiple path transformations under the influence of many different parameters. Careful studies on the pattern of changes in different conditions allow to forecast the future „behaviour" of the product during its processing. Information originating from such studies helps controlling the production process which will generate products featuring the desired quality parameters. One of applicable tools is the instrumental colour evaluation which is used as a immediate gauge for determination of different qualitative changes occurring in food products [Özdemir & Devres, 2000; Denoyelle & Berny, 1999] since colour changes are a result of mechanical operations on raw materials [Biller & Neryng, 2003; Ekielski *et al*., 2005], of thermal processing [Biller *et al*., 2005], chemical changes, and are correlated with textural changes in food [Biller & Ekielski, 2005] as well as with chemical composition, *i.e.* contents of certain compounds, such as *e.g.* proteins level in meat [Florowski *et al*., 2002].

The study was designed to analyse the possibility of applying instrumental colour evaluation as a tool for the determination of qualitative changes occurring in wheat bakery products during their production.

The scope of the study covered instrumental colour measurement applied to cross-sections of wheat bakery products manufactured from two different types of flour and kneaded for different periods of time.

MATERIALS AND METHODS

Test materials covered wheat bakery products manufactured from two different types of wheat flour: "Mąka Luksusowa" manufactured by PZZ Szymanów (Type 550; hereinafter referred to as „Flour 1") as well as "Mąka Babuni" manufactured by Młyny i Spichrze Zbożowe "Musioł i Sp.", Kędzierzyn-Koźle (Type 650; hereinafter referred to as "Flour 2"). The recipe was composed of the ingredients as follows: 1 kg of flour, 0.5 kg of water, 30 g of yeast, 10 g of salt, and 2.5 g of sugar. The dough was produced by means of single-phase method and kneaded in a Sigma MG 12 brand mixer equipped with a helical agitator. The periods of kneading were equal to 10, 15, 20 and 25 min. Every specimen was processed by means of fermentation in an incubator (2 h at 32°C). After fermentation the dough was divided into batches, each 600 g, placed in a rectangular baking tin and processed by means of thermal treatment at 200°C in a convection-type oven (AR6 ESP, Elektrolux) for 20, 30, 40 and 50 min. After cooling down to ambient temperature the product was cut to expose its cross-sections which were measured by means of instrumental chromometry using the L*a*b* system (CR-310 photocolorimeter by Minolta, type of light – D_{65}; the apparatus was calibrated with white plate standard).

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The results were calculated by means of Statistica 6.0. software, central composite surface response model. Analysis of variance was conducted to determine significant differences between the various treatment combinations. The goodness-of-fit of the surface response models was evaluated using the adjusted R^2.

RESULTS AND DISCUSSION

Changes in lightness of product cross-section area (L*) during thermal treatment

Changes in lightness (L*) of wheat product cross-section area during thermal treatment are shown in Figures 1 a and b as a function of dough kneading and thermal treatment periods.

The values of lightness (L*) of cross-section area of the bread produced from Flour 2 were lower in every case than those of the bread produced from Flour 1: cross-section area of the bread produced from Flour 2 was darker. Hence, it can be concluded that the type of flour has had an influence on bread lightness produced after thermal treatment.

Changes in the value of a* parameter (red colour axis) of bread cross-section area during thermal treatment

Changes in the value of a* parameter (red colour axis) of bread cross-section area during thermal treatment are shown in Figures 2 a and b.

The bread produced from Flour 1 featured lower values of a* parameter than the bread produced from Flour 2. The curve illustrating the changes in values of this parameter was different in the case of the two types of flour. This indicates the differences between the properties of the flours used in the tests.

a) R^2=0.640 b) R^2=0.668

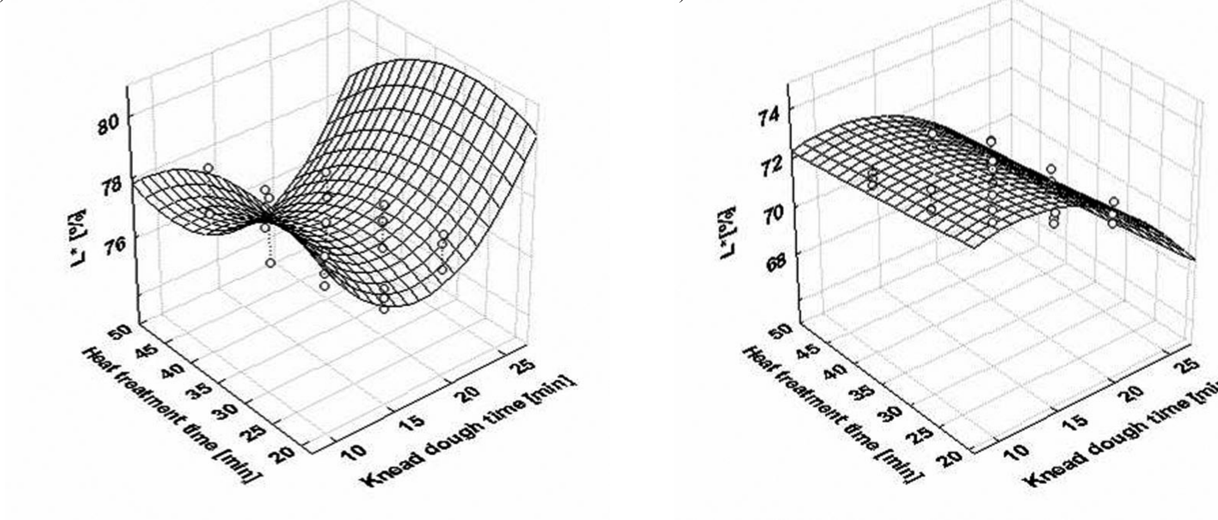

FIGURE 1. Changes in lightness (L*) of cross-section area of the bread produced from dough kneaded and baked for different periods of time: (a) dough produced from Flour 1; (b) dough produced from Flour 2.

a) R^2=0.982 b) R^2=0.957

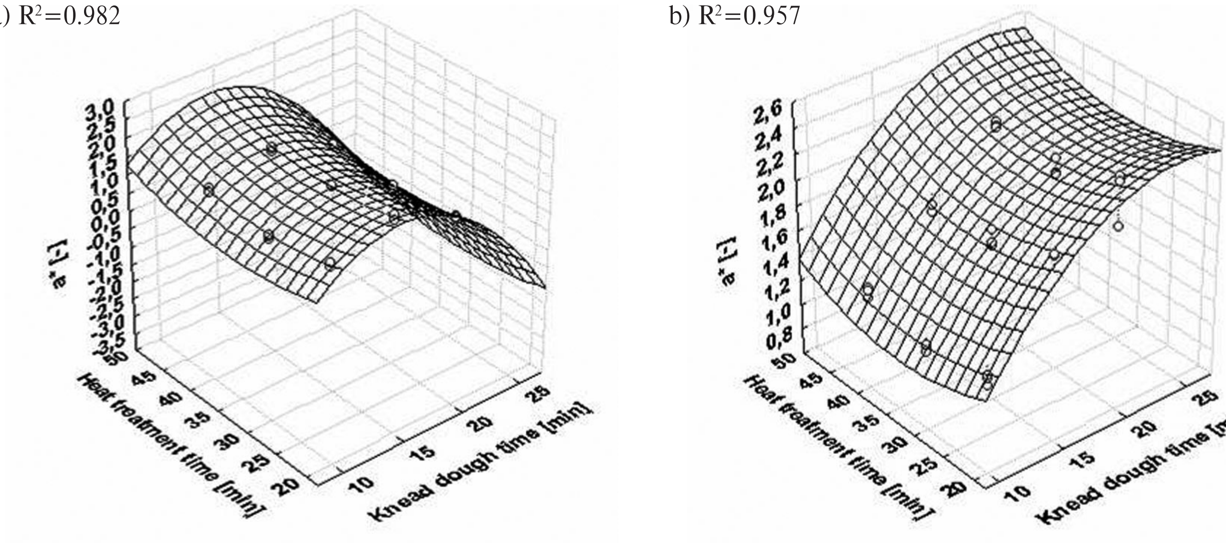

FIGURE 2. Changes in value of a* parameter (red colour axis) of cross-section area of the bread kneaded and baked for different periods of time: (a) dough produced from Flour 1; (b) dough produced from Flour 2.

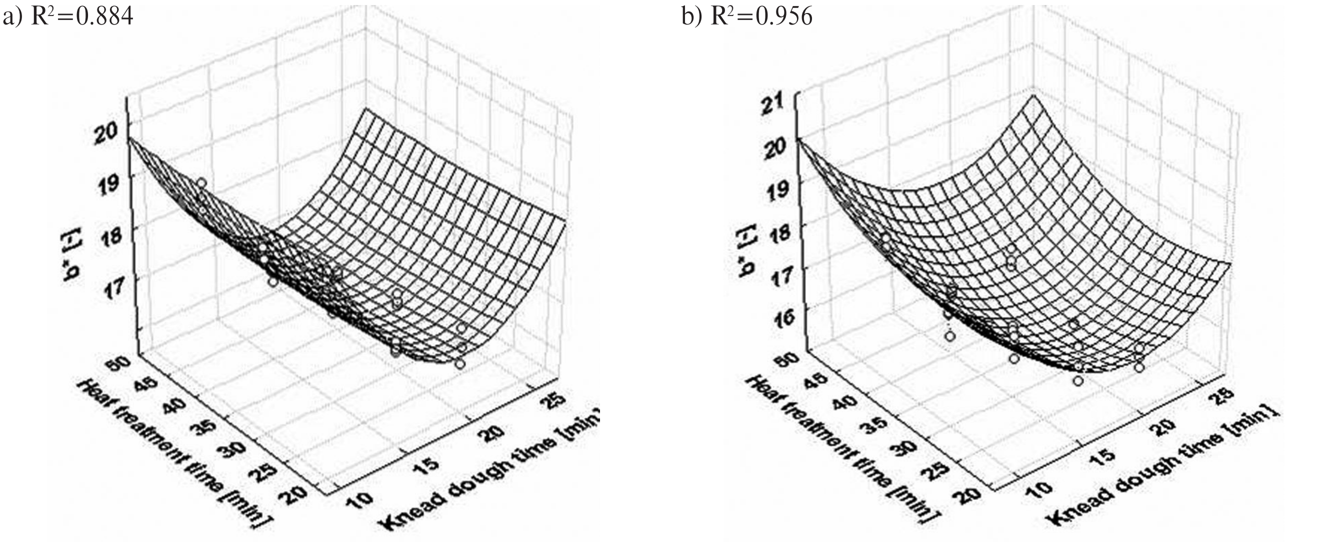

FIGURE 3. Changes in value of b* parameter (yellow colour axis) of cross-section area of the bread kneaded and baked for different periods of time: (a) dough produced from Flour 1; (b) dough produced from Flour 2.

Changes in the value of b* parameter (yellow colour axis) of bread cross-section area during thermal treatment

Changes in the value of b* parameter (yellow colour axis) of bread cross-section area during thermal treatment are shown in Figures 3 a and b.

The values of b* parameter of wheat bread after thermal treatment, produced from Flour 1 and 2 were close to each other (they were contained in a similar interval of values).

It was concluded that parallel to kneading time extension, the product features lower values of this parameter, thus the bread is of less yellow colour.

Effect of kneading and thermal treatment period on changes in wheat product colour

The test results were estimated by means of Statistica 6.0. software package. An average value of colour parameters – L*, a*, and b*, respectively – was used as an estimator. By way of Shapiro-Wilk test it was abandoned our preliminary hypothesis that all the average values of L*, a*, b* of samples were equal (at a significance level of $p<0.05$).

The following working hypotheses were assumed:

1. H_1: kneading period has no influence on L*, a*, b* parameters of the product.

2. H_2: thermal treatment period has no influence on L*, a*, b* parameters.

Simultaneously, alternative hypotheses were assumed as follows:

3. H_1': kneading period has an influence on L*, a*, b* parameters of the product.

4. H_2': thermal treatment period has an influence on L*, a*, b* parameters.

Verification of the above-mentioned hypotheses was conducted by means of the analysis of Statistica 6.0 software variances, separately for the two types of products baked from different types of flour.

Results of verification of these hypotheses for the bread produced from Flour 1 are shown in Tables 1 – 3.

An analysis of the results shown in Table 1 allows us to conclude that the hypotheses H_1 and H_2 (at a significance levels of 0.0 and 0.0013, respectively), which assume no effect of the kneading and thermal treatment periods on the value of L* parameter, should be abandoned. Simultaneously, no interaction was found between these parameters.

Table 2 shows results of a significance test for a* parameter and a significance level of $p<0.05$ (for Flour 1).

On the basis of the above-mentioned results, the hypotheses H_1 and H_2 (at significance levels of 0.00 and 0.00, respectively), which assume no effect of the kneading and thermal treatment periods on the value of a* parameter, should be abandoned. Simultaneously, we found an interaction between these two parameters. This means that collective action of the said two factors will have an influence on the value of a* parameter.

Table 3 collates data of a significance test for b* parameter and a significance level of $p<0.05$ for Flour 1.

On the basis of the analysis (Table 3), the hypotheses H_1 and H_2 (at significance levels of 0.00 and 0.00, respectively), which assume no influence of the kneading and thermal treatment periods on the value of b* parameter, should be abandoned. Simultaneously, we found an interaction between these two parameters. Hence, collective action of the said two factors will have an influence on the value of b* parameter.

When drawing the response area, the occurrence of interaction should be taken into account.

Results of verification of hypotheses for the bread produced from Flour 2 are shown in Tables 4 – 6.

The hypotheses H_1 and H_2 (at significance levels of 0.00 and 0.00, respectively), which assume no influence of the kneading and thermal treatment periods on the value of L* parameter, should be abandoned. On the basis of analytical results it was found an interaction between these two parameters. Hence, kneading and thermal treatment periods will affect the value of L* parameter.

Table 5 collates results of a significance test for a* parameter and a significance level of $p<0.05$ (for Flour 2).

TABLE 1. Results of a significance test for L* parameter and a significance level of p<0.05 for Flour 1.

Effect	One-way analysis of variance (Flour 1) Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
Free term in the expression	284683.9	1	284683.9	680349.1	0.000000
Knead dough time	42.6	3	14.2	33.9	0.000000
Heat treatment time	8.3	3	2.8	6.6	0.001349
Knead dough time x heat treatment time	5.3	9	0.6	1.4	0.221483
Error	13.4	32	0.4		

TABLE 2. Results of a significance test for a* parameter and a significance level of p<0.05 for Flour 1.

Effect	One-way analysis of variance (Flour 1) Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
Free term in the expression	94.39760	1	94.39760	30914.84	0.000000
Knead dough time	2.84128	3	0.94709	310.17	0.000000
Heat treatment time	0.47845	3	0.15948	52.23	0.000000
Knead dough time x heat treatment time	0.10369	9	0.01152	3.77	0.002503
Error	0.09771	32	0.00305		

TABLE 3. Results of a significance test for b* parameter and a significance level of p<0.05 for Flour 1.

Effect	One-way analysis of variance (Flour 1) Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
Free term in the expression	13372.92	1	13372.92	299480.6	0.000000
Knead dough time	25.53	3	8.51	190.6	0.000000
Heat treatment time	1.56	3	0.52	11.6	0.000026
Knead dough time x heat treatment time	1.61	9	0.18	4.0	0.001666
Error	1.43	32	0.04		

The hypotheses H_1 and H_2 (at significance levels of 0.00 and 0.00, respectively), which assume no effect of the kneading and thermal treatment time on the value of a* parameter, should be abandoned. Simultaneously, an interaction was found between the analysed parameters, which means that collective action of the two analysed factors has an influence on the value of a* parameter.

In turn, Table 6 shows results of a significance test for b* parameter and a significance level of $p<0.05$ (for Flour 2).

An analysis of the results in Table 6 allows us to abandon hypothesis H_1 which assumes no effect of the kneading period on the value of b* parameter. Simultaneously, hypothesis H_2 cannot be abandoned. This means that extended thermal treatment period has caused no essential statistical changes in the values of this parameter.

CONCLUSIONS

On the basis of the investigation it could be concluded that the changes in each colour parameter were different depending on the type of flour. The values of L* and a* parameters were included in different ranges (values of b* parameter were included in a similar range). The different values of L* and a* parameters must have been due to different properties of materials applied in production process; in this case, the said different values point to different properties of flour and different properties of dough which was next exposed to thermal processing.

In spite of different curves of selected parameter variability, in each case a significant statistical influence has been confirmed of the kneading time on the colour of bread cross-section area. This means that the selection of suitable kneading time may help to produce the desired colour of a finished product.

On the basis of Figures 1-3 it has been concluded that extended kneading period allows to produce the bread which will be darker and less yellow. Red colour profile proved different subject to the type of flour: for Flour 1, extended kneading period initially produced more red bread after thermal treatment (until the 14^{th} min of kneading)

TABLE 4. Results of a significance test for L* parameter and a significance level of $p<0.05$ for Flour 2.

Effect	One-way analysis of variance (Flour 2) Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
Free term in the expression	248724.0	1	248724.0	1715114	0.000000
Knead dough time	24.6	3	8.2	57	0.000000
Heat treatment time	19.1	3	6.4	44	0.000026
Knead dough time x heat treatment time	8.1	9	0.9	6	0.000050
Error	4.6	32	0.1		

TABLE 5. Results of a significance test for a* parameter and a significance level of $p<0.05$ for Flour 2.

Effect	One-way analysis of variance (Flour 2) Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
Free term in the expression	194.0689	1	194.0689	44713.02	0.000000
Knead dough time	8.4983	3	2.8328	652.67	0.000000
Heat treatment time	0.1455	3	0.0485	11.17	0.000036
Knead dough time x heat treatment time	0.1213	9	0.0135	3.11	0.008522
Error	0.1389	32	0.0043		

TABLE 6. Results of a significance test for b* parameter and a significance level of $p<0.05$ for Flour 2.

Effect	One-way analysis of variance (Flour 2) Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
Free term in the expression	14550.55	1	14550.55	591351.3	0.000000
Knead dough time	55.86	3	18.62	756.7	0.000000
Heat treatment time	0.10	3	0.03	1.4	0.265133
Knead dough time x heat treatment time	0.42	9	0.05	1.9	0.091490
Error	0.79	32	0.02		

while from 14^{th} min of kneading the share of red colour kept decreasing. For Flour 2, the extended kneading time was connected with a successive increase in red colour share.

Thermal treatment period has an essential effect on the product's colour parameters in most cases. No discriminant was stated in the case of b* parameter of the bread produced from Flour 2. In the case of this type of flour, extended baking period brought about more intensive changes in red colour rather than in yellow, in the same period of time. This points to different properties of flour, *i.e.* different susceptibility to non-enzymatic browning.

The investigation results enable concluding that instrumental colour measurement may be an accurate measure of quality of wheat bakery products, given that the colour of finished bread depends on varying conditions of the process (kneading time, thermal treatment time and interactions between these two factors). This means that the dough will feature different properties which in turn, will have their further effect on the colour of the product.

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ZASTOSOWANIE INSTRUMENTALNEGO POMIARU BARWY JAKO WSKAŹNIKA ZMIAN ZACHODZĄCYCH W PIECZYWIE PSZENNYM W CZASIE PROCESU TECHNOLOGICZNEGO

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W pracy dokonano analizy zmian barwy pieczywa pszennego wytworzonego z dwóch rodzajów mąk. Uwzględniono różny czas wyrabiania masy ciasta i różny czas obróbki termicznej analizując ich wpływ na barwę gotowego produktu. Na podstawie wyników badań stwierdzono rożną zmienność wyróżników L*a*b* w zależności od rodzaju zastosowanej mąki. Na barwę produktu gotowego miał wpływ czas wyrabiania ciasta (w każdym przypadku), czas obróbki termicznej (w zależności od badanego parametru i rodzaju mąki) oraz interakcja obydwu czynników.