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**Presenter Information**

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# The changes in colour of biscuits during baking depending on time and different proportion of barley flour

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**Abstract.** Biscuits hold an important position in food industry due to variety of taste, nutrition, crispiness and digestibility. The nutritional value of biscuits can be enhanced by fortification with a wide variety of protein rich cereal such as barley. Colour is essential to the manufacture of biscuits of good quality. During baking, complex chemical reactions take place in the biscuits, such as the Maillard reaction and caramelization. The aim of this study was to evaluate the changes in colour of biscuits during baking. Biscuits were produced according to AACC 10-50D method. Wheat flour was replaced with barley flour at varying levels (30, 50, 70 and 100%) in biscuit formulations. Color measurement of biscuits was carried out using a colorimeter on the basis of CIE L\*, a\*, b\* color system. Some of the biscuits were stored in room temperature and change of their color was determined after 6 and 12 months.

**Keywords:** Biscuits, Baking, Colour

## INTRODUCTION

Biscuits are a baked product based on wheat flour. Generally, soft wheat flour is recommended to produce biscuits. Soft wheat flour is preferred due to its low hydration properties, low protein content of 8-10%, small level of starch damage and arabinoxylans and weak gluten network [1]. The composition of biscuits includes fats and sweeteners [2], as well as various enhancers and other additives, and because of this, they differ in the type, composition, mass, consistency, structure and technology of production [3].

Biscuits appear on the market, which are produced by mixing together wheat flour and flour from other cereals such as rye, oats, buckwheat, corn, barley, etc. Barley is an important cereal crop that is an excellent source of soluble and insoluble dietary fibers ( $\beta$ -glucans, arabinoxylans) and other bioactive compounds such as vitamin E, B-complex vitamins, enzymes, minerals and phenolic compounds [4-8]. The well-known health benefits of barley consumption [8-11] have increased the barley processing and barley requirements in the new biscuits formulations. Many authors, who examined the quality characteristics of crackers produced using barley flour together with wheat flour, concluded that barley flour improves their quality [6, 12-14].

Colour is a characteristic of food products, which is first noticed and directly transformed into a positive or negative sign of the overall quality of the product. During the cooking of biscuits, the surface colour changes as a result of complex chemical reactions in the dough, such as Maillard

reaction and caramelization. The colour change depends on the composition of the dough, i.e. the type of flour used, the percentage and activity of the water, the sugar content, the pH value, etc. Different types of flour have a different colour, different gluten quality, that affect the dough, shape and surface of the finished product. On the other hand, the speed of colour creation varies depending on the conditions of the process during baking (temperature, baking time) [14, 15]. Considering the previously stated findings, we thought that it would be of particular interest to determine how the baking time and the different percentage of barley flour affect the colour change of the biscuits.

## MATERIALS AND METHODS

To produce the biscuits, barley flour was produced by grinding the barley (OSK-6-24/2-12) into a laboratory mills (IKA MF10) at the Institute for Cereals, Osijek, Croatia. White wheat flour T-550 and other raw materials were purchased from local stores.

The biscuits were produced in the laboratory of Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology, Osijek, Croatia, in accordance with the AACC Method 10-50D [16]. Five kinds of biscuits were produced: basic control biscuits (100% wheat flour) and biscuits in which wheat flour was partially and completely replaced with barley flour (30%, 50%, 70% and 100% barley flour).

The biscuits were baked in a convection oven (Wiesheu Minimat Zibo, Wiesheu GmbH, Germany), at a temperature of 205 °C. The change in the colour of the biscuits was monitored during a time interval of 5 to 10 minutes baking, at every minute. Part of the biscuits that were baked for 10 minutes were stored at room temperature and after 6 and 12 months of storage a change in the colour of their surface was determined.

The measurement of the colour of the biscuits (at 5 different places on the surface) was evident on the basis of CIE L\*, a\*, b\* color system using a colorimeter (Konica Minolta Chroma Meter CR-400, Japan), and the calculations for the total colour difference (colour change,  $\Delta E$ ) are made according to the described from Budžaki et al., [17].

The relation between the calculated value  $\Delta E$  and the human eye tolerance for perceiving differences between colours is given in Table 1 [18].

**Table 1.** Ratio between calculated values  $\Delta E$  and the tolerance of the human eye for noticing color difference [18]

Total colour difference ( $\Delta E$ )	<0,2	0,2 -1	1-3	3-6	>6
Meaning	not visible	hardly visible	slightly visible	visible	very visible

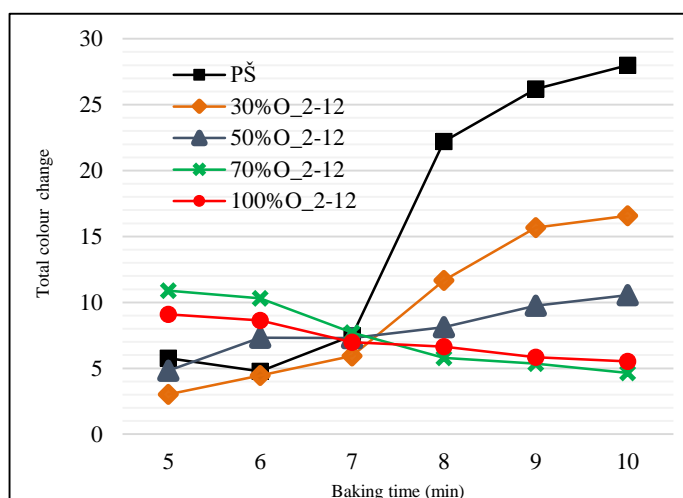
On the day of production, all types of biscuits were scanned using the Epson Perfection V500 Photo Scanner

Data have been statistically processed and shown with the help of Microsoft Office Excel 2016. The relation between the share of barley flour in the produced biscuits and the colour change for the baking time is expressed through Pearson's correlation coefficient (R) and then the statistical significance is determined ( $p < 0.05$ ) [19-21].

## RESULTS AND DISCUSSION

Colour is one of the most important visual changes occurring during food processing. During baking simultaneous heat and mass transfer occur due to elevated temperatures. Heat is transferred from the hot air to the product surface by convection and throughout the product by conduction while the moisture evaporates from the product. These processes influence the qualitative parameters of cookies including colour formation. Browning is the final step of both the Maillard reaction and caramelization, one of the end-points of the baking process and the final result of sugar degradation during baking [17].

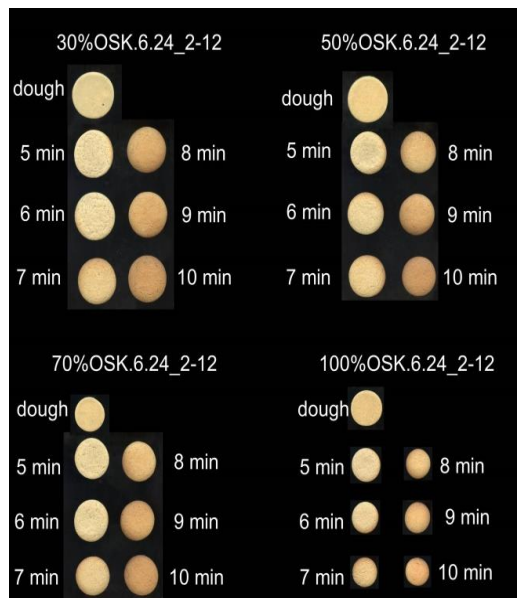
Results of the conducted analysis are shown graphically.



**Fig. 1.** Colour changes of biscuits during the baking process

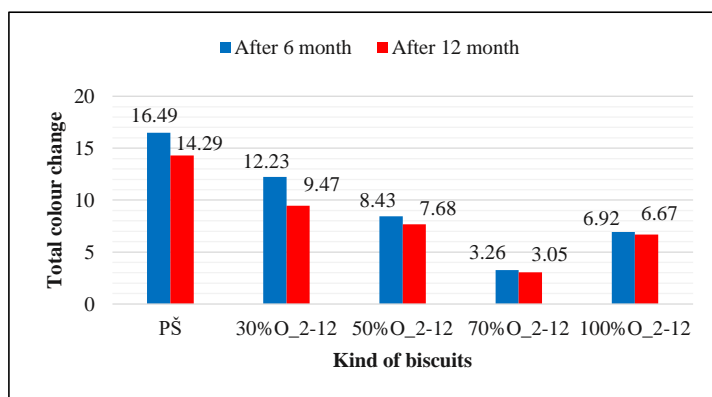
Figure 1 shows the results of the total colour difference ( $\Delta E$ ) of the produced biscuits: a control sample with 100% wheat flour and biscuits in which partial and complete replacement of wheat with barley flour 30%, 50%, 70% и 100% barley flour) is made on the day of manufacture. Very visible colour change ( $\Delta E > 6$ ) can be noticed in biscuits with 70% barley flour ( $\Delta E = 10.89$ ) and 100% barley flour ( $\Delta E = 9.09$ ) after 5 minutes of baking and it decreases with increasing baking time (6 min.–10 min./  $\Delta E = 10.31 - 4.46$  & 6 min.–10 min./  $\Delta E = 8.64 - 5.52$ , respectively). This change is noticed later in other biscuits. In the control biscuits (100% wheat flour), a very visible colour change can be seen after 7 minutes of baking ( $\Delta E = 7.47$ ) and this change increases with the increase of baking time (8 min./  $\Delta E = 22.21$ , 9 min./  $\Delta E = 26.20$  & 10 min./  $\Delta E = 27.98$ ), which is contrary to colour change in biscuits with 70% barley flour and 100% barley flour.

Also, on the day of production all types of biscuits are scanned every minute during a baking time interval of 5 to 10 minutes (Figure 2). From Figure 2 it can be seen that in different biscuits (control sample, 30%, 50%, 70% и 100% barley flour), colour change occurs at different times during baking.



**Fig. 2.** Colour of dough and biscuits on the day of production

The results of the total colour difference ( $\Delta E$ ) of biscuits that were baked for 10 minutes and stored at room temperature for 6 and 12 months are shown in Figure 3. From the results shown, it can be seen that only in biscuits with 70% barley flour there is a visible colour change ( $\Delta E=3-6$ ) after 6 and 12 months of storage (3.26 & 3.05, respectively). In the remaining biscuits, after 6 and 12 months of storage, very visible changes in colour can be observed ( $\Delta E>6$ ), with the largest being in biscuits with 100% wheat flour (6 month/  $\Delta E=16.49$  and 12 month/  $\Delta E=14.29$ ).

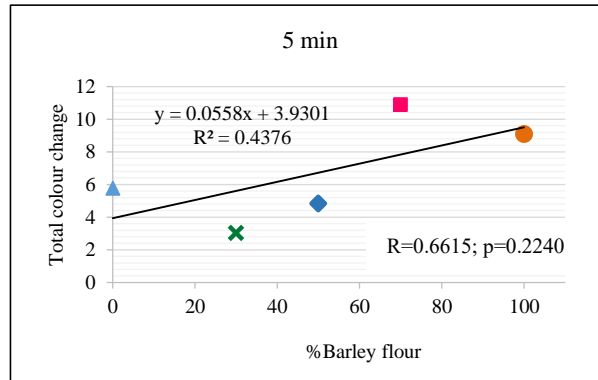


**Fig. 3.** Colour changes of biscuits after 6 and 12 months of storing (baking process of 10 min.)

If we compare the total colour difference of biscuits (baked 10 minutes) on the day of production (Figure 1) with the total colour difference of the same biscuits after 6 and 12 months of storage

(Figure 3) it can be concluded that there is generally a tendency in reducing the colour change by increasing the time of storage.

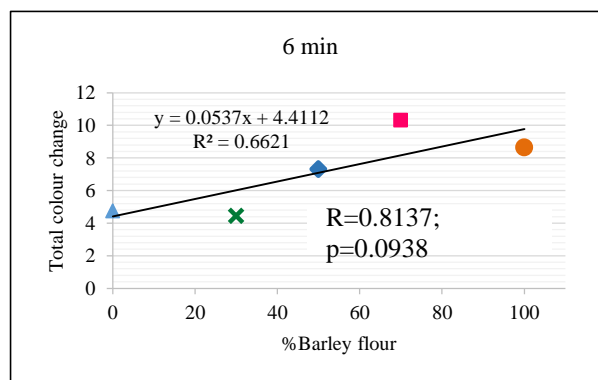
The obtained results from the made correlation analysis are shown graphically (Figure 4-9).



**Fig. 4.** Correlation between the content of barley flour in the biscuits after 5 min. of baking and the total colour change

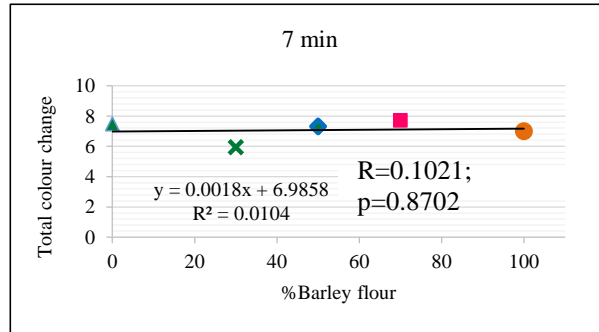
The resulting correlation coefficient between the content of barley flour in the examined samples of biscuits after 5 min. of baking and the total colour difference ( $R=0.6615$ ), suggest a moderate positive correlation, meaning that there is a tendency for high variable value of the content of barley flour in the biscuits to go with high variable value of the total colour difference and vice versa (Figure 4).

The achieved value of the coefficient of correlation between the content of barley flour in the examined samples of biscuits after 6 min. of baking and the total color change given in Figure 5 ( $R=0.8137$ ) show that there is a strong positive correlation, which means that high variable value of the content of barley flour in the biscuits goes with high variable value of the total color change (and vice versa).



**Fig. 5.** Correlation between the content of barley flour in the biscuits after 6 min. of baking and the total colour change

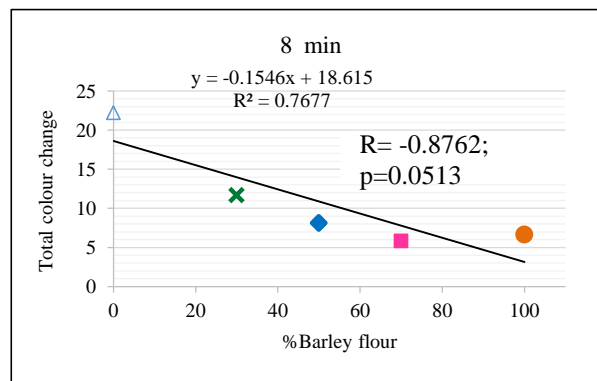
Regarding the examined samples of biscuits after 7 min of baking, the value of  $R$  is 0.1021 (Figure 6). Although it is technically a positive correlation, the relationship between the variables is weak.



**Fig. 6.** Correlation between the content of barley flour in the biscuits after 7 min. of baking and the total colour change

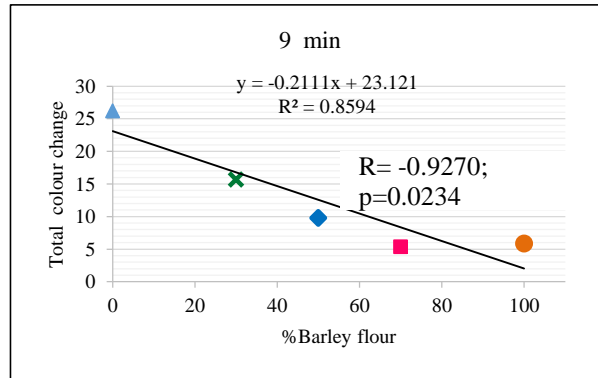
The achieved value of the coefficient of correlation between the content of barley flour in the examined samples of biscuits after 8 min., 9 min and 10 min. of baking and the total color change is given in Figure 7, Figure 8 and Figure 9 ( $R = -0.8762$ ,  $R = -0.9270$  and  $R = -0.9307$ , respectively). It refers to the strong negative correlation, which means that high variable value of the content of barley flour in the biscuits to go with low variable value of the total colour change (and vice versa).

Significant difference was noted only after 9 min. and 10 min. of baking ( $p < 0.05$ ).

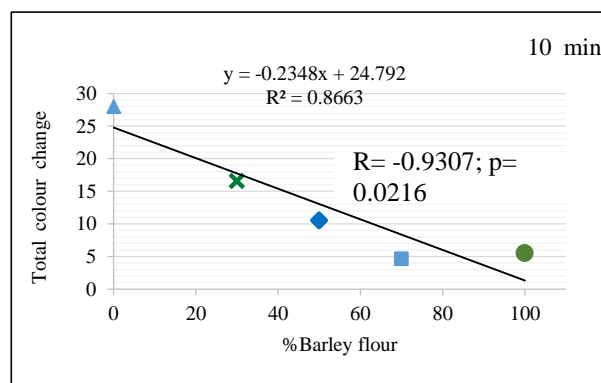


**Fig. 7.** Correlation between the content of barley flour in the biscuits after 8 min. of baking and the total colour change





**Fig. 8.** Correlation between the content of barley flour in the biscuits after 9 min. of baking and the total colour change



**Fig. 9.** Correlation between the content of barley flour in the biscuits after 10 min. of baking and the total colour change

## CONCLUSION

On the basis of the analysis conducted it can be concluded that:

In biscuits with 70% barley flour ( $\Delta E=10.89$ ) and 100% barley flour ( $\Delta E=9.09$ ), very visible colour change happens after the 5th minute of baking, while with other biscuits this change occurs later during the baking.

In biscuits with 100% barley flour, the colour change decreases during the baking, and in biscuits 100% wheat flour, the total colour difference increases with an increase in the baking time.

In biscuits stored for 6 and 12 months, there is generally a tendency to reduce colour change by increasing the time of storage.

There is a positive correlation between the content of barley flour in the examined biscuit samples after 5, 6 and 7 min. of baking and the total colour change. By increasing the content of barley flour in biscuits, the overall colour change is also increased.

There is a negative correlation between the content of barley flour in the examined samples of biscuits 8, 9 and 10 min. of baking and total colour change. By increasing the content of barley flour in biscuits, the overall colour change is reduced.

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