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DYNAMICS OF COLOUR CHANGES IN DIFFERENT APPLE VARIETIES DURING DRYING

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Key words: color changes, L*a*b*, drying, apples

In this work the dynamics of colour changes was examined in apple slices during convectional drying. The drying was carried out at a temperature of 60°C until 10% of moisture content was obtained. During drying, the colour of the tested apples was measured using the L*a*b* system. Three different apple varieties were used for tests (*Ligol*, *Champion* and *Alwa*). Each sample was divided into three parts – the first was dried without preliminary processing, the second was blanched in water at 98°C for 2 min, and the third was blanched in water (98°C, 2 min) with sugar and citric acid added. Based on the results obtained, the rate of changes in all colour parameters during the process was determined. It was concluded that the dynamics of colour changes depends on the variety. The type of preliminary treatment had an influence on the dynamics of colour changes mainly in the case of *Ligol* variety.

INTRODUCTION

Colour is the basic qualitative characteristic determining attractiveness of dried apples as well as the possibility of their further utilisation, for example, for production of convenient food. However, preservation of the desired colour of dried apples poses a problem, since browning takes place immediately after peeling due to enzymatic reaction and due to carmelisation reaction (which takes place during drying at high temperatures) but also due to non-enzymatic browning, which takes place during product's drying and further storage. Browning of plant tissues is caused by polyphenol oxidase [Iyidogan & Bayindirli, 2004], whose action leads to the production of water insoluble polycondensated pigments (melanoids), consisting of phenol derivates [Iyidogan & Bayindirli, 2004; Komthong *et al*., 2006]. Polyphenol oxidase action causes not only colour changes but also sensory changes (mainly aromatic) as well as structural and nutritional ones [Rocha & Morais, 2003], which determine the quality of dried stuff. There are many factors which facilitate browning, *i.e*.: the presence of oxygen, reducing substances (sugars), metal ions, pH, temperature [Lopez-Nicolas *et al*., 2007]. Tissue browning depends on the enzyme concentration as well as on the presence of other substances in apple tissues – such as catechins, epicatechins and chlorogenic acid [Rocha & Morais, 2001]. To prevent this unfavourable process, the material designed for drying is subjected to preliminary processing such as most often used blanching in different solutions [Beveridge & Weintraub, 1995]. Many other methods preventing browning are used as well (using different chemical compounds, and especially sulphur derivatives). However, these methods can change sensory characteristics of the final product [Perez-Gago *et al*., 2003]. The influence of different substances on inhibition of polyphenol oxidase activity was reviewed by Son *et al*. [2001].

In order to limit the content of additional chemical compounds in dried stuff, natural and/or safe compounds should be used, such as ascorbic acid or citrate acid, which can preserve the colour of dried stuff [Perez-Gago *et al*., 2006]. The method of drying is also important, since it strongly influences the change of colour. However, convective drying is still the most popular and traditional method [Krokida *et al*., 2001].

Due to the fact that the change of colour determines qualitative attributes of dried apples, tendencies of particular varieties to get brown at different conditions of the drying process should be examined. Natural possibilities of preventing or limiting the unfavourable processes during processing and storage of the final product should be searched for.

The aim of this work was to examine the dynamics of changes in distinguishing colour parameters of three different apple varieties, taking into consideration the type of preliminary material processing. The scope of this work included preparation of three types of materials, blanching in different conditions, drying in a laboratory drier with constrained air circulation as well as measurement of colour changes of the dried apples obtained (in L*a*b* system) at different drying steps.

MATERIALS AND METHODS

The following apple varieties were used for all tests: *Ligol*, *Champion* and *Alwa*. All three varieties originated from the same source. The apples were peeled, cut into 2 mm slices using Electrolux type TRS vegetable cutter. Each batch of

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apples was divided into 3 portions – the first was subjected to drying without preliminary processing, the second portion was subjected to blanching for 2 min in the water at 98°C, and the third portion was blanched in water (98°C for 2 min) with addition of 50 g of sugar and 1 g of citric acid per 1 L. The experiment was carried out in a laboratory drier with constrained air circulation (Binder FP 115). The weight of dried samples was 5 g, the temperature of the drying air – 60°C, time – maximally 360 min (up to 10% of moisture content).

On completion of the drying process the colour of apples was tested using the L*a*b* system. A Minolta CR-310 colorimeter was used for all tests. D_{65} light was used for all measurements and the equipment was calibrated using the white standard calibration plate. Determinations of L*a*b* parameters were carried out five times.

Measured L*, a*, b* values were saved as *.txt files. The saved data were analysed using one–way analysis of variance at confidence interval of 95%.

Dynamics of parameters L*, a*, b* indicating colour changes are determined as:

$$\Delta L_n^* = \frac{L_{n+1}^* - L_n^*}{L_n^*} \cdot \frac{1}{\Delta t} \quad (1)$$

$$\Delta a_n^* = \frac{a_{n+1}^* - a_n^*}{a_n^*} \cdot \frac{1}{\Delta t} \quad (2)$$

$$\Delta b_n^* = \frac{b_{n+1}^* - b_n^*}{b_n^*} \cdot \frac{1}{\Delta t} \quad (3)$$

where: L^*_n, L^*_{n+1} – average lightness value for n, n+1 sample; a^*_n, a^*_{n+1} – average redness-greenness value for n, n+1 sample; b^*_n, b^*_{n+1} – average yellowness-blueness value for n, n+1 sample; and Δt – time interval between measures (s).

RESULTS AND DISCUSSION

Dynamics of parameter L* color changes during apple drying

In the case of *Ligol* and *Champion* varieties, differences in the dynamics of colour change were noted between the material subjected and not subjected to preliminary processing before drying. Samples, which were not blanched (designated as I) showed significant changes in the amplitude of L* parameter. This meant that the rate of colour change during this process was different. However, after a defined period of the time passed, the amplitude was decreasing and the values were stabilised. For material obtained from *Ligol* variety, the moment of stabilisation was reached between 120 and 140 min of drying, whereas for *Champion* variety – at 95 minutes. *Champion* was the variety, which could have been subject to shorter drying than the samples of *Ligol* variety (Figures 1, 2 and 3). This fact had probably influence upon earlier stabilisation of the process for *Champion* variety in comparison to the *Ligol* one.

The essential observation resulting from the conducted analyses is that the dynamics of colour changes intensity

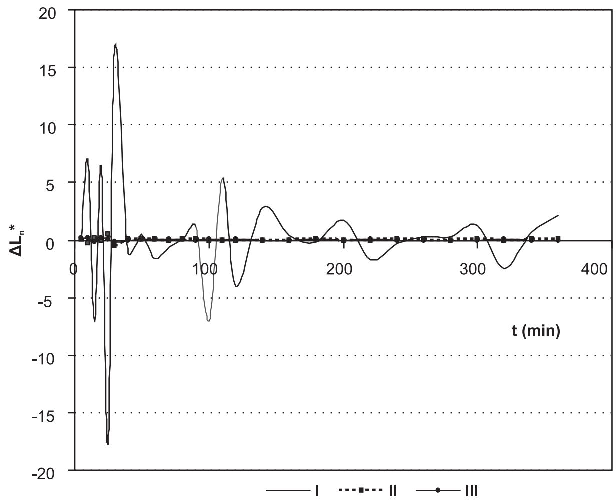

FIGURE 1. Dynamics of parameter L* colour change for apples of *Ligol* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

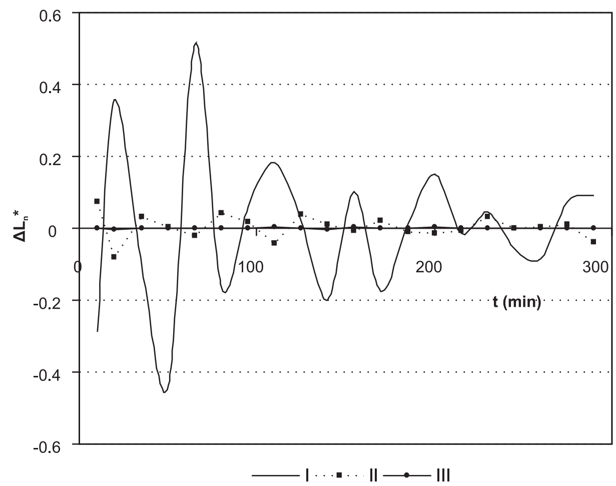

FIGURE 2. Dynamics of parameter L* colour change for apples of *Champion* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

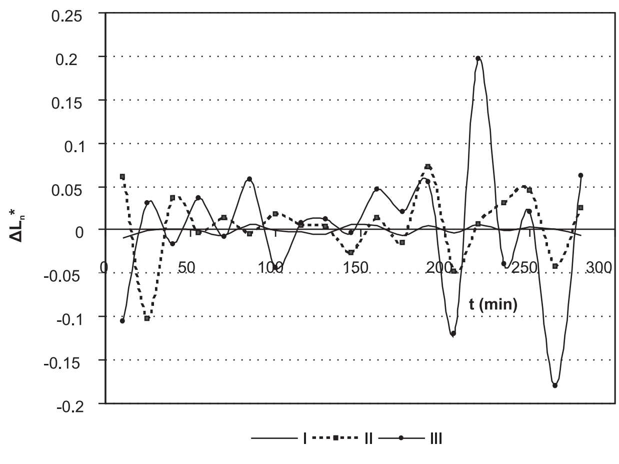

FIGURE 3. Dynamics of parameter L* colour change for apples of *Alwa* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

for the material subjected to preliminary processing is constant. Additionally, the fact that blanching was carried out in water or in water with sugar and citric acid added had no influence. This information is very crucial since it suggests that the course of colour changes during drying can be controlled, anticipated and guided since the change of colour in time (relating to unwanted browning of the material) is constant.

Different course of colour changes intensity was noted for *Alwa* variety, in comparison to *Ligol* and *Champion* varieties. This variety is completely different from the latter ones – its tissues are soft and are immediately oxidised after peeling, which results in browning. This browning must be related with the high intensity of enzyme activities. The surface of this material during drying was brown throughout the whole process of drying. The preliminary characteristics of this material were the probable cause of completely different dynamics of all colour parameters in comparison to the previously described varieties. Therefore it is the proof that not all apple varieties are useful for drying. It is also necessary to remember that the changes of plant material observed during drying depend on many factors. Apart from the variety, ripeness degree and conditions of storage are also of importance [Konopacka & Płocharski, 2002]. The quality of the material always influences the end quality of the product.

Dynamics of parameter a* changes during apple drying

The rate of parameter a* changes was mainly influenced by the type of the apple variety used for tests. Preliminary processing was essential in the case of *Ligol* variety – the rate of a* changes at the beginning fluctuated for the material not subjected to blanching, then it stabilised. Blanching proceeding drying caused that the speed of parameter a* was constant (Figure 4).

The rate of parameter a* changes stabilised (decreased) during drying also for *Champion* variety. For these samples, the moment of the dynamics of a* changes was comparatively constant at 170 min of drying – both for the material subjected to blanching and not subjected to blanching (Figure 5).

The dynamics of parameter a* changes for *Alwa* variety was variable in time, which additionally indicates that the changes in colour during drying depend on the variety (Figure 6). Rocha & Morais [2003] tested the colour changes during storage of Jonagored apple variety during the three following years. Based on these results, they showed that the tendency at each year was similar. The differences were observed at initial material colour between samples originating from different years, which is due to climate characteristics.

Dynamics of parameter b* changes during apple drying

The dynamics of parameter b* changes during the process of drying has a different course in each case. For *Ligol* variety, preliminary processing had a distinct influence upon b* processing (Figure 7). Blanching (both at hot water as well as in a water with additives) was stabilising the changes in this parameter. A significant change in results was noted at the beginning of drying for the sample not subjected to blanching. The dynamics of colour change was comparatively stable

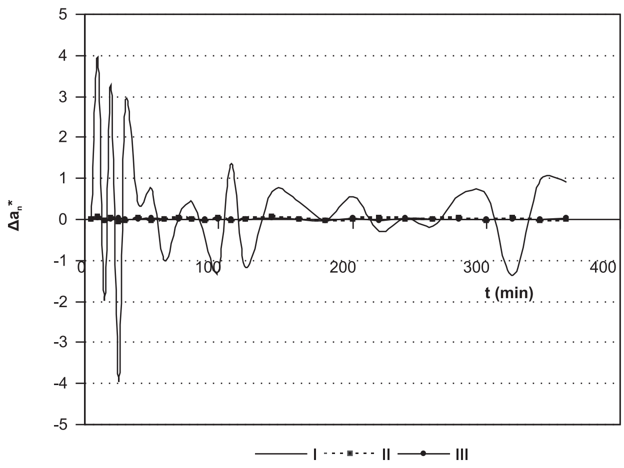

FIGURE 4. Dynamics of parameter a* colour change for apples of *Ligol* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

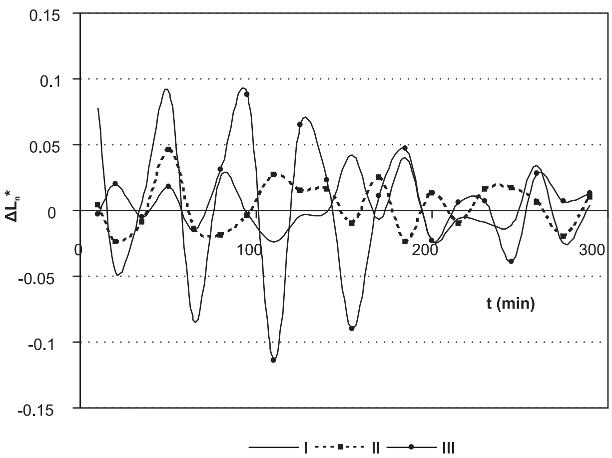

FIGURE 5. Dynamics of parameter a* colour change for apples of *Champion* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

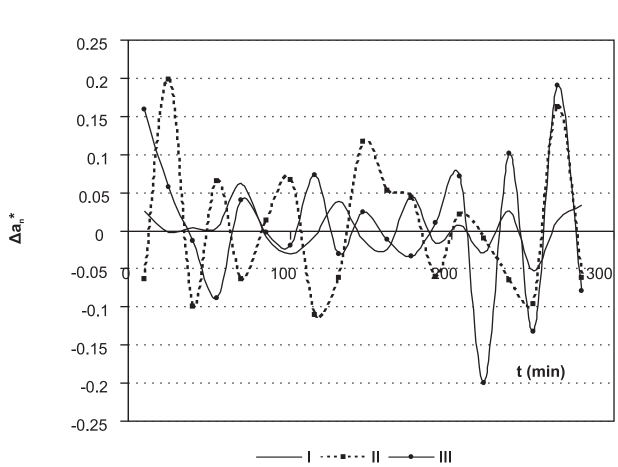

FIGURE 6. Dynamics of parameter a* colour change for apples of *Alwa* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

no earlier then at 160 min. Similar course was shown for the earlier described parameters. It can be concluded that in the case of *Ligol* variety, blanching of the material before drying stabilises the colour changes during the process.

The dynamics of parameter b* changes for two other varieties was different. When analysing the amplitude of parameter b* changes speed during drying for *Champion* variety, it was noted that the speed stabilised during the course of the process at 140 min of drying (Figure 8).

For *Alwa* variety, the greatest changes in b* parameter were noted for the sample not subjected to blanching (Figure 9). The rate of b* changes in the samples after preliminary changes showed smaller amplitude. Parameter b* was characterised with the highest amplitude in time during drying – it was different for each variety. It was already shown in the previous papers that in the case of many raw materials, ready-to-cook food [Biller & Neryng, 2003] and food products [Biller, 2006a,b], this parameter is most sensitive and changes significantly in time of carried operations (initial and thermal).

When analysing the causes of colour changes during apple drying, it is necessary to take into account two most important factors, *i.e*. enzymatic and non-enzymatic browning. Enzymatic browning takes place in the product not subjected to blanching. Blanching reduces enzymatic activity to a certain degree but it never inhibits it totally. Therefore, the enzymes which were not inactivated during blanching can cause changes during drying when the temperature of this process is not too high (this was the case in the experiment). Another cause of changes are Maillard's reactions (non-enzymatic browning), which can take place in tissues not only during high temperature processing but also during the storage of the final product. Maillard's reactions are the main reason for changes of dried products' colour during the storage. Experiments carried out earlier for bread browning during thermal processing [Biller, 2006a,b] showed that as a result of non-enzymatic browning, parameters a* and b* are both subjected to significant changes, while more variability is noted for parameter b*. Perez-Gago *et al*. [2003] also showed that browning causes significant changes, mainly in parameter a* and b*, which is accompanied by a decrease in L* value. The substrate for Maillard reaction is the reducing sugar content in tissues, which in turn depends on a variety. The degree of ripeness also influences the content of reducing sugars (which is a result of a variety type and of storage conditions). As shown above, apples from *Alwa* variety constituted a completely different test material than those from *Ligol* and *Champion* varieties. The tissues of the first variety were soft, easily disintegrated and oxidised, which probably influenced the course of the entire process and the quality of dried products obtained. The process of convective drying essentially changes the structure of tissues. Microscopic pictures taken from dried products (also in dried apples) obtained by different methods were shown by Lewicki & Pawlak [2003]. During convectional drying, the tissues are subjected to destruction, which in turn releases the enzymes and sugars taking part in the following Maillard's reaction. Such conditions may lead to rapid and uncontrollable colour changes.

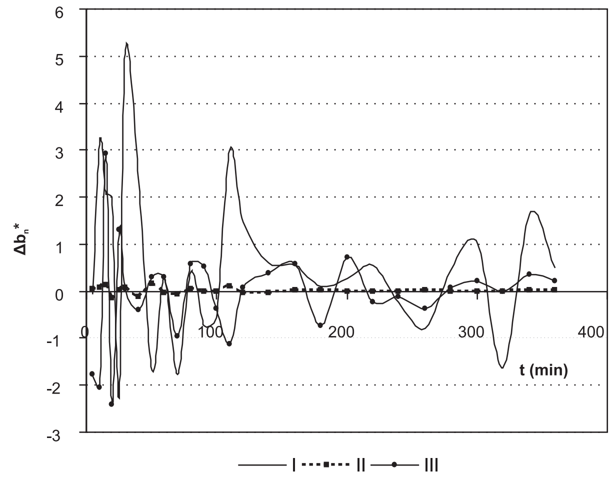

FIGURE 7. Dynamics of parameter b* colour change for apples of *Ligol* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

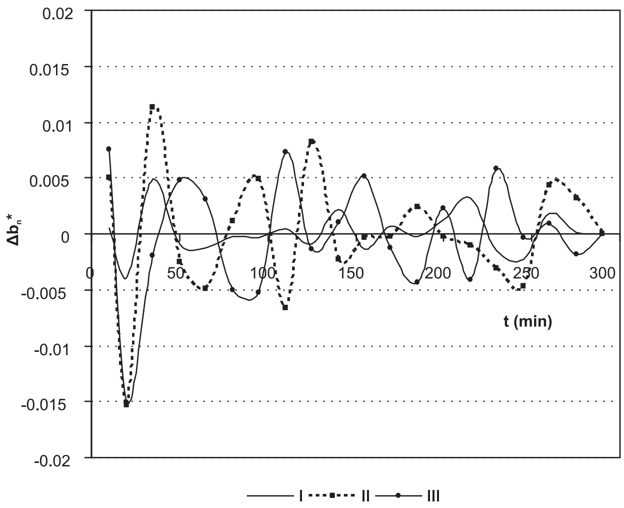

FIGURE 8. Dynamics of parameter b* colour change for apples of *Champion* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

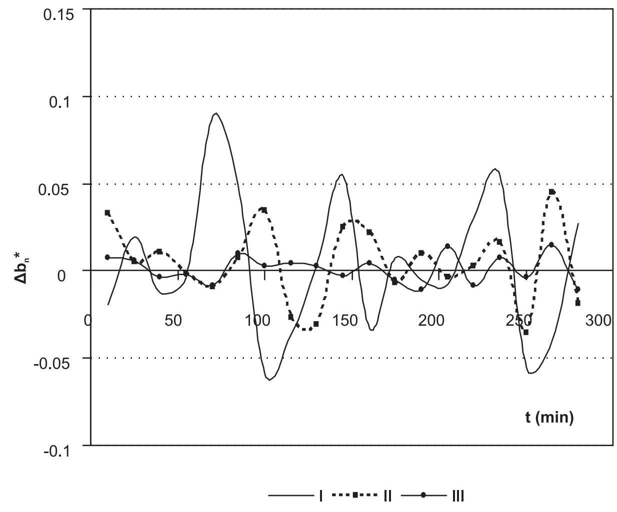

FIGURE 9. Dynamics of parameter b* colour change for apples of *Alwa* variety during drying; I – material not subjected to preliminary treatment, II – material subjected to blanching in hot water, III – material subjected to blanching in hot water with additives.

CONCLUSIONS

1. Based on the analysis of the results obtained it was concluded that the rate of changes in particular parameters of colour during apples drying depends on the variety of apples used for drying.

2. For *Ligol* variety, preliminary treatment had an influence on the rate of changes in all parameters of colour and caused that the dynamics of L*, a* and b* parameters was constant. The rate of changes in all parameters of colour in the material not subjected to blanching stabilised during drying.

3. Blanching affected colour changes in the case of *Champion* variety. The rate of changes in parameters a* and b* stabilised during the drying.

4. The dynamics of colour change for *Alwa* variety was different for each tested parameter, which was probably caused by the qualitative characteristics of the material used. These apples were soft and immediately got brown after peeling, which indicated a significant activity of enzymes responsible for enzymatic tissue browning.

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DYNAMIKA ZMIAN BARWY RÓŻNYCH ODMIAN JABŁEK W CZASIE PRZEBIEGU PROCESU SUSZENIA

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W pracy zbadano dynamikę zmian barwy plastrów jabłek w czasie przebiegu procesu suszenia konwekcyjnego. Suszenie przeprowadzono w temperaturze powietrza suszącego równej 60°C do uzyskania 10% wilgotności suszu. W trakcie trwania procesu fotokolorymetrycznie mierzono barwę badanych jabłek wykorzystując system L*a*b*. Do badań wykorzystano trzy różne odmiany jabłek (*Ligol*, *Champion* i *Alwa*). Każdą z prób podzielono na trzy partie – jedną suszono bez obróbki wstępnej, drugą blanszowano w wodzie o temperaturze 98°C przez 2 minuty, natomiast trzecią blanszowano w wodzie (98°C, 2 minuty) z dodatkiem cukru i kwasu cytrynowego. Na podstawie przeprowadzonych badań wyliczono szybkość zmian wszystkich parametrów barwy w czasie procesu. Stwierdzono, że dynamika zmian barwy jest zależna od odmiany. Rodzaj obróbki wstępnej miał wpływ na dynamikę zmian barwy głównie w przypadku odmiany *Ligol.*