Influence of cookies composition on temperature profiles and qualitative parameters during baking

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Summary

During baking of bakery products temperature of baking, temperature profiles, moisture content, volume and colour changes are strongly coupled. The objective of this paper was to study the influence of the cookies composition on temperature profiles and quality parameters (width and thickness, colour formation and textural properties: hardness, fracturability and work of breaking force) during baking process. Composition of cookies differs due to flour type and initial moisture content. Cookies were baked at 205 °C and temperature was measured in the centre of samples which were 7 mm thick with a 60 mm diameter. The results of temperature profiles of the cookies during baking have shown the same trend for all of the 18 samples. Samples with the higher initial water content have lower values of total colour difference and also significantly affect textural properties.

Keywords: cookies, temperature profiles, qualitative parameters, water content, flour quality

Introduction

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 (Gomaa and Boye, 2013; Lathrop, et al., 2014; Šarić et al., 2014).

One of the most popular parts of bakery industry is biscuits and cookies production. Nutritive value and long shelf life are the reasons of frequent cookie consummation (Zucco et al., 2011; Agama-Acevedo et al. 2012; Hyun-Jung et al., 2014). Cookie weight, dimensions, moisture content and flour quality are important in the manufacturing process. American Association of Cereal Chemists (AACC, 2000a) has developed a standard baking test for testing cookie flour baking quality. Since flour quality and cookie dough moisture content are the most essential for standard cookie production technology the effects of flour and other ingredients on cookie qualitative parameters have been studied extensively in the last few years (HadiNezdah and Butler, 2009; Torbica et al., 2012; Pérez et al., 2013; Šarić et al., 2014).

Baking is a complex process inducing physical, chemical and biochemical changes in the cereal matrix such as crust formation and colour changes (Zanoni et al., 1995). Colour is one of the most important visual changes occurring during food processing and the correlation between colour formation (browning) and acrylamide formation has been pointed out (Surdyk et al., 2004). During thermal processing of foods several reactions are taking place which have a direct impact on the sensory and nutritional properties of food. Maillard reaction is involved in the generating of characteristics of flavours and colour which dramatically influence the consumer's perception of food quality. However, Maillard reaction is also responsible for the formation of acrylamide during food processing at elevated temperatures (Tareke et al., 2002; Yaylayan et al., 2003).

Browning at the surface of product is generally quantified by CIE $L*a*b*$ scale using either a colorimeter or computer vision based image analysis systems (Pedreschi et al., 2006; Gökmen and Şenyuva, 2006; Gökmen et al., 2006). It is commonly used to control bread baking (Zanoni et al., 1995; Guerra-Hernández et al., 2000; Ramírez-Jiménez et al., 2001) and cooking of baby cereals (Ramírez-Jiménez et al., 2003). 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.

Product appearance plays a vital role in making a purchase decision. Among other, the colour is a significant factor that influences purchase decisions of bakery products. The objective of this study was to investigate the influence of the cookies composition (6 types of flour and 3 initial dough water contents)

on temperature profiles and quality parameters (width and thickness, colour formation and textural properties: hardness, fracturability and work of breaking force) during cookies baking process.

Materials and methods

Sample preparation

Cookie dough were prepared from six flour types: a commercial cookie flour (Belje d.d. PC Mlin, Beli Manastir, Croatia), wholegrain flour (Podravka d.d., Koprivnica, Croatia) and wheat flours T-1100, T-850 T-550 and T-400 with mineral content of 1.1%, 0,85%, 0.55% and 0.4% respectively (Podravka d.d., Koprivnica, Croatia). The other ingredients were shortening (Zvijezda d.d., Zagreb, Croatia), dextrose, sugar (sucrose), kitchen salt (sodium chloride) and sodium bicarbonate from a local market. The cookie doughs were prepared by weighing the appropriate mass of each constituent in accordance with AACC Method 10-50D (AACC, 2000a) and mixing the ingredients using an electronic mixer (Gorenje MMC800W, Slovenia) with a flat beater. First sugar, salt, sodium bicarbonate and shortening were mixed at low speed for 3 min (scrape down after each minute), then distilled water and dextrose solution were added and mixed at low speed for 1 min, scraped down and mixed for 1 min at medium speed. Finally, the flour was added and mixed at low speed for 2 min, scraped down after each 30 s. After mixing cookie dough rested in a refrigerator (up to 8 °C) for 30 min. Dough was flattened and rolled by a rolling pin to the desired thickness (7 mm). At the end of the sample preparation process cookie dough was cut with a cookie cutter (60 mm inside diameter) and shaped cookies were placed at the baking surface (cold baking pane covered with baking paper). Dough leftover was discarded.

Cookie dough samples were prepared with three different amounts of water: standard with 16 g water/225 g of flour (AACC Method), dry with 12 g water/225 g of flour and wet with 20 g water/225 g of flour.

Cookie baking and temperature measurement

Baking process was conducted in a convection oven (Wiesheu Minimat Zibo, Wiesheu GmbH, Germany). A 36 gauge copper–constantan, type T thermocouple (diameter 0.0254 cm, Cole-Parmer, International, U.S.A.) was used to measured cookie temperature during baking and also to record the temperature profile inside the cookies during baking. The temperature of the hot air inside the oven was maintained at 205 °C with the precision of ± 1 °C.

Baking and cooling process was conducted on all 18 sample types (5 replications of each type) during 10 minutes of baking and 30 minutes of cooling.

The thermocouples were placed in the cookie dough by threading the wire through the cookie dough cylinder on central positions inside the dough ball. Position of the thermocouple was observed at the end of each baking process to ensure the final placement of the probe. During baking, samples were extracted from the oven every minute and used for further analysis. One cookie dough cylinder was baked with inserted thermocouple for monitoring the temperature profile during baking which was repeated 10 times (10 replications) and the collected data was analysed in accordance with statistic rule 3σ.

Thermocouples sampling rate were 1 second, and values were acquired with data acquisition software and hardware, PicoLog Recorder and PicoLog Player, connected to a PC.

Moisture and mass analysis

Moisture analysis was preformed according to AACC Approved Methods (AACC, 2000b) before, during (every minute during 10 minutes of baking) and after baking.

Qualitative parameters analysis

Cookies diameter and thickness were measured according to AACC 10-50D method (AACC, 2000a) 30 minutes after baking. For cookies diameter six cookies were laid edge to edge and the width was measured. By rotating the cookies through 90° and rearranging them, an average of six readings was a recorded. The average value was divided by 6 to gain single cookie width. For thickness measurements, six cookies were stacked on top of one another. By restacking them in different orders, an average of six readings was recorded. The average value was divided by 6 to gain single cookie thickness.

Colour measurement was performed by Minolta Chroma Meter (Konica Minolta, CR-400, Japan). Data were stored in CIE $L^*a^*b^*$ colour model and colour changes during baking process (10 minutes) were evaluated. The total colour difference (ΔE), in CIE $L^*a^*b^*$ colour model was calculated by the Eq 1. (Purlis et al., 2007):

$$\Delta E = \sqrt{\left(L_0^* - L^*\right)^2 + \left(a_0^* - a^*\right)^2 + \left(b_0^* - b^*\right)^2} \qquad (1)$$

where L_0^*, a_0^* and b_0^* indicate colour parameters of raw cookies (dough), parameter L^* refers to the

lightness of the samples, and ranges from black (L=0) to white (L=100), a negative value of parameter a^* indicates green and a positive one indicates red–purple colour, and positive value of parameter b^* indicates yellow while negative value indicates blue colour (R. G. McGuire, 1975). The Minolta CR-400 Chroma Meter D65 calibration plate was used for calibration. All measurements were repeated in five replicates.Textural analysis was performed by TA.XT2i SMS Stable Micro Systems Texture Analyzer (Stable Microsystems Ltd., Surrey, England). Six cookies were evaluated using the three-point break technique. Quantified parameters were hardness (g) - peak breaking force, fracturability (mm) - mean distance at break that represents the tendency of a cookie to fracture upon the application of force and work of breaking force (g s) - total area under curve which corresponds to the total amount of force required to perform breaking of sample. Measurement was performed with the test speed of 3 mm/s and the distance between the two bottoms

supports was adjusted to 50 mm. Textural analysis test was conducted three hours after baking.

Statistical data analysis

Obtained experimental values were analysed by analysis of variance (ANOVA) and Fisher's least significant difference (LSD), with significance defined at $p<0.05$. Statistical analysis was carried out with Statistica ver. 12.0 Stat Soft Inc. Tulsa, OK, USA.

Results and discussion

Temperature profiles, mass and moisture loss

The typical curves of temperature change in the middle of a cookie (made from T 850 flour) during baking for the standard samples of 16 g water/225 g of flour, dry with 12 g water/225 g of flour and wet with 20 g water/225 g of flour are shown in Fig. 1.
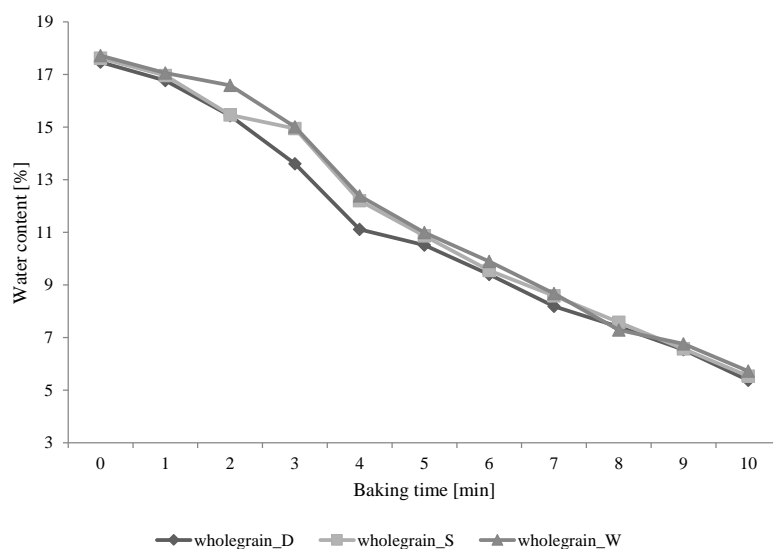

Fig. 1. Moisture loss from wholegrain cookies with different water content
(S_standard formula, D_dry formula, W_wet formula) during baking at 205 °C

Results show the same trend of temperature increase and decrease in the middle of a cookie for all 18 sample types. During the first 300 seconds (5 minutes) of baking, the temperature in the middle of the cookie increased to the boiling point (100.2-103.1 °C) which than remained constant during the process of water evaporation. After water has evaporated the temperature raised again and in a period of 320 seconds, the maximum observed temperature ranged from 108 °C (for the control sample) up to 117 °C (for a sample mixed with wholegrain flour_D). Water boiling point recorded

in cookie samples is higher in relation to the pure water boiling point because of dissolved substances found in the free water in the formula (Califano and Calvelo, 1991). Lowest boiling point during baking was 100.2 °C and it was recorded in the control sample which had the highest values of initial water content. A temperature of 103.1 °C represents the boiling point recorded in the cookies which had the lowest initial water content (sample made from wholegrain flour_D). It is assumed that it can relate to the concentration of dissolved substances in free water but since it was

not the subject of this study the hypothesis cannot be confirmed. Heat transfer from the heated fluid (air in the oven) through the surface of the cookie to the inside is used up on the water evaporation (phase transfer). During the 10 minute period of baking, the cookies with higher initial water content, has lower temperature in the middle compared with the

cookies that has lower initial water content.

Comparison of the results recorded by measuring the temperature of all of the samples shows that the boiling point is achieved in 300 seconds (5 minutes) regardless of the flour type or water content which coincides with the time of establishing the constant loss of moisture from the cookie samples (Fig. 2).
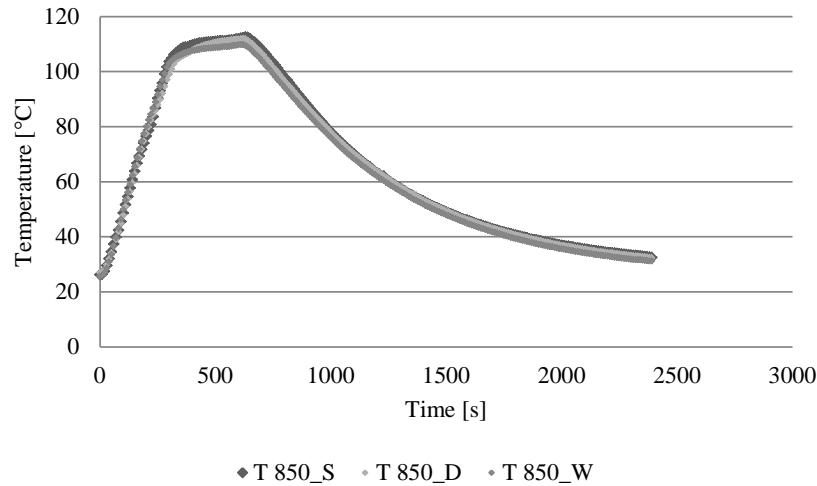

◆ T 850_S   • T 850_D   • T 850_W

Fig. 2. Typical temperature profiles of the T 850 flour cookies with different water content
(S_standard formula, D_dry formula, W_wet formula) during baking at 205 °C

Considering the loss of moisture during the baking process the reduction of mass has been recorded (marked as baking loss). Statistically, there are two significantly different groups (Table 1). The first group consists of the control sample and the sample mixed with type T-400 flour regardless of the initial water content while the second group consists of the samples made from T-550, T-850 and T-110 flour types. A more significant decrease in mass has been

recorded in the first group of samples. If the samples are observed with respect to the initial water content in the cookie dough (Table 2), the results indicate more significant decrease in mass in the samples with higher initial water content. After baking (10 minutes) all samples of cookies, regardless of initial water content, had equal water content. Due to the mentioned, the statistical analysis shown the baking loss for samples with higher initial moisture content.

Table 1. Characteristics of cookies from different flour types regardless of moisture content

Flour type	Baking loss [%]	Width [cm]	Thickness [cm]
Control	13.11 ± 1.29 a	6.79 ± 0.13 c	1.31 ± 0.02 b
Wholewheat	12.08 ± 1.23 b	7.02 ± 0.24 b	1.31 ± 0.07 b
T-1100	11.78 ± 0.78 b	6.81 ± 0.10 c	1.35 ± 0.05 ab
T-850	12.11 ± 0.68 b	7.04 ± 0.18 b	1.39 ± 0.04 a
T-550	11.94 ± 0.44 b	7.03 ± 0.11 b	1.34 ± 0.04 ab
T-400	13.31 ± 0.83 a	7.46 ± 0.12 a	1.15 ± 0.01 c

Values are means ± standard deviation. Values in the same column followed by different letters are statistically different according to Fisher's least significant difference (LSD) test ($p<0.05$)

The results of the cookies width and thickness (Table 1) have shown that the cookie samples made from T-400 flour are statistically significantly different in both width and thickness than other samples and that they had the biggest width and lowest thickness. Statistical

analysis of cookie samples considering the water content in the dough formula (Table 2) has shown that there is no statistically significant difference in the values of width and thickness between cookies of dry and wet formula.

Table 2. Characteristics of cookies with different moisture content regardless of flour types

Water amount in cookie dough	Baking loss [%]	Width [cm]	Thickness [cm]
Dry formula	12.21 ± 1.43 b	6.91 ± 0.22 a	1.30 ± 0.08 a
Standard formula	12.17 ± 0.91 b	7.03 ± 0.29 a	1.30 ± 0.08 a
Wet formula	12.79 ± 0.68 a	7.13 ± 0.25 a	1.33 ± 0.10 a

Values are means ± standard deviation. Values in the same column followed by different letters are statistically different according to Fisher's least significant difference (LSD) test ($p<0.05$)

Colour measurements

Fig. 3 shows the results of total colour difference (ΔE) of cookies made of different types of flour (control sample, T-500, T-400, wholegrain, T-1100, T-850) in relation to the baking time. Total colour difference from the first to the third minute increased (ΔE=1.87-7.58) and significant changes began after the fourth minute in all of the formulas and flour types (ΔE=1.79-22.75).
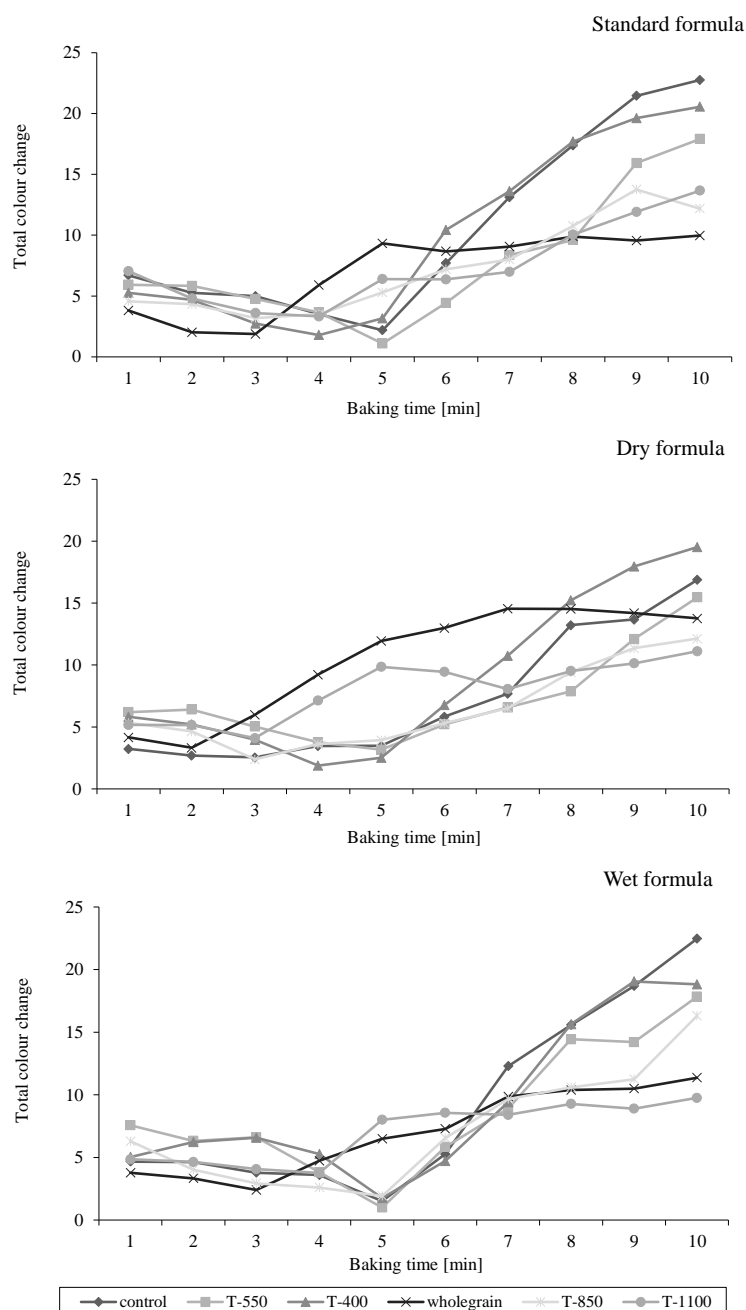

Fig. 3. Cookie colour changes during the baking process
(top – standard formula; middle – dry formula; bottom – wet formula)

Comparison of the total colour difference of various cookie formulas showed that the smallest values have been recorded for the wet formula (ΔE=1.52 control, ΔE=1.00 flour T-550, ΔE=1.76 flour T-400, ΔE=1.76 flour T-850). Exceptions have been recorded for the wholegrain wheat flour formula (ΔE=1.87) and flour type T-1100 (ΔE=3.32) where the lowest values of total colour difference have been recorded for the standard formula. Additionally the highest values of total colour difference have been recorded for the standard formula in most of the samples (control flour, T-400, T-550 and T-1100).

During baking, complex chemical reactions take place in cookies, leading to the formation of heat-generated toxicants such as acrylamide. The major components of cookies are cereal flour, sugars and fats. The dough is conventionally baked at high temperature (205 °C) for a few minutes (10 min), in order to obtain a low final water content and a brown surface. Formation of acrylamide was found to occur during a thermal process, by Maillard reaction, of reducing sugars with asparagine at temperatures above 120 °C. Based on the literature data (Zanoni et al., 1995; Ramírez-Jiménez et al., 2003) it can be hypothesized that Maillard reactions and caramelization responsible for the colour differences in cookie samples, began in the later phase of the baking process (after the fifth minute when also the boiling point in the middle of the cookies is achieved) with the cookie samples which have the highest initial water content (wet formula) and because of that the samples with higher water content have the lower values of total colour difference.

Textural analysis

Table 3 shows the effect of different flour types on textural properties of cookies. There were no significant differences in hardness between cookies from control flour, wholegrain flour, T-1100, T-850 and T-400 flours. The lowest hardness values have been recorded in the cookie samples made of T-550 flour. Results of fracturability and work of breaking force have shown that the cookie sample made from white flour T-400 is statistically significantly different from all other samples and that it has lower values of fracturability and highest values of work of breaking force.

Table 3. Texture profile analysis of cookies from different flour types regardless of moisture content

Flour type	Hardness [g]	Fracturability [mm]	Work of braking force [g s]
Control	10717 ± 1871 a	29.60 ± 0.37 b	17948 ± 3450 b
Wholewheat	10685 ± 3270 a	30.17 ± 0.44 a	14311 ± 4801 c
T-1100	9667 ± 1194 a,b	30.01 ± 0.31 a	11532 ± 2088 c,d
T-850	9822 ± 2447 a,b	30.18 ± 0.44 a	11453 ± 2948 c,d
T-550	8220 ± 1752 b	29.81 ± 0.37 a,b	10838 ± 1723 d
T-400	9522 ± 2636 a,b	28.80 ± 0.49 c	21654 ± 9620 a

Values are means ± standard deviation. Values in the same column followed by different letters are statistically different according to Fisher's least significant difference (LSD) test (p<0.05)

Results of the effect of water content in cookie dough on textural properties of cookie sample (Table 4) showed that the cookie samples with highest initial water content are statistically significantly different in hardness and work of breaking force from the standard and dry formula while there is no statistically significant difference in fracturability values of the tested samples considering the water content in cookie dough, regardless of the flour type.

Table 4. Texture profile analysis of cookies with different moisture content regardless of flour types

Water amount in cookie dough	Hardness (g)	Fracturability (mm)	Work of breaking force (g s)
Dry formula	11065 ± 2060 a	29.78 ± 0.79 a	16550 ± 6800 a
Standard formula	10427 ± 1721 a	29.94 ± 0.48 a	16413 ± 6050 a
Wet formula	7824 ± 1914 b	29.56 ± 0.50 a	10904 ± 3758 b

Values are means ± standard deviation. Values in the same column followed by different letters are statistically different according to Fisher's least significant difference (LSD) test (p<0.05)

Conclusions

The results of temperature profiles in the middle of the cookies during baking have shown the same trend of increase and decrease of temperature for all of the 18 sample types used in the study regardless of the initial water content and used flour type. Samples with higher initial water content have lower values of total

colour difference in relation to the cookie samples with standard and dry formula. It is possible to produce cookies with optimal brown surface with lower acrylamide and HMF concentration baking wet cookies formula (20 g water/225 g of flour) 10 min at 205 °C. Higher initial water content also significantly affects texture properties. Cookie samples with wet formula are statistically significantly different in hardness and work of breaking force from the standard and dry formula while there is no statistically significant difference in fracturability of samples.

Any treatment to reduce heat-generated toxicants content in foods should keep the quality parameters unaffected by the adjusted processing conditions.

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