Quality characteristics and drying behaviour of muffins baked in steam assisted and convectional ovens

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ABSTRACT

Advantages of steam-baking and natural and/or forced convection baking are shared in steam assisted baking which attracts increasing interest with the increasing health standards of the society. Steam assisted baking (steam+forced convection/turbo) is known as resulting in healthy foods.

Baking muffin by using steam assisted oven is not common as it is with bread. By the effect of steam assisted baking of muffins, the idea of lowering the formation of harmful chemical compounds, such as acrylamide, and keeping the physical quality at the same time was driven. Muffins by steam assisted baking were produced and it was evaluated the quality characteristics as a profile, as well as the drying behaviour during a complete baking process.

Steam assisted baking oven used in the study is a hybrid oven having an inner steam generator. The average moisture content, temperature profiles at the top surface, inner position of muffin and oven ambient and quality characteristics (height, bulk density, surface colour (Hunter a and browning index (BI) value) and acrylamide content) of muffins baked at steam assisted oven and natural and forced convection ovens at 160 °C were determined. Drying behaviour was observed making use of the total moisture loss values.

Steam assisted oven was not resulted in a significant difference in average moisture content of muffins, compared to natural and forced convection ovens (p>0.05), which is an important criteria in packaging and storage stage. Temperature profiles obtained at different ovens do nearly match. The oven ambient temperatures during steam assisted baking was a little lower than the other ones although the set values were all constant, due to the effect of condensation of steam injected to the oven chamber. Surface Hunter a and browning index (BI) values of the muffins baked at steam assisted oven and natural and forced convection ovens at 160 °C were determined. Drying behaviour was observed making use of the total moisture loss values.

Steam assisted oven was not resulted in a significant difference in average moisture content of muffins, compared to natural and forced convection ovens (p>0.05), which is an important criteria in packaging and storage stage. Temperature profiles obtained at different ovens do nearly match. The oven ambient temperatures during steam assisted baking was a little lower than the other ones although the set values were all constant, due to the effect of condensation of steam injected to the oven chamber. Surface Hunter a and browning index (BI) values of the muffins baked at steam assisted oven and natural and forced convection ovens at 160 °C were determined. Drying behaviour was observed making use of the total moisture loss values.

It was seen that steam assisted baking would be a good baking choice over natural convection or forced convection baking in that it was resulted in lower acrylamide content, and Hunter a and BI values, and nearly same moisture content that would be recommended for better quality muffins.

Keywords: Steam assisted; convectional baking; acrylamide; temperature and moisture profile

INTRODUCTION

Steam assisted baking (steam+forced convection/turbo) is a method of baking sharing the advantages of steam-baking and natural and/or forced convection baking. It attracts increasing interest with the increasing health standards of the society since it is known as resulting in healthy foods.
Baking muffin by using steam assisted oven is not common as it is for baking of bread and other type of dough products. By the effect of steam assisted baking of muffins, lowering the formation of harmful chemical compounds, such as acrylamide, and keeping the physical quality at the same time was aimed. Acrylamides are undesired chemical compounds that are formed by the Maillard reaction of reducing sugars and asparagine, occurring during a thermal process such as baking. Acrylamide occurs by thermal process, i.e. baking, in oven type products, such as cookies, cakes, muffins, with high temperatures, and it is neurotoxic and classified as a probable human carcinogen by the International Agency for Research on Cancer [1, 2, 3]. The acrylamide formation and its amount in food material is sensitive to food matrix, process conditions such as temperature and time, etc., also, moisture content, pH of material and storage conditions. By the study conducted at Swiss Food Institute, the acrylamide formed at the bread crust during steam baking was determined and it was found that its level (26 µg/kg) was lower by this method compared to convective baking (118 µg/kg) [4].

Some researchers studied the effects of different baking process on quality parameters of baked products. It was compared the quality of cakes (weight loss, specific volume, firmness and colour of cakes) during baking in microwave, infrared (IR) and IR-microwave combination ovens by [5]. There are published works on optimization of different types of baking cakes [6, 7, 8]. It was investigated pancake and cup cake baking experimentally and mathematically by [9, 10, 11]. The experimental studies involved the measurement of temperature and moisture profiles, and the volume rise during cake baking. Numerical model was also developed to predict the temperatures and moisture contents during baking.

In recent years, there have been many studies that establish the relationship between baking process and baked product’s drying behaviour. It was investigated the convective oven layer cake baking process for the determination of product’s dynamic drying behaviour [11]. The experimental drying curves, such as moisture loss, moisture profiles at three different positions, average moisture contents were determined. The temperature profiles of layer cake (at the center and top surface) were related to the total moisture loss and to the surface colour generation. Quality parameters such as surface colour, percent volume rise/height increase and bulk density were determined. By an other study, it was examined the microwave baking characteristics (drying kinetics, surface and internal temperatures, and height) of Maderia cake during baking in a bench-scale microwave oven [12].

Muffins produced by steam assisted and natural and forced convectional ovens were evaluated in terms of quality characteristics, as well as the drying behaviour during a complete baking process.

MATERIALS & METHODS
The muffins were prepared using the following formula (% mass ratios of total batter weight): 53.1% ready dry muffin mix (Dr. Oetker’s; containing wheat flour, sugar, corn starch, baking powder), 9.7% homogenized whole egg, 27.9% whole fat milk and 9.3% corn germ oil. The ingredients were mixed using a kitchen type electrical mixer, then the cylindrical muffin cups having 4.5 cm diameter were filled with the batter. The initial moisture content of the batter was 36.7 % and kept constant for all experiments.

Baking experiments were carried out in a steam assisted oven and also in a domestic use electrical convectional oven (Blomberg, BKO 9566). Steam assisted baking oven used in the study is a hybrid oven with 48×43×25 cm dimensions having an inner steam generator mounted at the back panel of the oven. The steam generated from 150-200 g water was injected into the oven cavity, three times, at the 11th, 16th and 21th minutes of baking, determined by preliminary experiments. The convectional oven used was at the same dimensions with steam assisted baking oven.

The ovens were preheated to eliminate heat deviations. The muffins were baked at 160°C at steam assisted oven and at convectional oven both at natural and forced convectional conditions. For supplying same oven charge, 5 muffins from the same muffin batter batch were used and positioned at same place in the oven at each baking performance. In order to supply constant baking conditions for each time interval, a fresh batter was prepared. The baking experiments were interrupted at definite time intervals (10 min).

The moisture content of muffin samples was determined at the end of each time interval by an infrared moisture analyser (Ohaus, MB45) as two parallel. These results were validated by the standard oven method for total solids and moisture in baked products, as 1 h at 130°C [13]. The average moisture content at each time interval was calculated from the percent moisture loss data. The moisture loss is the net weight loss observed at a definite
time interval (Δt) of baking. Temperature profiles at the top surface, inner position of muffin and oven ambient were recorded. At each baking temperature, temperature changes of muffins were measured using type-K thermocouples with data logger.

Out of the other physical quality characteristics height (mm) was determined at several position, side and middle positions, using digital caliper. The bulk densities of baked muffins were calculated by taking the ratio of a known amount of muffin to its volume [14]. The volume of baked muffin samples was determined by the rape seed displacement method [15]. The surface colour of the muffin samples (Hunter a and browning index (BI) value) was measured by Hunter Colourflex [16]. The standard deviations and mean values were recorded. The browning index (BI) were calculated from following equations;

\[
BI = \left[ \frac{100(a - 1.75L_t)}{a + b - 1.75L_t - 0.31} \right] \times 0.17
\]

\(a_t\): a colour value; \(b_t\): b colour value; \(L_t\): L colour value at a definite time (t) of baking

Acrylamide content determination method includes extraction with water, addition of D3 acrylamide as an internal standard, bromination and GC-MS analysis in the selected ion monitoring (SIM) mode. Bromination of acrylamide to 2,3-dibromopropionamide (2,3-DBPA) was achieved using potassium bromide and potassium bromate under an acidic condition. The operating parameters for GC-MS were as follows: oven temperature 65°C (1 min), 15°C/min, 240°C (10 min), injection temperature 250°C and transfer line temperature 240°C. In the SIM mode, m/z 149 for 2,3-DBPA and m/z 153 for internal standard were used for quantification.

The drying rate was calculated as the amount of moisture lost per unit baking time per unit drying surface area of the muffin. It was presented as a function of average moisture content. Two replications were used for each experimental condition.

RESULTS & DISCUSSION

The average moisture contents of muffins were reduced to ~25% (w/w) at all ovens. Steam assisted oven was not resulted in a significant difference in average moisture content of muffins, compared to natural and forced convection ovens (p>0.05), which is an important criteria in packaging and storage stage.

Temperature profiles at the top surface, inner position of muffin and oven ambient were given in Figure 1. Temperature profiles obtained at different ovens do nearly match. The oven ambient temperatures during steam assisted baking was a little lower than the other ones although the set values were all constant, due to the effect of condensation of steam injected to the oven chamber.

![Figure 1](image_url)

*Figure 1. Temperature profiles of muffins baked at ○: natural convection, ◊: forced convection, Δ: steam assisted oven, a) top surface, b) center of muffin and oven ambient.*
Dimensional characteristics (height and bulk density) were observed during baking. Although no significant difference was observed between oven types in terms of muffin height (p>0.05), muffins baked at steam assisted oven was lower in height and a little denser (0.43) compared to natural (0.35) and forced (0.39) convectional oven baked ones, all in g/cm³, because of less volume rise.

Surface Hunter a and browning index (BI) values of the muffins (Figure 2) were observed that steam assisted oven had significantly lower values than the natural and forced convection ovens at all baking times (p<0.05).

![Figure 2. Surface colour, a) Hunter a; b) browning index (BI) value.](image)

The acrylamide content was determined to be at a lower (22.56 (±0.16) ppb) value for steam assisted baked muffins, where it was 62.73 (±4.68) ppb for forced convection and 59.5 (±13.12) ppb for natural convection baked muffins, each for 40 minutes baking at 160°C (Figure 3). The drying rates calculated for the three ovens were compared (Figure 4) and the maximum drying rate was observed for the forced convection oven baked muffins, where the steam assisted ones showed the minimum drying rates. This would mean that it would be required a longer baking time for steam assisted baking to reach a similar eventual moisture loss value.

![Figure 3. Acrylamide content of muffins baked at o: natural convection, ◊: forced convection, ∆: steam assisted oven](image)

![Figure 4. Drying rates calculated for o: natural convection, ◊: forced convection, ∆: steam assisted oven](image)

**CONCLUSION**

It was concluded that steam assisted baking would be a good baking choice over natural convection or forced convection baking in that it was resulted in lower acrylamide content, and Hunter a and BI values, and nearly same moisture content that would be recommended for better quality muffins.

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