Vacuum baking

Baking is a complex process in which certain chemical and physical changes take place simultaneously. It is important not only in terms of the shelf life stability of biscuit, but also in terms of eating quality, taste and texture. Beside its desirable properties, baking come with certain food safety concerns caused by PCs such as acrylamide and HMF. Temperature, cooking time, and final moisture content are closely related in the baking process. Temperature is one of the most significant parameters affecting acrylamide and HMF formation in biscuits. Apart from the processing conditions, ingredients play also an important role in the formation of PCs.

Mitigation strategies propose modifying the product formulations or processing conditions. **It is hypothesized that reducing the thermal energy load during baking may generally lower the formation of harmful compounds in biscuits.** Although lowering the temperature may generate less acrylamide or HMF, prolonged cooking time is usually required to achieve desired moisture content and textural properties in the final product. The literature is lacking in investigation of the effects of low-pressure at elevated temperatures on the formation of thermal PCs in bakery products. **The objective of this project was to investigate the effect of baking under vacuum on acrylamide and HMF formations in biscuits.** The principle of vacuum baking was to decrease pressure in the oven, thus to decrease boiling point of water during baking. Baking under vacuum allowed us to decrease cooking temperature without retarding the drying process, because moisture evaporation was accelerated under vacuum. Reducing atmospheric pressure in the oven by half enables to decrease baking temperature by 20^{o}C with approximately same drying rate.

The basic recipe given in Table 1 was used to produce biscuits using conventional atmospheric baking and vacuum baking technologies. It was adapted from AACC method 10-54. The dough prepared by mixing the ingredients has been rolled out to obtain the discs having a diameter of 5 cm with a thickness of 3 mm.

Biscuits were baked using three different processes, namely conventional baking, vacuum baking, and combined conventional-vacuum baking in order to determine their effects on acrylamide and HMF contents of biscuits. Conventional baking process was performed using an oven at 180, 190, 200^{o}C for different times up to 15 min. Vacuum baking process was performed using a vacuum oven at 160, 180, 200^{o}C and at 500 mbar for different times up to 17 min.

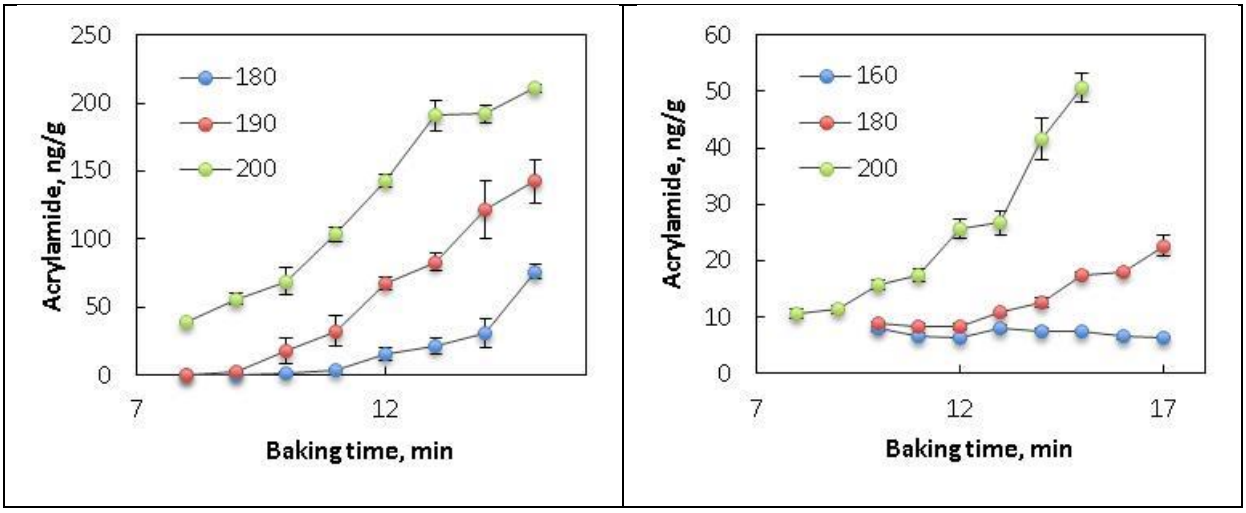
For combined conventional-vacuum baking process, a set of biscuits was first partially baked in the conventional oven at 220^{o}C for 2, 3, and 4 min, and then they were post baked in the vacuum oven set at 180^{o}C and 500 mbar for 6, 5, and 4 min, respectively, keeping a total baking time of 8 min for final products. Control biscuits were baked in the conventional oven at 220^{o}C for 8 min.

Table 1. The basic recipe used to produce biscuits under atmospheric and vacuum baking conditions

Ingredient	Amount, g
WHEAT FLOUR (T55 / W150)	80
REFINED PALM OIL	20
SUCROSE	35
NaCl	1
WATER	17.6
SODIUM BICARBONATE	0.8
AMMONIUM BICARBONATE	0.4

Figure. 1a shows acrylamide formation in biscuits at different temperatures during conventional baking. Expectedly, increasing baking temperature or time significantly increased the amounts of acrylamide formed in biscuits during conventional baking. As shown in Figure 1b, similar kinetic

trends were obtained in biscuits during vacuum baking at 180°C and 200°C. Interestingly, no significant acrylamide formation (<LOQ) was observed in biscuits during vacuum baking at 160°C. Obviously, the heat load was limited to form acrylamide in biscuits under these conditions. The results indicated that the levels of acrylamide concentrations attained during vacuum baking were significantly lower than those attained during conventional baking at all temperatures studied ($p<0.05$). This was in parallel to less browning of the vacuum baked samples which indicates a lower degree of desired baking (Maillard) reactions and accordingly a different flavour profile. Similar to acrylamide, HMF formation had also an increasing trend with increase of temperature and time. This exponential increase was remarkable at 200°C due to high heat load. However, there was no HMF formation (<LOD) in biscuits during vacuum baking at a temperature range of 160 and 200°C. It is a fact that sucrose hydrolysis leading to the formation of HMF during baking requires higher thermal load at elevated temperatures.



(a) (b)

Figure 1. Change of acrylamide concentration in biscuits with time during (a) conventional baking and (b) vacuum baking at different temperatures.

Biscuits had a typical time-temperature profile during baking at 200°C under conventional baking conditions. The biscuit temperature rapidly rose to the boiling point of water (96.8°C in Ankara) within 2 min of baking and remained constant at the range of 97 and 103°C for 3 min until the moisture of biscuits largely evaporated. After a critically low moisture level was attained, the biscuit temperature began to rise again reaching to 200°C at the end of baking. The time-temperature profile of biscuits was different during vacuum baking at 200°C and at 500 mbar. The biscuit temperature rapidly rose to 71°C in 2 min, and then slowly to 81°C. It continued to rise very slowly reaching to 105°C at the end of baking. In comparison to conventional baking, noticeably low time-temperature profile of vacuum baked biscuits was the main reason of reduced formation of acrylamide and HMF. Loss of moisture in biscuits gives also insights on differences between conventional and vacuum baking processes. As expected, the low pressure of vacuum baking accelerated the drying rate of biscuits. The drying rate of biscuits in conventional baking at 180°C was found to be similar to that in vacuum baking at 160°C.

As shown in Figure 2, there were significant differences in the development of browning in biscuits during conventional and vacuum baking processes ($p<0.05$). Since oven air was partially removed in vacuum baking, convective heating was limited, but conduction and radiation took place inside the oven. A recent study indicated that adding Maillard reaction products to the dough could solve lack of browning in cookies.

Figure 2. Biscuits baked at 180°C in conventional and vacuum oven

In the combined process, the dough was partially baked at 220°C for short times (2-4 min) in the conventional oven. Then, partially baked biscuits were post baked in the vacuum oven for accelerated drying at 180°C and 500 mbar for 4-6 min until the desired final moisture content was attained. In the combined process, exposure of biscuits to high temperature long time conditions, which were essential to facilitate the chemical reactions leading to the formation of thermal PCs, was prevented. There was no acrylamide or HMF formations (<LOD) in biscuits baked in the combined process. Control biscuits that were baked at 220°C for 8 min in the conventional oven were found to contain acrylamide content of 140 ng/g.

In conclusion, **vacuum baking allows production of biscuits with very low PC content linked to the lighter colour of the biscuit due to a lower degree of desired Maillard reaction which also results in different sensorial profiles.** It is a new technology to produce biscuits with lower acrylamide levels as a result of the effect of lower temperatures. As to be concluded from the lighter colour of the vacuum baked samples, other chemical reactions including the desired Maillard reaction determining the flavour profile may get effected in a similar manner.
. Since it lowers the thermal input without extending total processing time, vacuum baking limits significantly the formations of acrylamide and HMF in biscuits. Although lack of browning development of biscuits appears as a disadvantage of this technology, the light coloured biscuits may be particularly preferable for chocolate-coated products. Combination of conventional partial baking of biscuits followed by vacuum post-baking process can improve surface colour of biscuits. Moreover, adding brown-coloured Maillard reaction products can modify the colour characteristics. As a promising technology considering PCs, the vacuum baking process may be of importance for the production of baby biscuits in which the highest level of product safety is required in terms of thermal PCs.

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