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Effect of crust temperature and water content on acrylamide formation during baking of white bread: Steam and falling temperature baking

Lilia Ahrné[a,*], Claes-Göran Andersson[a], Per Floberg[a], Johan Rosén[b], Hans Lingnert[a]

[a]SIK—The Swedish Institute for Food and Biotechnology, P.O. Box 5401, SE-402 29 Göteborg, Sweden
[b]National Food Administration, Box 622, SE-751 26 Uppsala, Sweden

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Abstract

The effect of crust temperature and water content on acrylamide formation was studied during the baking of white bread. To assess the effect of over-baking, we used a full factorial experimental design in which the baking time was increased by 5 and 10 min at each baking temperature. Additional experiments were performed with steam baking and falling temperature baking. Immediately after baking, the crust was divided into the outer and inner crust fractions, and the water content and acrylamide concentration of each fraction was measured. The outer crust had a significantly lower water content and higher acrylamide concentration than the inner crust did. Crust temperature in combination with water content had a significant effect on acrylamide formation, higher temperatures resulting in higher acrylamide concentrations. However, at very high temperatures and lower water contents, acrylamide concentration was observed to decrease, though the bread colour was then unacceptable for consumption. Steam and falling temperature baking, on the other hand, decreased the acrylamide content while producing bread crust with an acceptable colour. The lowest acrylamide values and an acceptable crust colour were produced by steam baking.

Keywords: Baking; Acrylamide; Steam baking; Crust; Temperature; Water content

1. Introduction

Bread baking is a complex process involving many physical and chemical changes. The optimum baking process depends on the type of bread to be baked and the desired bread characteristics. The surface colour of bread is an important quality associated with aroma, texture, and appearance characteristics important to consumers. Surface colour is often used as indicator of baking completion. Bread colour develops late in baking, simultaneously with crust formation, and arises from chemical reactions such as the Maillard reaction and sugar caramelization. The extent of these chemical reactions is largely influenced by the physical mechanisms of heat and water transport during baking. Thus, bread crust colour is influenced by the dough recipe and by the processing conditions during baking, i.e., time, temperature, air velocity, relative humidity, and rate of heat transfer.

The Maillard reaction is important for the formation of colour and aroma in the bread crust, but may also be associated with the formation of toxic compounds, such as acrylamide (Mottram, Wedzicha, & Dodson, 2002; Stadler, Blank, Varga, Robert, & Riediker, 2002; Zyzak et al., 2003). Since the Swedish National Food Administration announced in April 2002 that acrylamide had been found in food products, research has been conducted worldwide to attain a better understanding of acrylamide formation mechanisms and to find ways to reduce such formation. Acrylamide has been found in substantial amounts in many different food products, mainly of plant origin, processed at temperatures above 100–120 °C. The highest amounts of acrylamide have been found in French Fries, potato crisps, and crisp bread (Tareke, Rydberg, Karlsson, Eriksson, & Tornqvist, 2002). Later studies, taking intake data into account, have shown that the main food categories responsible for acrylamide intake are potato products,

*Corresponding author. Tel.: +46 31 33 55 600; fax: +46 31 833 782.
E-mail address: lia@sik.se (L. Ahrné).

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cereal products (including bread), and coffee (Svensson et al., 2003; Matthys et al., 2005). CIAA, the Confederation of the Food and Drink Industries in the Europe, published in 2005 and updated in October 2006, the "Acrylamide Toolbox" containing relevant information about acrylamide in foods and ways to reduce its formation (www.ciaa.be).

Several approaches to reducing the acrylamide content of bread have been reported in the literature in recent years. Haase, Matthaeus, and Vosmann (2003) discussed the formation of acrylamide in baked products, and identified flour milling intensity and baking temperature as important factors affecting acrylamide concentration in bread. Springer, Fischer, Lehrack, and Freund (2003) reported a 50% reduction in the acrylamide content by changing the temperature/moisture profile during the baking process. Surdyk, Rosen, Andersson, and Aman (2004) examined the effect of asparagine and fructose on acrylamide formation in white leavened bread at baking temperatures over 200 °C, finding a strong correlation between crust colour and acrylamide formation when the recipe remained constant. However, when a flour with a lower ash content was used, a lower acrylamide content and a similar crust colour were obtained. Fredriksson, Tallving, Rosen, and Aman (2004) suggested that extensive fermentation with yeast may be one strategy for reducing the acrylamide content of bread. Brathen and Knutsen (2005) examined the effect of time and temperature on the formation of acrylamide in bread, flat bread, dry starch systems, and dried rye-based flat bread. Mustafa, Andersson, Rosen, Kamal-Eldin, and Aman (2005) studied the effects of baking time and temperature and of changing the recipe for yeast-leavened whole-grain rye crisp bread (by adding fructose, asparagine, and oat bran concentrate) on its acrylamide content and colour. Brathen, Kita, Knutsen, and Wicklund (2005) and Fink, Andersson, Rosen, and Aman (2006) observed that the addition of glycine to dough significantly reduced the acrylamide content of both flat bread and bread crust.

Baking temperature is an important parameter influencing acrylamide formation. Although the temperature of importance for the formation of acrylamide is the exact temperature in the bread surface, most studies only report the oven temperature. The heat is transported from the oven air to the bread, and since bread is a poor heat conductor, a temperature and water profile arises in the bread. This temperature profile and its development over time during baking are strongly influenced by the rate of heat transfer from the oven to the bread surface, and by the thermal and structural properties of the dough/bread that determine heat and water transport inside the bread. Bread crust is formed at the end of the baking process, when the bread surface temperature is over 100 °C and water loss in the bread surface is considerable. The crust fraction in contact with the bread crumb may become dried, as is typical of a crust, but may have poor colour development compared with the outer surface. The extension of chemical reactions, including the formation of acrylamide or colour, depend on the temperature and water distribution in the crust during baking. Very little research has examined the effect of the in situ water content and temperature of the bread crust during baking and their effect on acrylamide formation. This present research aimed to determine the effect of crust temperature and water content on acrylamide formation in bread crust, and to suggest ways to reduce it.

2. Material and methods

2.1. Recipe

Wheat flour (Bagarns Bästa, 18% protein, 0.45% ash, 0.017% aspargine, 0.013% glucose, and 0.005% fructose) obtained from Nordmills (Uppsala, Sweden), was used in this study. Bread dough was prepared as described in Table 1.

The yeast was dissolved in 20 °C water and then added to the dry ingredients. All the ingredients were mixed for 2 min at slow speed and then 5 min at high speed in a spiral kneader (CDE Freviglio, Italy). Portions of dough, each weighing 200 g, were placed in rectangular baking tins and allowed to rest for 10 min at ambient temperature before proofing for 45 min at 35 °C and 80% RH.

2.2. Baking process

The fermented dough was baked in the baking tins in a deck oven without air circulation (Dahlen-Nova, Sveba Dahlen AB, Fristad, Sweden) following the 2^3 factorial design with three central points as described in Table 2.

During baking, the temperature was measured in the bread crust at depths of 1 and 2 mm from the surface and in the centre of the bread. Very thin copper–constantan thermocouples, 0.07 mm in diameter (type T; Pentronic AB, Sweden), connected to a logger and a computer were used to record the temperature.

Additional experiments were done in a convection oven (Dahlen S400; Sveba Dahlen AB, Fristad, Sweden) to assess the effect of steam on the water content of the crust and on acrylamide formation. Steam was injected into the oven after 5, 10, and 15 min and retained in it until the end

Table 1
Recipe for the bread dough

Recipe	Weight (g)
Wheat flour	1850
Water	1000
Yeast	90
Salt	18.5
Improver (Lecimax 2000, Nordbakels, Sweden)	18.5
Total	2977