THE INFLUENCE OF THE CLASSICAL COOLING PROCESS ON THE OCCURRENCE OF THE ROPE SPOILAGE IN BREAD

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Abstract: The aim of this paper was to present the results of a study on the classical cooling process of bread performed at Cahulpan bread producer (Cahul, Moldova Republic). Four types of bread have been chosen for the experiments: long loaf "Cahuleanca" and "De capitală", bread in trays "Deosebită" and bread on the hearth "De grâu c.1". The cooling has been performed in two separate spaces with different air temperatures: 26.0±1.0°C and 17.5±0.5°C by using classical bread cooling with natural air convection. The results were similar for both situations, but the cooling process and the final temperature of the bread depend also by the shape of the bread. Thus, long loaf breads have higher cooling rates and lower final temperatures than the other bread types. In addition, the occurrence of bread ropiness has been delayed for the bread cooled at 17.5±0.5°C due to a faster cooling of the crumb.

Keywords: bread, rope spoilage, ropiness, cooling, air temperature, bread shape.

Introduction

Bread is a perishable food with a short physical-chemical and microbiological shelf-life. The main microbiological alteration that appear several days after baking is the "rope spoilage" caused by spore-forming bacteria coming from raw materials (Valerio et al., 2014).

Bread ropiness is initially detected as a sweet and unpleasant fruity odour that resembles overripe melons or pineapples (Thompson et al., 1998), followed by an enzymatic degradation of the crumb that becomes soft and sticky due to the production of extracellular slimy polysaccharides (Bordei, 2004, p. 356). The spoilage organisms are heat-resistant spores of bacteria belonging to *Bacillus* genera namely *Bacillus subtilis* with *Bacillus subtilis vulgaris* or *Bacillus subtilis* subsp. *mezentericus* as synonyms (Dan, 2001, p. 402; Puchkova et al., 2005, p. 441; Yudina et al, 2011). Some researchers consider that other species of *Bacillus* are capable of occasionally causing rope and these include *B. licheniformis*, *B. pumilus*, *B. cereus*, *B. megaterium*, *B. mycoides*, *B. polymixa* , *B. amyloliquefaciens* etc., but their role is less important (Pepe et al., 2003; Valerio et al., 2012; Yibar et al., 2012; Lvova & Yajckih, 2013).

One of the factors that influence the occurrence of the rope spoilage in bread and bakery products is the cooling process of the bread after baking. The disease occurs more frequently during the warm period of the year when the cooling process of the bread is slow and the bread removed from the oven is maintained for longer time at temperatures greater than 20°C in storage rooms (Dan, 2000, p. 233). Some researchers consider that for the growth of *Bacillus* species of bacteria it is enough to have at least 15°C in the cooling space (Yudina et al., 2011). Bacteria causing the bread ropiness are thermophilic with optimum temperatures of 37...44°C. Therefore, the fast cooling of the bread after baking to a temperature of 15...20°C is meant to eliminate the risk of the disease occurrence (Dan, 2000, p. 233).

Currently, the methods used for the cooling of the bread and bakery products in the industry are:

a) Classical method consisting in the arrangement of the products on racks in the cooling space with natural air circulation;
b) Mechanized method by using special equipment for the bread cooling such as coolers and cooling cabinets with either natural or forced air circulation.

Thus, the air parameters (temperature, type of air circulation) are important both during the cooling process and during the bread storage before delivery.

The aim of the research was to study the process of cooling of the bread and determine the correlation between this process and the occurrence of the rope spoilage in bread and bakery products.

Materials and Methods

Bread. Four types of bread manufactured at Cahulpan (Cahul, Republic of Moldova) have been chosen for the experiments: long loaf "Cahuleanca" ("Bread from Cahul") and "De capitală" ("Bread from the Capital"), bread in trays "Deosebită" ("Special bread") and bread on the hearth "De grâu c.1" ("Wheat bread c.1").

Other materials and equipment: racks, digital thermometer, room thermometer, thermostat, balance, equipment to determine the loaf volume, special rulers.

Cooling conditions. The cooling process was simultaneously carried out in two separate spaces with different air temperatures: the bakery section with 26.0±1.0°C and the warehouse of delivery with 17.5±0.5°C. Bread was cooled by using classical cooling with natural air convection in both situations.

Temperature measurement. In order to study the cooling process of the bread the following steps have been performed:

- The arrangement of the bread on the shelves immediately after baking;
- The insertion of the needle of digital thermometer in the centre of the loaf of bread;
- The record of the bread temperature at every 5 minutes;
- The record of the air temperature in the cooling space.

The test for bread ropiness occurrence. Cooled bread samples were wrapped in cloth moistened with water then introduced in incubator where they have been maintained at 37°C for up to 72 hours.

Physical properties of bread analysed to characterise the bread were the mass, volume and dimensions: maximum length, width and height (Table 1).

All the tests were performed in triplicate.

Table 1. Methods used to determine the physical properties of the bread

Physical property	Materials and equipment	Standard method
Mass	Balance	SR 878/1996
Volume	Balance, 500 mL glass cylinder, 10 L plastic container with 35 cm diameter, clean rapeseeds	STAS 91/1983
Dimensions (length, width, height)	Special rulers	-

Results and discussion

Physical properties of bread samples after cooling

The cooling rate of the bread and bakery products is directly determined by the surface area of the heat exchange. However, this parameter is difficult to be determined due to the irregular shape of the bread and bakery products. Therefore, many researchers use the mass to characterize these products because the surface area of the heat exchange depends on the mass of bread. Moreover, the volume and dimensions of bread may have a certain influence on the cooling process. Data obtained for the physical properties of bread samples after cooling are presented in Table 2.

The mass of bread samples varies between 365 and 518 g. It is obvious that the higher the mass of bread is, the higher the volume is. Thus, the volume varies between 710 and 1365 cm^3 as a function of the bread type. Also, the maximum dimensions of the bread samples vary widely being determined by their shape.

Table 2. Physical properties of bread samples after cooling

Physical property / Product type	Mass, g	Volume, cm^3	Length max., mm	Width max., mm	Height max., mm
Long loaf “De Capitală”	367.5±2.5	747.5±37.5	309.0±1.0	76.5±2.5	70.5±0.5
Long loaf “Cahuleanca”	426.5±3.5	1067.5±27.5	258.0±0.0	129.0±0.0	60.0±1.0
Bread on the hearth “De grâu c.1”	501.0±2.0	1162.5±7.5	175.0±2.0	175.0±2.0	73.0±0.0
Bread in trays “Deosebită”	515.5±2.5	1360.0±5.0	191.0±1.0	85.0±0.0	122.5±2.5

Temperature evolution during the cooling process of bread samples

The temperature of bread samples was measured both in the bakery section with 26.0±1.0°C (Figure 1) and the warehouse of delivery with 17.5±0.5°C (Figure 2).

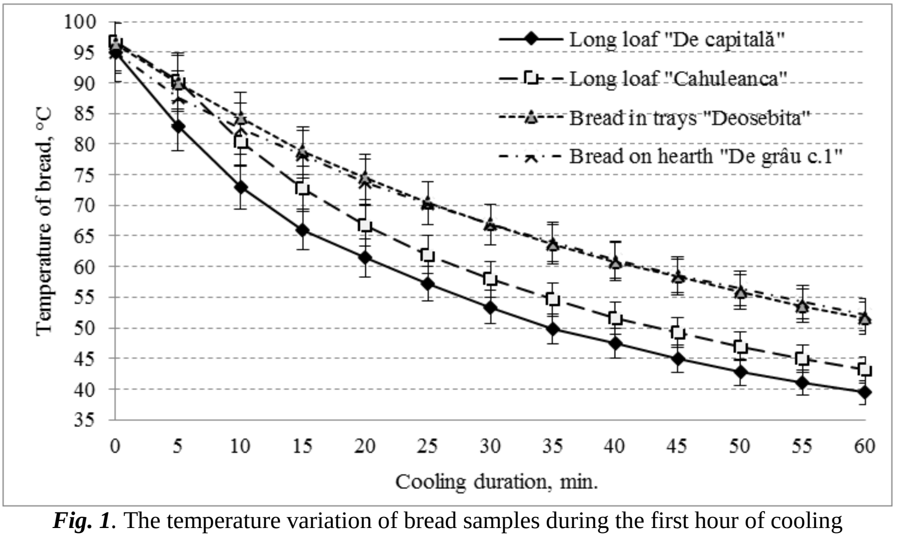


Fig. 1. The temperature variation of bread samples during the first hour of cooling in the bakery section with the air temperature of 26.0±1.0°C.
(The error bars represent standard deviation between triplicate results.)

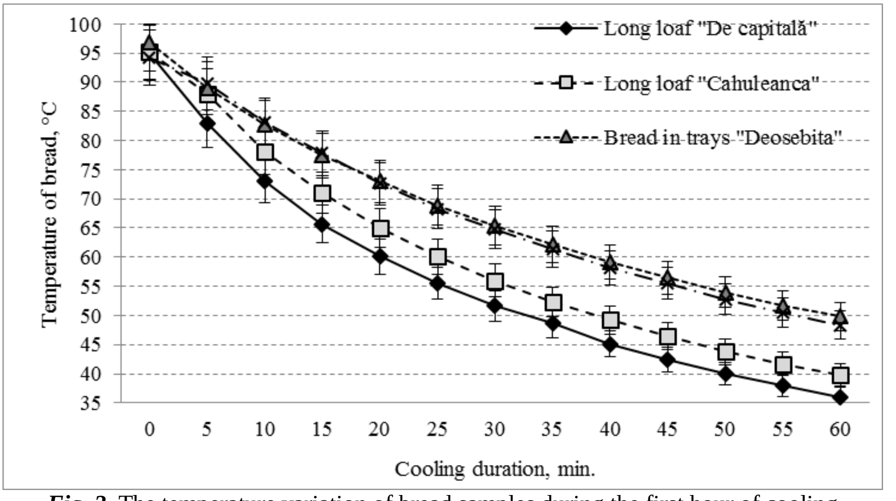


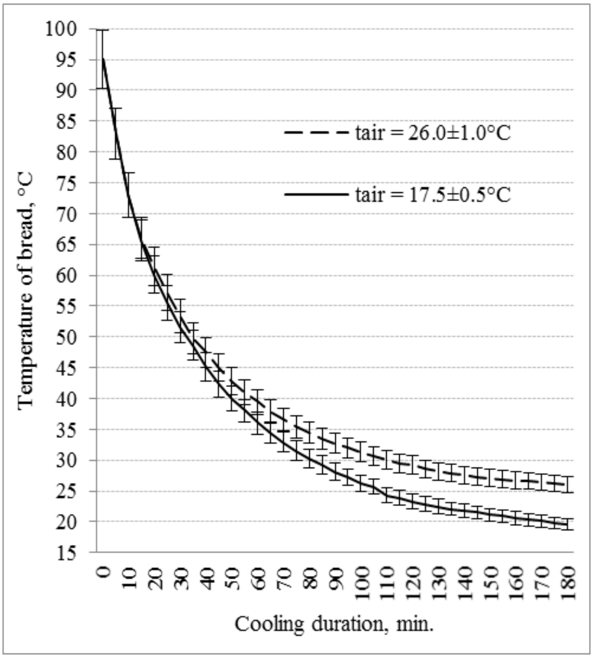
Fig. 2. The temperature variation of bread samples during the first hour of cooling in the warehouse of delivery with the air temperature of 17.5±0.5°C. (The error bars represent standard deviation between triplicate results.)

The temperature of all bread samples decreased during cooling and reached values between 35...55°C at the end of the first hour of cooling (Figures 2 and 3). The lowest temperature after one hour of cooling was recorded for the long loaf "De capitală" which was the sample with the lowest mass and volume values. On the contrary, the highest temperature after one hour of cooling was recorded for the bread on the hearth "De grâu c.1" which was the sample with the highest mass and volume values. This can be explained by the fact that bread samples with low mass and volume values accumulate, during cooking, a lower quantity of heat energy than those with higher mass and volume values, and this heat energy will be faster removed during cooling. It can also be mentioned that the surface of the loaf is nicked which increases the surface area of heat exchange and, as a result, the heat loss is faster in this case.

The analysis of the cooling process in the two situations, namely cooling in the bakery section with 26.0±1.0°C and in the warehouse of delivery with 17.5±0.5°C, showed that the difference between the bread temperature after one hour of cooling, for the same type of bread is about of 3...4°C. This means that the difference between the air temperatures in the two cooling spaces of about 8...10°C has a rather low influence on the bread temperature decrease. A more rapid cooling of bread and bakery products immediately after baking could be obtained by using a forced air circulation with temperature lower than 17°C.

Study of the dynamic of cooling process for long loaf "De Cahul"

The long loaf "De Cahul" has been chosen for the study of cooling process during the whole cooling time of three hours, recommended for bread with 300-500 g per loaf. Thus, the temperature in the centre of bread loaf was forward recorded until the total time of cooling, 180 min. (Figure 3) when the final temperature in the centre of the bread should be under 20°C (Dan, 2000, p. 233).



This figure shows that the bread samples cooled in the warehouse of delivery with the air temperature of 17.5±0.5°C reached a final temperature lower than 20°C (more precisely 19.2°C), while in the case of bread cooling in the bakery section with the air temperature of 26.0±1.0°C the final temperature was around 26°C. This temperature is appropriate for the growth of *Bacillus* bacteria and, as a result, the occurrence of bread ropiness is possible.

Fig. 3. Total cooling process of the long loaf "De capitală"
(The error bars represent standard deviation between triplicate results.)

Figure 4 presents the variation of cooling rate as a function of cooling time. One could see that the cooling rate is high in the first 10 minutes of cooling (about 2°C/min) for both cooling situations. This is the result of the high difference between the bread and the air temperature. Further, between 15-120 minutes, it is observed that the cooling rate begins to decrease, remaining with 0.05°C/min higher in the warehouse of delivery. In the last cooling hour the cooling rate has the same values. As a consequence, the dynamic of the cooling process can be divided into three periods: a) intensive cooling phase, b) slow cooling phase, and c) stationary phase. The difference between the cooling rate occurs in the slow cooling phase, this giving the difference between the final temperature of bread samples.

After cooling, bread samples were maintained at 37°C in an incubator. Bread ropiness occurred after 48 days in bread samples cooled in the bakery section and after 72 hours in the warehouse of delivery. This highlights the fact that classical cooling process at lower temperatures (17.5±0.5°C) delayed occurrence of bread ropiness due to a faster cooling of the crumb. However, is not adequate for the cooling of bread made from flour infested with spore-forming bacteria of *Bacillus* species.

Conclusions

Classical cooling process could be satisfactory only for the bread made by using wheat flour which is not infested with spore-forming bacteria of *Bacillus* species. However, the shelf life of bread is 24-48 hours and if it is consumed to meet this indication, the rope spoilage does not occur in bread. Moreover, the bread is usually kept in cold and dry places, different than those created in the incubator. Therefore, in normal situations of using wheat flour with low level of infestation, manufacturing bread in clean environment, and cooling the bread after baking as soon as possible, rope spoilage will not occur in such bread.

As a conclusion, if the wheat flour is highly infested with spore-forming bacteria of *Bacillus* species responsible for the occurrence of bread ropiness, classical cooling has to be combined with other prevention methods such as increasing the dough acidity, or replaced with fast cooling using forced air circulation.

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