Optimization through simulation

SIMULATION IS A METHOD USED FOR PROCESS OPTIMIZATION TO IMPROVE THE QUALITY OF BAKED GOODS

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+ At IGV, the vacuum cooling process of par-baked rolls was mathematically modeled. Simulation results provide important information on product-specific process optimization, in particular regarding quality improvements of baked goods. Compared to par-baked frozen rolls, vacuum-cooled rolls have a much easier logistics chain and generate less energy costs. Vacuum-cooled goods have a shelf-life of several day thus making frozen storage capacities superfluous. To a large extent, the recipes can be adjusted to the special conditions of vacuum cooling.

Advantages

The main advantage of a vacuum cooling process is the very short cool-down time. Following the comparably short par-baking time, the baked goods have simply no time to collapse or develop wrinkles. On the contrary, vacuum cooling stabilizes the structure of bakery items. The result: After bake-off the crust will stay crisper longer.
Systematic test series show that the time history of the vacuum cooling process largely influences the product quality. For thermodynamic optimization of the process, the vacuum cooling of par-baked rolls was mathematically modeled. The simulation program was developed within the scope of a research project of the IGV Institut für Getreideverarbeitung GmbH [1] in cooperation with the University of Applied Sciences of Lausitz.
The physical law according to which the evaporation of water is dependent on the atmospheric pressure (the lower the pressure the lower the temperature required for evaporation) is technically implemented in the vacuum cooling process. Water-containing products can be quickly cooled down because they provide the required evaporation energy themselves.

The cooling speed is dependent on the rate with which the vacuum pump reduces the pressure in the chamber. During this process a large pressure differential develops between the water vapor pressure inside the baked goods and the total pressure within the vacuum chamber.
This pressure differential, which can assume very high values and may cause the crumb of sensitive products to split, is the driving thermodynamic force of the vacuum cooling process. The controlled application of this driving force during the process opens up new possibilities for further improvement of the quality of vacuum-cooled baked goods.

Results from the simulation

The mathematical model of the transient vacuum cooling of baked goods developed by IGV is based on the following physical fundamentals:
+ maintenance of energy and maintenance of mass
+ transfer of heat and materials
+ law of ideal gases for air and water vapor.

The resulting equation system for the pressure differential is highly variable and allows the consideration of different product properties, loading status of the chamber and characteristic pump curves. From that the time history of all thermodynamically relevant parameters can be calculated.

For the experimental validation of the mathematical model, a vacuum plant provided by Koenig Maschinen GMBH, equipped with additional measurement instrumentation, was used. Figure 1 shows the measured and calculated core temperatures during vacuum cooling of par-baked rolls. As can be seen from the graphical depiction, the results from the simulation agree well with the measured values. +++