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Substitution of ice by a curing salt solution during meat batter production using the vane pump-grinder technology

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ABSTRACT

Extending vane pump-grinder systems by attaching a high-shear homogenizer enables the production of finely emulsified meat batters. The integration of an injection nozzle between grinder and high-shear homogenizer allows for a curing salt solution to be injected during meat emulsion production. In this study, we examined the effects of substituting crushed ice by a curing salt solution. We postulated that the injection of a salt solution instead of the addition of ice decreases the energy consumption of the size reduction units, since forces required to comminute the raw material mixture may decrease. To this purpose, the amount of crushed ice in the meat emulsion formulation was gradually substituted by a curing salt solution injected via the nozzle. Results show that the complete substitution of ice by injection of curing salt solution did not alter the product qualities, but that substantial energy savings of up to 25% during the production of finely dispersed meat emulsions were achieved. Specifically, the power consumption of the high-shear homogenizer decreased by up to 27%. Results should be of interest to meat product manufacturers looking for new approaches to reduce costs.

1. Introduction

The meat processing industry faces ever growing price pressures. This, in turn, is leading to substantial structural changes. For example, the number of small-scale meat processors in Germany has decreased by about 30% over the past 10 years, whereas the number of industrial manufacturers continues to grow (BVDF, 2014; DFV, 2014). Consequently, manufacturers are increasingly demanding the development and application of continuous rather than batch processes in meat product manufacture, since such processes are often more efficient tan batch operations (Weiss, Gibis, Schuh, & Salminen, 2010). The vane pump-grinder technology meets this requirement by continuously converting a raw material mixture into a meat batter and filling it directly into casings in a single processing step (Haack, 2001; Schmid, Reutter, Baechtle, & Braig, 2008). In addition to the production of coarsely ground dry-cured sausages, the manufacture of emulsion-type sausages with a freely modifiable degree of dispersion has recently become feasible via the implementation of a downstream high-shear homogenizer (Braig, Baechtle, Reutter, & Mueller, 2011; Irmscher et al., 2013; Irmscher, Gibis, Herrmann, Kohlus, & Weiss, 2016; Irmscher et al., 2015). There, an extended vane pump-grinder system consisting of a vane pump, an attached grinder component and a downstream homogenizer with a tooth-saw rotor-stator cutting tool has been developed (Irmscher, Gibis, Herrmann, Kohlus, & Weiss, unpublished results).

In extended vane pump-grinder systems, only small temperature increases occur during the comminution of the raw materials due to the short residence times in the size reduction zone of the grinder (Haack & Schnaeckel, 2004) derived via constantly conveying pumps (Maile, Mantz, & Staudenrausch, 2008; Rose, 1993). Because of this, the vane pump-grinder technology may potentially allow the substitution of ice by water during the manufacture of meat batters for emulsion-type sausages, since ice is typically only added to prevent overheating of the batter mass during homogenization (Haack, Schnaeckel, & Haack, 2003). Schnaeckel, Krickmeier, Schnaeckel, Micklisch, and Haack (2012)

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observed that the temperature increased by 9–10 K when 60% (w/w) ice was substituted by water during meat batter production using an extruder-grinder. The integration of an injector nozzle between the grinder component and the homogenizer in an extended vane pump-grinder system enables the continuous addition of a liquid, such as water or curing salt solutions, during the production of meat batters. In a previous study, we found that the short mixing time of the curing salt with the comminuted meat and fat mixture was sufficient to allow for high-quality emulsion-type sausages to be manufactured. Incidentally, we observed that power consumption decreased (Irmscher, Gibis et al., unpublished results).

The objective of this study was therefore to investigate the influence of a substitution of ice by an injected curing salt solution during the production of a meat batter using an extended vane pump-grinder system more systematically. We hypothesized that the torque acting on the motor of the grinder component and the homogenizer decreases with the substitution of ice, resulting in lower power consumption. This is because there are less forces needed to homogenize the raw material mixture. As a result, the meat batter may be exposed to higher temperatures, and thus product properties may be altered. To this purpose, meat batters with an increasing substitution of ice by a curing salt solution injected (0–100%) were produced using an extended vane pump-grinder system. All other process parameters were kept constant and the microstructure, particle size distribution, color of products and the power consumption of the system analyzed.

2. Materials and methods

2.1. Materials

Lean pork meat and pork fat from the shoulder and ham were obtained from Mega eG (Stuttgart, Germany). Meat and fat were ground to 5 mm using a grinder (Type W 114 T82 487-1, Seydelmann, Aalen, Germany) after standardizing materials to the categories SIII and SIX, according to the GEHA meat classification system (Hack et al., 2001). Curing salt was purchased from Zentrag eG (Frankfurt, Germany). A spice mixture “Aufschnitt Delikatess” was kindly provided by Tastemakers (Stuttgart, Germany). Tetrasodium pyrophosphate “Bullifos LL” and ascorbic acid were kindly provided by Frutarom Savory Solutions (Korntal-Münchingen, Germany). Casings (Type NaloBar APM, Ø 60 mm) were supplied by Kalle (Wiesbaden, Germany). Water-vapor permeability of casings was 5 g/m^2 d at 23 °C and 85% relative humidity, while permeability to oxygen was 12 cm^3/m^2 d bar at 23 °C and 53% relative humidity.

2.2. Sample production

Emulsion-type sausages were produced according to a standard formulation containing 500 g/kg lean pork meat, 270 g/kg pork fat, 230 g/kg ice/water, 18.0 g/kg curing salt, 5.0 g/kg spice mixture, 1.5 g/kg pyrophosphate and 0.5 g/kg ascorbic acid using an extended vane pump-grinder system (vane pump VF616, grinder unit GD 93-3 and a homogenizer prototype from Handtmann, Biberach, Germany) having an injection nozzle inserted between grinder and homogenizer (Fig. 1 **A**). The grinder was equipped with a five-part knife-perforated plate assembly made of a standard precutting plate, a ring knife with eight blades, a perforated mid plate with 4 mm hole diameter, a second ring knife with eight blade, and a perforated end plate with 2 mm hole diameter (turbocut Jopp, Bad Neustadt, Germany). The homogenization zone of the homogenizer consisted of two rotor-stator systems. The first rotor-stator stage consisted of a rotor with a diameter of 150 mm and 22 bars and a stator with 28 blades, whereas the rotor diameter was 125 mm with 19 bars and the stator had 24 blades in the second rotor-stator stage (Hempe, Wagenfeld, Germany). Meat, fat, ice, spice mixture, pyrophosphate and ascorbic acid were mixed in a MVZ 150 T-paddle mixer (Asgo, Ermesinde, Portugal) at 30 rpm for 10 min. The amount of ice was substituted by various degrees (0, 20, 40, 60, 80 and 100%) with an injected curing salt solution with a temperature of 1 °C. To that purpose, the volume flow rate of the vane pump $\dot{V}_{vp}$ and the cavity pump $\dot{V}_{cp}$ was varied depending on the amount of ice substituted (Table 1) in order to keep the total volume flow rate $\dot{V}$ constant at $\dot{V}_{vp} + \dot{V}_{cp} = 40$ L/min. The grinder's knife rotational speed n_{knife} was set to 236 rpm and the rotational rotor speed of the homogenizer n_{rotor} was set to 3000 rpm for all samples. The processed meat batter was filled directly into impermeable casings, heated in a water bath at 75 °C until a core temperature of 72 °C had been reached, then cooled and stored at 1 °C until analysis. Fig. 1 **B** depicts the process flow chart of the samples' production.

2.3. Machine parameter acquisition

Machine parameters of the extended vane pump-grinder system were captured by internal sensors and recorded by the operating software of the vane pump-grinder system. The power consumed by the vane pump P_{vp}, the grinder $P_{grinder}$ and the homogenizer $P_{homogenizer}$ were recorded during the meat batter production. The temperature of the raw material mixture $\vartheta_{mixture}$ and the meat batter ϑ_{batter} were measured with a thermometer (Type 926, Testo, Lenzkirch, Germany).

2.4. Photographic images

Photographic images of the sausage cross-sections were taken using a digital single-lens reflex camera (Type K-5, Pentax Ricoh Imaging, Hamburg, Germany). Ten images per sample were taken under standardized conditions, i.e. lightness, distance to the sample and camera settings (ISO-200, aperture: 7.1, exposure time: 5 ms). The contrast of all images was enhanced equally using the open source image processing software GIMP 2.8.10 (The GIMP Team) to allow for a better differentiation of potential differences.

2.5. Visible lean meat particle size

The visible lean meat particle size of the sausage cross-sections was determined via image analysis (ImageJ 1.49a, Wayne Rasband, National Institutes of Health, Bethesda, MD, USA). The photographic images were converted to grey scale images, and binary black and white images were generated from the grey scale images by applying an automated grey scale threshold procedure (method: “triangle”) to the visible lean meat particles. The binary images were subjected to particle size analysis. Mean diameter d_{10} and mean volume-surface diameter d_{32} were calculated according to Equations (1) and (2):

$$d_{10} = \frac{\sum n_i \times d_i}{\sum n_i} \tag{1}$$

$$d_{32} = \frac{\sum n_i \times d_i^3}{\sum n_i \times d_i^2} \tag{2}$$

with the number of particles n_i of the diameter d_i in each size class of the population (McClements, 2005). Ten photographic images were analyzed for each sample.