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Development of a novel homogenizer using the vane pump-grinder technology for the production of meat batter

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A B S T R A C T

On the basis of the continuous operating vane pump-grinder technology, a novel high-shear homogenizer consisting of a saw-tooth rotor-stator system was combined with a vane pump to produce meat batters. The rotational rotor speed varied between 1000 and 3000 rpm and the volume flow rate varied between 10 and 60 L/min at either constant volume flow rate or constant rotational rotor speed. The meat batters were filled into casings and heated up to a core temperature of 72 °C in order to induce gelation. Characteristics of samples were assessed by structure, $L^*a^*b^*$ color values, texture, and water-binding analysis. The rotational rotor speed and the volume flow rate define the volumetric energy input that induces the degree of dispersion. Thus, the mean diameter of visible lean meat particles was between 0.361 ± 0.011 mm and 0.468 ± 0.017 mm, whereas the volume-surface diameter attained sizes between 0.626 ± 0.018 mm and 0.929 ± 0.066 mm.

1. Introduction

The concept of the vane pump-grinder technology is the combination of a positive displacement pump with a grinder system. Thus, the vane pump works as a feed pump ensuring a constant volume flow rate, whereas the grinder system facilitates the size reduction zone (Walther and Weisenfels, 2003; Büchele, 2009). Thus, a raw material mixture can be converted to a meat batter and filled directly into casings in a single processing step (Weiss et al., 2010). However, vane pump-grinder systems are still mainly used for the production of coarsely ground sausages, such as dry-cured sausages, so-called salamis (Irmscher et al., 2011, 2013). Ongoing investigations and the integration of approaches from material science have led to further developments of the conveyance technology as well as advancements regarding the cutting tools. Novel knife and perforated plate geometries increase the cutting quality, product quality, and the efficacy of the vane pump-grinder technology (Haack et al., 1998; Haack, 2007; Büchele, 2013; Schnaeckel, 2013a). Outputs of $\dot{m}$ = 170 kg/min during the production of minced meat, for instance, may be realized (Haack, 2009).

In addition to bowl choppers, continuously operating fine meat homogenizers also ensure the production of stable finely emulsified meat batters (Hammer, 1992a, 1992b). Several size reduction tools have been established, such as knife-perforated plate assemblies, perforated plate-perforated plate assemblies, as well as rotor-stator systems (Schnaeckel, 2013b). Along with the size reduction, mixing and homogenization is taking place (Weiss et al., 2010). However, after the meat batter production, its filling into casings as an additional processing step, is still necessary.

In general, the production of meat batters for emulsion-type sausages, such as Frankfurters, using the vane pump-grinder technology is feasible. In doing so, the degree of dispersion can be modified freely by the variation of the knife rotational speed of the grinder $n_{grinder}$ and the volume flow rate $\dot{V}$ of the vane pump. However, the volumetric energy input E_V is insufficient to produce emulsified meat batters. Nevertheless, the degree of dispersion can be modified freely within a certain range (Irmscher et al., 2015). Further developments are necessary for the realization of the production of finely emulsified meat batters in a continuous production system on the basis of the vane pump-grinder technology. The homogenization zone particularly needs to be improved, allowing a higher volumetric energy input. Schnaeckel et al. (2012) demonstrated that the production of finely emulsified meat batters

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with an extrusion grinder can be realized by attaching an additional grinder system with a separate motor. However, they did not vary the degree of dispersion producing only finely emulsified meat batters. In addition, the meat batter was not filled directly into casings. Nevertheless, this study demonstrated that the production of finely emulsified meat batter might be feasible by applying novel downstream homogenization devices. This approach, in terms of increasing the volumetric energy input, can also be applied to the vane pump-grinder technology.

In our study, we attached a newly developed high-shear homogenizer directly to a vane pump. The homogenization zone of the homogenizer consisted of a two-stage tooth-saw rotor-stator system (Anonymous, 2009). The objective was to assess its ability to produce emulsified meat batters and to determine a process-structure relationship for the vane pump-homogenizer system. For this purpose, we examined the influence of rotational rotor speed n_{rotor} (1000–3000 rpm) and the volume flow rate $\dot{V}$ (10–60 L/min) at either constant volume flow rate or constant rotational rotor speed. We hypothesize that the novel homogenizer increases the volumetric energy input and, thus, enhances the degree of dispersion of the meat batter. Consequently, the range of adjustable structures shifts to finer degrees of dispersion which may also permit the production of emulsified meat batters. This may affect also product properties due to an alteration in the comminution of meat and fat and in the solubilization of myofibrillar proteins.

2. Materials and methods

2.1. Materials

Lean pork meat and pork fat from shoulder and ham were obtained from Mega eG (Stuttgart, Germany) and standardized to SIII and SIX, according to the GEHA – meat classification system (Hack et al., 2001). Curing salt was purchased from Zentrag eG (Frankfurt, Germany) and a spice mixture “Aufschnitt Delikatess” was kindly provided by Tastemakers (Stuttgart, Germany). Tetrasodium pyrophosphate “Bullifos LL” and ascorbic acid were supplied by Frutarom Savory Solutions (Korntal-Münchingen, Germany). Casings type NaloBar APM, 60 mm diameter, were kindly provided by Kalle (Wiesbaden, Germany).

2.2. Production of emulsion-type sausages

Lean pork meat SIII and pork fat SIX were ground to 5 mm in a grinder (Type W 114 T82 487-1, Seydelmann, Aalen, Germany). A combination of 50 wt% lean meat, 27 wt% fat, and 23 wt% crushed ice were mixed with 18.0 g/kg curing salt, 5.0 g/kg spice mixture, 1.5 g/kg tetrasodium pyrophosphate, and 0.5 g/kg ascorbic acid for 10 min at 30 rpm in a MVZ 150 T-paddle mixer (Asgo, Ermesinde, Portugal). This raw material mixture was then fed into the funnel of a vane pump VF 616 equipped with a novel high-shear homogenizer (Handtmann, Biberach, Germany), shown in Fig. 1A. The homogenization zone was realized by a two-stage saw-tooth rotor-stator system (Anonymous, 2009). The rotor in the first stage had a diameter of 150 mm with 22 rotor bars, whereas the stator had 28 stator bars in which cutting plates were fixed. The gap between the stator bar and, thus, the effective cutting gap depended on the geometry of these cutting plates. In our study, cutting plates that cause a cutting gap of 1.8 mm were used. The second rotor-stator stage had a diameter of 125 mm, where a rotor with 19 bars, a stator with 24 bars, and cutting plates that resulted in a cutting gap of 0.9 mm were used. All parts of the system were made from stainless steel. No visible abrasion of metal from dispersion elements was observed after completion of this study. No “gray spot” formation in products was detected indicating absence of metallic fragments. As such, introduction of metal ions during processing was likely minimal (Weiss et al., 2010).

The raw material mixture was processed to a meat batter at (i) varying rotational rotor speed of the homogenizer $n_{\mathrm{rotor}} = 1000$, 1500, 2000, 2500, and 3000 rpm and constant volume flow of 40 L/min, as well as at (ii) varying volume flow rate $\dot{V} = 10$, 20, 30, 40, 50, and 60 L/min and constant rotational rotor speed of the homogenizer of 2000 rpm. All meat batter samples were produced in duplicate. The meat batter was filled directly into impermeable casings having a diameter of 60 mm. The casings were heated at 75 °C until a core temperature of 72 °C was reached. Samples were cooled and stored at 1 °C until analysis.

2.3. Machine parameter acquisition

Machine parameters of the vane pump equipped with a high-shear homogenizer were captured by internal sensors and recorded by the operating software of the vane pump. Thus, the normalized torque of the motors of vane pump and homogenizer, M_{pump} and M_{rotor}, as well as the vane pump and homogenizer power, P_{pump} and $P_{\mathrm{homogenizer}}$, were recorded during the meat batter production process. The temperatures of the raw material mixture prior to and after processing with the vane pump-homogenizer system were measured with a thermometer Testo 926 (Testo, Lenzkirch, Germany).

2.4. Photographic images

Photographic images of the sausage cross-sections were taken with a digital camera (K-5, Pentax, Tokyo, Japan). All images were taken under standardized illumination, camera distance to the sample, and magnification. The contrast of the photographic images, which are shown henceforth, was modified with the digital image processing and analysis software (ImageJ 1.49a, Wayne Rasband, National Institutes of Health, Bethesda, MD, USA).

2.5. Lean meat particle sizes

The structure of the emulsion-type sausages was evaluated from the photographic images of the cross-sections. The images were converted to grey scale images using ImageJ. From the grey scale images, binary black and white images were generated by applying a grey scale threshold on the visible lean meat particles. Binary black and white images were subjected to particle size analysis yielding the mean particle diameter d_{10} and mean volume-surface diameter d_{32} of the visible lean meat particles. Fifteen photographic images were analyzed for each sample.

Mean diameter d_{10} and mean volume-surface diameter d_{32} were calculated according to Equations (1) and (2):

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

$$d_{32} = \frac{\sum n_{\mathrm{i}} \times d_{\mathrm{i}}^3}{\sum n_{\mathrm{i}} \times d_{\mathrm{i}}^2} \tag{2}$$

where n_i is the number of particles of the diameter d_i in each size class of the population (McClements, 2005).

2.6. Color measurement

Product color was determined at the cross section of the emulsion-type sausages with a colorimeter CR200 from Minolta