REDUCTION OF ENERGY CONSUMPTION IN AN EXTENDED GRINDER-FILLER SYSTEM BY INJECTION OF CURING SALT SOLUTION PRODUCING MEAT EMULSIONS

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Abstract – Extending grinder-filler systems by attaching a high shear disperser enables the production of fine dispersed meat emulsions. The integration of an injector nozzle between grinder and high shear disperser allows the dosage of a curing salt solution during meat emulsion production.

In this study, we investigated if energy consumption of the size reduction units may decrease due to lower acting torques when crushed ice was replaced by injected solution. For this purpose the amount of crushed ice in the meat emulsion formulation was gradually substituted by a curing salt solution injected via nozzle. On one side temperature differences due to varied ice addition were compensated, in terms of cooling raw materials with liquid nitrogen. Otherwise raw material temperature was not adjusted resulting in different temperatures of the processed meat emulsions.

Water binding capacity, texture, structure, and reddening were not affected while crushed ice was exchanged. However, energy consumption of the high shear disperser noticeably reduced by up to 23%.

Results show that the entire replacement of ice by injection of curing salt solution did not alter the product qualities. Thereby, remarkable energy savings during production of fine dispersed meat emulsions were feasible.

Key Words – Acting torque, High shear disperser, Raw material temperature

I. INTRODUCTION

At the industrial manufacture of comminuted meat products continuous working grinder-filler systems noticeably replace the conventional bowl chopper technology. Currently, the application of such systems is limited to the manufacture of coarse sausages. However, the development of high shear dispersers attached after the grinder-filler may also permit the continuous manufacture of fine dispersed meat products [1].

Energy consumption E of a rotational system such as a motor is defined by:

$$E = 2\pi \cdot M \cdot n$$

Discernible from this equation, energy consumption is a function of the number of revolutions n and the acting torque M. Since meat emulsion structure should be constant, rotor speed cannot be altered to reduce energy consumption. Hence, solely the modification of the acting torque is practicable. The acting torque is influenced by raw material properties as they determine exerting resistance against being cut.

Integration of an injector nozzle prior to the high shear disperser allows continuously adding liquid components such as water or curing salt solutions (CS) into the production process [2]. In a previous study we could show that partially replacement of crushed ice by a CS solution at the production of fine dispersed meat emulsions is feasible.

The objective of this study was to investigate if energy consumption in the size reduction zones may be reduced while crushed ice is replaced by CS solution via nozzle injection.

II. MATERIALS AND METHODS

Meat emulsion preparation. In a T-paddle mixer a pre-mixture of 50wt% lean pork meat (5 mm ground), 27wt% pork belly (5 mm ground), and crushed ice with 5.0 g/kg spice mixture, 1.5 g/kg diphosphate, and 0.5 g/kg ascorbic acid was generated. Crushed ice content of the pre-mixture varied from 0-23wt%. To achieve a constant total ice/water addition the difference to 23wt% was injected via nozzle as CS solution. CS concentration varied to set total CS concentration in the meat emulsion to 18 g/kg (Table 1).

Table 1. Ratio of ice to CS solution and CS concentration of the solution replacing 0-100wt% ice by CS solution (*19.6wt% added with solution, 19.5wt% added straight before end of mixing).

Ice replacement (%)	Ice:solution ratio	CS conc. in solution (wt%)
0	1:0	0.0
20	4:1	39.1*
40	3:2	19.6
60	2:3	13.0
80	1:4	9.8
100	0:1	7.8

Meat emulsions were prepared in an extended grinder-filler system (Figure 1) consisting of a vacuum filler (A) with an attached grinder unit (B) and a high shear disperser (D). An injection nozzle (C) was integrated between grinder and high shear disperser.

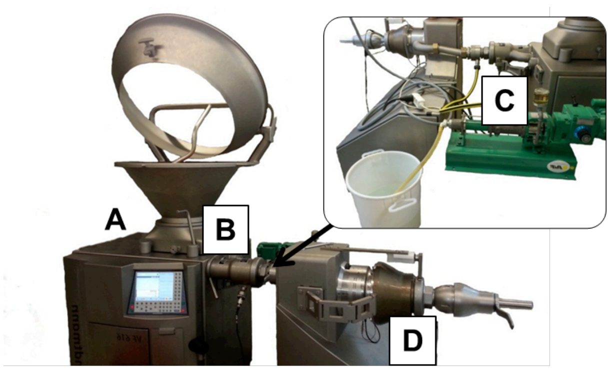

Figure 1. Extended grinder-filler system consisting of vacuum filler (**A**), grinder (**B**), injection nozzle (**C**), and high shear disperser (**D**).

Total volume flow rate V_{total} was 40 L/min. Depending on ice:CS solution ratio filler V_{filler} and pump V_{pump} volume flow rates were adjusted. Knife rotational speed of the grinder N_{knifes} was set to 236 rpm and rotor speed of the high shear disperser N_{rotor} was set to 3000 rpm. Meat emulsions were directly filled into impermeable casings, heat treated, and stored at 1°C until analysis.

Analysis. Photographic images were taken under defined conditions with a Pentax K5. Water, protein, fat, and sodium chloride content of sausages were analyzed according to the AOAC methods [3]. Water binding capacity of the raw meat batters was determined gravimetrically after a heat treatment (45 min at 98°C). Dissolved protein content was quantified by a color reaction according to Bradford after extraction in an isoionic sodium chloride solution. Firmness of sausage slices was measured in an Instron 1011 texture analyzer. Color of sausage cross sections was captured in the CIE L*a*b* color space with a Konica Minolta chromameter CR-200. Sausage slices were evaluated by a trained panel (n=25) regarding redness and texture.

III. RESULTS AND DISCUSSION

Besides its function as water addition and solvent for proteins, ice acts as cooling reserve. Thus, when ice is substituted by a liquid solution the cooling effect diminishes. To take this into account, two approaches were performed. While at the first, raw materials were cooled with liquid nitrogen to achieve constant temperature after processing, the second was performed without temperature compensation. In Table 2 the temperatures prior to and after process are listed, when temperature differences were compensated. During mixing of the ingredients raw materials were cooled to approx. -1°C prior to processing. The temperature rose to 8.3-12.0°C while processing in the extended grinder-filler system.

Table 2. Processing temperatures of meat emulsions prepared in an extended grinder-filler system varying ratio of ice to CS solution with compensated temperature.

Substitution of ice (%)	Ratio of ice to CS solut.	Temperature (°C) prior process	Temperature (°C) after process
0	1:0	-1.6	12.0
20	4:1	-1.3	8.3
40	3:2	-0.6	8.9
60	2:3	-0.7	8.5
80	1:4	-0.7	10.8
100	0:1	-1.0	10.5

Table 3 shows the temperatures of meat emulsion prepared without adjusted raw material temperature.

Table 3. Processing temperatures of meat emulsions prepared in an extended grinder-filler system with varying ratio of ice to CS solution without adjusting temperature.

Substitution of ice (%)	Ratio of ice to CS solut.	Temperature (°C) prior process	after process
0	1:0	-1.5	7.0
20	4:1	-0.7	11.4
40	3:2	-0.6	10.3
60	2:3	-0.3	12.1
80	1:4	2.6	14.8
100	0:1	6.2	18.5

Temperature prior to processing rose with increasing ice replacement from -1.5 to 6.2°C. Consequently, temperatures after processing increased from 7.0°C at 100wt% ice to 18.5°C at 0wt% ice. At such end temperatures a complete meat emulsion breakdown was not to be expected, despite it may impact physicochemical properties. Indeed, none of the sausages exhibited visible water/fat separation, whether cooling effect of ice was compensated or higher end temperatures were approved. Images of sausage cross sections are shown in Figure 2 and Figure 3.

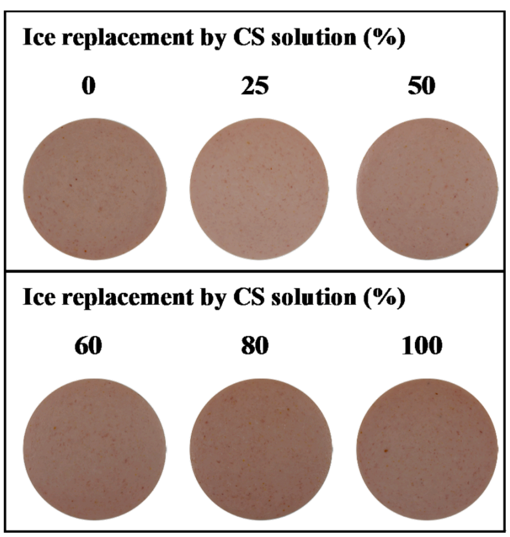

Figure 2. Photographic images of sausage cross sections prepared in an extended grinder-filler system with varying ratio of ice CS solution with compensated raw material temperature.

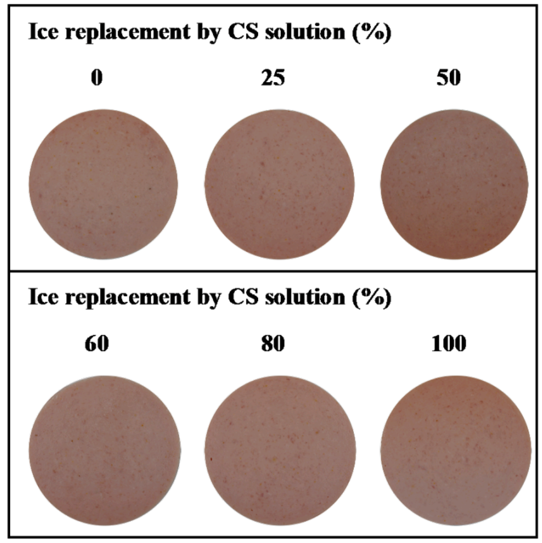

Figure 3. Photographic images of sausage cross sections prepared in an extended grinder-filler system with varying ratio of ice to CS solution without adjusting temperature.

Furthermore, sausages displayed no structural differences with respect to crushed ice replaced by using the CS solution. Moreover, L*a*b* measurements were nearly identical. Lightness L* ranged from 67.8±0.5 to 68.4±0.5 when the ice cooling effect was compensated using liquid nitrogen and from 68.2±0.3 to 68.8±0.2 when raw material temperature was not adjusted, respectively. Similarly, ice substitution did not affect redness. a* attained values of 10.5±0.2 to 10.8±0.2 for all samples regardless of temperature conditions. These findings confirm that curing was not influenced by the shorter exposure time of the CS in the meat emulsion.

Protein solubilization was also similar within both experimental approaches. Relative dissolved protein content was approx. 4.0 g/100g when cold reserve of the ice was compensated by increased cooling with liquid nitrogen. At the second approach without cooling around 3.6 g of dissolved proteins per 100 g meat emulsion were measured.

Table 4 lists the torques and energy consumptions of the two size reduction units during the preparation of meat emulsions in the first approach.

Table 4. Relative acting torques and energy consumption of grinder and high shear disperser of extended grinder-filler system during preparation of meat emulsions replacing ice by a CS solution with compensated raw material temperature.

Subst. of ice (%)	Rel. acting torque (%) grinder	disperser	Energy consumption (kW) grinder	disperser
0	25.9	108.1	2.3	20.0
20	27.6	109.5	2.5	20.3
40	27.3	102.5	2.4	19.0
60	30.3	97.1	2.7	18.0
80	26.2	94.6	2.3	17.5
100	31.0	94.2	2.8	17.5

As hypothesized, acting torque in the size reduction zone of the high shear disperser decreased with increasing ice replacement. Therefore, energy consumptions of the high shear disperser reduced from 20.0 kW at meat emulsions prepared with 100wt% ice to 17.5 kW when ice was completely replaced. Though, relative acting torque in the grinder motor was not affected since the CS solution was injected right after the grinder unit.
In particular, the acting torque of the high shear disperser was reduced when crushed ice was replaced without compensation of the cold reserve, as Table 5 illustrates.

Table 5. Relative acting torques and energy consumption of grinder and high shear disperser of extended grinder-filler system during preparation of meat emulsions replacing ice by a CS solution.

Subst. of ice (%)	Rel. acting torque (%) grinder	disperser	Energy consumption (kW) grinder	disperser
0	28.0	106.0	2.5	19.6
20	24.5	104.8	2.2	19.4
40	22.7	95.1	2.0	17.6
60	22.1	90.6	2.0	16.8
80	22.1	89.9	2.0	16.7
100	23.3	81.4	2.1	15.1

Likewise when temperature differences were compensated, the torque of the grinder unit was not affected by the ice replacement. Nevertheless, entire substitution of ice by CS solution reduced relative acting torques of the high shear disperser from 106% to 81.4% resulting in energy savings of up to 23%.
Comparing the two approaches, the energy savings without cold reserve compensation by cooling raw materials are with up to 23% remarkably higher than when cooling with liquid nitrogen (~12% energy savings). This can be explained by the altering raw material properties. Cooled raw materials become more rigid due to partially frozen muscle pieces. That causes higher resisting forces during cutting.

IV. CONCLUSION

These findings confirm the above mentioned hypothesis, that the substitution of ice by a CS solution causes noticeable reductions in energy consumptions of the high shear disperser. Moreover, higher process end temperatures do not impact formation of a stable protein matrix. Thus, product qualities with high consumer acceptance could be obtained.

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