

## Design and Operation of an Experimental Cheese Processor

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### ABSTRACT

The design and operating characteristics of a horizontal cheese cooker, which has a maximum capacity of 4 kg raw material per batch, are described. Considerations for processor design included comparability of experimental results with large commercial units, limitation of batch size to reduce raw material required, accommodation of a wide range of process variables, "sanitary" design, ease of operation, ease and speed of cleaning, and pressurization if desired. A screw speed of 70 rpm, cook temperature of 75 to 82°C, and total residence time of 4 min produced a process cheese of good melting and slicing characteristics. Detailed fabrication drawings may be obtained by writing to the authors.

### INTRODUCTION

The USDA Agricultural Stabilization and Conservation Service purchases and stores large quantities of Cheddar cheese under price support programs. When milk production is exceptionally high, available warehouse cooler storage is at a premium, and freezer storage may be utilized. Freezer storage significantly retards cheese ripening, so that cheese can be stored longer than is possible with cooler storage. Little information is available on the effects of freezing and thawing on the functionality of previously frozen curd when used for process cheese manufacture. Therefore, the investigation of processing characteristics of government-owned cheese of different ages that had been stored frozen for varying lengths of

time would be beneficial to both government and cheese processors.

Most process cheese is manufactured from nonfrozen cheese in large horizontal cookers built to specifications. Even the smallest cookers commercially available require approximately 18 kg of raw material per batch. Kosikowski (2) has described the conversion of a 50-quart ice cream freezer into a small capacity inexpensive horizontal cooker, processing 227 kg/h. However, this cooker still utilizes large amounts of cheese.

In this paper, the design of a horizontal cheese processor with a maximum capacity of 4 kg raw material per batch and the establishment of standard operating parameters are presented. Small size and pressure tightness permit the processor to be used to evaluate processing characteristics of other foods besides process cheese, e.g., foods that require continuous agitation while being heated with or without pressurization.

### MATERIALS AND METHODS

#### Cheese

In order to provide a basis for comparing the mini-processor with commercial units, "standard" process cheese, essentially identical to process cheese produced from nonfrozen cheeses in large commercial units, was produced with stirred curd cheese stored at 5°C. This cheese was purchased locally in 18.2-kg blocks that were all made from the same batch. These blocks were sliced into .5-kg pieces and aged at 5°C between 1 and 4 mo prior to processing. The cheese contained 36.5% moisture, 34.7% fat, 1.75% NaCl, 608 ppm K, and pH 5.43. For each batch, 3.2 kg of this cheese were coarsely ground in a Cuisinart<sup>2</sup> (Robot-Coupe, SA, France) Model CFP9 food processor (DLC 10 cutting head) and tempered at 24 ± .5°C for 30 to 60 min. A standard formula containing 11.7 g disodium phosphate, 26.7 g trisodium phosphate and 19 g sodium chloride per batch as

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emulsifying salts was used to establish the operational characteristics of the processor. Salts used in the cheese processing evaluation studies were 81 g tripotassium citrate and 19 g sodium chloride per batch.

### Analytical Methods

Meltability of the process cheese was evaluated using a modified Schreiber<sup>2</sup> test (3). A precise photograph of the melted cheese was utilized to measure its area with a planimeter. From this, an equivalent diameter was calculated and correlated to the semiquantitative values of the melt gauge using Equation [1]:

$$M_s = \frac{\frac{.16A}{\pi} - .75}{.2} - 1 \quad [1]$$

where  $M_s$  = equivalent Schreiber melt reading and  $A$  = planimeter area ( $\text{cm}^2$ ).

The force required to slice the process cheese was measured with an Instron<sup>2</sup> (Canton, MA) Model 1122 in the compression mode. Sample size was 10 cm × 10 cm × 10 cm. The crosshead attachment was a harp-type fixture with a single strand of piano wire of .38 mm diameter. The cross-head speed was 50 mm/min.

Moisture and fat were assayed by the atmospheric oven method (1) and the modified Babcock method (3), respectively.

Potassium levels by weight percentage were determined by atomic absorption analysis and adjusted for natural potassium content. After the entire cheese sample was grated, a representative sample, weighing .2 g, was transferred to a 50-ml Erlenmeyer flask. Twenty milliliters of deionized water were added, and the sample was heated on a steam bath with a funnel on top of the flask acting as a condenser. After a 4-h digestion, the sample was filtered through glass wool into a 50-ml volumetric flask to which a hot deionized water rinse of the sample flask was added. After cooling, the contents were made to volume. The potassium content was then determined with a Perkin-Elmer<sup>2</sup> (Norwalk, CT) 306 Atomic Absorption Spectrophotometer (Perkin-Elmer Manual, Jan-

uary 1982). Actual concentration was calculated from a standard curve.

Before and after each processing run, the equipment was cleaned with Oakite<sup>2</sup> (Berkeley, NJ) Alnate detergent followed by Oakite Elevate concentrated low foaming acid cleaner and hot water rinse. The inlet and outlet cover gaskets were removed and, after manually washing in the same Oakite solutions, were rinsed and soaked in chlorine water (200 ppm sodium hypochlorite) until reassembly. After assembly, the processor was filled with chlorine water at 20 to 25°C and held for a minimum of 15 min with the agitator running. After draining, the processor jacket was preheated to 121°C for 1 min; the processor interior was then flushed with steam at 121°C for 5 min. Warmup and processing was initiated immediately following this treatment.

Tests for adequate sanitation were conducted with Rodac (replicate organism direct agar contact) (Falcon Plastics, Brookings, SD) contact plates and swabs (4). Media used were Plate Count Agar (PCA) (Difco Laboratories, Detroit, MI) for enumeration of total colony-forming units per gram and Violet Red Bile Agar (VRB) (Difco Laboratories, Detroit, MI) or Emden-Meyerhoff Broth (EMB) (Difco Laboratories, Detroit, MI) for enumeration of coliforms.

### RESULTS AND DISCUSSION

Considerations that went into the processor design included: 1) comparability of experimental results with large commercial units; 2) limitation of batch size to reduce raw material required; 3) provisions to accommodate a wide range of all process variables; 4) "sanitary" design; 5) ease of operation; 6) ease and speed of cleaning; and 6) features that provided additional versatility.

#### Design

The processor (Figure 1) was designed as research equipment with sufficient capacity to make one 2.27 kg loaf of process cheese. To accomplish this, the design incorporated a 105-mm diameter × 350-mm long screw with a 100-mm pitch eccentrically located in a 130-mm inside diameter × 381-mm long steam-jacketed housing (Figure 2).

Inside this housing, the screw was cantilevered, eliminating the need for a potentially

<sup>2</sup>Reference to brand or firm names does not constitute endorsement by the US Department of Agriculture over others of a similar nature not mentioned.

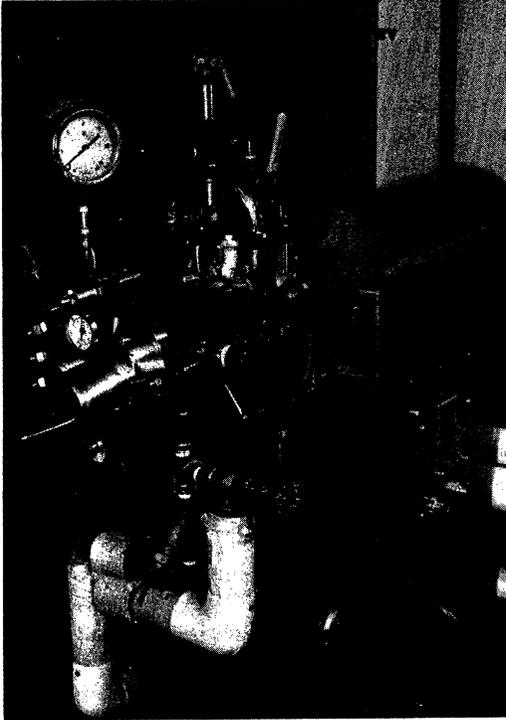


Figure 1. Photograph of mini-processor.

unsanitary forward bearing and simplifying the opening and closing of the front lid. One of the design features provided for internal pressurizing of the processor and thus allowed in-place sterilization of screw and housing, making screw removal unnecessary. The front lid and feed port lid were hinged. Pressure-tight sealing

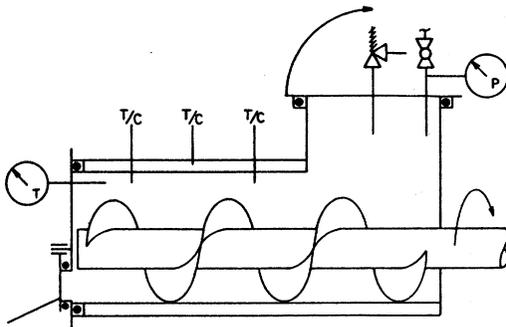


Figure 2. Schematic of processor.

of both lids was accomplished by standard o-rings located in grooves of the housing. These grooves had a depth somewhat less than the width of the o-rings resulting in a controlled compression of the o-rings when the lids made metal-to-metal contact with the faces of the housing. Adjustable hinge points and wing nuts on hinged lid bolts accommodated all around metal-to-metal contact.

The product discharge port was eccentrically located at the bottom of the front lid and sealed with a standard o-ring. Correct pre-loading of this o-ring was accomplished with a fitted plug inside the knurled nut at the pivot of the product discharge chute. Two stops on the face of the front lid limited the rotation of the discharge chute to two positions,  $90^\circ$  apart: open and closed. A dead space formed by the discharge port in the front lid was eliminated through the use of a plug that was in-place during processing and was easily removed at the start of discharge by using special tongs. A stuffing box at the rear of the housing completed the pressure-tight sealing of the processor. This stuffing box sealed between screw shaft and housing by means of soft braided Teflon packing and a lantern ring lubricated with sanitary grease.

A sanitary steam inlet valve located on the side of the housing provided for heating of the cheese being processed by direct injection of culinary steam. To prevent excessive condensation of this steam inside the housing, the latter was preheated by means of the steam jacket. During actual processing, however, the steam to the jacket was turned off.

Steam to the jacket was provided from a 830 kPa steam line through a pressure regulator with a 14 to 138 kPa range. This steam was also used to improve the quality of the culinary steam to 100% saturation by means of a  $.42\text{-m}^2$  shell and tube heat exchanger. Supplied by a 552 kPa clean steam generator, the culinary steam was further controlled with a 14 to 138-kPa pressure regulator and a manual shut-off valve just ahead of the sanitary inlet valve.

Approximate pressures and temperatures of housing and jacket were indicated with dial-type pressure and temperature gauges. Accurate measurements of the temperatures of the melted cheese were provided by thermocouples at three locations of the processor (Figure 2).

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### Operation

Capacity, temperature, and agitation characteristics of the processor were established. The optimal capacity range of the processor for good mixing was established by loading from 2 to 4.5 kg of coarsely ground Cheddar cheese into the processor. The criteria for establishing the capacity range of this processor were the distribution and flowback of the agitated molten cheese. Visual observations illustrated in Figure 3 indicated that the action of the screw caused the cheese to be swept toward the discharge end. This action was more pronounced with the ground cheese than with the melted

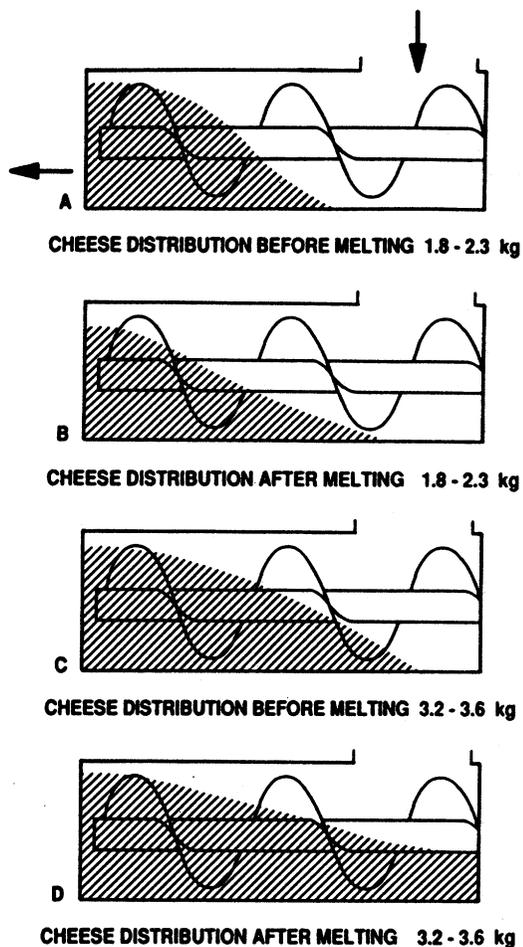


Figure 3. Cheese distribution at feed (3A and C) and melt (3B and D) for 1.8 to 2.3 kg and 3.2 to 3.6 kg, respectively.

cheese as illustrated by Figure 3A vs. 3B and 3C vs. 3D. These figures also showed that a minimum charge of 3 kg of cheese was required to establish a good rate of backflow over the screw, resulting in good mixing. Loads greater than 4.5 kg resulted in cheese splattering up into and out of the feed opening, especially at higher agitation rates.

Although many factors affect the functional characteristics of the finished process cheese, the thorough mixing of the raw materials during processing is necessary for a good dispersion and for a stable emulsion (5). To evaluate effects of rate of agitation on the process cheese, we studied uniformity of mixing during processing and examined the melting and slicing characteristics of the finished cheese.

Tripotassium citrate was used as the emulsifying salt in these studies, because we needed a means of tracing the mixing efficiency while maintaining homogeneity during cooking and at the same time giving the finished product a desirable body and texture. Both potassium and sodium citrates are permitted for use as an emulsifier in process cheese manufacture (9). Early work showed that tripotassium citrate behaved similarly to sodium citrate but imparted bitter flavor to the product (7), so we concluded that tripotassium citrate would function adequately under our experimental conditions.

Uniformity of mixing was evaluated by determining the standard deviation of the potassium concentration (corrected for the naturally occurring K) of three samples taken at 15-s intervals during cheese discharge. Total discharge time per batch was approximately 30 to 40 s. The deviations of the three samples from three or more replicate runs is shown in Table 1. In all cases, the deviation was less than 5% of the total potassium which by itself was .994% by weight. An analysis of variance of the data found no significant difference in degree of mixing ( $P < .05$ ).

Preliminary tests indicated that consistent experimental results could only be obtained by preheating the jacket with house steam and the processing cavity with culinary steam, both at a regulated pressure of 103 kPa for 7 min. This was done after cleaning and immediately preceding each experimental run. If the preheating step was omitted, cheese cooking

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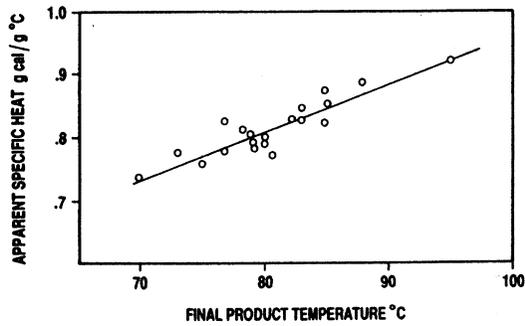


Figure 5. Effective specific heat of molten cheese as a function of cook temperature.

an equilibrium at 58.8°C after 52 seconds of steaming as determined by a time temperature profile. From this point on, injected steam raises not only the temperature of the cheese but also that of the processor itself, since steam to the jacket is shut off during each run.

The specific heat of stirred curd Cheddar cheese with 36% moisture ranges from .62 to .70 cal/g °C when obtained at 60°C with a Perkin-Elmer DSC II<sup>2</sup> (M. H. Tunick, personal communication). Starting with 3-wk-old cheese, the specific heat values peak after 42 wk of aging at -2 to 0°C. Mohsenin (6) reported a

specific heat of .5 cal/g °C for an unspecified cheese. We found that the specific heat increases with temperature and moisture.

Figure 5 shows the apparent specific heat for melted cheese over a final product temperature range of 73 to 88°C. The specific heat values were calculated using a heating efficiency of 40% and by experimentally determining the moisture increases in the cheese due to steam condensation only (no water was added to the feed with the emulsifying salts in these runs). These results demonstrate that the specific heat increases with temperature and moisture content of the cheese. The final moisture ranged from 38.0% at 73°C to 39.2% at 88°C.

Figure 6 shows meltability for three agitation rates as a function of final product temperature as determined by the modified Schreiber test. Better melting was found at lower cook temperatures and slower agitation speed. Higher temperatures and agitation rates tend to overcream the cheese mixture, resulting in lower Schreiber values and a harder, less melt-able cheese.

Figure 7 shows the sliceability of the process cheese expressed in gram force per gram of nonfat DM as a function of final product

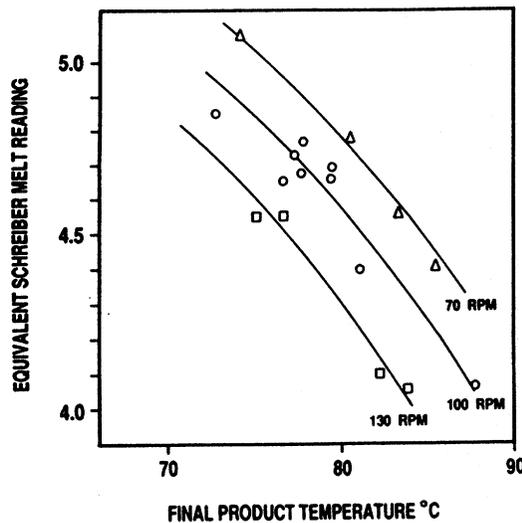


Figure 6. Effect of cook temperature and agitation rate on process cheese meltability.

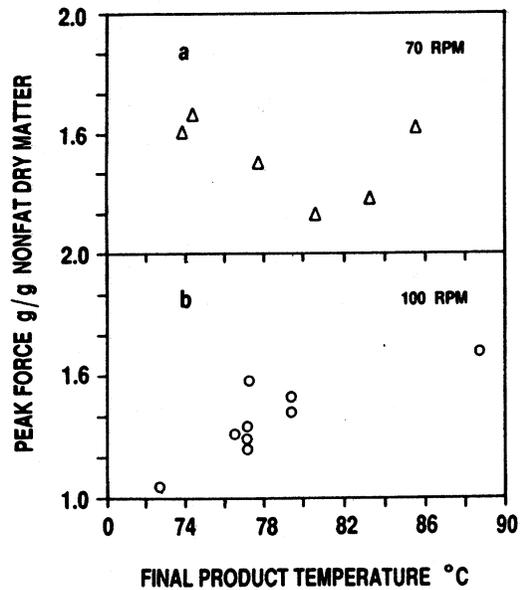


Figure 7. Effect of cook temperature on sliceability of cheese processed at a) 70 rpm; b) 100 rpm.

temperature for two rates of agitation. Peak force data represent the average of 4 replicate measurements at each condition ( $s = .05$  to  $.09$ ). At an agitation rate of 70 rpm, peak force to slice the process cheese reached a minimum at a cook temperature of  $80.6^{\circ}\text{C}$  and increased with increasing temperature thereafter. In contrast, at the higher agitation rate (100 rpm), as cook temperature increased, the force to slice the cheese increased. The differences in slicing forces may be explained by the propensity of the cheese to overcream as the combination of mechanical forces and temperatures is increased. No cheese produced by this method had brittle, crumbly textures. Although other conditions yielded satisfactory process cheese, we selected processing parameters of an agitation rate of 70 rpm, a final product temperature of  $82^{\circ}\text{C}$ , and a total processing time of 4 min as a standard for our equipment.

Preliminary studies to develop a proper sanitation procedure for the mini-processor showed that potential sources of contamination were the surfaces underneath the inlet and outlet cover gaskets and any of the areas where there were small openings. Coliforms were not detected after treatment either with chlorine water or chlorine water plus steam (103 kPa for 15 min). Steam treatment improved the sanitation on the surface beneath the inlet cover gasket as measured by total plate count, but sterility was not achieved, either there or in other susceptible areas of the processor. Because the front and feed covers of the processor are not insulated, the areas near the o-rings and tapped holes are cooler than the jacketed area, making steam sanitation less effective.

#### CONCLUSIONS

For conducting effective research, applicable to large processors, the small batch processor is an effective piece of research equipment. Control over the processing parameters is easily achieved and the equipment is readily adaptable to automatic rather than manual operations.

Product formulation appears to be readily reproducible.

Based on the results of our cheese processing evaluations, processing conditions of an agitation rate of 70 rpm, a cook temperature of  $75$  to  $82^{\circ}\text{C}$ , and a residence time of 4 min produced an acceptable standard cheese with good sliceability and melting quality.

To achieve microbiological sterility, some design modifications of the equipment will be required. These changes will address insulation of the front cover and smoothing or sealing of the small openings in the inlet and front covers.

#### ACKNOWLEDGMENTS

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#### REFERENCES

- 1 Association of Official Analytical Chemists. 1980. Official methods of analysis. 17th ed. Assoc. Offic. Anal. Chem., Washington, DC.
- 2 Kosikowsky (sic), F. V. 1951. How to convert an ice cream freezer into a small process cheese cooker. *Butter Cheese Milk Prod. J.* 42(2):30.
- 3 Kosikowski, F. V. 1977. Cheese and fermented milk foods. 2nd ed. Edwards Brothers Inc., Ann Arbor, MI.
- 4 Marth, E. H., ed. 1978. Standard methods for the examination of dairy products. 14th ed. Am. Publ. Health Assoc. Inc., Washington, DC.
- 5 Meyer, A. 1973. Processed cheese manufacture. Food Trade Press Ltd., London, UK.
- 6 Mohsenin, N. N. 1980. Thermal properties of foods and agricultural materials. Gordon and Breach Sci. Publ., New York, NY.
- 7 Templeton, H. L., and Sommer, H. H. 1936. Studies on the emulsifying salts used in processed cheese. *J. Dairy Sci.* 19:561.
- 8 US Department of Agriculture, Agricultural Stabilization and Conservation Service. 1976. Purchase of pasteurized process American cheese and pasteurized process cheese spread for use in domestic donation programs. Amendment No. 1 to Announcement PV-C-1. Shawnee Mission, KS.
- 9 US Food and Drug Administration. 1987. 21 CFR 133.169. Rev. April 1. US Government Printing Office, Washington, DC.