ENERGETIC ASPECTS OF OHMIC COOKING FOR PROCESSED MEATS

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Background

At the international *Framework Convention on Climate Change* in Kyoto (1997), many countries, including Canada, have committe themselves to put in place various means to significantly reduce the atmospheric release of gazes responsible for the greenhouse effect One way of achieving this is to promote the widespread use of more energy efficient technologies in the manufacturing sector. In this respect, the most promising new technology in food processing is likely ohmic heating, with a reported energy efficiency values over 90% (Rice, 1995; Skudder, 1991). However, even though a few industrial applications of ohmic heating in production of various prepared meal are already in place (Marcotte, 1999), application to solid foods is still under development and only one brief report has been made of successful use of ohmic heating for processed meats cooking (Peyron, 1996). With this in mind, a study was undertaken to evaluate th energy efficiency of ohmic heating applied to processed meat cooking, compared to traditional smokehouse cooking.

Methods

A 2% salt, 30% fat, raw bologna sausage emulsion was prepared by mixing 85% lean pork trimmings (9.27 kg), iced water (2.85 kg), pork back fat (2.57 kg), sodium chloride (45 g), sodium erythorbate (7.5 g) and sodium nitrite (3.1 g), in a 40 L capacity Stephan Mikrocut (fina core temperature 14°C ± 1°C) and cooked in 1 kg portions in a custom made ohmic heating prototype.

The ohmic prototype consisted in a 30 cm long, 7.5 cm internal diameter, 0.64 cm thick Nylon tube, in which the raw emulsion was inserte using a vacuum stuffer, and of two flat Titanium electrodes, connected to a 240 V15 A AC generator. The electrodes were pushed agains the emulsion at both ends and maintained in place under a pressure of 40 ± 4 kPa. Cooking was done under constant voltage of 64, 76, o 104 V (resulting in heating rates of 3.9, 5.6, and 10.3°C · min^{-1}, respectively) until the product core temperature reached 70, 75, or 80°C Temperature at the product core was continuously monitored during cooking, as well as the electrical current intensity and voltage. The temperature distribution at randomly selected locations within the product mass and against the tube internal and external surfaces wa measured in a series of separate experiments in which a 2% salt, 22% fat, bologna emulsion, prepared as above, was cooked from 15°C to 85°C at an average rate of 10.4°C · min^{-1}. Also, a separate series of experiments was carried out to measure the emulsion specific hea Cp in the range of temperatures experienced during cooking. This was achieved on a series of 20 mg samples by use of a model 291 modulated DSC, adjusted to provide a temperature increase rate of 0.5°C · s^{-1}, from 0°C to 100°C.

Results and discussion

Temperature distribution across the product section at various times during cooking is shown in Figure 1. It can be seen that, apart from the regions immediately adjacent to the cooking cell walls (within 5 mm), temperature was fairly constant within the product section an reached values of 25.0 ± 0.4°C after 2.2 min of cooking (CV = 1.6%), 40.0 ± 0.8°C after 3.5 min (CV = 2.0%), 55.0 ± 1.1°C after 4.5 mi (CV = 2.0%), and 70.0 ± 1.5°C after 5.7 min (CV = 2.2%). As cooking progressed, a gradient between temperatures against the cell wa and inside the product mass established itself and increased with time, from 0.4°C afer 2.2 min, to 2.3, 4.8 and 9.1°C after 3.5, 4.5, an 5.7 min, respectively, reflecting an increasing heat loss as temperature rose. The gradient was larger (about 15°C for a core temperatur of 70°C) when the thickness of the Nylon tube was increased to 1.24 cm and it was not affected by external insulation of the cooking cel wall with various commercial insulating materials, suggesting that the heat lost was mostly used to raise the temperature of the cell wal initially equilibrated at 12°C to match the emulsion temperature.

The total amounts of energy spent during cooking are given in Figure 2, for the three experimental heating rates and the three final cor temperatures. This energy was not affected by the rate of cooking, since similar values were found, 233, 210, and 218 kJ, for the highes intermediate, and slowest cooking rates, respectively. In contrast, increasing the final core temperature from 70°C to 75°C and 80°C (intermediate rate) resulted in an increase in total energy used (210, 239, and 258 kJ, respectively). Overall, the specific energy consumptio for ohmic cooking of the bologna sausage ranged between 210 and 258 kJ·kg^{-1} (this study), representing 24 to 30% of the correspondin consumption typically measured in smokehouse cooking of processed meats (859 ± 528 kJ·kg^{-1}, average value for various products fro the following sources: Statistics Canada, various smokehouse manufacturers; Piette, unpublished results; Vandeuvre, person communication; Huang, 1986; Reichert and Thumel, 1986; Reichert, 1991).

The specific heat of the bologna emulsion, C_p (kJ·kg^{-1}·°C^{-1}), was found to increase linearly with increasing temperature within the limi of cooking (12-80°C), according to the relation $C_p = aT + b$, with $a = 0.00236 \pm 0.00120$ kJ·kg^{-1}·°C^{-2} and $b = 2.4094 \pm 0.4571$ kJ·kg^{-1}·°C^{-1} The energy required to cook the product, E_c (kJ), could then be calculated by integrating the equation $dE_c = mC_p dT$ between the initial an final cooking temperatures, in which m is the mass of product being heated (kg), and T is the temperature (°C). Results are also present in Figure 2. As for total energy, E_c was not affected by the cooking rate (143, 137, and 140 kJ for fast, intermediate, and slow cooking respectively) but it increased with increasing final core temperatures (137, 155, and 167 kJ, for 70, 75, and 80°C, respectively).

The energy efficiency of the various cooking cycles is given by the ratio δ of E_c over total energy used and varied between 61% (fastest cooking) and 67% (slowest cooking). This is considerably higher than what is considered as a good efficiency value for smokehouse cooking under industrial operating conditions (δ =45%, Freeland Smokehouse, personal communication), but also considerably lower than what has been reported for ohmic heating of various foods (δ =90-95%; Rice, 1995; Skudder, 1991), indicating that large heat losses in or through the cell wall had occurred during cooking.

The exact amount of heat lost in the cooking cell wall during the previous experiments could not be evaluated since temperatures on both sides of the Nylon tube was not measured. However, these temperatures had been measured in a previous experiment aimed at evaluating temperature distribution during cooking. While core temperature rose from 15°C to 70°C at a rate of 10.4°C · min^{-1}, temperatures at the inside and outside surfaces of the Nylon tube rose from 15.1 ± 0.1°C to 60.5 ± 1.1°C and from 17.7 ± 0.2°C to 29.2 ± 1.0°C, respectively. Assuming that the temperature profile within the cooking cell wall was linear at all time, the amount of energy that was transferred to Nylon through conduction could be calculated, knowing the thermal conductivity of the material (0.2452 W·m^{-1}·°K for Polypenco® Nylon 101, used in the prototype design), and found to be 86 kJ. If this value was substracted from the total energy consumed during the fastest cooking cycle in Figure 2, a theoretical value of 147 kJ was obtained for the energy either used for heating the product and lost through the electrodes. This value is very close to the 143 kJ figure calculated from the specific heat of bologna sausage emulsion measured previously, representing the energy theoretically required to heat the product from15°C to 70°C (clear triangles in Figure 2). This suggests that the major reason why energy efficiency values measured in this study were markedly lower than values previously reported is indeed the dissipation of energy in the cooking cell wall.

The heat loss in the cell wall could have been greatly reduced by a variety of means (higher initial temperature of the cell wall; thinner cell wall, well insulated on the outside; progressive heating of the cell wall from the outside, to match the increase in product temperature), but the result would not have been worth the effort. It is clear that ohmic heating will have to be used in continuous or semi-continuous systems in order to become practical on an industrial viewpoint. Under these operating conditions, the cell wall will always be at the same temperature as the product, eliminating the source of the heat loss observed in this study.

Conclusions

Ohmic cooking of bologna sausage was found to be considerably more efficient energetically (61-67%, this study) than traditional smokehouse cooking (45%), even though efficiency was evaluated in a batch prototype in which large heat losses occurred. When the efficiency was corrected for the calculated losses, its value increased to over 90%, typical of efficiency values reported for ohmic heating on various food commodities. On this ground, the actual potential use of ohmic cooking in meat processing should be investigated further.

Pertinent literature

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Data

Figure 1: Temperature profile across the product section at various times during cooking

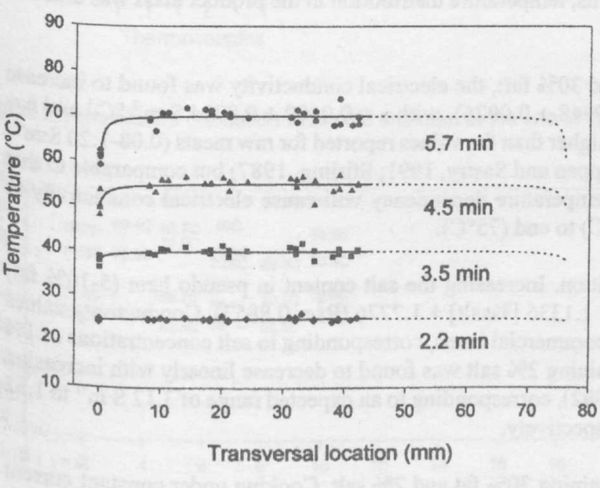

Figure 2: Energy consumption during ohmic heating