MEASUREMENT OF THERMAL PROPERTIES OF BEEF BURGERS DURING FRYING FOR PREDICTION OF HEAT TRANSPORT

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Background

In earlier reports on heat and mass transfer of beef burgers on frying, the predictability of the suggested mathematical models so far has proved to be insufficient (e.g. Dagerskog et al., 1978). Therefore a work has been initiated between the Department of Food Engineering and the Department of Heat and Power Engineering at Lund Technical University, where the mass and heat transfer on cooking of beef burgers will be modeled. As a first part in this investigation the heat transfer properties are studied. In order to obtain a relevant prediction of heat transfer during frying of a beef burger the following properties should be monitored as a function of temperature and time: density [kg/m^3], thermal conductivity [W/mK], specific heat [J/kgK] and heat transfer coefficient [W/m^{2}K]. Since thermal conductivity is differently performed in the varying structural parts of the beef burger, the overall thermal conductivity is a weighted average of the thermal conductivity originating from the different structural parts. As a starting point the following compositional and structural features have been identified to influence the heat transfer the most: the fat, the water and the connective tissue content. Ultimately the amount of the meat proteins that is in the fibrous state and in the gel state, respectively, should be considered. The most commonly used approach so far is to relate the heat and mass transfer to the chemical composition only and not to consider the substantial structural changes that occur during frying (e.g. gelation and contraction).

Objective

The objective of this first part of our study is to show that our proposal of varying thermal conductivity in different compositional and structural parts of the beef burger is justified. Therefore temperature profiles of beef burgers during frying were registered, where the above mentioned different structures were dominating in the beef burgers. Moreover, the initial temperature of the beef burgers was varied.

Methods

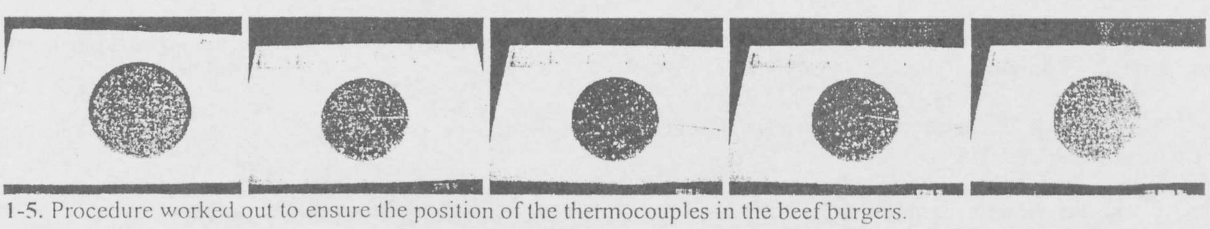
Raw material

Two types of meat raw material (brisket and shin) and 10 % added water to one of the samples were chosen to obtain different fat, water and protein content in the beef burgers (**Table.1**). The batter was ground once through a 3 mm grinder plate. All recipes contained 1.5 % salt. Beef burgers were made each 92 g with a height of 10 mm and a diameter of 100 mm.

Table. 1 Composition and pH of raw meat

Type of meat	Water content [%]	Fat content [%]	Protein content [%]	Connective tissue content [%]	pH
Brisket I	57.9	25.9	15.6	2.16	5.71
Brisket II	66.3	14.5	19.5	2.32	5.77
Brisket II + added water	69.5	13.0	17.5	2.32	5.77
Shin	72.7	6.1	20.2	2.24	5.82

For the temperature measurements two K-type thermocouples were used, one in the center and one 2 mm below the surface. They were glued with cyanoacrylate glue. Three 100 mm diameter plastic cylinders with three different heights (2 mm, 3 mm and 5 mm) were used to form beef burgers of that height and then these burgers were placed upon each other to ensure the position of the thermocouples. The method is shown in **Figs.1-5.** In this paper only the temperature profiles of the center temperature will be shown.



Figures 1-5. Procedure worked out to ensure the position of the thermocouples in the beef burgers.

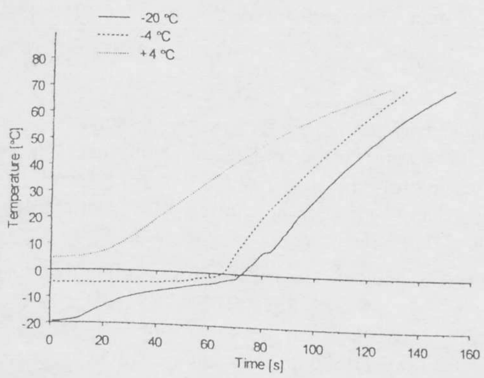
Frying equipment

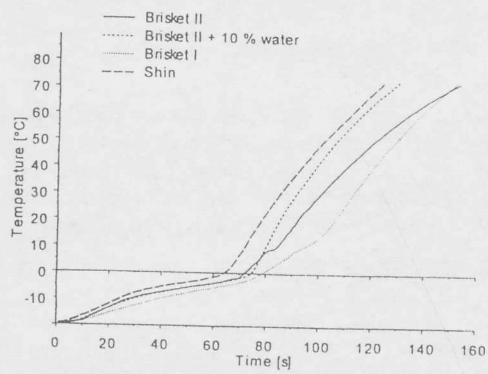
A rectangular shaped double – sided pan fryer was used, with heating surfaces of 22 × 22 cm. The distance between the two heating plates was 10 mm that was maintained during frying by means of a teflon frame with the outer dimension of 200×200 mm and the height of 10 mm. Maintaining this constant distance between the frying plates ensures that the contraction of the beef burgers mainly occurs in one dimension. Frying was performed at the frying pan temperature of 175 °C until 72 °C mid temperature was reached.

Results and discussion

Temperature profiles of the center temperature with various initial temperatures (T_0) are shown in **Fig.6** for the Brisket II beef burgers. Starting from a frozen state the starting temperature (T_0) seems to be irrelevant for the shape of the curve above zero degrees, indicating similar heat transfer properties. However, when T_0 is positive, the shape of the curve is significantly different. As suggested by the results, starting with frozen meat at any temperature, first the ice thawed at about – 4 °C (as the result of the salt content). After that, the temperature rises with the similar pattern for all cases due to the similar temperature difference (driving force) between the frying plate and the middle of the beef burger. On the other hand, when the initial temperature is + 4 °C the temperature rise is slower as a result of the decreased driving force.

In **Fig. 7** the temperature profiles of the center temperature of beef burgers with different fat and water content are shown, having the same initial temperature (-20°C). Adding water, as in the case of Brisket II has no effect on the curves below zero degrees, but above the melting point it enhances the heat transfer, resulting in a steeper profile. On the other hand substantially higher fat content, as in the case of Brisket I, has an influence on the profile both below and above zero degrees, due to the lower heat conductivity of the fat. In case of shin, where both the chemical and structural composition alters significantly from the other types, the curves also behave differently at all temperatures.





Figures 6-7. Temperature profiles during frying of beef burgers of different original temperatures and different compositions.

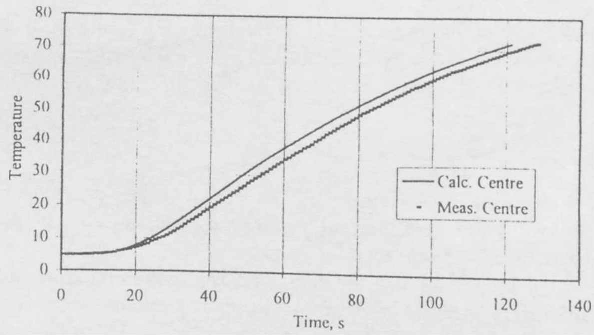


Figure 8. Comparison of calculated and measured temperature profiles of Brisket II beef burger.

In **Fig.8.** the temperature history is plotted for the measured and calculated temperature in the center of the Brisket II beef burger. The calculated data was provided by Dirk Sterner et al. [4] and the model was based on the assumption that density, thermal conductivity and specific heat is an average originating from the chemical composition of the burger. Both curves in **Fig.8.** show similar trends, although there is a shift towards higher temperatures for the calculated data.

Conclusion

Temperature profiles of the center temperature during frying of beef burgers of different compositions and original temperatures have been registered. The water and the fat content of the beef burgers are important factors controlling the heating rate. Moreover, a comparison has been made with calculated temperature profiles based on a model, where the thermal properties of the beef burgers was originating from the chemical composition

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