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MODELLING OF THE COOKING PROCESS EFFECT ON PROTEIN DENATURATION AND BEEF HARDNESS.

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During meat cooking the time–temperature relationship affects several quality factors such as: tenderness, juiciness, color and flavor. Meat tenderness is one of the most important quality criteria; heat induced alterations of the primary structure components in the muscle tissue; mainly collagen and myofibrillar proteins are associated with meat tenderness. The objective of the present dissertation is to discuss the effect of time-temperature relationship on the toughness of cooked beef and to simulate the behavior of large meat pieces of irregular geometry in order to optimize the industrial operating conditions. Different results obtained by our research group (1, 2, 3) are analyzed:

- ❖ Determination of the kinetic equations associated to textural changes in meat during cooking, using small meat pieces submitted to different time-temperature treatments.
- ❖ Analysis of the relationship between textural changes in beef due to the thermal treatment and denaturation of the main protein systems, measured by Differential Scanning Calorimetry (DSC).
- ❖ Development of a computer code to predict temperature profiles in large meat pieces of irregular geometry during the meat cooking process, applying a numerical method to simulate bidimensional heat transfer.
- ❖ Prediction of the hardness distribution in meat pieces of irregular geometries by coupling the kinetic equations associated to textural changes with the heat transfer simulation code.
- ❖ Experimental verification of the predicted hardness distribution.
- ❖ Application of the numerical model to analyze the influence of the operating industrial conditions on meat toughness.

Kinetic equations describing texture changes during meat cooking, were obtained with small cylindrical beef samples (1.5cm diameter x 2cm height) of *Semitendinosus* muscle. Samples were cooked in flexible packages (without thermal gradients) immersed in a stirred thermostatic bath. Tested temperatures ranged between 60 to 90°C and maximum heating times were 180 minutes. Meat hardness was determined by the Warner–Bratzler method using an Instron Universal Testing Machine. Protein denaturation during beef thermal treatment was tested by DSC, analyzing the peaks for myosin (peaks I and II), sarcoplasmic proteins and collagen (peak II) and actin (peak III). Between 60 and 64 °C hardness decreased with cooking time until the lowest asymptotic values were reached; this result was related to protein denaturation of peaks I and II. Between 66 and 68 °C, hardness decreased at short processing times but increased later due to actin denaturation. At temperatures between 81 and 98 °C hardness remained at the highest values without modifications because actin was already denatured. First order kinetic equations for both tenderizing and toughening processes were derived; activation energies of these processes were similar to those of protein denaturation of peaks II and III. Between 60 and 100 °C two opposite phenomena exist simultaneously: collagen denaturation makes the meat tender while myosin and actin denaturation have a toughening effect.

To optimize the industrial operating conditions of the cooking process, it was necessary to analyze the textural changes occurring in large meat pieces, where the existence of temperature profiles affects the hardness distribution. The average hardness of the meat piece depends on the texture of each point that is function of the thermal history. In order to predict temperature profiles in irregularly shaped meat pieces, the heat transfer process during meat cooking was modeled using the governing equations for unsteady two dimensional heat conduction in irregular solids. A numerical code using the boundary fitted grid was implemented in a conservative formulation (control volume). This technique consists of finding a numerical coordinate transformation, which fits a regular grid to the irregular domain of integration. An explicit discretization scheme with respect to time was applied. The calculated domain was divided in several small discrete control volumes surrounding each grid point. Kinetic equations for hardness decrease and toughness, previously obtained, were dicretized and used simultaneously to calculate the predicted hardness in the grid at each node temperature. Numerical simulations of the isotherms and iso-hardness curves were obtained as computer outputs at different cooking times. The area of each hardness zone of the muscle cross sections was measured using a digitized method; these areas corresponded to the predicted toughness values.

In order to validate the proposed models, entire muscles (long cylinders with average weight 1.6 Kg and different cross-sections) were packaged in Cryovac CN film (Grace Argentina) and immersed in a stirred cooking bath; thermocouples were adequately placed to record time-temperature changes and hardness values were determined by the Warner Bratzler method in different zones of the meat piece. The models for heat transfer and texture modifications showed a good agreement with experimental data of thermal penetration and hardness. The longer cooking times needed, when processing large meat pieces, produced a higher degree of actin denaturation then, the areas of maximum hardness were larger. Validated numerical simulations permitted to analyze the effect of several factors such as: cooking fluid temperature, heat transfer coefficient and size of the product on hardness distribution in cooked meat, in order to optimize the industrial operating conditions.

References.

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