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Predicting frankfurters quality metrics using light backscatter

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ABSTRACT

The objective of this study was to determine whether light backscatter response from fresh pork meat emulsions is correlated to final product stability indices, such as textural parameters, susceptibility of the emulsion to phase separation during cooking and lipid oxidation during subsequent storage. A specially designed fiber optic measurement system was used in combination with a miniature fiber optic spectrometer to determine the intensity of light backscatter within the wavelength range 300–1100 nm at different radial distances (2, 2.5 and 3 mm) with respect to the light source in pork meat emulsions with two fat levels (15%, 30%) and two levels (0%, 2.5%) of the natural antioxidant hydrolyzed potato protein (*HPP*). Textural parameters (hardness, deformability, cohesiveness and breaking force), cooking loss, *TBARS* (1, 2, 3, and 7 days) and CIELAB color coordinates of emulsions were measured. The results showed that light backscatter response measured during meat emulsification has potential as an early predictor of emulsion stability during finely comminuted meat products manufacturing.

1. Introduction

Meat emulsions such as frankfurters and bolognas are finely comminuted and cooked products composed of water, muscle proteins, fat particles, salt and small amounts of non-meat ingredients, where meat proteins serve as natural emulsifier. In this group of processed meat products, fat and protein concentration and their chemical interactions, especially those occurring during the emulsification process, exert a marked impact on the quality of the final product as they affect both emulsion stability (i.e., cooking losses) and lipid oxidation. Meat emulsion stability and cooking losses depends on fat stabilization by proteins. According to Barbut (1998), fat stabilization during chopping is due to the formation of a proteic film around the fat particles that allows retaining fat inside the protein matrix. During chopping, certain attractive forces (Jones, 1984) contribute to hold the raw materials together and create a homogeneous matrix structure (Allais et al., 2004). Excessive reduction of fat particles size and inadequate soluble protein extraction or fat to protein ratio could lead to reduced emulsification ability and increased fat oxidation tendency. Finely comminuted meat products are an integral part of diet in developed nations like the US (USDA, 2005) and have great economic importance. Frankfurters and bolognas are the most popular comminuted products in the US and account for the 25% of all sausages sold (NHDSC, 2008). Base on an average cooking loss (weight,%) of 2.64 (optimum chopping conditions), the estimated economic loss resulting from non optimum emulsion stability during the cooking process was estimated to range between 0.2 and 1.65 billion dollar per year. Improving process control and automation of the meat emulsification process will reduce the economical impact of emulsion breakdown in meat industry worldwide. Currently, there is a

Abbreviations: a^*, redness; F_B, breaking force; b^*, yellowness; C, cohesiveness; D, deformability; D, distance between optical fibers (D_1 = 2 mm, D_2 = 2.5 mm, D_3 = 3 mm); D_1Rat $_{P1}$, ratio distance 1 peak 1; D_1Rat $_{P3}$, ratio distance 1 peak 3; L^*, lightness; Lean, lean percentage; C_{ab}, Chroma; C_L, cooking loss; C_{Lnor}, normalized cooking loss; F_1, first compression peak; F_2, second compression peak; H_{ab}, Hue; *HPP*, hydrolyzed potato protein; *H*, Hardness; *IT*, integration time; *I*, normalized light backscatter intensity; I_{3D1}, normalized light backscatter intensity peak 3 distance 2 mm; I_{3D2}, normalized light backscatter intensity peak 3 distance 2.5 mm; I_{3D3}, normalized light backscatter intensity peak 3 distance 3 mm; *N*, Newton; R_{FL}, fat/lean ratio; *TBARS*, thibarbituric acid-reactive substances; *T*, temperature; TPA, texture profile analysis; W_F, weight of the final cooked emulsion; W_0, initial weight of the emulsion; W_s, weigh of the sausage sample; λ_{3D1}, wavelength at the maximum intensity for peak 3 distance 2 mm; λ_{3D2}, wavelength at the maximum intensity for peak 3 distance 2.5 mm; λ_{3D3}, wavelength at the maximum intensity for peak 3 distance 3 mm; ε, original height.

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lack of an effective on-line technology to select the optimum length of the chopping process during meat emulsification that results in maximum emulsion stability during the heat treatment. Control improvement will require the development of suitable sensor technologies to monitor the optimum level of emulsification that would maximize yield, quality and consistency of the finely comminuted meat products.

The application of light scatter sensors for process control and optimization has been deeply studied in the dairy industry. Castillo et al. (2005) designed an optical sensor for monitoring milk coagulation and curd syneresis to predict the changes in moisture while the curd is draining in the cheese vat. In meat, various methods have been proposed over the years to short and classify meat that could assist on preventing cooking losses induced by inappropriate meat emulsification – i.e., to determine PSE meats (Bendall and Swatland, 1988), but there is a lack of an effective inline method to monitor meat emulsification.

The use of a real-time meat emulsion stability sensor technology having the ability to determine the optimum chopping endpoint would significantly improve the current control over the chopping process preventing both under and over-chopping defects, which would result in evident final product yield, consistency and quality gain. According to Álvarez et al. (2007), monitoring meat emulsification would require a sensor capable of providing a representative signal from the beginning of the process, when the sample is extremely heterogeneous, to the end of the process, when the sample is relatively homogeneous. Our previous results suggest that an inline light scatter sensor might be able to provide useful information about the meat emulsification process. The goal of this work was to establish whether light scatter measured at several radial distances from the light source in fresh pork emulsions having a range of lipid oxidation and emulsion stability tendencies could be used to predict important final product stability indices such as textural parameters, susceptibility of the emulsion to phase separation during cooking and lipid oxidation during subsequent refrigerated storage.

2. Material and methods

2.1. Experimental design and meat emulsion manufacturing

A completely randomized factorial design with two factors and three replications was used. Two different *HPP* levels (0 –control– and 2.5% *w/w*) were tested within a range of emulsion breakdown and lipid oxidation tendencies that were induced by using two different levels of fat (15 and 30% *w/w*; i.e., fat/lean ratios $-R_{FL}-$ of 0.18 and 0.43, respectively). A total of 12 tests ($N = nab = 3 \cdot 2 \cdot 2$) were conducted with this design. A variety of final product quality indices (technological dependent variables) were determined to establish the degree of lipid oxidation (thiobarbituric acid-reactive substances or *TBARS*) and emulsion stability (cooking losses, hardness, "*deformability*", cohesiveness and breaking force) of the cooked meat emulsions. Reflection photometry parameters (CIELAB color coordinates) were collected from fresh emulsions. For further details regarding meat samples preparation, *HPP* preparation, meat emulsion manufacturing and measurement of mentioned final product quality indices see Nieto et al. (2009). Light scatter intensity (300–1100 nm) in fresh meat emulsions was measured at different radial distances (2, 2.5 and 3 mm: D_1, D_2 and D_3, respectively) with respect to the light source as described below.

2.2. Color

CIELAB color coordinates, L^*, a^*, and b^*, were measured 1 h after the emulsion was prepared using a hand held tristimulus Chroma Meter (CR-310 Minolta Camera Co., Ltd., Osaka, Japan) having a CIE standard "C" illuminant and 0° viewing angle geometry. Coordinates a^* and b^* were used, according to Hunt (1977), to calculate both Chroma, C_{ab}, and Hue, H_{ab}, values as follows:

$$C_{ab} = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

$$H_{ab} = \arctan(b^*/a^*) \quad (2)$$

2.3. Cooking losses

Once the chopping process was completed, cooking losses (C_L) of each emulsion sample was measured in triplicate. C_L was calculated from the weight of the final cooked emulsion (W_F) and the initial weight (W_0) of the sample before cooking as follows:

$$C_L = 100(1 - W_F/W_o) \quad (3)$$

2.4. Texture profile analysis (TPA)

The influence of *HPP* and fat concentration on textural properties of frankfurters was investigated by uniaxial compression tests using an Instron UTM Universal Testing Machine (Model 4301; Instron UTM Corp., Canton, MA, USA) as described by (Xiong et al., 1999). Cylindrical samples of 1.5 cm length were cut and compressed to 80% of its original height (strain, $\varepsilon = \Delta L/L_0 = 0.2$, were L_0 is the initial length of the cylinder) in a two cycle compression with 15 s delay between cycles. Hardness (H) of the sample was measured as the force (N) of the first compression peak (F_1). The force of the second compression peak was designated as F_2. The percent reduction in the compression force between the first and second compression peaks was defined as structure "Deformability" (D) and was calculated as $D\,(\%) = 100(F_1 - F_2)/F_1$. Cohesiveness ($C$), as defined by Bourne (1978) (ratio of total areas between the first and second compression peaks) was estimated as $(F_2/F_1)^2$ (dimensionless). Another set of samples was compressed to 20% of its original height ($\varepsilon = 0.8$) to determine the breaking force (F_B) (N).

2.5. Thibarbituric acid-reactive substances (TBARS)

TBARS were measured to evaluate lipid oxidation on days 0, 1, 3 and 7 of storage at 4 °C, according to the method described by Wang and Xiong (2005). The TBARS value, expressed as mg of malondialdehyde per kg of sausage sample, was calculated using the following equation:

$$TBARS = 9.48(A_{532}/W_s). \quad (4)$$

where A_{532} was absorbance at 532 nm, W_s was the sausage sample weight (g), and 9.48 was a constant derived from the dilution factor and the molar extinction coefficient ($1.52 \times 10^3\ M^{-1}\ cm^{-1}$) of the red TBA reaction product.

2.6. Light backscatter measurement of raw emulsions

A dedicated laboratory optical sensor prototype was designed, built and tested (Álvarez et al., 2009) in the Food Engineering Lab (University of Kentucky) to measure light scatter of comminuted meats at different distances with the aim of identifying and detecting physical–chemical changes occurring during chopping that may be correlated to emulsion stability. This optical sensor prototype was designed to set the radial distance between the emitting and detecting optical fibers by means of a micrometer. Two small plastic probes were built and configured such that light scatter from the sample could be detected using a High-Resolution Fiber Optic Spectrometer (Model HR4000, Ocean Optics, Inc., Dunedin, FL, USA). The light source utilized was a tungsten halogen