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Influence of fat structure on the mechanical properties of commercial pate products

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ABSTRACT

Five commercial brand pâtés were characterized by examining their texture, microstructure, fatty acid composition, melting profile, and polymorphism. Pâtés evaluated at 4 °C showed much higher hardness values compared to when tested at 22 °C. Pâtés with higher fat content and higher saturated fatty acid and triacylglycerol contents were found to be harder. Smaller fat globules were also found to be correlated to higher hardness values. Increases in solid fat content were correlated to an increased hardness at 4 °C vs. room temperature but could not explain differences observed at a specific temperature. Powder X-ray diffraction studies demonstrated that while the fat extracted from one of the pâtés crystallized in a β polymorphic form; while embedded in a pate protein matrix, it was crystallized in a β′ polymorphic form. This implies an effect of the food matrix on fat crystallization and structure and an interaction between fat and other components present in the food matrix.

1. Introduction

Pâté is classified as an emulsified meat product made primarily from liver, fat, meat, and spices. It is commonly consumed around the world due to its rich and smooth texture. Pâté's unique texture and taste can be attributed to the type of fat used and to its relatively high fat content. Various studies have suggested that saturated fats play a big role in texture, mouthfeel, moistness, and sensory acceptability of emulsified meat products (Barbut, Wood, & Marangoni, 2016; Chin, Keeton, Miller, Longnecker, & Lamkey, 2000; Hughes, Mullen, & Troy, 1998).

Unlike other emulsified meat products, pork meat is added precooked during the pâté making process. Therefore, liver proteins become the main emulsifying and binding agents. Temperature control during chopping is also a very important part of the pâté making process. During the process, the meat and fat must be added at high temperature (> 50 °C) to ensure proper emulsification of the fat globules. Furthermore, the pâté batter has to be stuffed properly, with sufficient pressure to avoid fat separation to the outer layer of the product. The lack of functional muscle proteins, during chopping, emphasizes the important contribution of liver proteins and fat to the texture of the final product. Milk protein concentration is commonly added to pate formulations to improve emulsification (Barbut, 2015; Morales-Irigoyen, Severiano-Perez, Rodriguez-Huezo, & Totosaus, 2012). Overall, only limited information regarding the processing characteristics of pâtés are available in the literature.

The demand for low-fat meat products is continually increasing as the general population becomes more health conscious (Marchetti, Andres, & Califano, 2014). To meet this demand, the meat industry has focused on lower fat formulations in their products. While fat content in traditional pâté can be as high as 50%, pâté with fat content of as low as 17% can now also be found in the market (Resurreccion, 2004). The understanding of factors influencing pâté texture and quality is generally lacking. In order to formulate low-fat pâté products, it is necessary to first understand the influence of fat and fat structure on pâté quality. In the present study, we focus on the characterization of the fat present in five commercial pâté products at different length scales. Molecular composition, solid state structure, and meting behaviours are characterized and their effect on mechanical properties are established.

2. Material and methods

2.1. Materials

Five commercial pâté products produced by commercial brands were purchased from local grocery stores. The products were chosen based on their fat levels and their major meat ingredients. Products were bought at the same time for the entire experiments to avoid variation between batches. Three sausages were bought per product type as replications.

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2.2. Back extrusion

The samples were carefully stuffed (to minimize fat smearing) into test tubes and kept in the refrigerator (4 °C) overnight to allow them to set. The following day, half of the samples were tested directly out of the refrigerator while the other samples were allowed to equilibrate at room temperature (22 °C) for 2 h. Back extrusion tests were performed using a texture analyzer (Texture Technologies Corp., Model TA.XT2, Scarsdale, NY, USA). A stainless steel cylindrical probe (height: 9.8 cm, diameter: 1.8 cm) with enlarged spherical tip (height: 1.3 cm, diameter: 2.0 cm) was used to penetrate the product, placed in plastic test tubes (27 mm diameter), for 30 mm at a rate of 1.5 mm/s. Results were recorded as described by Gravelle, Barbut, Quinton, and Marangoni (2014).

2.3. Fatty acid composition

The fatty acid composition of extracted pâté fats were determined using gas chromatography (Ghazani, García-Llatas, & Marangoni, 2013). Samples were subjected to a transmethylation procedure in accordance with Christie (1982). Fatty acid methyl esters (FAME) were analyzed by using a capillary GC equipped with a BPX70 column, 60 m × 0.22 mm internal diameter and with 0.25 μm film thickness (SGE Inc., Austin, TX, USA). A gas chromatograph (Agilent 6890 series, Agilent Technologies, Inc., Wilmington, DE, USA) with an auto sampler (7683 series) was used. The oven temperature was programmed to increase from 110 to 230 °C at a rate of 4 °C/min and held at 230 °C for 10 min. The injector and detector temperatures were 240 and 280 °C, respectively. Hydrogen was used as the carrier gas at an average velocity of 25 cm/s. Peaks were identified via comparison to FAME standards. Samples were measured in triplicate.

2.4. Microstructure

Sample were prepared for light microscopy following the method used by Barbut et al. (2016). Samples (20 × 20 × 5 mm), were cut from the center part of the liver sausages and then fixed and stained using Masson stain. Slides were observed using a light microscope (Model BX60, Olympus Optical Ltd., Tokyo, Japan) and images were captured using a computerized image analysis system (Image-Pro Plus, Version 5.1, Media Cybernetics Inc., Silver Spring, MD, USA).

2.5. Fat extraction

Samples were smeared onto the side of extraction thimbles, with the total amount not exceeding 4 g, to ensure maximum surface area for the extraction. The thimbles were dried at 60 °C to remove moisture until constant weights were obtained (~4 h). The thimbles were then placed in the soxhlet extraction apparatus. Approximately 200 mL petroleum ether was poured into the soxhlet flask, heated gently to allow a continual reflux of petroleum ether, and samples were extracted for 3–4 h. The petroleum ether was then evaporated in the drying oven.

2.6. Differential scanning calorimetry (DSC)

The melting and crystallization of pâtés and pâtés' fats were studied using a DSC unit (Q2000 TA instruments, New Castle, DE, USA) following the procedure outlined by Blake, Co, and Marangoni (2014). Samples were prepared by placing pâté or extracted fat (8–12 mg) in an aluminum pan (prepared at 4 °C inside a walk-in fridge). The thermal regimen used in the test was as follows: samples equilibrated at 4 °C for 10 min, heated from 4 to 80 °C at a rate of 5 °C/min, equilibrated at 80 °C for 10 min, followed by cooling from 80 to −5 °C at 5 °C/min, equilibrated at −5 °C for 10 min, and re-heated to 80 °C at 5 °C/min. The peak melting temperatures (T_m) and enthalpy of melting (ΔH_m) were determined from the DSC curves using the software supplied with the instrument (Universal Analysis Software, TA Instruments, New Castle, DE, USA). Results were obtained in triplicate.

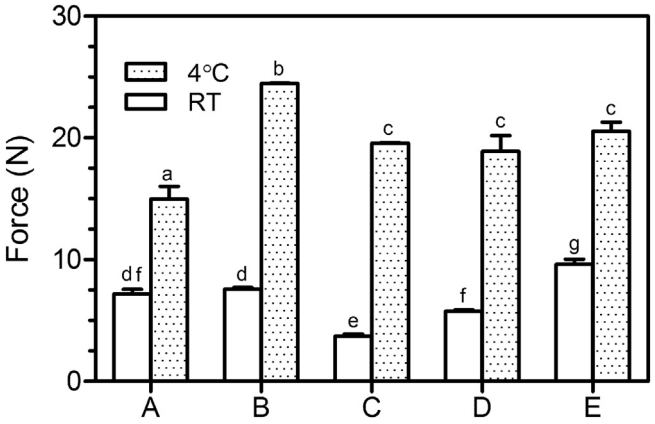

Fig. 1. Effects of temperature on the hardness values of commercial pâtés (Products A–E) tested at room temperature (RT) and 4 °C. Bars indicate standard error of the mean. n = 2–10 per sample.

2.7. Powder X-ray diffraction

Samples were prepared by filling the well of a metal sample holder with pâté or extracted fat until the unit was leveled with the surrounding slide. All preparations were done at 4 °C. Diffraction patterns were obtained using an X-ray diffractometer (Rigaku Multiflex, TX, USA) Cu source with k = 1.5459 A°, wide angle X-ray scans (15°–25° at 0.2°/min). The measurements were collected in triplicate at 4 °C.

2.8. Solid fat content

Solid fat content of the pâté samples was measured at 4 °C and at room temperature (22 °C) following the AOCS Official Method Cd 16b-93. The extracted fat was inserted into NMR tubes and melted at 100 °C for 60 min, incubated at 60 °C for 15 min and then incubated at 4 °C and RT (mimicking products served at refrigerated and room temperature respectively) for 30 min before testing. All measurements were done in triplicate using a pNMR analyzer (Bruker PC/20 Series Minispec, Bruker Optics Ltd., Milton, ON, Canada).

2.9. Triacylglycerol composition

Triacylglycerol (TAG) analysis of each extracted fat sample was carried out using high performance liquid chromatography (HPLC model 110, Agilent Tech, Palo Alto, CA, USA), equipped with a quaternary pump, auto sampler, refractive index detector, and software program (HP Chem Station version A.10, Hewlett-Packard, Palo Alto, CA, USA). 30 μL of each pâté fat sample was dissolved in 600 μL of chloroform and 1000 μL (60:40 v/v) acetone-acetonitrile solution. 10 μL of each sample was injected into a column (Econosil C18, 250 × 4.6 mm) in the isocratic mode at 1.0 mL/min flow rate. The mobile phase was (60:40 v/v) acetone-acetonitrile. The peaks were compared to internal standards (Sigma Aldrich, Oakville, ON, Canada) and quantified by integration of the relative peak area. The measurements were taken in triplicate following (Mottram, Crossman, & Evershed, 2001).

2.10. Fat globule size analysis

Image analysis of fat globules size were carried out using an image analysis software (Image-Pro, Media Cybernetics Inc., Rockville, MD, USA). The area of the fat globules was averaged and reported.