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Evaluation of protein structural changes and water mobility in chicken liver paste batters prepared with plant oil substituting pork back-fat combined with pre-emulsification

Guoyuan Xiong [a,b], Minyi Han [a], Zhuangli Kang [a], Yingying Zhao [a], Xinglian Xu [a,*], Yingying Zhu [a]

[a] Key Laboratory of Meat Processing and Quality Control, Ministry of Education, Synergetic Innovation Center of Food Safety and Nutrition, Jiangsu Collaborative Innovation Center of Meat Production and Processing, Nanjing Agricultural University, Nanjing 210095, China
[b] Animal Husbandry and Veterinary Institute, Anhui Academy Agricultural Science, Hefei 230031, China

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ABSTRACT

Protein structural changes and water mobility properties in chicken liver paste batters prepared with plant oil (sunflower and canola oil combinations) substituting 0–40% pork back-fat combined with pre-emulsification were studied by Raman spectroscopy and low-field nuclear magnetic resonance (NMR). Results showed that pre-emulsifying back-fat and plant oil, including substituting higher than 20% back-fat with plant oil increased the water- and fat-binding ($p < 0.05$) properties, formed more even and fine microstructures, and gradually decreased the NMR relaxation times (T_{21a}, T_{21b} and T_{22}), which was related to the lower fluid losses in chicken liver paste batters. Raman spectroscopy revealed that compared with a control, there was a decrease ($p < 0.05$) in α-helix content accompanied by an increase ($p < 0.05$) in β-sheet structure when substituting 20–40% back-fat with plant oil combined with pre-emulsification. Pre-emulsification and plant oil substitution changed tryptophan and tyrosine doublet hydrophobic residues in chicken liver paste batters.

1. Introduction

Liver pâté products are popular meat products consumed throughout the world and are renowned for their sensory properties, being highly flavoursome with a soft and spreadable texture. Traditionally, liver pâté is produced from pork liver and pork fat. In some regions in France, "pâté" is prepared with goose liver (called "pâté de foie gras", literal: "fat/gras liver/foie", or simply "foie gras"). For cost reasons, chicken livers are also used to produce liver pâté products. Generally, liver pâté products are classified according to processed raw (e.g., liver sausage) or precooked pork back-fat (e.g., spreadable liver pâté) (Allais, 2010). Both products are essentially emulsified meat products consisting of a weak gel (Morales-Irigoyen, Severiano-Perez, Rodriguez-Huezo, & Totosaus, 2012; Steen et al., 2014).

Spreadable chicken liver pastes are manufactured with chicken liver, precooked pork back-fat, water, sodium caseinate and small amounts of other additives, and are regarded as high in animal fat content (35–50%). Plant oils, which are regarded as healthy options because of their high polyunsaturated fatty acid (PUFA) contents have been used to partially substitute animal fats in reformulated meat products. However, there are a limited number publications dealing with the effect of substitution of animal fats with plant oils on liver pâté (Hong, Lee, & Min, 2004; Martin, Ruiz, Kivikari, & Puolanne, 2008; Morales-Irigoyen et al., 2012). These researchers investigated the effects of substitution of pork back-fat with plant oils (canola oil or soybean oil or olive oil, respectively) on the fatty acid profiles, cooking loss, rheological characteristics and texture of liver paste. However, the effects of structural changes in protein and water distribution characteristics of chicken liver paste batters were not investigated in these studies. In addition, the effects of sunflower and canola oil combinations substituting pork back-fat and of pre-emulsification of pork back-fat on the properties of chicken liver paste batters have not yet been investigated. When partially substituting pork back-fat with plant oil, it is common to simply pre-emulsify the plant oil with non-meat proteins at first, and then add pork back-fat to processed meat products. Generally, it has not been investigated if pre-emulsification of pork back-fat and different levels of plant oil together affects the protein structure and water mobility characteristics of meat products. Sunflower and canola oil have 88% and 92% PUFA per 100 g respectively (Shanghai Jiage Food Company, China). Emulsified pork back-fat and different proportions of

* Corresponding author.
E-mail address: xlxus@njau.edu.cn (X. Xu).

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sunflower and canola oil combinations will result in different compositions of emulsion.

Different compositions of emulsions and the emulsification technologies have shown various physicochemical and structural properties which result in altered characteristics of the food (Das & Kinsella, 1990; Herrero, Carmona, Pintado, Jiménez-Colmenero, & Ruíz-Capillas, 2011). Furthermore, there are limited available data concerning chicken liver paste. Abu-Salem and Abou Arab (2010) investigated the chemical, microbiological, and sensory properties of chicken liver paste products, which were composed of 65% liver and 35% butter.

The water- and fat-binding (WFB) of meat products is an important quality for both processors and consumers (Bianchi et al., 2004), and is also related to the other characteristics of meat products. High WFB often means a good economic benefit for processors and also contributes to various quality attributes of the comminuted meat product. Therefore, it is important and useful to estimate the effect of water distribution characteristics on chicken liver paste batters when substituting pork back-fat with various levels of plant oil combinations in a pre-emulsification step. The low-field NMR technique is useful for measuring properties such as T_2 relaxation times, which are sensitive to molecular motion of protons, and estimates the mobility and structural properties of water molecules in different fractions, which are partially immobilised by the structural protein system (Kuntz & Kauzmann, 1974; Yasui, Ishioroshi, Nakano, & Samejima, 1979). Those water molecules having longer T_2 times are bound more loosely to the macromolecules than those with shorter T_2 (Yasui et al., 1979). Thereby low-field NMR technique is a preferred method to estimate the water-holding capacity of emulsified meat products.

Raman scattering spectroscopy has been used to study structural changes in proteins of meat batter systems (Herrero, Carmona, Cofrades, & Jiménez-Colmenero, 2008; Shao, Zou, Xu, Wu, & Zhou, 2011). Because of weak background scattering from water, it is also directly applicable to aqueous systems (Li-Chan, 1996). Structural changes of proteins when using different lipids during processing have been evaluated in meat batter using this technique (Shao et al., 2011). Howell, Herman, and Li-Chan (2001) studied systems containing lysozyme (25% in D_2O), corn oil, and their emulsions (10% w/w oil/D_2O solution) by Raman spectroscopy and their findings suggested that the presence of lipids can alter the molecular structure of proteins and result in changes in exposure of hydrophobic groups, secondary structures, and conformation of disulphide groups. However, to our knowledge, Raman spectroscopy has not been used to examine the structural changes in liver paste-batters when substituting pork back-fat with various levels of plant oils combined with pre-emulsification treatment.

A better understanding of the structural changes and water mobility that occur in chicken liver paste batters plus different levels of plant oil combined with pre-emulsification treatments could be helpful to optimise the preparation conditions for chicken liver paste products and for the development of new healthy liver paste products. Therefore the objective of this study was to use Raman spectroscopy and low-field NMR to examine the protein structures changes and the water distribution, respectively, produced in chicken liver paste batters substituted with different levels of plant oil combined with pre-emulsification treatments.

2. Materials and methods

2.1. Materials

Sodium caseinate (protein 88.5%, carbohydrates 1.0%, fat 1.0%) was provided by Sfinc NV, Izegem, Belgium. Commercially available Duoli sunflower and canola oils (pure) produced by Jiage Food Company (Shanghai, China) were purchased from a local supermarket. The sunflower and canola oils contained 88–92% PUFA. Fresh chicken liver and pork back-fat were obtained from local commercial slaughterhouses. The chicken livers were freed of the large blood vessels and bile ducts, and the pork back-fat was trimmed of meat adhering to it. Chicken liver was ground through a grinder (MM-12, 8 mm plate, Guangdong, China) and mixed thoroughly to obtain raw liver batters, and pork back-fat was cut into small cubes (about 30 cm^3). Then, the cut pork back-fat and raw liver batters were packed separately into plastic bags and frozen (−18 °C) until use within 5 days. The day before preparation of experimental chicken liver paste-batters, the raw materials were thawed overnight in a refrigerator at 4 °C.

2.2. Preparation of spreadable chicken liver paste-batters

Spreadable chicken liver paste-batters were prepared in the pilot plant at Nanjing Agricultural University, China. All liver paste batters were prepared on the same day using the same ingredients listed in Table 1. Briefly, the thawed raw liver batters for all treatments were first chopped for 8 min at high-speed (3000 rpm, no vacuum) in a bowl cutter (UMC-5C, Stephan Nachinery, Schwarzenbek, Germany). Then, salt and sodium nitrite (Table 1) were added and mixed with the finely chopped liver for 2 min at low-speed (1500 rpm) under vacuum until the temperature increased to 4–7 °C, to obtain liver doughs. The liver doughs were stored at 4 °C until further processing.

Before manufacturing chicken liver paste batters, the thawed pork back-fat was cooked in water at 100 °C for 20 min to obtained pre-cooked pork back-fat and broth. For P0, P10, P20, P30 and P40, pre-cooked pork back-fat, broth and sodium caseinate, together with the respective five levels (0%, 10%, 20%, 30% and 40% substituting pork back-fat) of plant oils combinations (sunflower oil:canola oil, 1:1 w/w; see Table 1) were put into the cutter to be chopped and mixed at high-speed (3000 rpm) for about 5 min until a temperature of 50 °C had been reached, to give five emulsions. Then the prepared liver doughs, together with the remaining spices and additives (Table 1), were added into the emulsions and mixed in the cutter for 3 min at low-speed (1000 rpm) under vacuum, until five types of spreadable chicken liver paste batters were obtained. For treatment C, the pre-cooked pork back-fat together with the broth were added to the cutter and chopped and mixed at high-speed (3000 rpm) for 5 min until a temperature

Table 1
Formulation (%) used for the different chicken liver paste-batters.

Ingredients (%)[a]	Treatments[b]					
	C	P0	P10	P20	P30	P40
Liver	35	35	35	35	35	35
Pork back-fat	35	35	31.5	28	24.5	21
Sunflower oil	0	0	1.75	3.5	5.25	7
Canola oil	0	0	1.75	3.5	5.25	7
Broth	30	30	30	30	30	30
Sodium caseinate	1	1	1	1	1	1
Salt	1.8	1.8	1.8	1.8	1.8	1.8
Sodium nitrite	0.012	0.012	0.012	0.012	0.012	0.012
Sodium ascorbate	0.05	0.05	0.05	0.05	0.05	0.05
Glucose	0.5	0.5	0.5	0.5	0.5	0.5
Spices	0.97	0.97	0.97	0.97	0.97	0.97

[a] All additives and spices were calculated on the basis of total weight of liver, pork back-fat, oil and broth.

[b] C: control sample formulated with pork back-fact and had no pre-emulsification pork back-fat step. P0, P10, P20, P30 and P40 contained 0%, 10%, 20%, 30% and 40%, respectively of added plant oils substitution back-fat, meanwhile the back-fat and plant oil were subjected to pre-emulsification with the broth, as well as sodium caseinate.