INFLUENCE OF FAT CONTENT AND STORAGE DURATION ON OXIATION AND PHYSICOCHEMICAL CHANGES IN FROZEN PORK DUMPLING FILLER

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Abstract –This study was conducted to evaluate the contributions of fat addition levels and storage duration at -18 °C on the oxidation and physicochemical changes of frozen pork dumpling filler. With an increase in the fat addition, thiobarbituric acid-reactive substances and carbonyl production increased(P<0.05). Dynamic rheological measurements revealed a compromised viscoelastic network in filler protein gels with increased fat levels and storage time. Increasing the fat level also increased cooking loss and decreased breaking strength (P<0.05). The results suggest that oxidation and protein denaturation are the major cause of quality deterioration in pork dumpling filler during frozen storage.

Key Words–Dumpling filler, Frozen storage, Oxidation, Fat content, Physicochemical property

I. INTRODUCTION

Dumplings are made of fillers and wheat flour dough shaped by hand or machine. The fillers generally include meat (pork, beef or mutton), fat, vegetable, salt, and other auxiliary materials, and meat and fat are the important ingredients in dumpling filler [1]. The fat level influences the sensory quality and the physicochemical characteristics of meat products. Fat also exerts a significant effect on the binding, rheological and structural properties of meat foods.

For distribution and quality preservation, dumplings are usually stored frozen. Freezing and frozen storage can affect the chemical and structural properties of muscle foods [2]. Lipid oxidation products can interact with proteins to form lipid-protein complexes, which will cause muscle food quality to deteriorate [3]. Texture and colour deterioration of meat has been related to the protein oxidation phenomenon [4].

The aim of the present study is to assess the contributions of the fat content on the oxidation and physicochemical changes in pork dumpling filler at various frozen durations. In particular, protein dynamic rheological properties were investigated.

II. MATERIALS AND METHODS

1. Sample preparation

Three batches of dumplings were manufactured in a pilot plant (10-12 °C), and each batch was used as a replicate. Dumpling filler was prepared according to the product formulations (Table 1). They were stored for 0, 30, 60, 90 and 180 days at -18 °C, and other treatments were same as Huang et al [5].

Table 1 Formulations for dumpling fillers with different levels of fat

Ingredients (g)	Fat levels (%) ^{x}			
	0	10	20	30
Lean meat	1000	900	800	700
Fat	0	100	200	300
Soy oil	6	6	6	6
Salt	30	30	30	30
Soy sauce	40	40	40	40
Water	100	100	100	100
Fresh ginger	20	20	20	20
Green onion	20	20	20	20
Spices	8	8	8	8
Total	1224	1224	1224	1224

^{x} The fat level (%) means the percentage of added fat to the total meat amount.

2. Lipid and protein oxidation determination

Thiobarbituric acid-reactive substances (TBARS) were determined according to Wang and Xiong [6]. And carbonyl content determination was according to the method of Xia et al [2].

3 Dynamic thermo-mechanical analysis

The dynamic thermo-mechanical analysis (DTMA) of the prepared MP solution during thermal gelation was performed using a Bohlin Gemini2 rheometer (Malvern Corp, UK) as described by Xia et al [7].

4 *Cooking loss and breaking strength determination*

Cooking loss of dumpling fillers were etermined according to Xia et al [2].The breaking strength of the cooked fillers was measured by compression tests using a texture analyser (Stable Micro System; TA: XT2i, England) with a flat-surface cylindrical probe (P/50) 50 mm in diameter attached to a 25 kg load cell with 60 mm/min crosshead speed of probe. From each cooked filler, 25 × 20 mm（high × diameter）cores were compressed until the structure was disrupted. Both the break force (*B*) and distance (*D*) of the first break point was recorded automatically by the software, and the breaking strength was expressed as:

Breaking strength (N/m) = *B* / *D*

III. RESULTS AND DISCUSSION

1. Lipid oxidation

As shown in Fig. 1a, the TBARS in the frozen dumpling filler steadily increased from 0.18, 0.30, 0.33 and 0.43 mg/kg (0 d) to 1.60, 1.98, 2.41 and 3.29 mg/kg for 0%, 10%, 20% and 30% of fat addition (P<0.05), respectively, over 180 d of storage. TBARS production was significantly enhanced with increased fat levels, which indicated that high fat contents could significantly increase the formation of malonaldehyde or other secondary products. The influence of the frozen storage duration on TBARS was significantly higher than that of the fat levels (P<0.05). The results of the present study were in good agreement with the result of Soyer et al [9], who suggested that the fat level increased the frozen storage effect on lipid oxidation. Lipid oxidation is commonly linked to the textural attribute of meat products, leading to increasing cooking loss and weakening springiness and cohesiveness of the gel matrix [2].

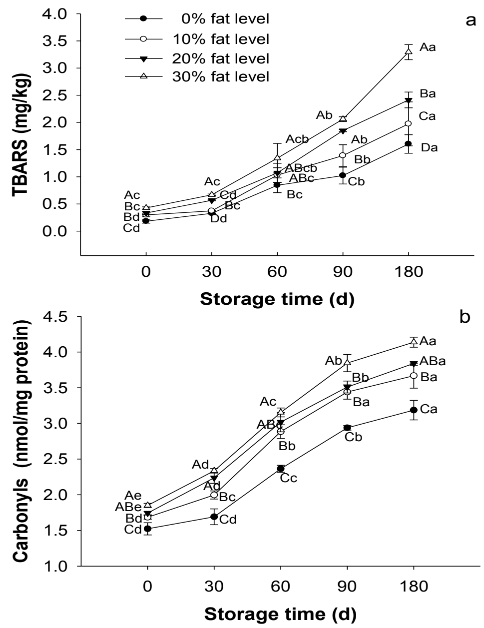

Fig. 1. Influence of different fat levels on TBARS and carbonyl content in frozen dumpling fillers.

2. Protein oxidation

An increase in the carbonyl contents during frozen storage for all products was observed (Fig. 1b). Protein oxidation progressed strikingly in four formulations (P<0.05). At 0 d, the protein carbonyl content was the lowest with 0% fat addition (1.52 nmol/mg protein), but protein oxidation in all samples developed very rapidly and the carbonyl content reached maximum (4.14 nmol/mg) with a 30% fat addition after 180 d of frozen storage (P<0.05). The formation of carbonyls in the filler was more sensitive to the storage duration than the fat level (P<0.05). The results were in good agreement with Soyer et al [8], who reported significant increases of the protein carbonyls in chopped chicken meat after 6 months of frozen storage at -18°C.

3 Changes in dynamic rheological properties

As shown in Fig. 2, for 0% fat level samples at 0 d, the G' started to increase from the beginning of heating to a maximum value (3602 Pa) when the temperature reached approximately 57 °C. From 57 °C to 68 °C, the G' dropped rapidly then rose again until the 85 °C. This observation was in agreement with other reported findings [9] and is a typical of muscle protein rheological patterns and reflects the transitions of heavy meromyosin and light meromyosin. When the dumpling was stored up to 30, 60, 90 and 180 d, the first peak G' values of the MP gel were decreased to 3109, 2331, 1825 and 1527 Pa, respectively, and peak temperature reduced by 2-4 °C. The G' for MP samples from the other three fat levels had a similar reducing trend, and the G' and peak temperature decreased more rapidly with increased fat levels. The transition temperatures of the subfragments of myosin suggested the stability of protein; thus, the decreases in transition temperatures indicated that the reduction in stability of MP was affected by oxidation or denaturation. A possible explanation for the deleterious effect of the high

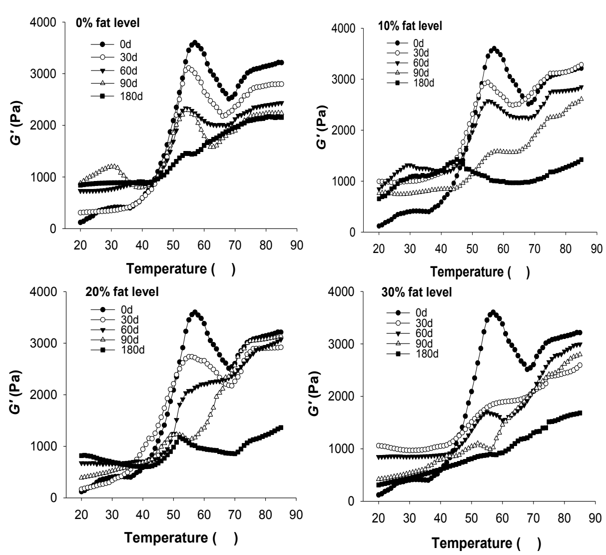

Fig. 2. Influence of different fat levels on shear storage modulus (G') of porcine myofibrillar protein in frozen dumpling fillers.

fat level on dynamic rheological properties of MP is that the high content of fat can cause more severe lipid oxidation (proven by TBARS, Fig. 1), and the aldehydes formed by lipid oxidation can react with the amino groups of proteins, causing protein structural changes, protein denaturation, and a decrease in the protein stability. As displayed in Fig. 2, the viscoelasticity of MP decreased as frozen storage time prolonged and fat level increased, which contributed to explain the reduction in breaking strength and cooking loss as seen below (Fig. 3).

4. Cooking loss

Cooking loss of dumpling fillers was affected by the fat level and changed significantly during storage (P <0.05) (Fig. 3a). In dumpling fillers of 0%, 10%, 20%, and 30% fat levels, the cooking losses were 17.8%, 19.4%, 20.4% and 21.5% at 0 d and increased to 22.0%, 23.1%, 24.3% and 27.0%, respectively, after 180 d (P<0.05). The higher cooking loss of filler samples may also be construed as a result of increased myosin denaturation as demonstrated above (Fig. 1) and possibly the weakening of the myofibril lattices because of protein degradation. Muscle proteins play a key role in the three-dimensional gel matrix development in meat products; the denatured and reduced protein decreased the gel-forming ability of fillers, so the poor-formed gel matrix possessed a lower water and lipid holding capacity [11], which resulted in an increase in loss of water as the frozen storage time increased.

5. Breaking strength

The fat addition levels had a remarkable effect on the breaking strength of the dumpling fillers. The increase of fat level significantly lowered the breaking strength (P<0.05) (Fig. 3b). In dumpling fillers of the 0%, 10%, 20%, and 30% fat levels, the breaking strengths were 0.95, 1.58, 2.07 and 2.69 N/m on 0 d and decreased to 1.33, 1.90, 2.21 and 2.65, respectively, after 180 d. There was only a slight increase in the breaking strength in the filler samples stored for 30 d, which may be attributed to the modest protein oxidation of MP as proven by the carbonyl content measurement (Fig. 1b). Liu et al confirmed that slow and mild-to-moderate oxidation could facilitate the formation of disulphide cross-links in myofibrils, resulting in the formation of a stronger gel [12]. However, the breaking strength decreased as storage duration was prolonged.

The pronounced decrease in breaking strength might be related to the fact that cohesiveness tended to decrease as animal fat content increased in the meat treatments, as suggested by Youssef et al [13].

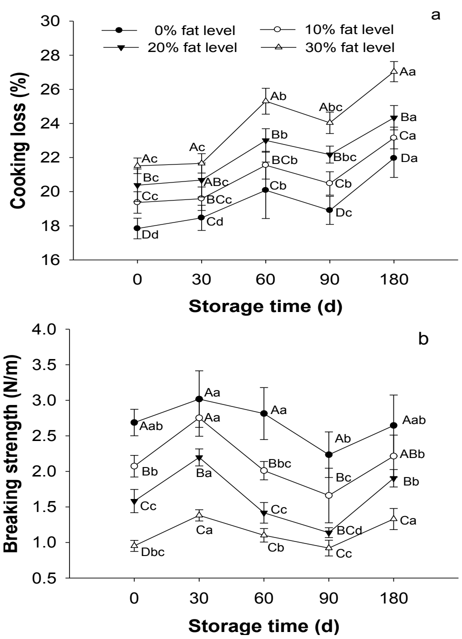

Fig. 3 Influence of different fat levels on cooking loss and breaking strength of frozen dumpling fillers.

IV. CONCLUSION

The results of this study demonstrated that the fat level and frozen storage duration have strong effects on lipid and protein oxidation, gel-forming ability, cooking loss, breaking force. Lipid and protein oxidation was closely related to protein denaturation and the gel-forming ability deterioration. The dumplings with a high fat level for long periods of time had significantly enhanced lipid and protein oxidation and cooking loss, lowered viscoelasticity and breaking strength.

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