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Viscoelastic properties and physicochemical characteristics of pressurized ostrich-meat emulsions containing gum additives

Utaiwan Chattong [a], Arunee Apichartsrangkoon [b,*], Pittaya Chaikham [c], Thawatchai Supavititpatana [a], Alan E. Bell [d]

[a] Faculty of Food and Agricultural Technology, Pibulsongkram Rajabhat University, Phitsanulok 65000, Thailand
[b] Postharvest Technology Research Institute, Chiang Mai University, Chiang Mai 50200, Thailand
[c] Faculty of Science and Technology, Phranakhon Si Ayutthaya Rajabhat University, Phranakhon Si Ayutthaya 13000, Thailand
[d] Department of Food and Nutrition Science, University of Reading, Reading RG6 6AP, UK

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ABSTRACT

Minced-ostrich meat was blended and chopped with various proportions of gum powder in terms of carboxymethyl cellulose (CMC), locust bean gum (LBG) and xanthan gum (XAN) and other ingredients such as sodium chloride, sodium tripolyphosphate, linseed oil and ice. The mixed batters were then pressurized at 600 MPa and 50 °C for 40 min. Subsequently, their viscoelastic and physicochemical properties were assessed in terms of their dynamic oscillatory moduli, their resultant creep behavior, water-holding capacity and electrophoretic profiles. The results showed that the addition of individual gums and composite gum mixtures influenced both viscoelastic behavior and water-holding capacity of resulting pressurized ostrich-meat emulsions. The most elastic system (greatest G' or smallest J_0 with 4.21×10^{-5} 1/Pa) was the meat emulsion with 1% LBG added, while the least were those formed by adding 1% XAN or 0.5% XAN plus 0.5% CMC (J_0 with 10×10^{-5} and 20.3×10^{-5} 1/Pa, respectively). Subsequent electrophoritic profiles and the measurement of the water-holding capacity of the materials suggested an evidence of ionic interaction between the basic ostrich-meat protein matrix and XAN or XAN plus CMC.

Industrial relevance: Ostrich meat emulsions containing composite gums were set by combined pressure and temperature. Subsequently, the pressurized gels were characterized by dynamic oscillatory, creep and other physicochemical measurements. In particular, the viscoelastic measuring system is a promising tool for ensuring quality of food biopolymers. Therefore, this methodology is relevant in the area of controlling quality or developing new products where difficulty exists in solubilising the samples.

1. Introduction

Reddish ostrich (*Struthio camelus australis*) meat or muscle is similar in taste and texture to veal and beef. It contains low intra-muscular fat content, a favorable fatty acid profile, a high content of iron and vitamin E and low sodium (Balog & Almeida Paz, 2007; Poławska et al., 2011). For these and other reasons, ostrich meat is frequently considered as a "healthy" food option. Emulsified ostrich-meat could be processed by ultra-high pressure instead of conventional thermal processes. Pressure has a tendency to modify the rheological structure of meat protein which has been shown to be dependent on the pressure, temperature and holding times used (Chattong & Apichartsrangkoon, 2009). Obviously, ultra-high pressure has been shown to have minimal effects on the sensory acceptability and nutritional values of these food products, while spoilage and pathogenic microorganisms are simultaneously reduced/eliminated (Chaikham, Apichartsrangkoon, & Seesuriyachan, 2014; Chattong & Apichartsrangkoon, 2009).

Several studies of pressurized meat products have been focused on sensory acceptability, microbial eradication, rheological characterization and structural or textural modifications, etc. (Bolumar, Andersen, & Orlien, 2014; Grossi, Søltoft-Jensen, Knudsen, Christensen, & Orlien, 2011). Sikes, Tobin, and Tume (2009) found that pressure increased the interaction between myofibrillar proteins and water, which was responsible for the aggregation of gelling or binding mechanisms. In other words, pressurization could improve water-binding capacity, reducing cook loss and modifying the rheological structure. Therefore, in the subsequent formulation of such pressurized meat sausage or emulsion, some water-binding substances such as salt or phosphate could be reduced (Chan, Omana, & Betti, 2011). Gums or hydrocolloids, another water-binding substance, is also commonly incorporated in the formula of meat emulsions (Montero, Solas, & Pérez-Mateos, 2001).

Ma et al. (2013) found that locust bean gum and κ-carrageenan could improve gelling properties, water-holding capacity, elasticity, cohesiveness and hardness of pressurized meat muscle, whereas

* Corresponding author. Tel.: +66 53 944031; fax: +66 53 941426.
E-mail address: arunee.a@cmu.ac.th (A. Apichartsrangkoon).

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Luruena-Martinez, Vivar-Quintana, and Revilla (2004) observed that the addition of locust bean/xanthan gum in low-fat frankfurters produced a significant increase in hydration/binding properties, characterized by lower cook losses, increased yield, better emulsion stability and lower jelly and fat separation. Moreover, Marchetti, Andrés, and Califano (2013) added xanthan-locust bean gums in low-fat meat emulsion and found that these products had the highest hardness, similar to control formulations with standard fat contents.

The most promising approach for characterizing the physical properties of food gels is the implementation of a viscoelastic measuring system such as dynamic oscillatory testing or creep and stress relaxation measurements. Chattong, Apichartsrangkoon, and Bell (2007) measured the creep behavior of pressurized (600 MPa/50 °C/40 min) ostrich-meat sausages incorporating xanthan gum, and found an increase in the instantaneous compliance, retarded compliance and overall retardation times with increasing levels of xanthan addition. The results also suggested that the larger deformations in creep testing were more helpful in assessing the mechanical properties of the products than the small strain deformations usually employed in oscillatory measurements. Further, Chattong and Apichartsrangkoon (2009) measured the mechanical oscillatory properties of pressurized ostrich-meat sausages and found that the storage modulus (G') was larger than the loss modulus (G'') and, consequently, a relatively small loss tangent (about 0.23) was usually obtained. These indicated essentially a "solid-like" behavior with the predominance of the "elastic" component. In addition, Supavititpatana and Apichartsrangkoon (2007) measured the stress relaxation of ostrich-meat sausages and found that both initial and equilibrium stress values of the severely pressure/heat-treated samples were greater than those treated under milder conditions, presumably due to the increased cross-link density in the more "treated" samples.

To add to the previous studies, an investigation into treated pressurized ostrich-meat emulsions was performed with the addition of composite gums in various concentrations [carboxymethyl cellulose (CMC), locust bean gum (LBG) and xanthan gum (XAN)], and their physiochemical properties were examined.

2. Materials and methods

2.1. Preparation of ostrich-meat emulsions

The ostrich-meat emulsions were prepared as follows: the minced ostrich-meat, purchased from a local market, was chopped and blended with 2% (w/w) sodium chloride, 5% (w/w) sodium tripolyphosphate, 5% (w/w) linseed oil, 5% (w/w) ice and appropriate proportions of gums using a meat chopper (Meissner GmbH & Co., Ltd., Bieenkopf-Wallau, Germany). The final temperature of the meat batter was maintained at about 10 °C. Eight emulsified formulas were developed varying the three types of gum added (0%–1%, w/w), i.e., medium molecular weight carboxymethyl cellulose (Nippon Paper Chemicals Co., Ltd., Japan), LBG (System Bio-Industries Maroc S.A., Morocco) and XAN (CP Kelco U.S., Inc., USA) including control emulsions without gum additions (Table 1). The quantities of the gum addition were followed Schuh et al. (2013) and Ramirez, Barrera, Morales and Vazquez (2002). Despite of all three gums did not showing the same weight efficiency on their own, in the presence of a large protein matrix, this characteristic could be partially compensated for the interaction with the protein matrix as shown in the electrophoregrams (Section 3.4).

Each batter was then packed into plastic casing (polyvinylidene chloride), 29 mm diameter and hermetically sealed in laminated plastic bags (polyamide/polyethylene) prior to pressure treatment. Samples were pressurized at 600 MPa at 50 °C for 40 min (Chattong & Apichartsrangkoon, 2009) using "Food lab" high-pressure rig (Stanted Fluid Power, Essex, UK). The rate of pressure increase was about 330 MPa/min, and the inside temperature of the rig was 50 °C for a holding pressure at 600 MPa.

Table 1
Physical characteristics of pressurized ostrich-meat emulsions with the addition of composite gums.

Treatments (T)	Composite gums			Released plus expressible water (%)	Gel strength (N.mm)
	CMC	LBG	XAN		
T1	1	0	0	14.12 ± 1.47[b]	14.02 ± 0.56[e]
T2	0	1	0	9.65 ± 0.84[c]	39.27 ± 0.96[a]
T3	0	0	1	18.50 ± 0.30[a]	11.11 ± 0.46[f]
T4	0.5	0.5	0	12.83 ± 1.20[bc]	22.05 ± 0.52[d]
T5	0.5	0	0.5	19.78 ± 1.16[a]	7.86 ± 0.24[g]
T6	0	0.5	0.5	12.24 ± 0.54[bc]	36.79 ± 0.45[b]
T7	0.33	0.33	0.33	12.73 ± 0.54[bc]	38.96 ± 0.76[a]
T8	0	0	0	13.27 ± 0.23[bc]	24.80 ± 1.21[c]

Means followed by the different letters within the same column are significantly different ($P \le 0.05$). All values are the mean ± standard error (SE) from triplicate batches ($n = 9$).

According to our previous study, this pressurized condition was chosen corresponding to the state of protein denaturation as depicted by the DSC thermogram (data not shown). After treatment, the emulsions were kept overnight at 4 °C for further analysis.

2.2. Rheological measurements

The viscoelastic characterisation of all treated samples were determined using a controlled stress rheometer (Advance Rheometer AR2000, TA Instruments-Waters LLC, New Castle, DE, USA) In order to ensure that all measurements were carried out within the linear viscoelastic regions (LVR), a stress sweep was initially done at a frequency of 1 Hz for all samples (Apichartsrangkoon & Ledward, 2002), as shown in Fig. 1. The edges of the samples were covered with light silicone oil (Sigma-Aldrich Co. Ltd, Gillingham, UK) to prevent the samples from drying out.

2.2.1. Dynamic viscoelastic oscillatory measurement

The oscillatory measurement of the storage (G') and loss (G'') moduli was performed over a frequency range of 0.01–10 Hz (Fig. 2) using a controlled stress of 50 Pa chosen from Fig. 1. Consequently, a parallel plate geometry of 25-mm diameter with a gap of 2 mm was used in order to avoid particle "bridging" during measurement. (Apichartsrangkoon & Ledward, 2002).

2.2.2. Creep testing

Creep measurement was performed under a constant stress of 50 Pa and the unloaded recovery was also measured after the stress was instantly removed. Accordingly, the compliance plots against time of 300 s for the creep curves and time of 900 s for the recovery curves

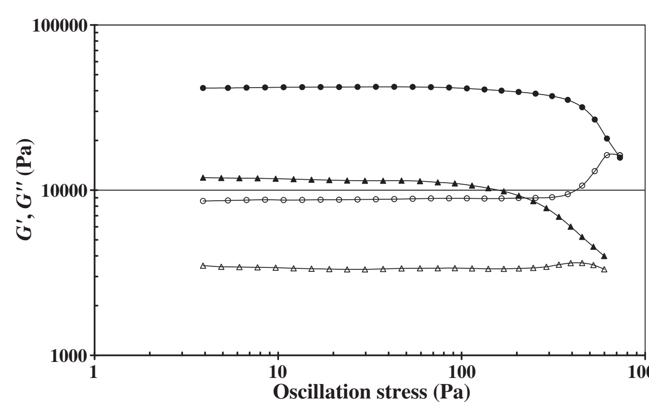

Fig. 1. Stress amplitude sweep (1–1,000 Pa) at frequency 1 Hz of pressurized ostrich-meat emulsion, storage modulus (G'; closed symbols) and loss modulus (G''; opened symbols), ▲, Δ added 1.0% (w/w) LBG (Treatment 2), ●, ○ added 0.5% (w/w) CMC plus 0.5% (w/w) XAN (Treatment 5).