Innovative Food Science and Emerging Technologies 32 (2015) 64–69

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

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

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ARTICLE INFO

Article history:
Received 12 March 2015
Received in revised form 30 June 2015
Accepted 2 July 2015
Available online 11 July 2015

Keywords:
Pressurized ostrich-meat emulsion
Viscoelastic behavior
Composite gums
SDS-PAGE
Water-holding capacity

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

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http://dx.doi.org/10.1016/j.ifset.2015.07.001
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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 ($P \leq 0.05$). 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

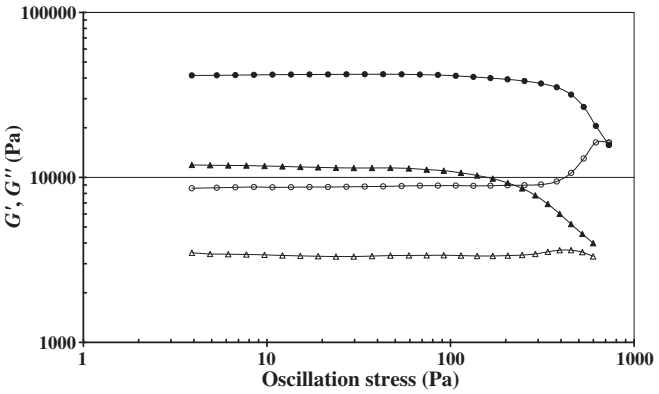

Fig. 1. Stress amplitude sweep (1–1,000 Pa) at frequency 1 Hz of pressurized ostrich-meat emulsion, storage modulus (G'; closed symbols) and loss modulus (G''; opened symbols), ▲, Δ added 1.0% (w/w) LBG (Treatment 2), ●, ○ added 0.5% (w/w) CMC plus 0.5% (w/w) XAN (Treatment 5).

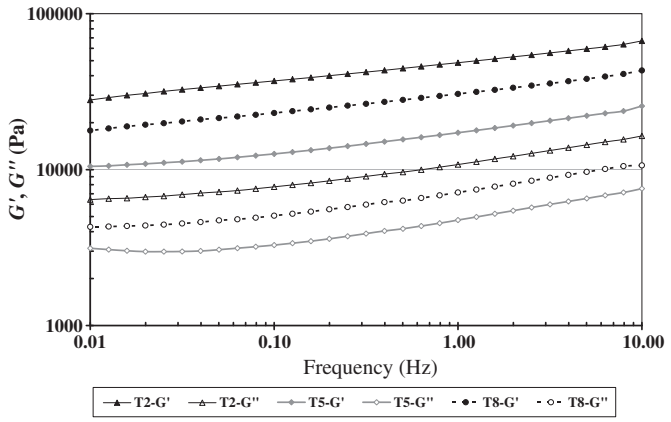

Fig. 2. Typical storage (G') and loss (G'') moduli as a function of frequency for pressurized ostrich-meat emulsions, ▲, Δ added 1.0% (w/w) LBG (Treatment 2), ●, ○ added 0.5% (w/w) CMC plus 0.5% (w/w) XAN (Treatment 5) and without gum addition (Treatment 8).

were achieved. In addition, mathematical modelling of these curves was also calculated (Chattong et al., 2007).

2.3. Water-holding capacity

Water-holding capacity (WHC) measured according to Supavititpatana and Apichartsrangkoon (2007) was expressed as the value of the freely released water plus the expressed water. The percentage of water released from the product was the weight of the sample left after blotting water from the surface. Consequently, the expressed water of the product was the water released under a compressive force (50 kg load cell to 70% strain for 60 s) applied toward the sample with 19.6 cm^2 compressive area. The measurement was carried out by Texture Analyser TA-XT Plus (Stable Micro Systems Ltd., Surrey, UK).

2.4. Electrophoretic analysis

Electrophoretic protocol was followed Chattong and Apichartsrangkoon (2009). Briefly, proteins from the pressurized and unpressurized emulsions were analysed by sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE) in a miniVE electrophoresis and electrotransfer unit (Amersham Biosciences, Uppsala, Sweden). Samples each weighting 0.2 g were dissolved in a mixed solution of Tris-HCl (pH 6.8), 10% (w/v) SDS, 0.02% bromophenol blue and 20% (v/v) glycerol. Subsequently, 5 μg extracted samples were loaded into the 7.5% polyacrylamide "running" gels. The reduced samples were heated in 5% (v/v) 2-mercaptoethanol prior to loading. A broad range standard of full-range rainbow-protein (GE Healthcare UK Limited, UK) was used to determine the molecular weight. To visualise the protein bands, the running gels were stained with a mixed solution of 0.25% (w/v) Coomassie blue G-250 (USB Corporation, UK), 40% methanol and 7% acetic acid.

2.5. Statistical analysis

Results for all treatments (T1–T8) were assessed by an analysis of variance using Completely Randomized Design and the general linear model procedure of the SPSS 11.5 software (SPSS Inc., Chicago, USA) with triplicate batches ($n = 9$) as random factor. Significant univariate difference was at $\alpha = 0.05$ and were assessed by Duncan's multiple range test.

3. Results and discussion

3.1. Viscoelastic oscillatory measurement

The effects of addition gums on storage (G') and loss (G'') moduli as a function of frequency (0.01–10 Hz) for ostrich-meat emulsion following pressure treatment at 600 MPa at 50 °C for 40 min and are shown in Fig. 2. Both the G' and G'' of all sample plots appeared to be similar with slight overall frequency dependence and with the storage moduli (G') predominating over the loss moduli (G'') by a ratio of G'' to G' (tan δ) of about 0.23. These results are all indicative of weak viscoelastic gels (Apichartsrangkoon, 2003; Ferry, 1980). Saowapark, Apichartsrangkoon, and Bell (2008) examined heat (70 °C/60 min) or high pressure (400 MPa/20 °C/10 min) set tofu gels adding either glucono-δ-lactone or calcium sulphate. They found that each frequency profile was characterized as weakly viscoelastic material, since the overall G' plots were higher than those G'' with little frequency dependence (tan δ ~0.18–0.27).

Fig. 2 shows the storage (G') and loss (G'') moduli of the various test compositions as functions of frequency. These ranged from the "weakest" materials, T3 (1% w/w XAN, data not shown) and T5 (0.5% w/w of CMC and XAN), to the "strongest" gels measured, T2 (1% w/w LBG). All profiles were consistent with a weak viscoelastic gel structure with G' predominating over G'' over all of the measured frequency range (Ferry, 1980). Gels with higher and lower values of moduli could be produced (compared to T8 control), depending on the gums added. Since both "enhanced" and "weaker" structures were possible, the results suggest that depending on the system, either "enhancement" or "interference" of the existing protein interactions may occur. Moreover, the values of gel strengths recorded in Table 1 and the creep parameters measured in Table 2 were also consistent with these oscillatory data. Apichartsrangkoon (2002) revealed that gluten gels yielded shear moduli, which were much higher than those of soy protein gels (in which the corresponding tan δ was much lower and displayed very little frequency dependence), suggesting a stronger overall gel structure with more solid-like characteristics.

3.2. Creep testing

Typical creep responses of ostrich-meat emulsion with various levels of gum addition under a step load of stress 50 Pa within the linear viscoelastic region are illustrated in Fig. 3. All samples exhibited a typical pattern of weak viscoelastic solids which would illustrate a non-linear response to strain, due to their ability to recover some structure by storing energy. As expected, the strongest emulsion sample curve, which was the lowest line, represented sample with 1% (w/w) of added LBG. The relative strengths of the other samples could be elucidated from the levels of compliance shown by the following sequence:

Table 2
Creep parameters of pressurized ostrich-meat emulsion with the addition of composite gums.

Treatments (T)	Parameters of creep compliances			
	J_0 (1/Pa) ($\times 10^{-5}$)	J_1(1/Pa) ($\times 10^{-5}$)	λ_{ret} (s)	η_0 (Pa.s) ($\times 10^6$)
T1	6.95 ± 0.19^{d}	5.40 ± 0.12^{b}	50.63 ± 0.14^{ab}	8.70 ± 0.30^{c}
T2	4.21 ± 0.20^{f}	2.69 ± 0.08^{e}	46.51 ± 1.11^{d}	17.11 ± 1.10^{a}
T3	10.00 ± 0.17^{b}	5.70 ± 0.20^{b}	52.65 ± 0.18^{a}	8.85 ± 0.15^{c}
T4	8.10 ± 0.17^{c}	4.70 ± 0.09^{c}	50.60 ± 0.14^{ab}	9.58 ± 0.45^{c}
T5	20.30 ± 0.28^{a}	13.95 ± 0.36^{a}	53.13 ± 0.46^{a}	3.63 ± 0.17^{d}
T6	4.51 ± 0.28^{f}	3.01 ± 0.09^{e}	47.16 ± 1.99^{cd}	16.14 ± 0.58^{a}
T7	4.37 ± 0.18^{f}	3.93 ± 0.25^{d}	48.55 ± 0.47^{bcd}	11.51 ± 0.52^{b}
T8	5.46 ± 0.35^{e}	3.89 ± 0.30^{d}	49.58 ± 0.64^{bc}	12.41 ± 0.66^{b}

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

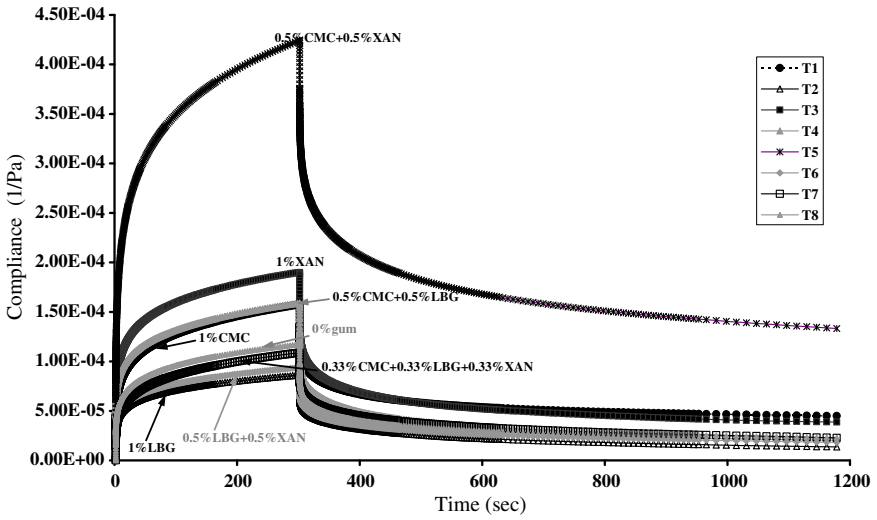

Fig. 3. Typical creep–recovery curves of ostrich-meat emulsions with various levels of gum addition.

samples with added LBG-XAN > CMC-LBG-XAN > 0% gum > 1% (w/w) CMC > CMC-LBG > 1% (w/w) XAN and CMC-XAN (the weakest gels).

In addition, the creep curves were best characterized using a four-element "burger" model (Barnes, 2000; Steffe, 1996) consisting of initial instantaneous compliance ($J_0 = 1/G_0$), viscosity (η_0), retarded compliance ($J_1 = 1/G_1$), retarded viscosity (η_1) and retardation time ($\lambda_{ret} = \eta_1/G_1$) represented by Eq. (1) for the series of a Maxwell and Voight–Kelvin model as shown in Fig. 4.

$$J(t) = J_0 + J_1[1 - exp\,(-t/\lambda l_{ret})] + t/\eta_0 \quad (1)$$

where

J_0 = instantaneous elastic compliance (1/Pa)
J_1 = retarded compliance for Kelvin–Voigt model (1/Pa)
λ_{ret} = retardation time for Kelvin–Voigt model (s)
η_0 = Newtonian viscosity (Pa.s)
t = time (s)

All creep parameters used in these models are listed in Table 2, which showed that the addition of gum to the samples significantly affected ($P \leq 0.05$) their viscoelastic parameters. The mixture of CMC-XAN (T5) exhibited the highest values of J_0, J_1 and λ_{ret} but lowest η_0, and from Fig. 3, this treatment also gave rise to the "highest" creep–recovery curve. This means that the structure of this sample had the lowest viscoelastic characteristics, since it could be easily deformed with a relatively small imposed stress. The strongest viscoelastic structure created was made by the addition of 1% (w/w) LBG (T2), this exhibited the lowest values of J_0, J_1 and λ_{ret} but the highest η_0 and was consequently the most resistant to flow. Similar trends could be observed for the rest of the treatment conditions. These parameters vary in the expected way according to the functionality of each gum and its contribution to the sample structure.

Messens, Van de Walle, Arevalo, Dewettinck, and Huyghebaert (2000) studied the rheological properties of pressurized Gouda cheese and pointed out that J_0 may be related to the network structure and was an indication of the rigidity of the material. They found that the decreasing J_0 value of the samples caused by ripening indicated more rigidity in the structure. According to Chattong and Apichartsrangkoon (2009), an increase in J_1 was associated with a less solid-like behavior of ostrich-meat sausages; therefore, a lower gel rigidity as also evidenced by a higher J_0 or a lower G_0 value. In general, for these

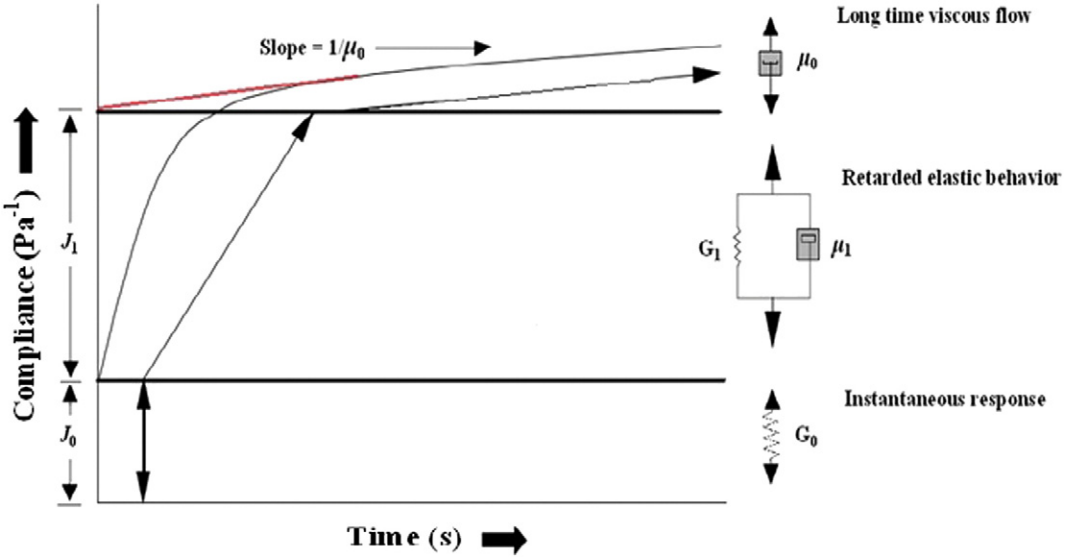

Fig. 4. A standard creep curve with an indication of a four-element "burger" model.

types of viscoelastic systems, the shorter the retardation time, the greater the elasticity and the smaller the change in the coefficient of viscosity associated with the Voight–Kelvin unit and a greater stability of structural elements (Yilmaz, Karaman, Dogan, Yetim, & Kayacier, 2012). Also, Sun and Hayakawa (2002) reported that η_0 might be related to the breakdown of the network structure of ovalbumin in egg white protein, that is, larger η_0 values of ovalbumin gels suggest a greater resistance to flow.

It is noteworthy that the correlation analysis between the instantaneous modulus (G_0) from creep parameters and the storage modulus (G') from oscillatory parameters were performed, since both represented the elastic characteristics of viscoelastic materials. The results showed that G' had positive correlation with G_0 ($R^2 = 0.822$), which was a good indication of the consistent outcomes.

3.3. Water-holding capacity

Water-holding capacity (WHC) is the ratio of moisture retained in the sample to the initial moisture content, so that a high percentage of WHC indicates the release of less moisture. In this context, the addition of gums significantly influenced ($P \leq 0.05$) the percentage of released plus expressible water in the treated samples (Table 1). The results of released plus expressible water were divided into two groups. The highest value was found for the CMC-XAN (T5) mixture and 1% (w/w) XAN (T3) added sample, while the lowest value was found at 1% (w/w) LBG (T2) added sample, which showed no significant differences from the other four treatments. Decreasing released plus expressible water agreed well with the increase in the values of the storage and loss moduli or the decrease of the overall creep compliance. Morin, Temelli, and McMullen (2004) suggested that the water-holding capacity of a low-fat meat system was not due mainly to molecular interactions between the proteins and the hydrocolloids, but the ability of a meat system to hold water. This, in turn, was dependent on the strength of the protein network developed and the capacity of hydrocolloids to subsequently entrap water within it. However, there is evidence that proteins and polysaccharides could also interact directly either through covalent bonding or electrostatic interactions leading to an increase in emulsion stability (Bouyer, Mekhloufi, Rosilio, Grossiord, & Agnely, 2012).

Regarding the way that pressure acts on anionic hydrocolloids, Montero et al. (2001) stated that pressure-induced gels with anionic gums (CMC and XAN) gave higher water-holding capacity values than the equivalent heat-induced gels, while pressurization made no difference in gels formed using non-ionic gums. Schuh et al. (2013) reported that the addition of CMC (>0.7%) led to the destabilization of the meat "batter," probably due to the CMC enveloping the myofibrillar protein present in the system, while Luruena-Martınez et al. (2004) noted that the combined effect of locus bean and xanthan gums increased in hydration/binding properties of low-fat frankfurters.

At atmospheric pressure, solubilisation of LBG requires some heating (85 °C), whereas the rest of the gums (XAN, CMC) are cold-soluble. The reason for the differences in structure of the gums according to the pressure–time–temperature treatments could be that the "swollen" state is reached at different temperatures depending on the pressures applied. In the particular case of anionic gums, when XAN has little available water, it tends to aggregate and coil upon itself, CMC particularly requires a lot of water in order to disperse well. Hydrocolloids/gums are ordinarily added to meat systems in the form of dry powder since water is usually a limiting factor affecting the texture of the final product. Thus, these two hydrocolloids are not very appropriate to incorporate into a meat system (Montero et al., 2001).

3.4. Electrophoretic analysis

The SDS-PAGE electrophoregrams of pressurized ostrich-meat emulsions with different levels of gum addition dissolved in SDS and SDS plus reducing agent (2-mercaptoethanol) are shown in Fig. 5. Without reducing agent (Fig. 5a), samples C (with XAN) and E (with CMC plus XAN) display some slight decrease in the band intensity in comparison with other samples, suggesting that the charge density of XAN or/and CMC interacted to some degree with the meat protein matrix and protected them against subsequent solubilisation in SDS (a hydrophobic

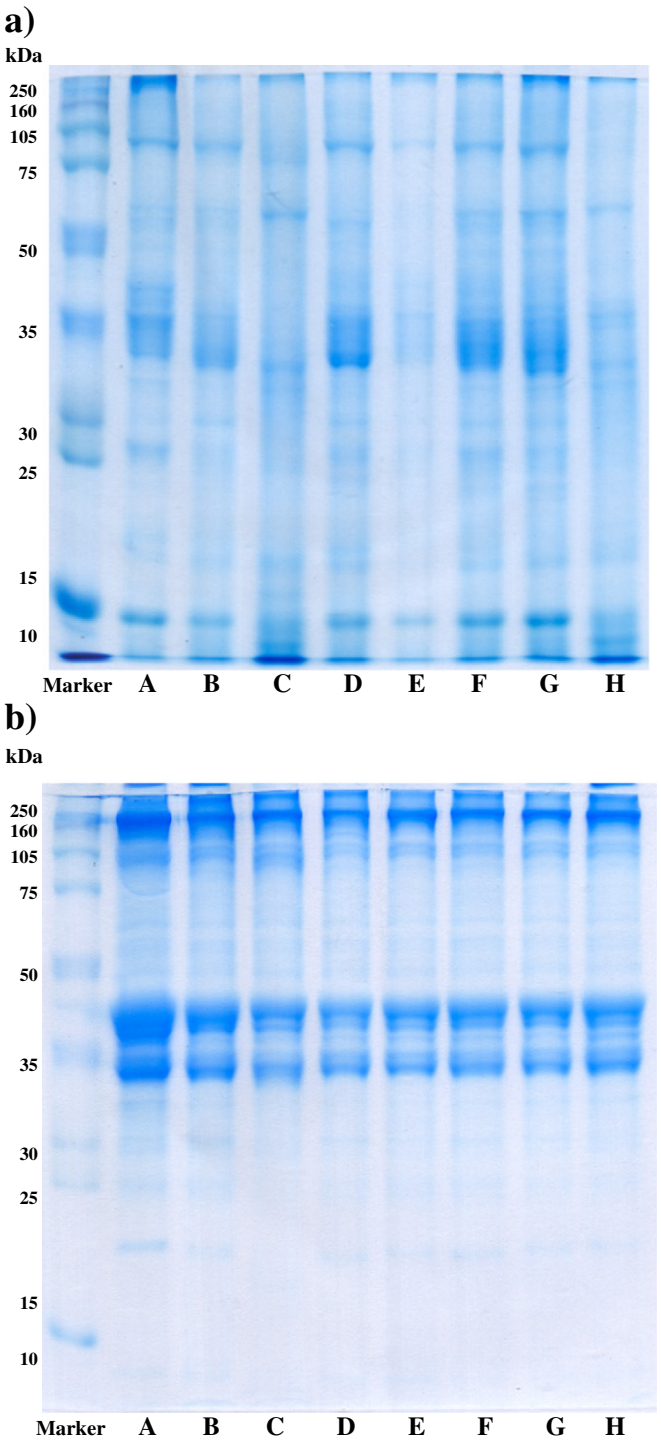

Fig. 5. (a) SDS-PAGE electrophoregrams of pressurized samples with added various gums: A = added 1% (w/w) CMC; B = added 1% (w/w) LBG; C = added 1% (w/w) XAN; D = added 0.5% (w/w) CMC and 0.5% (w/w) LBG; E = added 0.5% (w/w) CMC and 0.5% (w/w) XAN; F = added 0.5% (w/w) LBG and 0.5% (w/w) XAN; G = added 0.33% (w/w) CMC, 0.33% (w/w) LBG and 0.33% (w/w) XAN; H = no gum-treated sample. (b) SDS-PAGE electrophoregrams of pressurized samples with added various gums in the presence of 2-mercaptoethanol; with the same sequence as (a).

breaking reagent). The presence of a reducing agent, such as 2-mercaptoethanol, which ruptures any disulphide bonds, would solubilise the aggregates present so that the resulting electrophoretic patterns would be similar (Fig. 5b).

Overall, adding LBG has a marked effect by strengthening the elasticity of the meat emulsion structure, while the addition of CMC and XAN has an antagonistic effect. This is probably due to the fact that both CMC and XAN are anionic in nature ($-COO^-$), which would make the most likely interaction with the meat proteins by cross-linking with the positively charged side chains of amino acids in the meat proteins as they unfold during subsequent denaturation and aggregation (Morin et al., 2004). Therefore, this characteristic could prevent the protein matrix interacting directly with the water, leading to a reduced water-holding capacity of the corresponding ostrich-meat emulsion (Table 1).

Montero et al. (2001) investigated the gels of mixed proteins with various gums by light microscopy and found that the gums were located inside the "round cavities," which were evenly distributed throughout the matrix (i.e., a "mixed gel" system). In the case of XAN and CMC, some areas of bonding to the protein matrix were observed; however, this was not the case with non-ionic galactomannans such as locust bean or guar gum.

4. Conclusions

The addition of gums influenced the viscoelastic characteristics and water-holding capacity of pressurized ostrich-meat emulsions. The strongest elasticity, as measured for the plots of storage and loss moduli as well as the creep curves, was found for the sample created by adding 1% LBG. The lowest elasticity was those adding XAN and XAN plus CMC which were supported by the viscoelastic parameters and the gel strength values. In addition, evidence of the interaction between the protein matrix and XAN or CMC plus XAN was also reflected by a slight decrease in the band intensity of the corresponding SDS-PAGE. These emulsions also displayed the highest released plus expressible water or the lowest overall water-holding capacity.

Acknowledgement

The authors wish to thank Chiang Mai University, Chiang Mai 50200, Thailand for their financial support.

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