RHEOLOGIC CHARACTERISTICS OF GELS USED AS FAT REPLACEMENTS

SENIK I. and OLKIEWICZ M.

Meat and Fat Research Institute, Warsaw, Poland

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SUMMARY

The successful substitution of fats in meat products depends mainly on textural traits of the product. Plasticity, elasticity and fluidity of carrageenan, xanthan, locust bean gum and soya protein gels used as fat replacements in meat products were measured by the Continously Alternated Stress-Relax Analysis (CASRA) method according to Tyszkiewicz (1970) and the results compared to the same characteristics of pork lard used as a standard. Viscosity of gels was measured in a range of temperature and concentration of polysaccharides or proteins.

On the basis of the results of the experiments it can be concluded that there exists the possibility of creation of such a composition of carbohydrate-protein gels which would be very close to the lard pattern as far as its rheologic characteristic is concerned.

Introduction

It is generally accepted that the rheological behaviour of meat products and its consumer's palatability and acceptability are related to fat level in product (Huffman 1993, Mandingo et al., 1993). Depending on the extent of raw material processing and addition of fat, the products of different mechanical properties are obtained. Both proteins and polysaccharides have been used to develop or modify texture and can be used as fat replacement. Both of them can form gels.

The term "gel" classically defines a range of substances which exhibit solid-like properties while a vast excess of solvent is present. Gelation arises either from cross-linking or by way of covalent reactions or from physical cross-linking through polymer-polymer interactions (Miles 1988). A gel can also be described as "a substantially diluted system which exhibits no steady-state flow" (Ferry 1948).

The most of hydrocolloids exhibit pseudoplastic flow, i.e., their viscosity decreases with in-creasing shear rate. Most gums obey the power law: \ = k \$^{n}$ where \ is stress, \ is shear rate, k is consistency modulus and n is a constant which indicates deviation from Newtonian flow (n=1). Some hydrocolloid system show a plastic flow, i.e., they show a yield point \$_{o}$, below which no flow occurs. It is important that viscosity changes in a wide range following the changing shear rates (Surmacka-Szczesniak, 1986).

Some of the physical properties of a hydrocolloid that are responsible for modifying the rheo-logy of a solution are: molecular weight, degree of hydration, extent of intra- and intermolecular interaction. The rheology is also affected by concentration of hydrocolloids and temperature of measurement (Krumel et al., 1975).

In many studies hydrocolloids such as carrageenan, locust bean gum, xanthan and their com-binations with/or soya proteins have been presented as the most suitable fat substitutes in meat products (Dunkelberger et al., 1991; Foegeding et al., 1986).

In this study the rheological properties of pork lard were taken as reference ones for meat fat standard. The same rheological properties of carrageenan, locust bean gum and soya protein gels were then measured and compared to the standard ones in order to find the best composition simulating meat fat behaviour during consumption of meat products. It may be presumed that elasticity, fluidity and plasticity are the most important rheological properties of meat products affected by fat content.

Materials and methods

Preparation of gel samples

Carrageenan and carrageenan/xanthan (premixed in 9:1 ratio) gels were prepared at 0,6; 1,0 and 1,5%

(w/w) total polysaccharides concentration. Commercial food grade samples by Sanofi (France) were used. Xanthan gels were prepared using 0,1, 0,6 and 1,0% (w/w) native xanthan of Jungebunzlauller (Austria); xanthan/locust bean gum (1:9 ratio premix) 0,6% gels by Meyhall Chemical. Isolated soya proteins were obtained from Protein Technologies International (USA). The protein gels were prepared at concentration 16,8 and 20,0% (hydration ratio 1:4 and 1:5) of commercial food grade samples: Supro 500E, Supro 595.

The pork lard (containing 0,012% of water and 99,88% of fat) was obtained in a standard manufacturing process.

Hydrocolloid or protein powders were dispersed in distilled water (6-10°C). The solutions were poured out into glass standard probe utensil (65mm diameter, 40mm height), then heated in 76°C to reach in the centre of sample temperature 68°C and kept in it during ten minutes. Then solutions were chilled quickly and stored in 4°C for about 3 hours.

Instrumental measurements

The viscosity of materials was measured at 20°C and 37°C which are the temperatures characteristic for sensoric impression, so called mouthfeel. The cone system of Rheotest type RV2, full range of shear rate 1,5-1310 [s^{-1}] was used.

Rheological characteristic of samples was determined by the Continously Alternated Stress-Relax Analysis (CASRA) method (Tyszkiewicz, 1970) using an Universal Testing Machine Zwick model 1445. This method is based on inducing and evaluating deformation of sample in the alternative stress and relief cycles with the stress increased in each cycle and sample relaxation possible during the relief period. As a result the characteristic rheograms (deformations of sample after stress and relief versus time, fig. 1) were obtained. The rheograms were used to determine rheological parameters like: plasticity [N/m^2], fluidity [m^2/Ns] and elasticity [m^2/N]. Test parameters: a blunt edge rectangular probe with rectangular contact-surface (2 x 20mm), stress variation from 250 N/m^2, stress step increasing - 250 N/m̃ , stress time - 15s, relief time - 15s, crosshead speed - 120mm/min, temperature of measurements 20°C. Standard sample dimensions \ 65 and 20mm height.

Results and discussion

The results presented in the Table No.1 show that viscosity of pork lard measured at 20\C is the highest one and its value is 9067 cPs. The most similar viscosity measured in the same con-ditions was shown by the carrageenan/xanthan gel of the concentration of 1,5% (w/w) but of the value by 30% lower. The raise of temperature to 37\C resulted in substantial fall of lard viscosity (by 92,0% as compared to the initial value). A similar influence of the temperature was confirmed for 0,6% carrageenan gel. For higher carrageenan concentrations the changes of viscosity fell folowing the raise of concentration showing respectively the following values: 68% and 46%. At higher temperature gels (xanthan, carrageenan/xanthan) showed small changes of viscosity not exceeding 14%. The most similar viscosity to that of lard at 37\C (740 cPs) was shown by 1,0% carrageenan (830 cPs) and 1,0% xanthan (870 cPs).

The tested gels showed different influence of concentration on viscosity values. Carrageenan tested at 37\C proved to be the most variable and showed the raise of viscosity respectively 13 and 29 times following the raise of concentration but such an influence was not shown at 20\C. Xanthan in lower concentrations (0,1% and 0,6%) showed constant viscosity irrespective of temperature. In the highest tested concentration (1,0%), high raise of viscosity (respectively 13 and 14 times) at both the temperatures was observed. Mixed gel (carrageenan/xanthan) showed moderate raise of viscosity in both the temperatures, followingg the raise of concentration. While comparing the flow curves (fig. 2 and 3) of the tested preparations to that of lard it was stated that they were similar and close to the pseudoplastic fluids flow curves.

In the Table No.2 the rheologic characteristic parameters (plasticity, elasticity, fluidity) of lard and tested preparations were presented. Neither of the tested preparations, both protein and polysaccharide, showed identical nor similar characteristic of all the rheologic parameters as com-pared to the lard standard. In the tested range lard shows very good plasticity without any clear limit. On analysis of the elasticity and plasticity curves calculated on basis of the rheograms, the plasticity limit was defined on the level of 13 x 10^3 N/m^2. The plasticity most similar to that of lard was shown by 1,0% carrageenan/xanthan gel and Supro 595 soya protein isolates of 1:4 and 1:5 hydration ratio as well as Supro 500E of 1:5 hydration ratio. As far as elasticity is concerned, protein preparations were more similar to lard (3,5 x 10^{-6} m^2/N). Polysaccharide gels, except 1,5% carrageenan/xanthan (8,5 x 10^{6} m^2/N) and locust bean/xanthan (4,3 x 10^{-6} m^2/N), were substantially different from the standard.

Lard showed fluidity on the level of 24 x 10^{-7} m^2/Ns. A similar values were shown by carrageenan gels in all concentrations. As far as this parameter is concerned, protein preparations differ substantially from the standard showing much smaller fluidity varying from 5 to 7 x 10^{-7} m^2/Ns.

Conclusions

From the rheologic characteristic shown above one may conclude that there will be possible to obtain a gel of mixed protein/polysaccharide composition showing characteristic similar to that of the standard one in which the elements of elasticity and plasticity will be determined by protein preparations and the element of fluidity - by polysaccharide gels.

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Table 1 Effect of temperature and concentration on viscosity of pork lard and polysaccharide gels (shear rate 9,00 s^{-1})

Table 2 Rheological characteristic of pork lard and polysaccharide or protein gels.

Fig. 1 Characteristic rheograms of pork lard (a), 1,5% carrageenan gel (b) and ISP Supro 595 in 1:4 hydration ratio (c) obtained by CASRA method.

Fig. 2 Flow curves of pork lard and polysaccharide gels at 20°C

Fig. 3 Flow curves of pork lard and polysaccharide gels at 37°C