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RHEOLOGICAL PROPERTIES OF OIL-IN-WATER EMULSIONS WITH FLAXSEED GUM

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Abstract

There are many hydrocolloids that are used as thickening agents in food emulsions and improve their quality and shelf life. Flaxseed is one of the healthy grains that could be used in functional foods development. The objective of this work was to evaluate the effect of flaxseed gum concentration and temperature on the rheological properties of oil-in-water (O/W) emulsions with flaxseed gum (FG). FG solution and O/W emulsions with different hydrocolloids were prepared. The rheological behavior of the samples was determined, the flow behavior index (n) and a consistency index (k) values were assayed. The emulsions containing the greatest percentage of gums presented higher viscosity than the reference emulsions. This study shows a good potential of flaxseed gum to be used as a thickening agent in O/W emulsions.

***Key words**: flaxseed gum, O/W emulsions, rheological properties.*

INTRODUCTION

The interest in flaxseeds renewed in recent years. Flaxseed is a food source of lignans, α-linolenic acid, and flaxseed gum (C. Hall Iii et al., 2006). Soluble dietary fibre has significant benefits for human health. Flaxseed gum has nutritional value as a dietary fibre preventing colon and rectal cancer, coronary heart disease risk and the incidence of obesity. Included in the daily ration, flaxseed gum reduces the levels of blood glucose and cholesterol in type 2 diabetic patients (G.Thakur et al., 2009).

Previous studies revealed that flaxseed gum is a mixture of water-soluble polysaccharides composed mainly of L-galactose, D-xylose, L-rhamnose, and D-galacturonic acid. A recent study showed that flaxseed gum contained about 20% (w/w) of dietary fibres, not reported before. Monosaccharide compositions depend on the type of extraction. (H. D.Huihuang et al., 2014).

Flaxseed gum forms weak gel similar to guar gum. Included as a food hydrocolloid, flaxseed gum can significantly increase the water-holding capacity (WHC) of food (J.Sun et al., 2011).The effect of the addition of flaxseed gum on the physicochemical properties of oil-in-water emulsions was investigated. It has been demonstrated that the electrostatic interactions between flaxseed gums and protein-stabilized emulsions need to be controlled in order to prevent bridging flocculation (S. Khalloufiet al., 2009).

The food emulsions are thermodynamically unstable systems and should be stabilized. Stabilizers are used to provide long-term emulsions stability. The most used emulsifiers and thickener agents are proteins, biopolymers and polysaccharides.

Polysaccharide gums are used in food due to their ability to control texture and improve the sensory attributes. Xanthan gum is produced by some bacteria of the genus *Xanthomonas.*This polysaccharide is widely used in various food applications including the stabilization of food emulsions (J. Higiro et al., 2007; S. Desplanques et al., 2014; V. Krstonoŝicet al., 2015).

In the present study the influence of temperature and pH on rheological properties of flaxseed gum water solutions and oil-in-water emulsions has been studied.

MATERIALS AND METHODS

Aaccording to an adapted methodology, the flaxseed gum (FG) was extracted from flax seeds by an aqueous extraction process at 80ºC, pH 6.5 –7.0 and water: seed ratio 13:1 (W Cui. et al., 1994). Flaxseed gum (FG), Xanthan gum (XG) and Xanthan + Guar Gum (X-GG) aqueous solutions were prepared at room temperature (25ºC) at three different concentrations (0.8, 1, and 1.2 % w/w).

Commercial xanthan and guar gum were used for analysis, with characteristics according to the producer's specification.

Xanthan gum and guar gum were dissolved in water and left at room temperature for 4 h to total dissolution.

Double-distilled water was used to prepare solutions and emulsions. Emulsification was performed on a laboratory homogenizer POLYTRONR KinematicaGmbH PT-G 45/80, (Switzerland) for 30 sec at 523s^{-1} and 20°C. The oily phase for oil-in-water (O/W) model emulsions was sunflower oil at volume fraction 30%, v/v.

Commercially available sunflower oil was obtained from local market and incorporated into emulsion preparations without further purification.

Rheological measurements, apparent viscosity and shear stress of model emulsions were measured at various shear rates via digital viscometer FUNGILAB PREMIUM (Spain).

Power law model (Eq. (1)) was used to analyze the flow curves:

$$\tau = K.(\dot{\gamma})^n \quad , \qquad (1)$$

where τ (Pa) is shear stress, $\dot{\gamma}$ (s^{-1}) is shear rate, **n** (no dimensional) is flow behavior index and **K** (Pa. s) is consistency index.

Emulsion stability was evaluated visually by measuring the extent of gravitational phase separation. For this test, 10 ml of the prepared emulsions were transferred in graduated cylinders at ambient temperature (25 ±1 C°).

RESULTS AND DISCUSSIONS

The influence of temperature and gum concentration on the rheological characteristics of the flaxseed solutions is shown in Figure 1. The increase in gum concentration led to the increaing viscosity and non-Newtonian behavior. These results are in accordance with previously reported results by Chen H et al., 2006. The most common reason of the shear thinning behavior in FG solutions is the disruption of particle aggregates caused by the increase in shear rate. The solution viscosity increased with temperature decrease. Flaxseed gum is a hydrocolloid with good water-holding capacity and similar to other gums is influenced by temperature (Dhiaa, 2012).

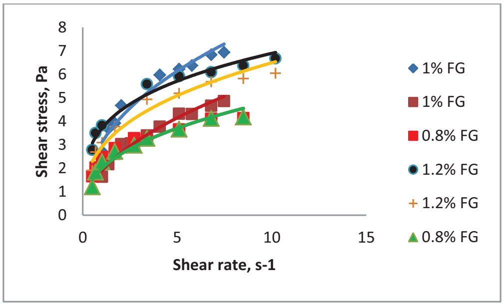

Fig.1 Shear stress versus shear rate for FG solutions with different concentration of gum at 25°C (▲, ♦, ●) and 60°C (■, ■, +)

The influence of temperature and pH on the viscosity of the oil-in-water emulsions with flaxseed gum is illustrated in Figure 2.The emulsions showed shear-thinning flow behavior. The viscosity decreased with increasing the shear rate. The results indicate that temperature did not affect the viscosity of the O/W emulsions but this viscosity increased with decreasing pH. These results are necessary for future use of FG gum in food applications.

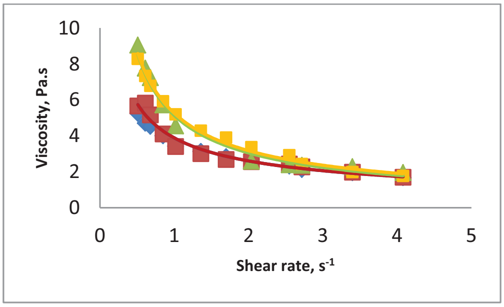

Fig. 2 Viscosity of oil-in-water emulsions with 1 % FG at 25°C, pH- 6.5-7 -♦, at 25°C, pH- 4- ▲; 60°C, pH- 6.5-7 - ■ and 60°C, pH- 4 - ■

The rheological characteristics of O/W emulsions with different concentration of FG were illustrated by the flow curves (shear stress versus shear rate) shown in Fig. 3. They demonstrated the rheological behavior of the samples. The viscosity decreased with increasing shear stress (pseudoplasticity). The differences between the viscosity of emulsions with 1 and 1.2 % FG were not significant. The emulsions exhibited a shear-thinning behavior that may be caused in part by the presence of aggregated particles.

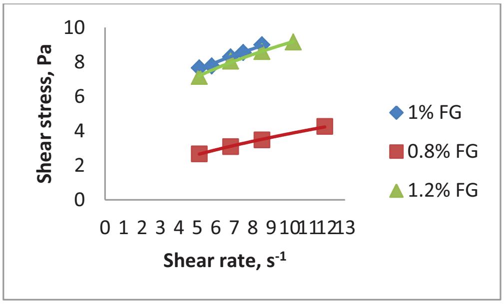

Fig 3 Shear stress versus shear rate for FG emulsions with different concentration of FG

O/W emulsions with different hydrocolloids were analyzed – Flaxseed Gum (FG), Xanthan Gum (XG) and Xanthan + Guar Gum (X-GG). The data of the shear stress versus shear rate for the emulsions fitted well the power law model equation (the values of R^2 were higher than 0.95). Table 1 shows the effect of different hydrocolloids of different concentrations on the consistency index (k) and flow behavior index (n) of oil-in-water emulsions.
According to Table 1, it can be observed that the flow behavior index (n) increased with decreasing the hydrocolloids concentration (HYDC). The increase of (HYDC) led to a higher viscosity (higher k values) and pseudoplasticity (lower n values). Regarding the type of hydrocolloid, the results indicated that the emulsions with X-GG showed the highest viscosity.
The consistency index K of model emulsion with FG were lower than the emulsion with other thickening agents.
The data of emulsion stability (ES) were collected and evaluated. The emulsions with different hydrocolloids thickeners exhibited stability during the entire investigated period.

Table 1 Effect of the type of hydrocolloid at different concentrations on the consistency index (k) and flow behavior index (n) of oil-in-water emulsions

Hydrocolloids	%, w/w	k (Pa.s)	n
FG	0.8	1.1^{a}	0.54^{a}
	1	2.67^{b}	0.48^{b}
	1.2	3.57^{c}	0.43^{b}
XG	0.8	12.17^{d}	0.18^{c}
	1	18.38^{e}	0.18^{c}
	1,2	19.37^{f}	0.11^{d}
X-GG	0,8	10.17^{g}	0.77^{e}
	1	22.95^{h}	0.62^{f}
	1,2	29.24^{i}	0.55^{a}

Different letters mean significant differences ($p<0.05$) in the same column

CONCLUSIONS

Flaxseed gum exhibit good thickness property and can be used as a thickener agent in O/W food emulsions. The results showed that temperature did not affect significantly the viscosity of model emulsions.
The viscosity of all evaluated model emulsions increased with decreasing pH.
The rheological characteristics of the investigated oil in water emulsions showed dependency on the type and concentration of the used thickeners. The viscosity increased with increasing of gum concentration.
The viscosity increasing was most pronounced at the emulsions with X-GG.
The model emulsions with flaxseed gum exhibited non-Newtonian behavior. The analysed samples with higher viscosity presented pseudoplasticity.
Regarding the measured emulsions stability, all samples were stable over the storage period at room temperature.
The results indicated that the viscosity of emulsion with FG was the lowest compared with other thickeners. FG should be used in combinations with other hydrocolloids for food technologies application.

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