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Effect of combined treatments on viscosity of whey dispersions

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Abstract

Whey proteins, enriched protein fractions from milk, are of great interest as ingredients due to nutritional value associated with its functional properties. These proteins could have their structural properties improved when some treatments are applied, such as thermal and gamma irradiation or when some compounds are added. The current work aimed to study the viscometer behavior of whey dispersions submitted to two different combined treatments: (1) thermal plus irradiation and (2) thermal plus vacuum and N_2 plus irradiation. Dispersions of whey protein in water (5% and 8% protein (w/v) base) and containing proteins and glycerol at ratios 1:1 and 2:1 (protein:glycerol) were submitted to both combined treatments. The irradiation doses were 0, 5, 15 and 25 kGy. The viscosity of the two combined treatments and for four levels of absorbed doses is presented and the combined effects are discussed. The thermal treatment combined with gamma irradiation contributed to increase the viscosity as irradiation doses increases for both (5% and 8%) concentrations of proteins ($p<0.05$). For protein and glycerol solutions, the irradiation dose seemed to result in a slightly increase. The vacuum applied before the irradiation showed a small contribution.

Keywords: Viscometer; Whey protein; Gamma irradiation; Combined treatments

1. Introduction

The whey concentrate milk protein could have their structural properties improved when some treatments are applied, such as thermal and gamma irradiation or when some compounds are added (Sabato et al., 2001). Heating milk above 70°C predominantly induces the denaturation of whey proteins and their complex formation with casein micelles (Beaulieu et al., 1999). When whey proteins are heat-denatured at low ionic strength, they form aggregates. Temperature associated to rheological trends suggested that hydrophobic forces are responsible for gelation (Mleko and Foegeding, 2000). One study about edible films showed the gamma irradiation was efficient for inducing cross-links in protein solutions forming films. The cross-linking reactions affected moderately the protein structure. Combination of irradiation and thermal treatments of the films resulted in an increase in mechanical and physic-chemical properties of these films (Lacroix et al., 2002). When ovalbumin (OVA) and bovine serum albumin (BSA) were irradiated in the presence of N_2, the molecular mass increased significantly while in O_2 atmosphere, the molecular mass increased slightly at low dose range but decreased at a higher dose showing that oxygen prevents aggregation (Kume and Matsuda, 1995).

Abbreviations: IT5%, thermal plus irradiation in 5% protein solution (w/v); ITV5%, thermal plus vacuum and N_2 plus irradiation in 5% protein solution (w/v); IT8%, thermal plus irradiation in 8% protein solution (w/v); ITV8%, thermal plus vacuum and N_2 plus irradiation in 8% protein solution (w/v); IT11, thermal plus irradiation in 1:1 (protein:glycerol) solution (w/v); ITV11, thermal plus vacuum and N_2 plus irradiation in 1:1 (protein:glycerol) solution (w/v); IT21, thermal plus irradiation in 2:1 (protein:glycerol) solution (w/v); ITV21, thermal plus vacuum and N_2 plus irradiation 2:1 (protein: glycerol) solution (w/v)

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The objective of this work aimed to study the viscometer behavior of whey dispersions in different concentrations (5% and 8%) and mixed with glycerol (1:1 and 2:1, protein:glycerol) submitted to two different combined treatments: (1) thermal plus irradiation and (2) thermal plus vacuum and N_2 plus irradiation.

2. Experimental

2.1. Materials

New Zealand Milk Products, New Zealand, provided whey protein concentrate (Alacen 392). Dispersions containing protein were prepared in distilled water with a total protein concentration of 5% and 8% (w/v). Dispersions containing proteins and glycerol (Glycerol, 99.5%, was from CAAL, SP, Brazil) at ratios (1:1 and 2:1, protein:glycerol) were prepared in distilled water with a total protein concentration of 8% (w/v). The solutions were kept at 4°C until irradiation and measuring.

2.2. Treatments

The four dispersions (5%, 8%, 1:1 and 2:1) were heated at 60°C during 20 min. Each solution was fractionated in two parts. One was irradiated in three levels 5, 15 and 25 kGy, without any modified atmosphere. The second one was evacuated and passed N_2 during 30 min and after, was irradiated in three levels 5, 15 and 25 kGy.

The irradiation was performed in a ^{60}Co Gammacell 220 (AECL), at a mean dose rate of 5.59 kGy/h and at room temperature. Dosimetry was carried out using an Amber routine dosimeter (Harwell, United Kingdom) and dose rate was established using a Fricke reference dosimeter to plot calibration curves. The whole dosimetry system is in IDAS program from International Atomic Energy Agency.

2.3. Viscosimetry

Viscosity measurements were carried out using a Brookfield viscometer, model LV-DVIII, spindle SC4-18, as described previously (Sabato and Lacroix, 2002; Bernardes and Del Mastro, 1994), at temperature at 10.0 ± 0.1°C, employing a Neslab water bath. The measurements were carried out at shear rate 330 seg^{-1} (250 rpm).

For each measurement, four replicates were carried out, in different days. The set of data from the whole experimental design was submitted to a statistical treatment, consisting of F-test between treatments and ANOVA among all data (Statistica 5.1, StatSoft, 1998).

3. Results and discussion

The averages of the measurements of viscosity, and their standard deviation, for the whole experimental design (two treatments: IT and ITV; four irradiation doses: 0, 5, 15 and 25 kGy; and four solutions: 5%, 8%, 1:1 and 2:1) are presented in Tables 1 and 2. These results are better visualized in Figs. 1 and 2, where Fig. 1 shows the viscosity related to 5% and 8% whey solutions and Fig. 2, to whey and glycerol solutions (at ratios 1:1 and 2:1).

The ITV treatment (evolving vacuum and N_2 plus thermal and irradiation) for 5% and 8% whey solutions did not contributed as we could expect. On the other hand, the ITV treatment brought significant improvement ($p < 0.05$) for whey and glycerol solution at ratio 1:1 in the 15 kGy dose and for whey and glycerol solution at ratio 2:1 in 15 and 25 kGy doses (Table 1). This fact can be attributed to the plasticizer role. Indeed, glycerol, a polyol, was found to enhance significantly the formation of cross-linkings within protein chains (Brault et al., 1997).

Irradiation caused an improvement for protein solutions (5% and 8%) in higher doses. In IT5% the

Table 1
Apparent viscosity (averages and standard deviation) for IT and ITV treatments, four levels of irradiation dose at 5% and 8% whey solutions

Dose (kGy)	Viscosity (cP)			
	5%		8%	
	IT	ITV	IT	ITV
0	2.31 ± 0.07 (a)	2.31 ± 0.07 (a)	3.27 ± 0.07 (a)	3.27 ± 0.07 (a)
5	2.33 ± 0.03 (ab)	2.36 ± 0.07 (a)	3.26 ± 0.03 (a)	3.30 ± 0.03 (a)
15	2.41 ± 0.04 (b)	2.46 ± 0.06 (b)	3.40 ± 0.03 (b)	3.41 ± 0.04 (b)
25	2.50 ± 0.03 (c)	2.55 ± 0.05 (c)	3.56 ± 0.03 (c)	3.54 ± 0.08 (c)

Note: Means values followed by different letters in the same column are significantly different ($p < 0.05$).

Table 2
Apparent viscosity (averages and standard deviation) for IT and ITV treatments, four levels of irradiation dose at 1:1 and 2:1, whey:glycerol solutions

Dose (kGy)	Viscosity (cP)			
	1:1		2:1	
	IT	ITV	IT	ITV
0	3.85±0.73 (a)	3.89±0.03 (a)	3.48±0.03 (a)	3.59±0.07 (a)
5	3.81±0.13 (a)	3.96±0.15 (a)	3.36±0.06 (a)	3.53±0.26 (a)
15	3.77±0.10 (a)	4.01±0.19 (a*)	3.28±0.15 (a)	3.56±0.28 (a*)
25	3.86±0.18 (a)	4.06±0.19 (a)	3.39±0.09 (a)	3.70±0.27 (a*)

Note: Means values followed by different letters in the same column are significantly different ($p<0.05$).
Means values followed by asterisk in the same row are significantly different ($p<0.05$) for a certain concentration.

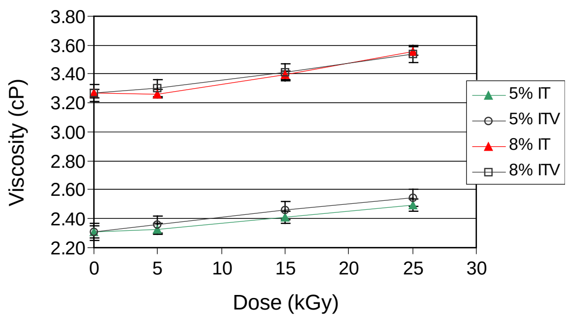

Fig. 1. Viscosity versus irradiation dose for whey dispersions (5% and 8%).

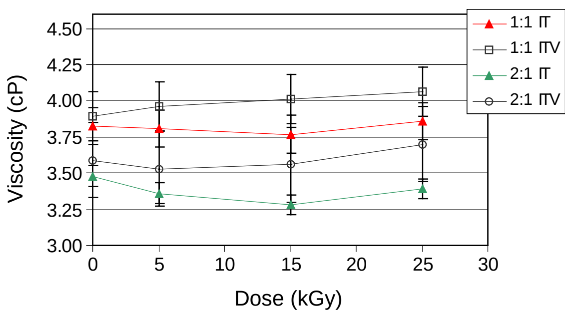

Fig. 2. Viscosity versus irradiation dose for whey dispersions (1:1 and 2:1).

apparent viscosity at a dose of 25 kGy was significantly higher ($p<0.05$). The same behavior was found for ITV5% (doses 15 and 25 kGy), for IT8% (doses 15 and 25 kGy) and for ITV8% (doses 15 and 25 kGy). For protein and glycerol solutions (ratios 1:1 and 2:1) the irradiation did not bring improvement, and the viscosity remained almost stable with oscillations with no statistical significance.

In addition, the rheological behavior of all treatments consisting of up and down shear rates and viscosity as a function of shear rate was studied (data not shown). Anyway, the data resulted from these studies demonstrated Newtonian behavior once all presented linear correlation between shear stress shear rate plots and correlation coefficients of these straight varied in the interval from 0.9984 till 0.9999 for all cases.

4. Conclusion

Thermal and irradiation treatments combined with inert atmosphere (vacuum and N_2) brought a significant improvement in whey solutions containing plasticizer, named glycerol, especially for higher doses (15 and 25 kGy). In protein solutions (5% and 8%), although inert atmosphere did not contribute for increasing the apparent viscosity, the gamma irradiation caused an enhancement in viscosity in higher doses.

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