Relative influence of α-lactalbumin and β-lactoglobulin on the viscosity of whey protein solutions

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ABSTRACT

In this study the viscosity of aqueous solutions of α-lactalbumin, β-lactoglobulin, whey protein concentrate (WPC) was studied to investigate the relative contribution of α-lactalbumin and β-lactoglobulin to the viscosity of whey protein solutions. Furthermore, the temperature dependence of the viscosity of the solutions was measured to investigate if the protein-protein interactions were different for the two proteins. The β-lactoglobulin solutions had the highest viscosity but the temperature dependence of the viscosity was the same for all protein solutions.

INTRODUCTION

Whey proteins are used as ingredients to improve texture and water binding in food matrices. The main whey proteins in bovine milk, α-lactalbumin and β-lactoglobulin, are both globular proteins but have different functional properties. Commercial whey protein powders contain mixtures of both α-lactalbumin and β-lactoglobulin, however, the relative contributions of α-lactalbumin and β-lactoglobulin to the total viscosity of whey protein solutions has not been studied in detail. The objective of this study was to investigate the relative contributions of α-lactalbumin and β-lactoglobulin to the viscosity of whey protein solutions. Furthermore, the two proteins contribution to changed viscosity at increasing temperature was explored.

MATERIALS AND METHODS

Solutions of α-lactalbumin, β-lactoglobulin and whey protein concentrate (all from Arla Foods Ingredients, Viby, Denmark) was prepared and then stored at 20°C for 24 h. The viscosity of the protein solutions was measured by capillary (Cannon Instrument Co., State College, PA, USA) and rotational viscometry (Bohlin C-VOR, Malvern Instruments, Malvern, UK) at various temperatures. Protein composition of all protein powders were analyzed by capillary electrophoresis with a Hewlett-Packard 3D CE system (Agilent Technologies A/S, Nærum, Denmark).

RESULTS AND DISCUSSION

Chemical composition of powders

The water content in all three protein powders were between 9.9 and 7.7 % (w/w). The concentration of lactose was less than 1 % (w/w) in all three protein powders.

The whey protein concentrate (WPC) contained 11 % (w/w) and 89 % (w/w) α-lactalbumin and β-lactoglobulin, respectively, of the total protein content. A broader peak in the capillary electrophoresis chromatogram from the analysis of the α-lactalbumin powder indicated that the proteins to some extent had undergone lactosylation.

Effects of protein concentration on viscosity

Solutions of all three protein powders showed Newtonian flow behaviour below 20 % (w/v). Relationships between viscosity and concentration (i.e. log(viscosity) *vs.* concentration) was found for solutions of α-lactalbumin, β-lactoglobulin and whey protein concentrate at concentrations 5-15 %, w/v (Fig. 1). Thus, the data in Fig. 1 could be fitted well by the straight line (Eq. 1)

$$Log(\eta) = A \cdot c + B \qquad (1)$$

, where η is the viscosity, c the powder concentration (%, v/w), and A and B constants. A represents the slopes of the straight lines in Fig. 1 and reflects the level of concentration dependence to the viscosity (Table 1). The viscosity was highest and most concentration dependent for solutions of β-lactoglobulin and least concentration dependent for α-lactalbumin (Table 1). The concentration dependence for the WPC was found to be A = 5.98 and close to the value of A = 5.9 reported by Tang et al[1].

Effects of temperature

The viscosity of protein solutions (10 %, w/w) in the temperature interval 5-60 °C followed the Arrhenius relationship (Eq. 2).

$$\eta = A \cdot e^{\frac{E_A}{RT}} \qquad (2)$$

, where η is the viscosity, A the pre-exponential factor, E_A the activation energy, R the natural gas constant and T the temperature. High values of E_A indicate more rapid change in viscosity with temperature[2]. In the case of globular proteins in aqueous solutions, large values of E_A is a result of increased interactions between proteins probably due to unfolding of proteins[2,3]. The values of E_A for the three different protein solutions in Table 2 were not different from each other and that showed that α-lactalbumin and β-lactoglobulin are not that different in terms of changed protein-protein interactions during temperature changes. All the values of E_A for the protein solutions were comparable to values reported in the literature[1,4,5].

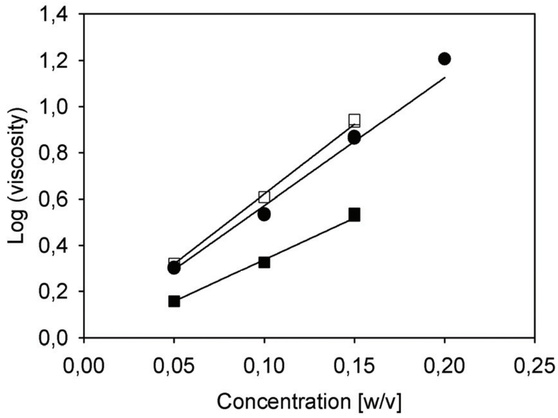

Figure 1. Viscosity of α-lactalbumin (■), β-lactoglobulin (□) and whey protein concentrate (●) at various concentrations. The measurements were performed by means of capillary viscometry at 21 °C. The straight lines indicate the linear relationships between the logarithm of the viscosity and the protein concentration (Eg. 1) for the three protein powders in aqueous solutions.

Table 1. Slopes of linear relationships (Eq. 1) visualised in Fig. 1. The magnitudes of the slopes indicate the level of concentration dependence to the viscosity of the different protein powders in aqueous solutions.

Protein powder	***A* in Eq. 1**
α-lactalbumin	3.75
β-lactoglobulin	6.17
WPC	5.98

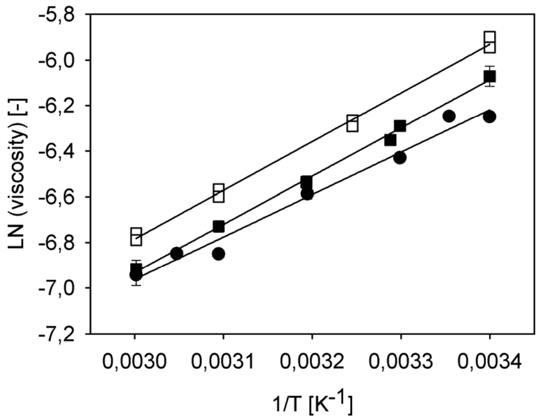

Figure 2. Viscosity of α-lactalbumin (■), β-lactoglobulin (□) and whey protein concentrate (●) solutions (10 %, w/v) at various temperatures. The measurements were performed by means of capillary viscometry. Measured viscosities followed the Arrhenius equation (Eq. 2).

Table 2. Activation energy (E_A) of flow using the Arrhenius model (Eq. 2) for aqueous solutions (10 %, w/v) of α-lactalbumin, β-lactoglobulin and WPC.

Protein powder	E_A
α-lactalbumin	18.6
β-lactoglobulin	17.4
WPC	17.9

Effect of protein composition

The viscosity of protein solutions (10 %, w/v) with different ratios of α-lactalbumin and β-lactoglobulin increased when the relative concentration of β-lactoglobulin increased (Fig. 3). This showed that β-lactoglobulin, relatively, more contributes to the total viscosity of whey protein solutions. This is in line with the results in Fig. 1 that β-lactoglobulin solutions have higher viscosities.

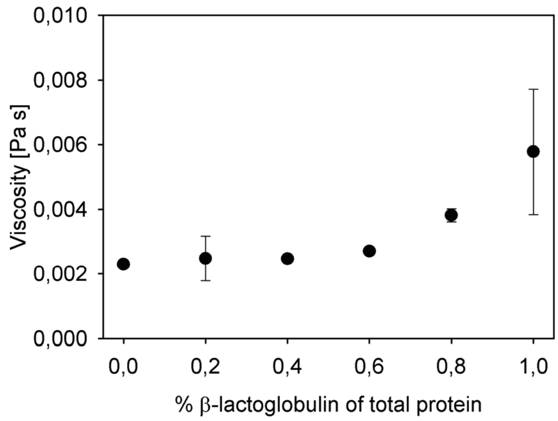

Figure 3. Viscosity aqueous protein solutions (10 %, w/v) with different ratios of α-lactalbumin and β-lactoglobulin. The measurements were performed by means of capillary viscometry at 21 °C. Means of three measurements. Bars indicate standard deviation.

CONCLUSION

In this study we found that solutions of β-lactoglobulin had higher viscosities than solutions of α-lactalbumin. The activation energy (E_A) of flow was not that different between the protein solutions and that revealed that the protein-protein interactions did not change differently between α-lactalbumins, β-lactoglobulins or between α-lactalbumin and β-lactoglobulin when the temperature increased. The relatively very small contributions of α-lactalbumin to the viscosity of protein solutions was also revealed when viscosities of α-lactalbumin and β-lactoglobulin solutions with different protein ratios was measured. For 10 % (w/v) protein solutions, the viscosity first increased when β-lactoglobulin was 60 % (i.e. 6 %, w/v) of the total protein concentration.

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REFERENCES

1. Tang, Q., Munro, P.A. and McCarthy, O.J. (1993), "Rheology of whey protein concentrate solutions as a function of concentration, temperature, pH and concentration", *J. Dairy Res.*, **60**, 349-361.

2. Herceg, Z. and Lelas, V. (2005), "The influence of temperature and solid matter content on the viscosity of whey protein concentrates and skim milk powder before and after tribomechanical treatment", *J. of Food Engineering*, **66**, 433-438.

3. Rha, C.K. and Pradipasena, P. (1986), "Viscosity of proteins", in J.R. Mitchell and D.A. Ledwars (Eds.), *Functional properties of food molecules*, Elsivier, New York, pp. 95-97.

4. Morision, K.R. and Mackay, F.M. (2001), "Viscosity of lactose and whey protein solutions", *Int. J. Food Properties*, **4**, 441-454.

5. Marcelo, P.A. and Rizvi, S.S.H. (2008), "Physicochemical properties of liquid virgin whey protein isolate", *Int. Dairy J.*, **18**, 236-246.