Microstructure and viscosity of yoghurt with inulin added as a fat-replacer

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ABSTRACT

Replacement of milk fat with inulin in yoghurt manufactured in 1 kg batches was investigated. Up to 3% milk fat was replaced with a commercial inulin product and the permeability, syneresis and flow curves of the yoghurts were obtained. The microstructure was evaluated using confocal laser scanning microscopy and image analysis.

The results show a gradual coarsening of the acid-induced protein network in the manufactured yoghurts with increasing amount of inulin. This was also reflected in increased syneresis, increased permeability and generally lower shear stress.

The sample containing 0.1% fat and 3% inulin, however, exhibited a flow-behaviour comparable to the sample containing 1.1% fat, pointing to a possible synergistic effect between the fat globules in milk and the added inulin.

INTRODUCTION

Inulin is an oligosaccharide consisting of linear chains of fructosyl units joined by β (2-1) bonds that renders it resistant to hydrolysis in the human stomach and intestine. Inulin thus passes directly to the colon where it is fermented by the *Bifidobacteria*, a group of bacteria that have a number of reported health benefits at high population levels in the intestine. Inclusion of inulin in yoghurt can thus provide the same benefit to the consumer as a yoghurt incorporating *Bifidobacteria* and further substantiate yoghurt as a functional food, i.e. as a prebiotic product with enhanced physiological effect[1].

Furthermore, it is of interest to lower the fat content of yoghurt, in order to lower the intake of saturated fatty acid and thus reduce risk of obesity and cardiovascular diseases. However, without the participation of the fat-globules in network formation, the viscosity of the yoghurt is much reduced and unsatisfactory. The present investigation was therefore undertaken in order to investigate the effect of inulin added as a partial fat-replacer on the viscosity and microstructure of yoghurt.

MATERIALS AND METHODS

Materials

Skim milk powder was obtained through Fællesindkøbet (DK-6000, Kolding, Denmark). Commercial cream with 38 % fat was bought in a local supermarket. The starter culture used was standard yoghurt starter (YC 470 from Chr. Hansen A/S, DK-2970 Hørsholm, Denmark). The inulin used was a commercial product derived from chicory root (Raftiline HP, Orafti, 3300 Tienen, Belgium). This product has an average degree of polymerisation exceeding 23% according to the manufacturer, and is recommended for replacement of fat.

Yoghurt manufacture

Yoghurt was made in 1kg batches using an incubator and a small-scale homogeniser (Rannie, DK-2620 Albertslund, Denmark). The process is outlined in Fig. 1.

The amount of inulin was varied inversely with the amount of fat and the following 6 yoghurts were made: 0% fat + 0% inulin, 0% inulin 3% fat, 0.1% inulin + 3% fat, 1% inulin + 2.1% fat, 2% inulin + 1.1% fat, 3% inulin + 0.1% fat.

Flow curves

Flow curves (shear rates from 20 s^{-1} to 250 s^{-1}) were obtained using a Bohlin V88 viscosimeter fitted with a C25 measuring system. A waterbath kept the sample and measuring system at 15°C for the duration of the measurement.

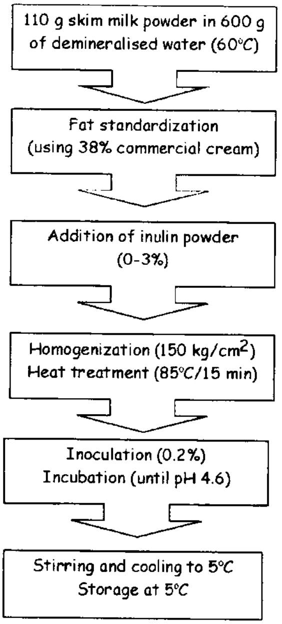

Figure 1: Outline of the process used for manufacture of yoghurt

Syneresis

100g of yoghurt was poured into teabag hung on a support and placed on a scale. The whey released from the yoghurt was collected, and the weight of the yoghurt in the tea bag was recorded every minute for a duration of 20 min. Syneresis was expressed as the whey lost in grams per 100g of yoghurt. The assembly was kept at a temperature between 5 and 8°C during the experiment.

Confocal laser scanning microscopy (CLSM)

A small amount of sample was carefully transferred to a small concavity on a microscope slide. A drop of solutions of flourophores (fluorescein isothiocyanate for the protein phase and Nile Red for the fat phase) were put onto a coverslip, which was then left to dry. The cover slip was then placed over the sample, which was examined using a Leica TSC SP system (Leica, Heidelberg, D) with an inverted microscope (Leica DM IRBE) and an ArKr laser.

Permeability

Permeability was determined according to Færgemand & Qvist[2].

Image analysis

Images from CLSM was converted to greyscale and the autocorrelation function was obtained in the following manner using a program defined in MathCad 2000: The image was defined as a matrix of pixels with a given greyscale value (from 0 to 255). This matrix was then shifted a distance ranging from 1 to 50 pixels and the correlation between superimposed values in the original and the shifted matrix was calculated as a function of pixel distance. In the case of a fine microstructure the autocorrelation function will drop off rapidly with shifting distance, as a fine structure implies that only a small shift is necessary to have a given particle pixel occur outside the particle after the shift. Conversely, a coarser structure will be indicated by a slower drop-off with distance. Hence the initial rate of decrease of the autocorrelation function was determined as the 1st order derivative obtained by Savitzky-Golay differentiation.

All experiments were done in duplicate and image analysis was performed on four separate images.

RESULTS

The effect of substituting fat for inulin on the flowcurves of the manufactured yoghurt is shown in Figure 2. It is obvious that the fat, as expected, had an important role in building consistency in yoghurt, as the shear stress increased linearly with the fat content of the yoghurt. The fat globules are known to associate with the protein network that constitutes an acid milk gel[3].

The permeability and syneresis of the yoghurts made with different levels of fat and inulin is illustrated in Figure 3. There is a strong correlation between the two parameters and the effect of having fat globules present to strengthen the formed gel network is obvious from these results: As the fat content was reduced, both the permeability and syneresis increased.

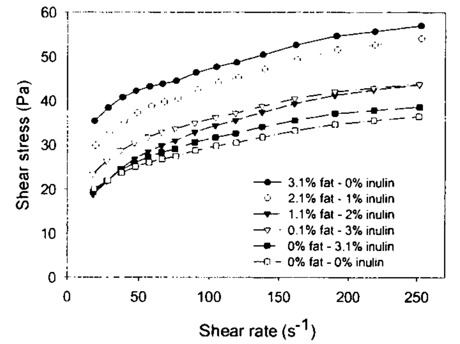

Figure 2: Flow curves for yoghurts made with varying degrees of substitution of fat with inulin.

Addition of inulin (3%) reduced the permeability coefficient compared with the sample without fat or added inulin, possibly by increasing the viscosity of the serum phase or by partially plugging the pores, but the effect on syneresis or flow curves was not pronounced. However, when 3% inulin was added together with 0.1% fat the shear stress at shear rates exceeding 100 s^{-1} was very similar to what was obtained with the sample containing 1.1% fat and 2.1% inulin, indicating that perhaps a synergistic effect is present between inulin and fat at low levels of fat.

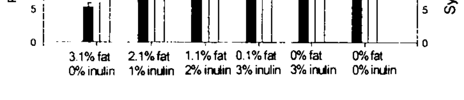

Figure 3: Permeability (black bars) and syneresis (grey bars) of yoghurts made with varying degrees of substitution of fat with inulin.

The microstructure of the manufactured yoghurts did not differ when inspected visually. Using image analysis, i.e. by using the initial rate of decrease of the autocorrelation function to quantify the coarseness, the microstructure could be related to the permeability and the syneresis as well as to the flow properties (Figure 4). Substituting fat with inulin resulted in a coarser structure in the yoghurt, and this was reflected in an increased permeability, increased syneresis and a lower shear stress.

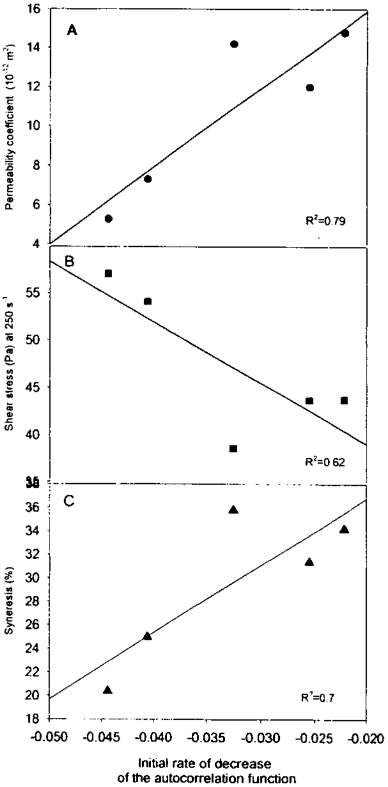

Figure 4: The microstructure of manufactured yoghurts, characterized by the initial rate of decrease of the autocorrelation function, related to the permeability, shear stress at 250 s^{-1} and syneresis.

It should be noted that the aberrant sample in Figure 4 (A to C) is the sample that contains 0% fat and 3% inulin, and it seems this sample has higher permeability, lower shear stress (at 250 s^{-1}) and higher syneresis than expected from the image analysis. Thus the effect of having a small amount of fat present (0.1%) could be an association between inulin and fat, coarsening the acid-induced network, strengthening the overall structure and also hindering excessive syneresis and permeability perhaps by increasing viscosity or partial plugging of pores.

CONCLUSION

The present work has shown that addition of increasing amounts of inulin as a fat-replacer to yoghurt leads to a coarser texture and a correspondingly higher permeability coefficient, increased syneresis and generally lower shear stress (at rates from 20 to 250 s^{-1}). Thus, the examined inulin preparation was not able to replace the fat and retain the texture or consistency of the yoghurt with 3% fat. The sample containing 0.1% fat and 3% inulin exhibited, however, a similar flow-behaviour (at shear rates exceeding 100 s^{-1}), to the sample containing 1.1% fat, pointing to a possible synergistic effect between the fat globules in milk and the added inulin.

Using the initial decrease in the autocorrelation function obtained from CSLM images to quantify the coarseness of the yoghurt gel network has been shown to correlate well with the permeability of the gels, the syneresis and the shear stress.

The microstructural analysis corroborated the observation on the sample containing 0.1% fat and 3% inulin, as this sample exhibited a somewhat coarser microstructure compared to the sample without fat. This coarsening was, however, accompanied by a strengthening of the acid-induced gel network and not by an increased syneresis or permeability compared to the sample with no fat.

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