Gel and hot paste rheology of coarse starch rich fractions from air classified milled pea and faba bean

Catherine Taylor Nordgård[1], Cátia Saldanha do Carmo[2], Ulla Holopainen-Mantila[3], Pia Silventoinen[3], and Kurt I. Draget[1]

[1] Department of Biotechnology and Food Science, NTNU, Trondheim, Norway
[2]NOFIMA, Norwegian Institute for Food, Fisheries and Aquaculture Research, Ås, Norway
[3]VTT Technical Research Centre of Finland Ltd., Espoo, Finland

ABSTRACT

The FoodProFuture project aims to develop a knowledge platform for turning raw materials from plants into tasty, healthy and attractive food products full of protein. Dried peas and faba beans (cultivated in Norway) were milled and air classified giving rise to a fine fraction and a coarse fraction. All fractions contained both protein and starch with the fine fraction being enriched in protein and the coarse fraction being enriched in starch. To maximise the exploitation of Norwegian plant based raw materials it is of interest to investigate the functional properties of not only the protein rich fine fraction but also the starch rich coarse fraction.

Aqueous suspensions of the starch rich fractions were prepared, loaded on to the rheometer fitted with parallel serrated plates at 20°C, heated to 90°C with a 30 minute hold time, then cooled to 20°C under continuous rheological monitoring (1Hz 0.1% strain). Frequency and strain sweeps were carried out immediately after cooling to 20°C or during the hot paste stage at 90°C and after cooling to 20°C.

For both the pea and faba bean the hot paste stage showed gel behavior with elastic dominance during the frequency sweep and a strain of over 50% necessary to induce viscous dominance although the moduli values were low compared to the gel phase at 20°C.

INTRODUCTION

There is a growing consumer interest in plant-based foods, driven by both health and environmental concerns. The FoodProFuture project aims to develop a knowledge platform for turning raw materials from Norwegian crops into tasty, healthy and attractive protein rich food products. Environmental assessments show that plant proteins have a lower climate impact than protein from meat, seafood and dairy products. Grain legumes give high protein yields and are important to increase sustainability in cropping systems. Maximising the utilization of the whole legume, which includes starch rich as well as protein rich fractions, improves both the environmental profile of plant-based foods and the economic feasibility of grain legume crops. Against this backdrop, it is of interest to investigate the functional (rheological) properties of not only the protein rich fine fraction but also the starch rich coarse fraction (presented here) from Norwegian grain legume crops.

METHODS

Yellow peas (Pisum sativum L. var. Ingrid) and Faba beans (Vicia faba L. var. Kontu) were grown and harvested in 2017 at Vollebekk, Norway. Test samples were produced by milling and air classification by VTT.

Sample code	Description	Protein content (% dm)	Moisture content (%)	Starch content (% dm)
FPF6	Starch-rich fraction from whole peas	8.6	6.66 ± 0.20	58.57 ± 2.43
FPF23	Starch-rich fraction from whole faba beans	21.6	8.55 ± 0.13	51.73 ± 0.66

Table 1. Characteristics of the coarse starch rich fraction from whole pea and faba bean

The gelling properties of the coarse starch-rich fractions were assessed. Briefly, 1.5g of dry sample was suspended/solubilised in 10ml of MQ water with stirring at room temperature and pressure. Heat induced gelation was investigated using a Kinexus Ultra+ (Malvern panalytical, Malvern, UK) fitted with a deep base plate and 40mm diameter serrated upper plate with a 1.5mm gap. The sample was completely covered in low viscosity silicon oil during measurement to prevent any dehydration. The rheological behaviour of the sample was continuously monitored (1Hz and 0.1% strain) under heat induced gelation (20-90°C, 2°C/minute, 30-minute hold at 90°C, 90-20°C, 2°C/minute) followed by a frequency sweep (0.01-100Hz, target strain 0.1%) and strain sweep (0.1-100% strain, 1Hz). To investigate the rheological properties of the hot paste phase a similar experiment was performed where the 30 minute hold time at 90°C was replaced by a frequency sweep and strain sweep plus a 5 minute hold time to maintain the same time exposure at 90°C. Again, the sample was subjected to frequency (0.01-100Hz, target strain 0.1%) and strain (0.1-100% strain, 1Hz) sweeps after cooling to 20°C.

RESULTS

The rheological properties of the coarse starch rich fractions during heat induced gelation were broadly comparable to what is seen in a typical viscoamylograph (which looks at starch viscosity under heat induced gelation), although the parameters measured are elastic and viscous moduli rather than viscosity. Both samples showed a rapid increase in G’ at around 62°C, before going through a maximum and fall-back, remaining stable during the hold at 90°C, and beginning to rise as the temperature reduced (Figure 1). The faba bean sample shows both the largest initial maximum and largest fall-back, but the pea sample shows the greater gel development as the temperature is reduced.

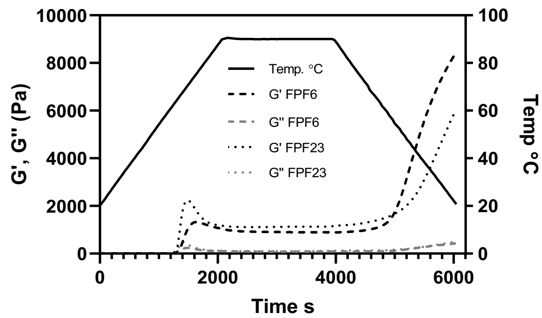

Figure 1. Heat induced gelation profile of FPF6 and FPF23 showing elastic modulus (G’) and viscous modulus (G’’).

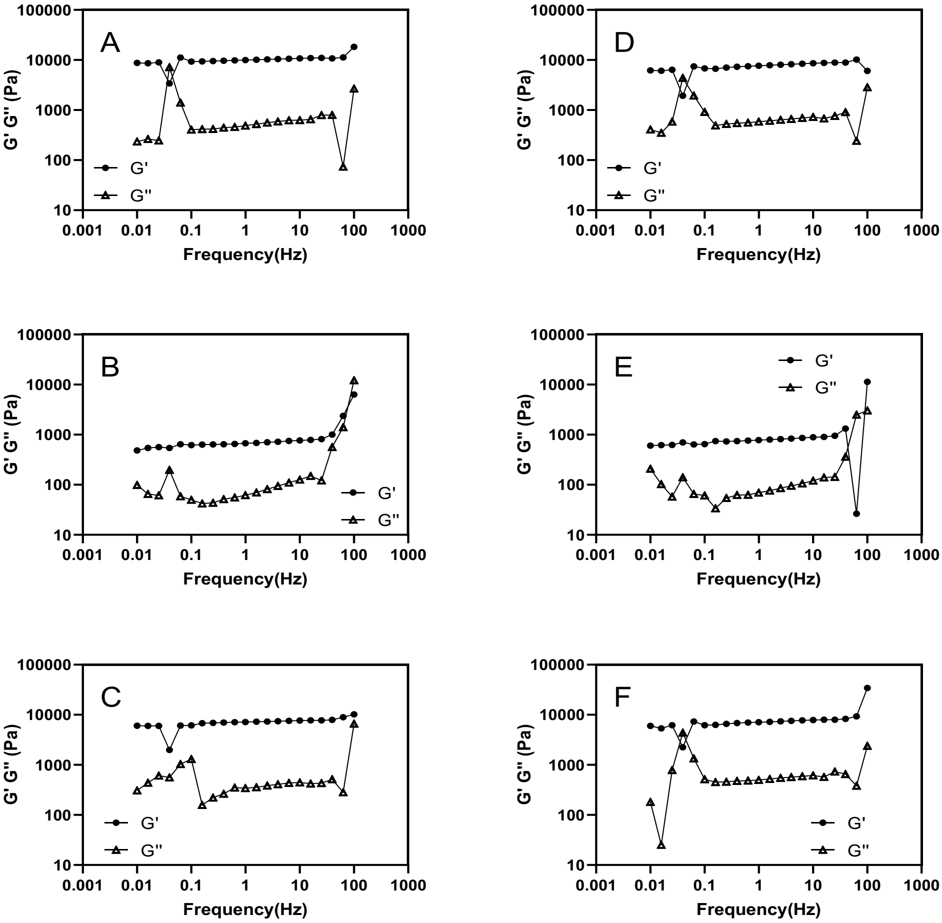

Figure 2. Frequency sweeps of starch rich pea fraction FPF6 at 20°C after completion of the standard gelling sequence (A), during the hold phase at 90°C (B) and at 20°C after the completed gelling sequence with frequency and strain sweeps at 90°C (C), and starch rich faba bean fraction FPF23 at 20°C after completion of the standard gelling sequence (D), during the hold phase at 90°C (E) and at 20°C after the completed gelling sequence with frequency and strain sweeps at 90°C (F).

The heat induced gelation sequence indicated that both coarse starch rich fractions from both pea and faba bean exhibited gel behaviour with G'>G'' as soon as the elastic modulus started to rise and maintained this elastic dominance throughout the gelation sequence. Frequency (Figure 2) and strain sweeps (Figure 3) carried out at 20°C after completion of the standard gelling sequence, during the hold phase at 90°C and at 20°C after the completed gelling sequence with frequency and strain sweeps at 90°C confirmed elastic dominant gel behaviour throughout the gelation sequence. The frequency sweeps showed elastic dominant behaviour over the whole frequency range (with the exception of an artefact at around 0.05Hz) and the strain sweeps showed a clear transition from small amplitude deformation (linear behaviour) to large amplitude deformation and destruction of the gel matrix. Both the frequency and the strain sweeps demonstrated that both the pea and faba bean starch gels has substantially

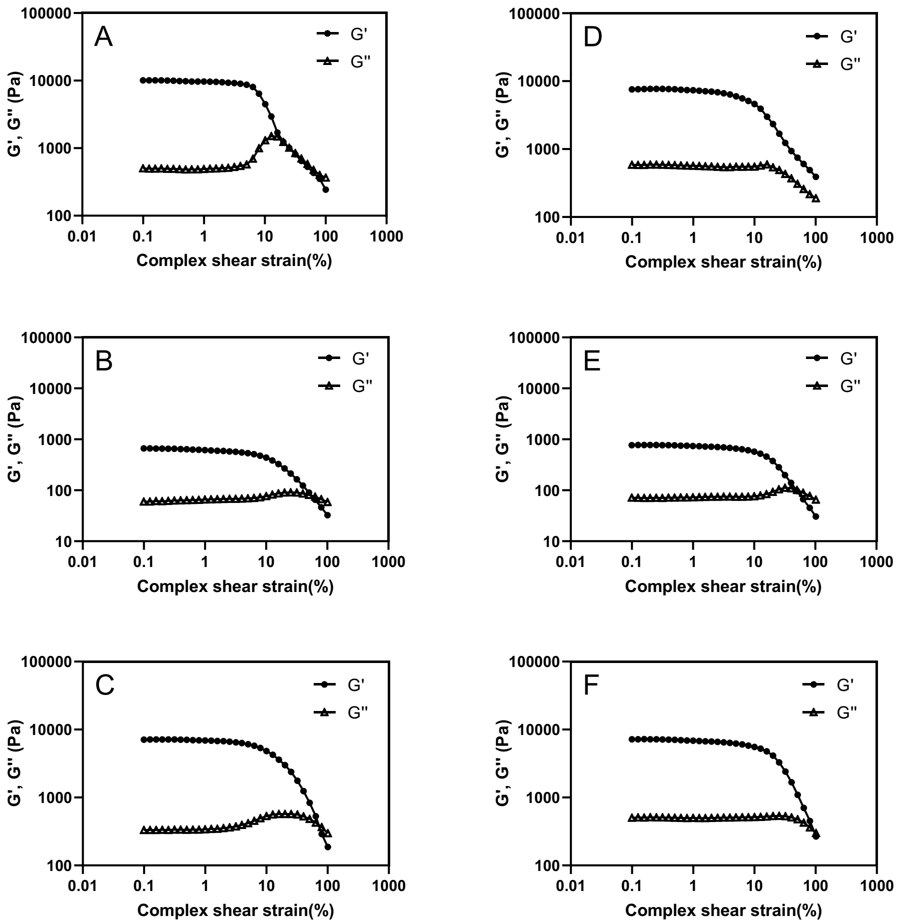

Figure 3. Strain sweeps of starch rich pea fraction FPF6 at 20°C after completion of the standard gelling sequence (A), during the hold phase at 90°C (B) and at 20°C after the completed gelling sequence with frequency and strain sweeps at 90°C (C), and starch rich faba bean fraction FPF23 at 20°C after completion of the standard gelling sequence (D), during the hold phase at 90°C (E) and at 20°C after the completed gelling sequence with frequency and strain sweeps at 90°C (F).

lower moduli values at 90°C (panels B and E in Figure 2 and 3) than at 20 °C (panels A, C, D and F in Figure 2 and 3). When comparing the stress strain relationship for the pea and faba bean gels under the three different conditions described above we see that the test temperature is the major determinant of gel behaviour, having a much larger influence than both mechanical history and whether the sample came from pea or faba bean (Figure 4). Interestingly mechanical history appears to influence gel behaviour predominantly in the large amplitude non-linear region (Figure 3 & 4). Overall, the behaviour of pea and faba bean gels were similar but it is worth noting that the pea gels showed more gel structure development during cooling and less during heating than the faba bean gels. This may reflect the higher protein content of the faba bean samples as proteins tend to undergo heat induced gelation. It may also reflect the greater starch content of the pea sample.

DISCUSSION

The coarse starch rich fractions obtained after milling and air classification from both

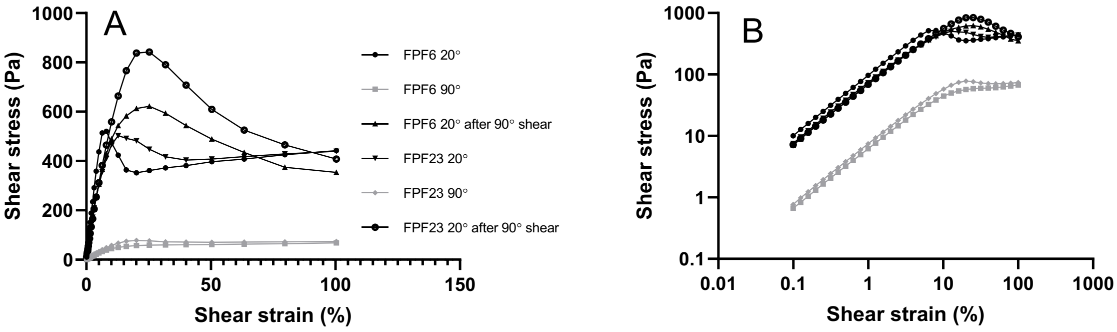

Figure 4. Stress strain relationship during the strain sweep presented in figure 3 above plotted on both a linear (A) and log (B) scale.

pea and faba bean are able to form typical starch type gels as a result of heat induced gelation. These fractions may potentially be used to optimise the functional properties of plant protein-based food products, avoiding the use of other additives, maximising the utilization of the Norwegian grain legume crops and, in the case of the faba bean fraction, also utilizing more of the total protein content of the grain legume.

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