Shear processing of rapeseed meal: effects on protein solubility.

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Introduction

The processing technologies used for feed manufacturing (i.e. pelletizing and extrusion) are complex systems in which the different processing factors and their effects can be confounded. The selected process parameters (i.e. temperature, moisture, screw configuration) have a direct effect on the system parameters (i.e. specific mechanical energy input, residence time, throughput). Changes on the process parameters in these complex systems will also affect the system parameters, making it difficult to predict the effects on the physical and nutritional quality of a diet.
Model systems, such as the shearing cell device, can help to isolate and explain the effects of individual processing factors on ingredients or diets. The shearing cell device can resemble the processing conditions during extrusion and allows an estimation of the mechanical energy input into the material via torque measurements, and a separation of the effects of mechanical energy from the effects of heat. It has been successfully used before to test the techno-functional properties of soy, rapeseed and lupine protein concentrates (Draganovic et al. 2014).
Processing can have major effects on the physicochemical characteristics of proteins. Heat processing usually leads to protein aggregation, which affects protein solubility. Furthermore, the molecular weight of protein aggregates changes with varying amounts of specific mechanical energy input (Fang et al. 2013), which could also be reflected on the solubility of proteins.
The main objective was to test the effects of mechanical energy and heat input on the physicochemical characteristics of the protein fraction in rapeseed meal. A secondary objective was to assess the effects of particle size and soaking time on the torque profiles of rapeseed meal.

Materials and methods

The shearing cell device was designed by the Laboratory of Food Processing Engineering of Wageningen University (Wageningen, The Netherlands). The device is able to produce shear stress in the material between the cones up to 2 bar, which reflects the conditions used during commercial extrusion processing. Heat is generated by a circulating water flow and monitored, along with torque, by a Thermo drive unit (ThermoScientific, Staffordshire, UK). The contact surface of both cones in the shearing device is serrated in order to avoid slippage of the material.
In the first experiment effects of temperature (70 vs. 140°C), rotational speed (50 vs. 100 rpm) and residence time (2 vs. 10 minutes) on the physicochemical characteristics of solvent-extracted rapeseed meal were assessed using a 2x2x2 factorial arrangement of treatments. Water was added to the rapeseed meal at 20% (w/w) and thoroughly mixed by hand. From this mixture, 20 g was used to fill the preheated shear cell, which was hydraulically closed immediately at a vertical compression force of 3500 N which was maintained constant throughout the shearing process. Water evaporation was prevented by adjusting the pressure in the closed space between the cones to 2 bar. Blank measurements of the torque were performed with an empty shear cell as a reference, in order to allow the calculation of specific mechanical energy input (SME).
In the second experiment the effects of particle size and soaking time of the same rapeseed meal were assessed after grinding in a Retsch mill through a 0.25 mm sieve. Water was added to this material either 12 hours before or immediately before the shearing experiment. This part of the study was performed at 140°C, 100 rpm and 5 minutes, with a water addition of 20% (w/w) and a shear cell filling of 20 g. A soy protein isolate (SPI) was processed under the same conditions and its torque profile determined for comparison reasons.

The nitrogen solubility index (NSI) in 0.2% KOH and the protein dispersibility index (PDI) in water were determined on the samples obtained from Experiment 1 using modifications of the methods described by Parsons et al. (1991) and the AOCS (1979), respectively.
The NSI and PDI measurements from Experiment 1 were statistically analysed using the proc glm procedure in SAS (2008). Interaction terms were not significant and were excluded from the model.

Results and discussion

The average torque profiles were not affected by the treatments in Experiment 1 nor in Experiment 2 (Figure 1). These findings suggest that it is not possible to put any mechanical energy in solvent-extracted rapeseed meal (Exp. 1) and that by changing particle size and soaking time this cannot be altered (Exp. 2). Moreover, the large difference between the torque profile of the SPI and rapeseed meal samples could indicate that the input of mechanical energy depends on the composition of the materials (i.e. protein and fibre contents) with influence on energy dissipation.
There were no effects of rotational speed or residence time on NSI or PDI of rapeseed meal. Nevertheless, significant effects of temperature ($p<0.001$) where found for both solubility parameters. The NSI was reduced from 34% in the unprocessed rapeseed meal to 31 and 13% on the 70 and 140 °C treated samples, respectively. According to Anderson-Hafermann et al. (1992), a NSI in 0.2% KOH of canola meal lower than 35% can be considered as an indication of overprocessing. PDI measurements were also significantly affected by temperature ($p<0.001$), but not by rotational speed or time. PDI was reduced from 7.8% in the untreated rapeseed meal to 6.9 and 4.6% in the 70 and 140 °C treatments, respectively.
We conclude that, under the conditions of these experiments, mechanical energy input into rapeseed meal is not possible. Furthermore, the solubility of proteins in rapeseed meal is highly sensitive to heat treatments. Future research will focus on elucidating the mechanisms that affect mechanical energy input into the materials and studying the effects of the mechanical energy input, heat and moisture on the physicochemical properties of proteins. The relation between the physicochemical changes and digestibility of the protein fraction will also be analysed.

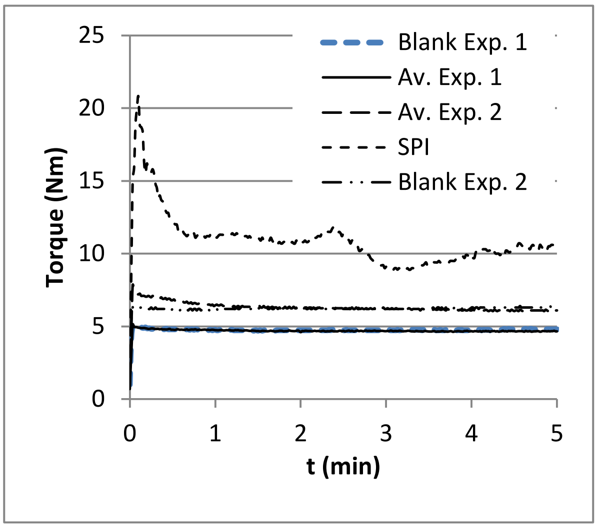

Figure 1. Comparison of the torque profile of soy protein isolate (SPI) and the average profiles obtained from the treatments and the blanks in Experiment 1 and Experiment 2.

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