Proteins Used for Plant-Based Food: How to Evaluate their Functionality

Relevant for: MCR, Starch Cell, Pressure Starch Cell, Protein, Pea, Soy, Plant-Based Foods, Meat Alternatives, Fish

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Plant-based proteins are a valuable alternative to animal-based proteins and have become increasingly important in the food industry in recent years. Reliable analytical methods are essential to understand the raw materials necessary to select the perfect ingredients and define the right processing parameters. The Starch Cell from Anton Paar offers the possibility to study the functionality of proteins under different thermomechanical conditions and in different mixtures. This allows correlation of the measured viscosity profiles with functional behavior such as water solubility and binding as well as denaturation.

1 Introduction

Plant-based protein ingredients are becoming increasingly popular in the food industry as alternatives to meat, fish, or dairy in order to reduce animal proteins and thus improve the sustainability for our diets. The proteins are usually mixed with water and other ingredients and can be further processed at elevated temperatures and pressures. Since proteins can be denatured under certain conditions such as heat, moisture, pH, pressure or shear, they can lose their native structure resulting in physical changes and different functionalities such as decrease in protein solubility.

During denaturation, the globular proteins hydrate and swell in the presence of water and heat. These granules burst after reaching a critical temperature and the tertiary structure unfolds. Upon cooling, the unfolded molecules align and crosslink to form a 3D network or gel.

One way to measure the functionality of proteins is to expose them to a temperature-stirring profile, as traditionally used to study the pasting behavior of starch, since denaturation can be analyzed similarly to starch gelatinization. During the pasting process, the starches or proteins are subjected to a temperature and stirring profile consisting of mixing, heating, holding and cooling. By monitoring the viscosity, conclusions can be drawn with regard to the functionalities.

2 Measurement method and samples

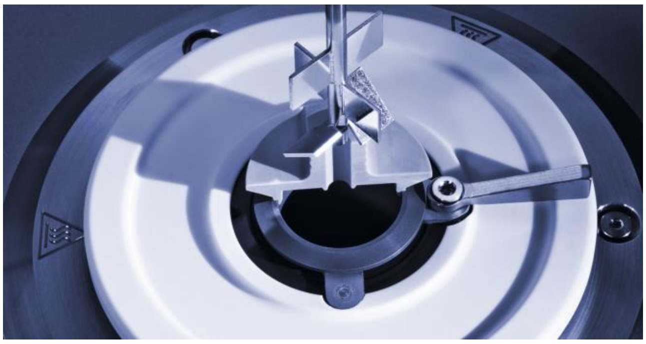

Figure 1: Starch Cell with stirrer to avoid sedimentation

All experiments were performed with an air-bearing Modular Compact Rheometer (MCR) and a Starch Cell, both from Anton Paar. The starch cell consists of an electrically heated temperature device and a counter-cooling system to ensure proper temperature control and fast heating and cooling rates. The measuring cup with a large specific surface for heat transfer allows efficient and homogenous temperature distribution in the sample. Both a stirrer and a bob can be used as a measuring system. The starch stirrer is useful to avoid sedimentation, while the bob is used for absolute rheology measurements. To avoid water and heat loss, the cup is covered with a lid.

If the sample is exposed to temperatures above 100 °C, the starch pressure cell must be used to avoid boiling over and losing the sample. In this case, the protein suspension is sealed in the pressure cup, with no pressure specified.

Two different commercially available pea protein isolates (PP1 and PP2) and two soy protein concentrates (SPC) were used. They were mixed with distilled water (15 w% of protein powder) and stirred with a magnetic stirrer to ensure homogeneity.

The protein suspension was subjected to a well-defined stirring and temperature profile consisting of five intervals: mixing, equilibration and water absorption, heating, holding, and cooling. The measurement was repeated to ensure good reproducibility. The heating and cooling rate was set to 6 °C/min.

3 Results and Discussion

Figure 2 shows the viscosity profile of two protein isolates and the soy protein concentration. All three samples have similar initial viscosity, with increasing temperature their viscosity decreases. The minimum viscosity of PP2 is reached at 60 °C and is lower than the one of PP1. The minimum viscosity of PP1 is reached at 64 °C. Their final viscosity is also similar, but much higher than their initial viscosity. The soy protein concentrate behaves qualitatively different. When the temperature is increased, the viscosity decreases. During the holding and cooling phase, the viscosity increases again and reaches a much higher value than the initial viscosity.

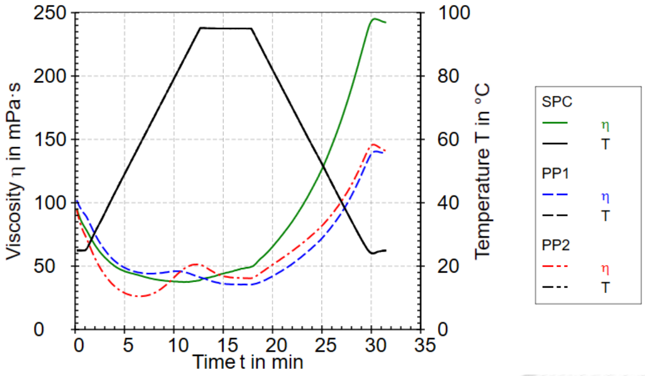

Figure 2: Viscosity profile of two different pea protein isolates and a soy protein concentrate

The viscosity profile is useful to analyze the functionality of the proteins. The initial viscosity is due to the solubility and water binding capacity of the protein. The higher the viscosity, the lower the water solubility and the higher the water binding capacity. A sudden increase in viscosity at elevated temperatures (above 75 °C) may be related to denaturation of native proteins, resulting in a decrease in protein solubility (1).

Figure 3 shows the heating profiles at a holding temperature of 125 °C and 140 °C of a soy protein concentrate. Here, the minimum viscosity is reached at about 115 °C. When the temperature is kept below 125 °C, the viscosity continues to increase during the holding and cooling phase. However, when a higher temperature is reached, the viscosity shows a peak value, which leads to a viscosity drop during the holding phase. This indicates that the melting zone has been reached (2). On cooling, the viscosity increases again, but shows different viscosity values from those at the lower holding temperature.

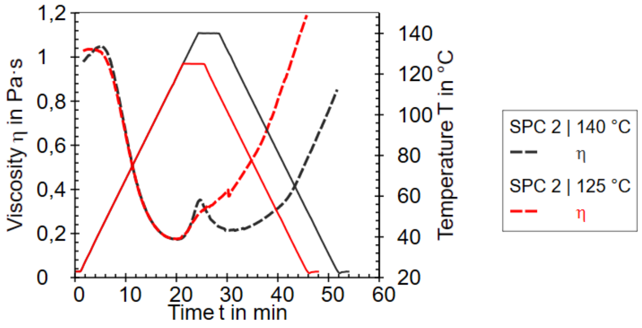

Figure 3: Viscosity profile of a soy protein concentrate for two different holding temperatures

4 Summary

Pasting or gelation curves are useful to study the functionality of proteins when exposed to thermo-mechanical stress. The Starch Cell in an MCR rheometer is the ideal device for studying not only individual isolates, but also the effects of concentration, pH, pressure, temperature, acid treatment, mixtures with starch and other ingredients in a fast, simple and reliable way. Needless to say, understanding the behaviour of raw materials is critical to setting the right process parameters for extrusion cooking of high-moisture meat analogs, for example.

5 References

1. Osen et al. "High moisture extrusion cooking of pea protein isolates: Raw material characteristics, extruder responses, and texture properties". Journal of Food Engineering 127 (2014): 67-74

2. Schmid et al. "High moisture extrusion cooking of meat analogs: A review of mechanisms of protein texturization". Comprehensive Reviews in Food Science and Food Safety 21 (2022):4573-4609

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