SOME FUNCTIONAL PROPERTIES AND MICROSTRUCTURE OF SOY PROTEIN PRODUCTS

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Soybeans are among the most important and most valuable industrial plants from which different soy protein products are produced. The soy bean products can be subdivided essentially into three groups: soy flour, soy protein concentrate and soy protein isolate. Soy flour should contain at least 50%, soy protein concentrate at least 70% and soy protein isolate at least 90% of protein as related to dry matter (SCHRÖDER et al., 1985).

Soy proteins are macromolecular substances with several functional properties comprising the physicochemical characteristics (swelling, water absorption, solubility, gel forming and emulsion capacity) that make influencing of food quality possible. Soy proteins should have acceptable features such as taste, texture, colour, good nutritive value and the functional properties required for the utilisation intended (KINSELLA, 1976; HERMANSSON, 1972). For example in manufacturing Bologna type sausages soy proteins are used to enhance the binding forces of the meat mass, i.e. the water binding capacity and fat stability. This may contribute to reduced fat rendering and jelly deposits in Bologna type sausages.

The aim of the present study was to investigate some functional properties (swelling, gelation, emulsification) of five different soy protein products and to test the microstructure of the swollen soy protein samples, gels and emulsions.

Material and Methods

Five different soy protein preparations were used as test materials (Tab. 1) and their functional properties were determined as follows.

Swelling

The swelling capacity of soy protein products was measured in a BAUMANN's glass apparatus (BAUMANN, 1967) as described by HERMANSSON (1972) and KATSARAS et al. (1994).

Preparation of Soy Protein Suspensions and Emulsions

When preparing gels (dispersions) soy protein must be entirely dissolved in water. Depending on the protein concentration of soy protein products dispersing is carried out with different amounts of water. It is essential to select the amounts of soy protein and water in such a way so as to obtain a considerably solid gel. In the present investigations one part of full-fat soy flour, defatted soy flour and soy protein hydrolysate were respectively each mixed with three parts of water, one part of soy protein concentrate with four, and one part of soy protein isolate with five parts of water to yield an uniform dispersion.

When preparing emulsions, the ratio of soy protein, water and sunflower oil was 1:3:3 with full-fat soy flour, defatted soy flour and soy protein hydrolysate, 1:4:4 with soy protein concentrate and 1:5:5 with soy protein isolate.

Dispersions and emulsions were respectively homogenized in a homogenizer (household appliance, Krups Rotary 500) for 2 min. at grade II. In preparing emulsions soy protein was first hydrated and subsequently, after the addition of the oil, the emulsification was continued for another 2 min. Dispersions and emulsions were then heated in a water bath upto 70°C core temperature and subsequently cooled in ice water.

Microscopic Studies

The microstructures of the swollen soy protein products, gels and emulsions were determined by using the scanning electron microscope. The samples (5 x 5 x 5 mm) were cryofractured in liquid nitrogen and then fixed in

KARNOVSKY solution. This was followed by a post-fixation in buffered osmium tetroxide (KATSARAS et al., 1989). The samples were dehydrated in an increasing ethanol series, critical point dried with CO_2 replacing ethanol, mounted on aluminium stubs, coated with gold in a sputtering device and observed in a JEOL JSM-840 scanning electron microscope at an accelerating voltage of 25 kV.

Results and Discussion

Powdery proteins such as soy flours, soy protein concentrates and isolates have to be hydrated prior to using, i.e. they must swell and take up water. The association of water with soy protein is described as a "site-binding-phenomenon" (HANSEN, 1976). Water uptake and retention affect consistency and viscosity of foods in a decisive way. The results of swelling of the soy protein products are shown in Fig. 1. At the beginning the swelling of soy protein isolate showed a higher value than compared to the other products; still at the end of the test period this sample had taken up the maximum amount of water. On the other hand only small differences were observed between the rest of the samples. Thus, soy protein isolate behave somewhat differently having a greater swelling capacity. The worst swelling properties were found with full-fat soy flour which also had the lowest protein content and the highest carbohydrate and fat content compared to the rest of the soy protein products. Factors such as protein concentration, time, ionic strength, etc. affect the forces underlying the protein-protein and protein-water interactions and thus also influence the swelling capacity.

The process of hydration of soy proteins changes the protein structure. Fig. 2 shows the presence mainly of swollen but also of some small unswollen protein particles. The swelling capacity of different soy protein particles is not only different but also limited, i.e. they may take up water to form swollen particles, however, the latter do not start getting dissolved. If, on the other hand, soy proteins have been enzymatically treated prior to swelling as, e.g., with soy protein hydrolysate, swelling leads to the formation of a gel structure with an irregular network consisting of thin fibres interwoven with and connected to each other (Fig. 3). The continuity of this fine threadlike network is repeatedly interrupted by the presence of numerous cotyledone tissue remnants.

On heating of soy protein concentrate dispersions, a denaturation occurs, bringing about changes in the globular structure of the proteins. Heating in this case includes dissociation of the quaternary structure and causes a partially unfolding of polypeptides of protein subunits (WOLF, 1974; HUANG and RHA, 1974). Upon cooling, the unfolded polypeptides reassociate to form gels (CATSIMPOOLAS and MEYER, 1970; SAIO et al., 1975). Such gel structures have binding properties and possess water binding and fat stabilizing characteristics.

Full-fat soy flour forms a gel structure of heat coagulated protein conglomerates with a size distribution varying within a large range containing many cavities. In these cavities not only immobilized water but also a number of husk and cell wall debris as well as particles of cotyledone tissue is embedded (Fig. 4). The micrograph (Fig. 5) illustrates fat globules of soy flour dispergated in the protein matrix .

The hydrated proteins of *defatted soy flour* often aggregate and form protein conglomerates. Upon heat denaturation they are clustered to a protein matrix in which lots of cell wall remnants are loosely embedded (Fig. 6). It is obvious that this "fissured" network is not essentially different from the structure of fullfat soy flour.

The *soy protein hydrolysate* gel has a more irregular but denser network than the gels obtained from fullfat and defatted soy flour. This more solid feature might be attributed to better protein aggregation obviously occuring when soy protein molecules are enzymatically degraded. However, even this protein matrix contains many parts of cotyledone tissue (Fig. 7) and thus polysaccharides.

In *soy concentrate* dispersions aggregated protein particles form bigger agglomerates (Fig. 8) than in soy flours and this network structure contains definitely less nonprotein components.

The structure of the gels obtained from *soy protein isolate* shows a coherent protein matrix with a dense and solid appearance and many cavities. The individual cavities have diameters smaller than 1 μm (Fig. 9). The soy protein isolate indicates a network typical for protein gels which seems to lend itself to water binding. Soy proteins taking up liquid on preparation of dispersions change their structure to form fat stabilising protein matrices.

In preparing *soy protein emulsions* neither the microstructure of the protein matrix nor the fragments of cotyledone tissue and fat globules appear to be uniform. The fluid fat mass and the structure forming soy protein get linked and

penetrate each other (Fig. 10). In this state, fat mass and protein matrix are "interlaced" in such a way that they form in common a "penetration structure".

The *soy protein concentrate emulsion*, though showing a continuous structure, is irregular due to the great number of cavities; such a structure is not able to disperse fat uniformly and completely and cannot hold it together in an emulsionlike way.

On the other hand, and in most cases the *soy protein isolate emulsion* shows uniformly distributed fat globules surrounded by a very thin protein film (Fig. 11). Such protein coatings do not only prevent the coalescence of the fat globules but are also in contact with adjacent fat particles, thus representing a "true emulsion".

Fig. 6: Defatted soy flour suspension (SEM, 2 000 x); **Fig. 7:** Soy hydrolysate suspension (SEM, 500 x); **Fig. 8:** Soy protein concentrate suspension (SEM, 2 000 x); **Fig. 9:** Soy protein isolate suspension (SEM, 10 000 x); **Fig. 10:** Soy flour emulsion (SEM, 500 x); **Fig. 11:** Soy isolate emulsion (SEM 12 000 x)

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