

# Modification of the Soluble Protein Content of Heat-Processed Soybean Flour

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## Abstract

An important and frequently observed effect of food processing is the reduction of protein nutritive quality. Heat treatment of soybeans can reduce the activity of trypsin inhibitors and thereby improve protein digestibility. Overheating, however, may destroy or reduce the availability of certain heat sensitive amino acids and reduce the nutritional value of soy protein. The simplest criterion used for the characterization of proteins is their solubility in various media. The objective of this study was to evaluate the thermal effect on protein solubility of soybean flour (SBF). Heat-processed SBF was obtained in a forced air oven at 120°C, and by exposing to microwaves at 2450 MHz frequency. Protein solubility was determined according to the procedure of Araba and Dale, based on the solubility of soybean proteins in 0.036 M KOH. The experimental data show that, whatever the heating process used, the heating time is negatively correlated with the protein solubility. To maintain a good nutritional quality to heated soybean flour, microwave treatment has to be shortly applied compared to cooking one.

**Keywords:** soya flour, protein digestibility, protein solubility, microwave treatment

## Introduction

Soybean (*Glycine max*) is an important source of oil (17-25%) and protein (35-45%). It contains large amounts of Vitamin B1 and B2 but it is rather low in vitamin C (Singh *et al.*, 2008). The crude protein of soybean meal ranges from 41 to 50% (dry matter basis) depending on the amount of hull that is removed, and the processing method used (Liener, 1994).

Soy is applied in a variety of products including bread, cakes and snacks. In spite of its widespread use in foods, only a small percentage of global soy protein production goes into such products. Today soybeans are grown primarily for the production of vegetable oil for human consumption but, as a by-product, soybean meal is becoming increasingly important. On a global scale, soy is dominating the market for protein meals due to its high protein content and good availability.

The soybean is the only vegetable food that contains complete protein, meaning all of the eight amino acids needed for human health are present (Lonnerdal, 1994).

By far, the most important process encountered with soya products is heat treatment. Defatted soya flour and grits, full-fat soya flour and grits, soyamilk, soyamilk curd and soya protein concentrate, among others, include a heat treatment step in their production.

An important and frequently observed effect of food thermal processing is the reduction of nutritive value of proteins (Friedman, 1977; Vachon *et al.*, 1982). The mechanism is thought to involve the reaction of amino

acids to form products that are resistant to digestion and absorption.

Protein digestibility is a major index of protein quality because a certain amount of amino-acids may be present in a food and it may not necessarily be available to the organism for nourishment.

The denaturation of the protein and reduction in amino acid availability by cross-linking, racemization, degradation and formation of complexes with sugar may result in loss of digestibility (Del Valle, 1981; Friedman, 1996; Woodward and Carroll, 1985). Therefore, when attempting to estimate protein quality, one of the first factors that must be evaluated is its digestibility (Araba and Dale, 1990).

The anti-nutritional factors in soybean are often associated with the low acceptance of soybean products as they also inhibit protein digestibility. These mainly consist of the heat labile (trypsin inhibitors, lectins, goitrogens, phytates) and heat stable (oligosaccharides) factors. In order for the nutritional value of soybean meal to be maximised, these anti-nutritional factors need to be inactivated or minimised (Liener, 1983, 1994; Liu, 1997). Heat treatment of soybeans can reduce the activity of trypsin inhibitors and thereby improve protein digestibility. Overheating, however, may destroy or reduce the availability of certain heat sensitive amino acids and reduce the nutritional value of soy protein.

The simplest criterion used for the characterization of proteins is their solubility in various media. The solubility of a molecule in water depends on how much of the unfavorable aspects of creating a cavity in water, are com-

compensated by favorable interactions with the surrounding water molecules (Mangino, 1994). As in all legumes, the bulk of soybean proteins are globulins, characterized by their solubility in salt solutions. For optimum functional properties of soybean, a solubility index above 90% is required. Good protein solubility generally correlates with optimum gelation, emulsifying and foaming ability of the protein (Lakemond et al., 2000).

The objective of this study was to evaluate the thermal effect and the influence of processing conditions on protein solubility of soybean flour (SBF).

### Materials and methods

Two laboratory processes have been developed for the treatment of SBF. All the processes are essentially based on heating for a certain time. Heat-processed SBF was obtained in a forced air oven Froilabo AC60 at 120°C, and by exposing to microwaves. Microwave treatment was carried out in a microwave oven (Vortex WD800D-823) with a power output of 800 W and a frequency of 2450 MHz.

SBF with 43.7% crude protein (48.63% dry basis) was ground to pass each the 200  $\mu$  sieve.

Crude protein of SBF was determined by the Kjeldahl method, using a Kjeltac Foss Analyser Unit (AOAC, 1990).

The protein solubility was determined according to the procedure of Araba and Dale (Araba and Dale, 1990). The KOH protein solubility test is based on the solubility of soybean proteins in a dilute solution of potassium hydroxide. The procedure involved incubation of 1.5 g sample with 75 mL 0.2% KOH (wt/vol; 0.036 N) solution for 20 min at room temperature using a Barnstead SP135930-33 magnetic stirrer. Following this incubation, the sample was centrifuged for 5 minutes at 6,000 rpm with a Hettich 320R centrifuge, and the supernatant was analyzed for the protein concentration by the biuret method. The solubility of the protein, expressed as a percentage, was calculated by dividing the protein content of the KOH-extracted solution by the protein content of the original soybean sample.

Spectrophotometric measurements were performed using a PerkinElmer UV/VIS-Lambda 35 spectrophotometer.

### Results and discussions

Processing conditions may have different effects on SBF quality. Microwave treatments are usually applied in the processing of grain legumes, particularly soya, to remove unpleasant taste and destroy trypsin inhibitors (Esaka *et al.*, 1987; Hafez and Singh, 1983; Pour-El *et al.*, 1981; Yoshida and Kajimoto, 1988).

Microwave ovens for cooking follow the principle of dielectric heating. Microwaves penetrate partially, are

partly reflected and partly absorbed. After penetration, microwaves interact with the electric dipoles of water molecules and the molecules rotate as a result of forces of attraction and repulsion between the dipoles and the electric field. These movements lead to breakage of hydrogen bonds between water molecules and generate heat by friction. Microwave heating implies a direct energy transfer since proteins have a dipolar moment and microwaves can induce rotatory motions on them.

Besides temperature, in procedures for processing the time of heat treatment has also effect on quality of soy products.

A comparative study was performed on two heating methods of soy beans: heating in oven at 120°C and heating in a microwave device at 800 W and 2450 MHz.

Heating did not alter the protein content but it induces some changes in the protein structure.

The experimental data show the effect of the heating time on protein solubility. The results presented in Tab. 1 and Tab. 2 show that in both treatments the soluble protein content was reduced under the influence of high temperatures. Excessive heat or heating time reduces the availability of amino acids due to the Maillard reaction (Del Valle, 1981) and tends to destroy certain amino acids (Shede and Krogdahl, 1985). Dry heating of proteins in the presence of oxygen leads to thermal degradation of certain amino acids such as tryptophan, tyrosine, methionine, and cysteine (Damodaran, 1996). This leads to development of burnt flavors, browning accompanied by formation of new intra- and intermolecular cross-links, and isopeptide interactions that may form insoluble protein polymers (Otterburn, 1989).

Protein solubility decreased below 50% when heating at microwaves for 3 minutes and at 120°C for 20 minutes. Heating at 120°C for 30 minutes decreased protein solubility to 21%. Microwave heating for 5 minutes decreased protein solubility to 18.76%. The rapid decrease in protein solubility is because heating by microwaves begins within the cells and molecules where water is present and where the energy is transformed into frictional heat. When heating in air forced oven, heat transfers convectionally from without to within. The protein insolubilization during heating is the result of protein polymerization by the disulfide bond interchange reaction (Zayas, 1997) with the increased number of SH groups. As a result of the interchange reaction between the SH and disulfide groups, new intermolecular disulfide bonds are formed. Major soy proteins glycinin (11S) and  $\beta$ -conglycinin (7S), representing over 70% of soluble protein, have more than two active free SH groups on their native molecular surface with small distances between molecules.

Protein solubility values lower than 74% reflect an incremental decrease in lysine availability for human and animals (Parsons *et al.*, 1991). This limit was reached at 10 minutes of conventional thermal heating and at 2 minutes of microwave heating.

Tab.1. Effect of heat treatment on protein solubility

Treatment	Heating time (min)	Soluble protein in KOH (%)
Thermally untreated soybean flour	0	32.79
Heating at 120°C	5	27.45
	10	24.40
	15	20.25
	20	13.20
	30	6.20

Tab. 2. Effect of microwave treatment on protein solubility

Treatment	Microwave exposing time (min)	Soluble protein in KOH (%)
Thermally untreated soybean flour	0	32.79
Microwave treatment	1	26.60
	2	22.48
	3	16.15
	4	6.40
	5	6.15

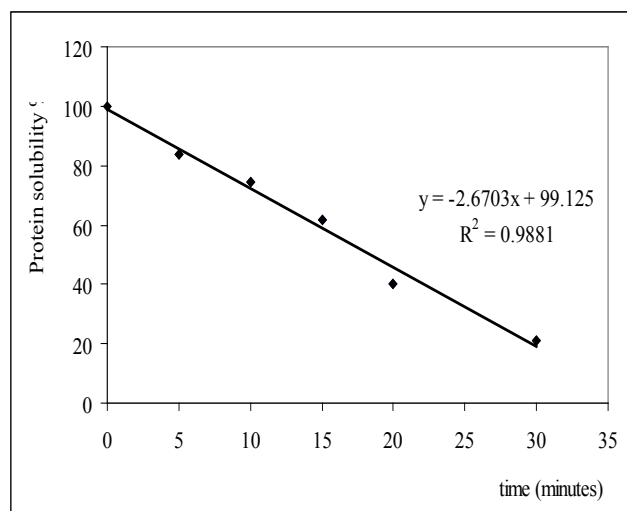


Fig. 1. Variation of protein solubility with the heating time in air forced oven

The heating time is negatively correlated with the protein solubility  $R^2 = 0.9881$  when heating in air forced oven (Fig. 1) and  $R^2 = 0.9696$  when heating in microwave oven (Fig. 2).

The percentage of decrease in protein solubility during the studied heating intervals was variable in both procedures. The most significant decrease was observed between 3 and 4 minutes of microwave treatment. A microwave treatment over 4 minutes didn't induce a significant drop in protein solubility.

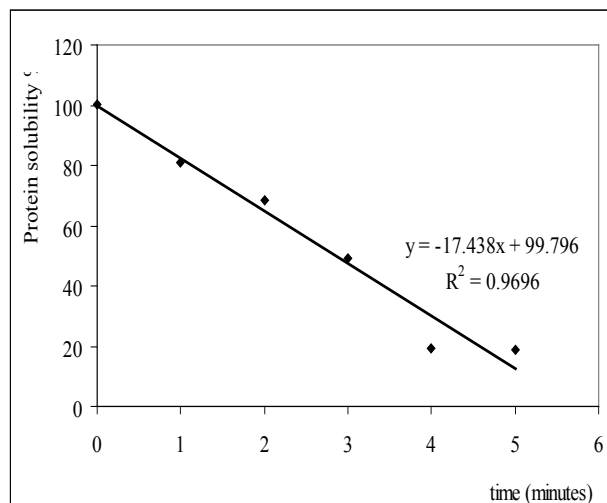


Fig. 2. Variation of protein solubility with the heating time in microwave oven

### Conclusions

To maintain optimal nutritional value, soya flour must not be subjected to excessive heat, as this will denature the protein pool, making it less soluble and less digestible. Solubility therefore gives an indication of the extent of cooking.

Protein solubility decreased more rapidly in microwave treatment than in conventional thermal heating. Protein solubility of 74%, considered as lower limit acceptable for lysine digestibility, was reached after 10 minutes when heated in a thermal oven at 120°C and only after 2 minutes when heated in a microwave device. Therefore, to maintain a good nutritional quality to heated soybean flour, microwave treatment has to be shortly applied.

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