# Manufacturing of soy protein concentrate for animal nutrition

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**SUMMARY –** Soy protein concentrate (SPC) is produced from defatted soy flakes. Soluble carbohydrates (oligosaccharides) are removed from the defatted flakes. Currently two methods are applied in the manufacturing of SPC: the extraction method or the enzymatic degradation of carbohydrates. The two methods lead to slightly different nutrient composition in the derived products. SPC has significantly higher nutritional value than soybean meal and is characterized by a low content of oligosaccharides (<3%) and antigenic factors (<100-p.p.m. glycinin). SPC offers a cost efficient alternative to high quality proteins of animal origin such as skim milk powder or fishmeal in feeds for calves, piglets and pets. In aquaculture, SPC has a potential to replace up to 50% fishmeal on a protein basis in diets for salmonids.

**Key words:** Soybeans, soy protein concentrate, processing, oligosaccharides, animal nutrition.

***RESUME –*** *"Fabrication de concentré protéique de soja pour la nutrition animale". Le concentré de soja (SPC) est produit à partir des flocons dégraissés de soja. Les glucides solubles (oligosaccharides) sont séparés des flocons. En ce moment deux méthodes sont utilisées pour la production de SPC : la méthode d'extraction et la méthode de dégradation enzymatique des glucides. Les deux méthodes résultent en produits légèrement différents concernant leur composition nutritive. Le SPC a une valeur nutritive significativement plus élevée que le tourteau de soja et est caractérisé par un contenu très bas en oligosaccharides (<3%) et facteurs anti-géniques (<100 p.p.m. glycinine). Le SPC offre une alternative économique pour substituer les protéines de haute qualité comme la poudre de lait écrémé ou la farine de poisson dans l'aliment pour les veaux, les porcelets et les chats et chiens. En aquaculture, le SPC peut remplacer jusqu'à 50% de la farine de poisson sur la base du taux protéique dans les aliments pour les salmonidés.*

***Mots-clés :*** *Graines de soja, protéique concentré de soja, traitement, oligosaccharides, alimentation animale.*

## Introduction

Soybeans together with corn belong to staple food of mankind since ancient ages. In human diets soybeans have been used as a protein source for over 5000 years. A vast array of products can be derived from soybeans and are found nowadays in more than 20,000 items in the food shelves of supermarkets worldwide. But also nutrition of high performing animals is unthinkable without soy products. Utilization of soybeans in livestock and poultry diets grew in many parts of the world as a result of the development of the soy oil market. In the context of animal nutrition, soybean meal has an overwhelming importance as a reliable source of protein with a high content of essential amino acids. On a worldwide basis, soybeans supply over one-fourth of the fats and oils, two-thirds of the protein concentrates for animal feeds, and three-fourths of the total world trade in high protein meals.

Nevertheless, soybeans contain several factors with anti-nutritional properties (ANFs) and demand processing before consumption. ANFs may limit the usage of soy products in feeds for certain species, in particular in diets for young animals with still undeveloped digestive tract. This is the case in young piglets and calves. Feeding unprocessed soy protein leads to intestinal morphological and physiological changes and a pronounced immune response.

In aquatic species soy products are increasingly used, mainly in herbivorous and omnivorous fish. They seem to tolerate higher dietary levels of soybean meal without detrimental impact on the performance. However, in carnivorous fish like salmonids, for the above mentioned reasons, restrictions of usage still exist.

In the fast developing aquaculture sector, the need to replace mainly fishmeal but also other animal by-products from the rendering industry is becoming evident. This is driven by three major factors: (i) the limited production of fishmeal with concurrent increase in worldwide aquaculture production; (ii) consumer concerns about food safety in context with dioxin contamination; and (iii) ethic objections on the use of edible protein in animal diets in view of the world population development.

Sophisticated processing of soy in order to remove its anti-nutritional factors offers the possibility to use soy protein concentrate (SPC) also in feeds for salmonids and replace fishmeal. SPC together with soy protein isolate belongs to the high end products from the processing chain of soy. The manufacturing process of SPC and other soy products is presented in this paper.

## Anti-nutritional factors in soybean seeds

According to their temperature resistance the anti-nutritional factors can be classified in heat labile and heat stable ANFs (Table 1).

Table 1. Anti-nutritional factors in soybeans

| Heat labile | Heat stable |
|---|---|
| Protease inhibitors | Saponins |
| Lectins | Estrogens |
| Goitrogens | Cyanogens |
| | Phytate |
| | Oligosaccharides |
| | Antigens |

Protease inhibitors are actively inhibiting the digestive enzymes trypsin and chymotrypsin and lower protein digestibility. Lectins are glycoproteins, which cause agglomeration of red blood cells. Goitrogens lead to an enlargement of the thyroid gland. All three are easily to be destroyed or inactivated with appropriate heat processing, e.g. toasting, extrusion, and treatment with hot air or microwaves (infrared) after wetting.

Saponins are glycosides and characterised by a bitter taste. They may hemolyze red blood cells. Estrogens (Isoflavonids) can cause an enlargement of the reproductive tract and cyanogens are split in the digestive tract to the poisonous hydrogen cyanide. Phytate is interfering with mineral utilization (Ca, Fe, Zn, Mn, Cu) and is responsible for the low phosphorus utilization in soy products.

Oligosaccharides form the majority of the carbohydrate fraction in soybeans. Only about 2% of the carbohydrate fraction are starch and 6% cellulosic compounds. The non-starch oligosaccharides impair digestion (intestinal cramps, diarrhoea, and flatulence) due to lack of the appropriate digestive enzymes of the host specie.

Antigenic factors (glycinin and β-conglycinin) cause the formation of antibodies in the serum of pre-ruminant calves and small piglets. They prevent the proliferation of certain beneficial bacteria in the gastro-intestinal tract. Therefore the use of soybean meal bears certain risks in diets for young mammals.

However, the presence of heat stable factors in soybeans is with the exception of the oligosaccharides and the antigenic factors, rather small and not very likely to cause problems under practical conditions. But removal of the oligosaccharides and glycinin/β-conglycinin from defatted flakes contributes to a significant increase in the nutritional value. Further, the protein concentration in the SPC is much higher than in soybean meal, which makes it an interesting ingredient for high protein, high energy diets.

## Manufacturing of soy products

A schematic view of soybean processing is shown in Fig. 1. The first step is the selection and cleaning of high quality soybeans. Then the beans are dehulled, cracked, flaked and steam conditioned before they enter the solvent extraction process. The oil is removed and further processed. The crude soy oil can be fractionated and refined to soy oil and lecithin. The soy oil is used for various purposes in the food but also in the chemical industry.

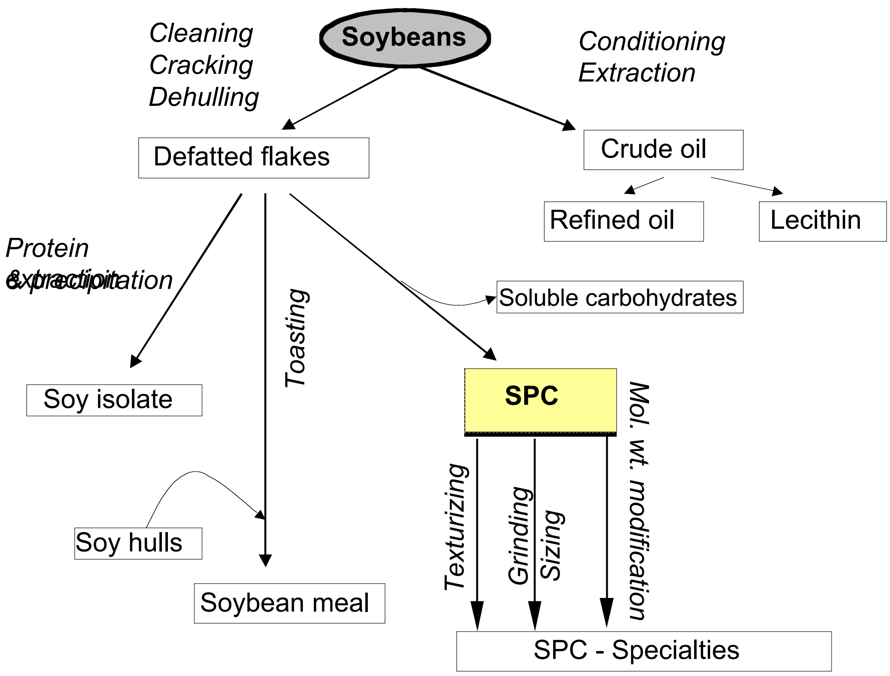


Fig. 1. Manufacture of soy products.

After extraction remain defatted flakes. They can be used in various further processing steps. The most commonly known and most widely used product that is made from defatted flakes is soybean meal. The flakes are steam toasted to remove the residual solvent (currently a mix of n-hexane and hexane isomers, 50:50, is used as extraction solvent) and to inactivate the heat labile ANFs. Depending on the amount of soy hulls that are added back to the flakes, the protein level of soybean meal is adjusted. In high protein meals (48-50% crude protein as fed), no hulls are added back. Low protein meals contain 42-43% crude protein. The major application of soybean meal is in animal nutrition. However, edible defatted flakes can be ground, sized and texturized, forming texturized vegetable protein products (TVPs). TVPs are used in the food chain as meat substitutes and vegetarian foods.

When the protein is extracted and precipitated from the defatted flakes, soy protein isolates or commonly known as soy isolate is the resulting end product. Soy isolate contains 90% protein (Table 2). The final destination of isolated soy proteins is in meat systems, sauces, gravies, dairy blends, high protein beverages and infant formulas. For use in animal nutrition soy protein isolate is not cost efficient.

## Manufacturing of soy protein concentrate (SPC)

In order to avoid browning reactions in the production of speciality soy proteins the defatted flakes are not entering the common desolventizer/toaster. The hexane is removed without altering the functional characteristics of the soybean proteins by low heat vacuum drying. This yields the so-called "white flakes". The removal of the soluble carbohydrates from the white flakes leads to SPC.

Currently two methods are applied for this processing step of manufacturing SPC: removal by extraction or by enzymatic degradation. The two methods lead to slightly different nutrient composition in the derived SPC as shown in Table 2. However, the vast majority of SPC is produced by the extraction method. Aqueous alcohol leaching selectively removes the soluble carbohydrates. With this processing step also other ANFs than the oligosaccharides are removed simultaneously – estrogens and antigenic factors. Recently a method has been developed to extract the estrogens from the solubilized carbohydrates and formulate a high isoflavones containing nutraceutical for human consumption.

Table 2. Proximate composition and ANF content of soy products (as is)

| | Soybeans | Soybean meal | SPC enzyme treated | SPC alcohol extracted | Protein isolate |
|---|---|---|---|---|---|
| Moisture (%) | 10-12 | 10-12 | 6.5 | 7 | 6.5 |
| Crude protein (%) | 35.5 | 42-50 | 57.5 | 65 | 90 |
| Fat (%) | 19 | 1-1.5 | 2.5 | 1 | 1 |
| Ash (%) | 4.7 | 5.5-6 | 6.8 | 6 | 5 |
| Urease activity (pH-rise) | 2.0 | 0.05-0.5 | <0.05 | <0.05 | <0.05 |
| Trypsin Inhibitor, mg /g | 45-50 | 1-8 | 1 | 2 | <1 |
| Glycinin (p.p.m.) | 180.000 | 66.000 | <100 | <100 (<3 Soycomil) | |
| $\beta$-conglycinin (p.p.m.) | >60.000 | 16.000 | <10 | <10 | |
| Lectins (p.p.m.) | 3.500 | 10-200 | <1 | <1 | 0 |
| Oligosaccharides (%) | 14 | 15 | 1 | 3 (Raffinose 0.2-0.3; Stachyose 2-3) | 0 |
| Saponins (%) | 0.5 | 0.6 | 0 | 0 | 0 |

Modification of the aqueous alcohol mixture, the temperature and time of processing can further reduce the antinutritional composition of the SPC. Other processing steps as texturizing, grinding and sizing or modification of the molecular weight can be applied to form protein speciality products for the use in the food chain.

## Use of SPC in animal feeds

The SPC is distinctly different to the soybean meal (Table 2); thus it contains just traces of oligosaccharides and the antigenic substances glycinin and $\beta$-conglycinin. Therefore it can be used in milk replacer feed for non-ruminant calves, piglet pre-starter feed, pet food, feed for fur bearing animals and in aquaculture.

In milk replacer feed, SPC substitutes dried skim milk to a large extent. In pig starter feeds it also can replace dried skim milk, whey powder and fishmeal. The nutritional value is only slightly below that of dried skim milk. The negative influence of dietary soybean meal on the intestinal tract lining of pigs and on the serum antibody titer is not observed when SPC is used.

Whereas in feeds for young mammals the use of SPC has been established for many years, in aquatic diets it is still at the beginning. The focus of nutritional research today is to evaluate the possibilities of replacement of fishmeal in diets for salmon and trout. Also the fast growing shrimp industry is investigating the use of SPC in their shrimp diets. Based on current knowledge, the percentage replacement of fishmeal on isonitrogenous level by SPC is shown in Table 3. However, the dietary amino acid pattern has to be balanced according to the species specific amino acid requirements. Due to the fact, that methionine plus cystine are the limiting amino acids in soy protein, DL-methionine should be added to the diets when necessary.

## Conclusions

The specially processed soy products have much lower ANF activities than soybean meal. In particular the amount of oligosaccharides and antigenic substances is significantly lower. Therefore they are much better utilized than soybean meal and can be added at higher levels to animal feeds. The nutrient value of SPC comes close to that of dried skim milk. SPC offers a cost efficient alternative to high quality proteins of animal origin such as skim milk powder or fishmeal.

Table 3. Replacement of protein from fishmeal by SPC in diets for salmon, trout and shrimps

| Species | Max. replacement (%) | Reference |
|---|---|---|
| Rainbow trout (high fat diets) | 50 | Mambrini *et al.*, 1999 |
| Rainbow trout (low fat diets) | 100 | Kaushik *et al.*, 1995 |
| Atlantic salmon | 40 | Refstie *et al.*, 1998 |
| Atlantic salmon | 20 < 40 | Hamlet Protein, 1995 |
| Shrimps | 40 | Hamlet Protein, 1997 |

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