Extruding full-fat soya for maximum quality

By Mian Riaz, director, food protein research and development centre, Texas A&M University, College Station, United States

Prior to extraction, soya beans are referred to as full-fat soya beans. Properly processed full-fat soya beans are a valuable feed ingredient because of their energy, protein, linoleic acid, vitamin E and lecithin contents.

There are a number of different products on the international market being sold as full-fat soya bean meal. These products are produced through a variety of processes, all of which have a different impact on the nutritive value of the product and its quality in terms of anti-nutritional factor levels. The focus of this paper is using extrusion technology to process quality full-fat soya beans for animal feed.

Soya beans are the most important crop in the world and are grown for a variety of agricultural and industrial uses. There are eight major oilseed meals in the world. Soya bean meal represents more than 50% of the total oilseed meal production worldwide. Raw soya beans cannot be used as such for animal feed or human consumption because they contain several different anti-nutritional factors, such as trypsin and chymotrypsin inhibitors, phytohaemagglutinin (lectins), urease, allergenic factors, and lipases and lipoxygenases.

These factors affect the digestion of soya beans in the stomach. All of these can be deactivated, modified or reduced through proper heat treatment to minimise or eliminate their adverse effects. Since all these inhibitors are proteins, caution should be taken to assure that no destruction of the oilseed protein occurs. This can be accomplished only through optimum processing and quality control measures.

The oil in full-fat soya, which is properly processed by extrusion, is very stable and provides a remarkably long shelf life for such a high-fat product.

Producing full-fat soya bean meal

As stated, full-fat soya bean meal is produced through a variety of processes, all of which have a different impact on nutritive value and quality. The following processes can be applied to the production of full-fat soya bean meal: boiling/autoclaving, roasting/toasting, micronising, jet-sploding and extruding (wet or dry). All these methods have both advantages and disadvantages.

Extrusion cooking has some additional advantages, which other methods do not offer, for example a high temperature and shorter time (HTST) cooking process which will minimise degradation of food nutrients while improving the digestibility of protein by denaturation. In addition, during extrusion cooking, most of the cells are ruptured, making oil available for the animal. The critical factor during extrusion cooking is the prevention of over- or under-processing since either will reduce the nutritional value.

It is worth mentioning that wet extrusion cannot lend itself to mechanical extraction of the oil. Moisture does, in fact, interfere with oil expelling. A 'dry' extrusion process is one in which mechanical energy from the extruder's main drive motor is the only energy used to process the soya beans. A 'wet' extrusion process not only uses mechanical energy, but also uses steam that is injected into either a preconditioner, or the extruder barrel.

Optimally processed extruded full-fat soya beans result in the following objectives:

Minimised trypsin inhibitors

Full-fat soya beans are thermally processed to destroy anti-nutritional factors and to increase oil availability, while preserving the nutritional quality of the protein. The major anti-nutritional factor of concern in raw soya beans is a trypsin inhibitor. A trypsin inhibitor is a protease that is harmful to most animals and humans, and nutritionists have documented this effect conclusively. This protease enzyme can be inactivated by heat treatment. A reduction of at least 85% of the trypsin inhibitor units is considered necessary by feed technologists to avoid nutritional problems.

Both moist and dry extrusion are effective in the reduction of the trypsin inhibitor and urease activities. Full-fat soya

Properly processed full-fat soya beans are a valuable feed ingredient because of their energy, protein, linoleic acid, vitamin E and lecithin contents.

beans can be moist or dry extruded to destroy over 90% of the trypsin inhibitor without damaging lysine. The degree of destruction of trypsin inhibitors is influenced by the moisture content, as well as the processing time and temperature. With dry extruders, the highest reduction in trypsin inhibitor activity (TIA) seems to occur at the temperature range of 150 to 160°C, and a process moisture content of 9 to 11%.

Release of intra-cellular oil and natural tocopherols

Vitamin E results in improved digestion and stability and facilitates the physical extraction of the oil. The cooked full-fat soya bean can then immediately enter a mechanical press where the majority of the oil is removed. This oil can be utilised for other processing uses, including biodiesel and the production of oils that are 'natural', since they have not been through a traditional hexane extraction process. The cake can be used as a protein source for animal feed.

This process must be done in a low moisture environment as added water will affect the expelling efficiency and oil stability. It is usually done via a dry extrusion system.

Increased bypass protein level

Heat treatment through extrusion increases the bypass protein for ruminants. In dry extrusion, utilising the inherited moisture in the soya beans (9 to 11%) is sufficient to denature the protein without affecting the primary structure or changing the optimum extrusion temperature of 150 to 160°C. However, some processors may choose to exceed those parameters by increasing the temperature even more to assure a higher bypass protein. This will, however, be accompanied by minor discolouration or browning of the full-fat soya bean meal.

The amount of denatured or bypass protein produced during extrusion may be quantified by determining the nitrogen solubility index (% NSI) of the final product.

Benefits of extrusion

Extrusion is a continuous process and has obvious advantages over simple batch cooking processes such as boiling or autoclaving. It is also quicker than boiling since the beans have to be kept at boiling point for around 30 minutes to achieve reasonable levels of inhibitor destruction.

The main variables associated with product quality and process efficiency as far as soya bean processing is concerned are time, temperature, moisture content and the degree of physical damage needed to render the oil content more digestible. Extrusion is a readily controllable process where temperature, time (to some extent), moisture content and the degree of physical damage can all be manipulated. The net result of this is that a very high-quality product can be produced when the extrusion process is properly handled.

The term 'dry extrusion', as opposed to 'wet extrusion', refers to the fact that this type of extruder does not require an external source of heat or steam. Dry extruders generate heat and pressure mechanically as a result of the frictional and shear forces produced within the extruder barrel. Provided that an adequate operating temperature is reached (150 to 160°C), this combination of heat and pressure is sufficient to substantially denature the important anti-nutritive factors in soya beans and render the material usable in feed.

> The oil in full-fat soya, which is properly processed by extrusion, is very stable and provides a remarkably long shelf life for such a high-fat product.

Dry extruders are single screw extruders with a segmented screw put together around the shaft. In-between the screw, a restriction (steam lock, choke plate) of different diameters can be placed to increase the cook and shear. When material moves in the barrel and comes across these restrictions, it is unable to pass through and, consequently, pressure builds up and a backflow is created.

Usually, these restrictions are arranged in such a way that they increase in diameter towards the die end of the screw, creating more pressure and shear as they reach the die. This build-up of pressure and temperature, together with shear stresses developed, tends to plasticise (gelatinise)

the raw materials into a viscous paste or puffed shape, depending on the raw material. In dry extrusion, pressure and temperature should be at a maximum just before leaving the die.

The die design and opening also play a very important role in pressure build-up. Different dies are used for different material and shapes. The cooking range in a dry extruder can be 90 to 160°C with very high pressure. As soon as the material leaves, the extruder dies and pressure is instantaneously released from the products, which causes internal moisture to vaporise into steam, making the product expand.

Higher shaft speed

Most standard dry extruders are manufactured in such a way that the speed of rotation of the main shaft is around 550 revolutions per minute (rpm). This shaft speed is ideal for general purpose use where everything from cereal starch to full-fat soya beans needs to be processed in the same machine. However, if the machine is to be used exclusively for full-fat soya bean meal production, a slightly higher shaft speed (around 620 rpm) is necessary in combination with an extended three-chamber barrel, since this will give a higher throughput per hour without compromising product quality.

In dry extrusion, whole oilseeds can be used, and this type of extruder has the ability to grind the oilseeds during extrusion processing. Dry extruders capitalise their source of heat through internal friction for cooking, and therefore no external steam or heat is injected into an extruder barrel during cooking. The dry extruder can process the soya beans which have a wide range of moisture contents (9 to 13%). Usually, in dry extrusion, we lose moisture in the form of steam at the exit, and this moisture loss depends on the initial start-up moisture in the soya bean.

The heat and pressure generated in the extruder barrel typically raises the temperature from 150 to 160°C. This temperature and pressure are sufficient to denature the anti-nutritional factors in the soya beans and rupture the oil cells. This can be accomplished only through optimum processing and good quality control measures.

> The term 'dry extrusion', as opposed to 'wet extrusion', refers to the fact that this type of extruder does not require an external source of heat or steam. Dry extruders generate heat and pressure mechanically as a result of the frictional and shear forces produced within the extruder barrel.

If too much heat and pressure are applied, significant damage may be done to the protein component of the soya beans, thereby reducing digestibility and availability in non-ruminants. Thus, the process must be carefully controlled to ensure sufficient heat is applied to denature anti-nutritive factors without excessive cooking, which would damage the protein component.

Preconditioning increases output

Recently, several developments have occurred in dry extruder design and its components. Recent research has shown that if the starting material can be preconditioned with steam, the efficiency of the extruder increases almost doubled. Such technology can also reduce the wear of the extruder barrel components by 20%, reduce the electricity cost by around 40%, improve the destruction of the anti-nutritional factor, improve the protein efficiency ratio of full-fat soya bean meal, allow the production of a finely textured end product, and avoid the shrinkage of extruded full-fat soya bean meal due to lower moisture contents.

With care, full-fat soya bean meal can be produced with the use of a steam conditioner, but without the necessity of adding a drier to the processing line, since moisture is lost both at the extruder die and during cooling. However, the availability of a drier increases the flexibility of processing options and may yield a material with better keeping qualities.

Researchers also found that in some applications, a longer barrel will work much better than the normal barrel used for soya beans. Several dry extrusion operations for full-fat soya have retro-fit their dry extruder with steam preconditioning.

Method varies oil content

Since nothing is added or taken away in the full-fat soya process, the gross composition of full-fat soya will depend on a constant moisture basis. The most serious variation is with the level of moisture of the beans and the percentage of impurities such as dust, straw or weed seed, among others. Full-fat soya will obviously contain the same level of oil as found in whole soya beans with a similar moisture basis.

The average oil content of full-fat soya will be 17 to 18% if determined by the Soxhlet method using petroleum ether. This figure will be higher if oil is determined by the acid hydrolysis method. The oil in full-fat soya, which is properly processed by extrusion, is very stable and provides a remarkably long shelf life for such a high-fat product.

The long shelf life can be explained by the fact that full-fat soya contains a high level of tocopherol and lecithin (4%), which inhibits oxidation of the full-fat product. At the same time during extrusion, heat will destroy the enzymes lipase and lipoxygenase, which cause rancidity. If full-fat soya is not processed at the proper temperature, it will show signs of rancidity (increased peroxide value and free fatty acid level). This is no doubt due to the incomplete destruction of lipoxidases. A moisture level above 12% will favour hydrolytic rancidity, which triggers oxidative rancidity and mould growth.

This article has been shortened for publication in *Oilseeds Focus*. To read the full article, visit *www.allaboutfeed.net/animal-feed/feed-additives/extruding-full-fat-soy-for-maximum-quality/*.