Contratto di ricerca tra DII-UNIPR e Natura Nuova s.r.l. sul tema:

"Semilavorati testurizzati per nuovi prodotti a base di soia e di frutta" (marzo 2011-2013)

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RELAZIONE SULLE ATTIVITÀ DI RICERCA
EFFETTUATE NEL PERIODO: MARZO 2011 – DICEMBRE 2012

Parte A. Semilavorati Testurizzati per Nuovi Prodotti a Base di Soia

Allegato A.4 – Trattamenti di cottura-estrusione

sintesi della bibliografia richiamata

Introduzione

Il processo di cottura-estrusione è basato su una stretta correlazione tra trasferimento di massa, di energia e quantità di moto, al fine di determinare nel prodotto trattato complesse modificazioni chimiche, chimico-fisiche e fisiche (quali la gelatinizzazione e destrinizzazione degli amidi e la denaturazione delle proteine.

Un cuocitore-estrusore è costituito da una o due viti rotanti all'interno di una camera, così da trasportare il prodotto dalla zona di alimentazione alla zona di scarico. La distanza tra la/le vite/i e la parete interna della camera, liscia o corrugata in funzione del grado di attrito voluto, diminuisce progressivamente andando dall'estremità di alimentazione all'estremità di scarico costituita da una trafila, in maniera tale da aumentare progressivamente le perdite di carico, la pressione e la temperatura (derivante dal calore endogeno e da quello apportato dall'esterno). A parità di configurazione della camera, gli sforzi di taglio applicati aumentano con rapporto di compressione, ovvero riducendo il passo delle spire (fisso o variabile) e passando dalla versione monovite a quella bivite e, per quest'ultima, aumentando il grado di intersezione delle spire.

Per un dato assetto base dell'estrusore (configurazione della camera) e della sua attrezzatura (tipo di viti e della trafila), il processo di estrusione comprende molteplici variabili operative indipendenti (le caratteristiche del prodotto in entrata, la sua portata e il contenuto di umidità, la velocità di rotazione delle viti, il profilo di temperatura all'interno della camera e il tipo di trafila) e variabili dipendenti ad esse correlate (profili di temperatura e di pressione e viscosità del prodotto nella trafila), dalla cui combinazione dipendono le caratteristiche finali del prodotto estruso.

Ad esempio, a parità di altri parametri operativi, una variazione del contenuto di umidità nel prodotto in entrata (dovuto a disuniformità del contenuto della materia prima o di quella aggiunta nel pre-condizionamento) comporta variazioni di energia meccanica, di pressione e di sforzo di taglio e, conseguentemente, variazioni delle caratteristiche del prodotto estruso.

Il processo di testurizzazione delle proteine di soia mediante cottura-estrusione era stato originariamente descritto da J.K. Mc.Anelly nel 1964 (U.S. Patent 3,142,571), ma è stato reso applicabile industrialmente con l'apposita apparecchiatura continua descritta da W.T. Atkinson nel 1970 (U.S. Patent 3,488,770). Il processo applicato alla farina di soia disoleata consiste nella applicazione opportunamente combinata di umidità, pressione, calore a temperature comprese tra 150 e 200°C), e sforzo di taglio, al fine di provocare una profonda denaturazione delle proteine, che devono essere srotolate, allineate e legate tra loro così da ottenere una massa visco-elastica all'interno dell'estrusore, una struttura fibrosa e porosa dopo decompressione ed essiccamento, insolubilità e masticabilità-elasticità analoghe a quelle della carne dopo reidratatazione. Usando la terminologia commerciale inglese, il prodotto estruso è denominato TVP (Textured Vegetable Protein) o TSP (Textured Soy Protein).

Più in dettaglio, nelle condizioni di alta temperatura, umidità e sforzo di taglio all'interno della camera di compressione a vite, la struttura quaternaria delle proteine si apre dando origine ad una massa visco-plastica. Successivamente le proteine polimerizzano, per formazione di legami ramificanti *cross-linking* che le insolubilizzano, e nella trafila si orientano in fasci creando una struttura fibrosa analoga a quella della carne.

Lo scarico del prodotto dalla trafila comporta una caduta di pressione tale da provocare, in funzione della temperatura, il flash evaporativo di una parte più o meno grande dell'acqua contenuta e, quindi, una corrispondente espansione e porosità del prodotto estruso.

La cottura-estrusione della farina di soia parzialmente disoleata permette di ottenere due diversi tipi di prodotto testurizzato, riferiti a due distinte finalità di impiego:

- un estruso impiegato per parziale sostituzione di carne macinata (*meat extender*). In questo caso il prodotto deve essere molto espanso, con fibre ben separate ed elevata reidratabilità;

- oppure un estruso impiegato come sostituto integrale di carne anche in pezzatura macroscopica (*meat analogs*). In questo caso il prodotto deve avere elevata densità e fibre allineate in strati.

In base alla classificazione funzionale, per la testurizzazione si impiegano estrusori formatori bivite co-rotanti ad alto sforzo di taglio, ovvero con viti e relativamente molto lunghe e, preferibilmente, costituite da moduli a diverso profilo per aumentare progressivamente l'azione meccanica). Gli elevati sforzi tangenziali applicati alla massa. che comportano elevata dissipazione di energia meccanica, alte temperature per trattamenti HTST (pochi secondi a 150-200°C) e pressioni relativamente modeste. In questo modo è privilegiata la denaturazione proteica rispetto alla gelatinizzazione e destrinizzazione dell'amido e, con umidità in alimentazione relativamente elevata (20 al 25 %), dalla massa plastica all'uscita della trafila evapora istantaneamente parte dell'acqua con elevata espansione del prodotto estruso che, raffreddandosi altrettanto istantaneamente per cessione del calore latente di evaporazione, assume una struttura porosa e lamellare. Qualora, invece, si voglia ottenere un estruso a maggiore densità, oltre ad aggiungere inizialmente meno acqua (15-20%), si deve raffreddare la massa plastica prima e/o durante il passaggio attraverso la trafila.

L'orientamento delle macromolecole del prodotto estruso, oltre che dalla geometria della trafila, dipende dal flusso quello effettivo (che determina la distribuzione dei tempi di permanenza) dato dalla risultante delle seguenti due componenti antagoniste:

- <u>flusso di trasporto</u> (l'estrusore si comporta come una pompa positiva);

- <u>flusso di ritorno</u> (dovuto alla pressione che spinge il materiale in senso opposto).

Per una data composizione e viscosità del prodotto alimentato, le caratteristiche di densità, struttura, grado di denaturazione proteica, formazione delle fibre e idratabilità. del prodotto estruso dipendono da:

- lunghezza della vite L;
- rapporto di compressione della vite h_1/h_2 (con h_1 = distanza fra sezione di alimentazione della vite e parete interna della camera e h_2 = distanza fra sezione di pompaggio della vite e parete interna della camera);
- diametro della trafila.

Uno schema generale di processo per la produzione di proteine di soia testurizzate prevede le seguenti operazioni:

- i fagioli di soia sono sottoposti a pulitura, riscaldamento, schiacciatura (fioccatura) ed eliminazione della cuticola esterna mediante aspirazione;
- i "fiocchi" di soia sono disoleati con esano e trattati con vapore per eliminare il solvente;
- i fiocchi di soia disoleati (detti fiocchi "bianchi") possono seguire due vie:
  - macinazione, umidificazione, estrusione e essiccamento, ottenendo come prodotto la farina di soia testurizzata con circa il 50% di proteine (da reidratare con acqua nel rapporto 1:2);
  - oppure, estrazione con acqua dei carboidrati solubili (compresi gli oligosaccaridi non digeribili raffinosio e stechiosio che causano flauto lenza) e di sostanze aromatiche non gradite, separazione del residuo solido (ottenendo farina di soia concentrata), macinazione, estrusione e essiccamento, ottenendo come prodotto con circa il 70% di proteine di soia testurizzate (da reidratare con acqua nel rapporto 1:3).

Il prodotto reidratato "similcarne" (soy "meatless burger") può avere la seguente composizione centesimale: proteine 15%; grassi 6%; carboidrati 5% e fibra 2%

Lo “Stato dell’arte della tecnologia” contenuto nella relazione sulla attività ottobre-novembre 2012 è principalmente basato sulla seguente pubblicazione:

J. P. Kearns, et al. (1994) **Extrusion of texturized proteins.** *ASA –American Soybean Association* (Allegato A.4.1)

Textured vegetable protein
http://en.wikipedia.org/wiki/Textured_vegetable_protein

Textured or **texturized vegetable protein** (**TVP**), also known as **textured soy protein** (**TSP**), **soy meat**, or **soya meat** is a defatted soy flour product, a by-product of extracting soybean oil.

TVP is usually made from high (50%) soy protein soy flour or concentrate, but can also be made from cotton seeds, wheat, and oats. It is extruded into various shapes (chunks, flakes, nuggets, grains, and strips) and sizes, exiting the nozzle while still hot and expanding as it does so. The defatted thermoplastic proteins are heated to 150-200°C, which denatures them into a fibrous, insoluble, porous network that can soak up as much as three times its weight in liquids. As the pressurized molten protein mixture exits the extruder, the sudden drop in pressure causes rapid expansion into a puffy solid that is then dried. As much as 50% protein when dry, TVP can be rehydrated at a 2:1 ratio, which drops the percentage of protein to an approximation of ground meat at 16%.

Textured soy chunks

Flakes

TVP can be made from soy flour or concentrate, containing 50% and 70% soy protein, respectively; they have a mild beany flavor. Both require rehydration before use, sometimes with flavoring added in the same step. TVP is extruded, causing a change in the structure of the soy protein which results in a fibrous, spongy matrix, similar in texture to meat.

TVP is a factory-made food that originates from a soy protein isolate. The process involves separating the protein from the whole soybean. During this process, a slurry of soybeans is mixed with an alkaline solution that removes the fiber, which is separated from the protein in a large aluminum tank through an acid wash. The final product is a curd, which is then spray-dried at high temperatures. This results in a protein powder, which is put through a high-temperature and high-pressure process in a machine called an extruder. The result is TVP.

These processed proteins are a byproduct of soy oil production. Solvents such as hexane are used to extract the oil (see References 7), leaving defatted soy flour consisting largely of protein. This is mixed with water to make a stiff, dough-like substance, that is extruded under pressure through a die. As the soy leaves, the pressure of the die behind it expands, creating its characteristically spongy, meat-like texture. This is cut and shaped as needed to resemble various meats. It's then dried, making it a durable and shelf-stable food product.

Soya TVP is made from high quality, defatted, soya flour obtained from the process of seed cleaning, dehulling, oil extraction and pulverizing through a thermoplastic extrusion process under high temperature short time cooking to inactivate the anti nutritional factors present in the flour.

Zeki Berk (1992) **Technology of production of edible flours and protein products from soybean. Chapter 7 - Textured Soy Protein Products.** *FAO Agricultural Service Bulletin No. 97* (Allegato A.4.2)

Applied to soy protein products, the terms "**texturization** or **texturing**" mean the development of a physical structure which will provide, when eaten, **a sensation of eating meat**. Meat "texture" is a complex concept comprising visual aspect (visible fibres), chewiness, elasticity, tenderness and juiciness. The principal physical elements of meat which create the texture complex are: the muscle fibres and the connective tissue. It should be noted that the term "meat" is used here in the wide sense of "flesh food", and includes not only red meat but also poultry, fish and seafood.

The first approach tries to assemble a heterogeneous structure comprising a certain amount of protein fibres within a matrix of binding material. The fibres are produced by a "**spinning**" process, similar to that used for the production of synthetic fibres for the textile industry. The second approach converts the soy material into a hydratable, laminar, chewy mass without true fibres. Two different processes can be used to produce such a mass: **thermoplastic extrusion** and **steam texturization.**

The **extruder** consists basically of a sturdy screw or worm rotating inside a cylindrical barrel. The barrel can be smooth or grooved. The screw configuration is such that the free volume delimited by one screw flight and the inside surface of the barrel decreases gradually as one goes from one end of the screw shaft to the other.

As a result of this configuration, the material is compressed as it is conveyed forward by the rotating screw. Screws having different **compression ratios** are used for different applications. The barrel is usually equipped with a number of sections of steam heated jackets or induction heating elements or cooling jackets. A narrow orifice or "**die**" is fitted at the exit end of the barrel. The shape of the die opening determines the shape of the extruded product.

Defatted soy flour with a high protein solubility index is first conditioned with live steam, before entering the extruder proper. Well controlled conditioning is essential for good texturization and product uniformity. The moisture content of the feed is very important. A moisture level of about 20-25% is used for texturization. The conditioned flour usually assumes the form of small spheres.

The flour-water mixture is next fed into the extruder and picked up by the screw. As it advances along the barrel, it is rapidly heated by the action of friction as well as the energy supplied by the heating elements around the barrel. The high pressures attained through the compression mechanism explained above permits heating to 150-180°C.

This rapid "pressure cooking" process transforms the mass into a thermoplastic **"melt",** hence the name of **"themoplastic extrusion"** by which the process isalso known. The directional shear forces causes some alignment of the high molecular weight component while the proteins undergo extensive heat denaturation. The sudden release of pressure causes instant evaporation of some of the water and "puffing". The result is a porous, laminar structure. Puffing and therefore porosity can be controlled by monitoring melt temperature at the die. If a dense product is desired, the melt is cooled at the final section of the barrel, just before entering the die.

The extrudate is cut continuously by a rotating knife as it emerges from the die. It may be dried and sold as a shelf-stable product, or it can be hydrated, flavoured, mixed with other ingredients, shaped and marketed, usually, as a frozen food.

While texturizing the soy material, extrusion cooking also provides the heat treatment necessary to reduce the microbial load and to inactivate the trypsin inhibitor. It should be noted that, despite the high temperatures in the extruder, trypsin inhibitor inactivation may be incomplete, due to the relatively short processing time.

The so-called low-cost extruders which have been mentioned in connection with the continuous heat treatment of full fat soy flour or corn-soy-milk (CSM) food supplements are not suitable for texturization. These extruders work with low-moisture feeds and provide heat mainly by friction. The extrusion-cooking machines used for texturization are more sophisticated and expensive. Recently, double-screw food extruders have been replacing the older single-screw models in food processing applications. In double-screw extruders a considerable part of the mixing and friction-heating effect takes place between the screws.

Table 7.1 Characteristics of textured soy products - *Source: Campbell (1981)*

Characteristic	**Product based on:**		
	Soy flour	Soy concentrate	Soy isolate
Flavour	Moderate to high	Low	Low
Retort stable	Yes	Yes	Yes
Flavour development on retorting	High	Low	Low
Flatulence	Yes	No	No
Form/shape	Granules or chunks	Granules or chunks	Fibres
Cost (dry basis)	Low	Low	High
Recommended hydration level	2:1	3:1	4:1
Cost of hydrated protein	Low	Low	High
Fat retention	Moderate	High	Moderate
Optimum usage level in meat extension (% hydrated level)	15-20	30-50	35-50

Meat extenders - The principal use of texturized soy protein products is as a meat extender in comminuted meat product such as patties, fillings, meat sauces, meat balls etc. In such products, as much as 30% of the meat can be replaced by hydrated texturized soy products without loss of eating quality. Their ability to absorb water and fat results in increased product juiciness and permits the use of meat with higher fat content.

Meat analogs - Chunks of extrusion texturized soy protein products and spun fibre based preparations are marketed as "imitation meat" or "meat analogs". The market for these products was, at first, limited to the relatively small sector of vegetarians. Recently there is a marked trend to reduce the consumption of red meat, associated with the demand for low-cholesterol foods. The present marketing strategy for meat analogs is to present them to the public as new, high quality products, and not as inexpensive substitutes for meat. So far, this strategy seems to be successful.

Textured/Structured Soy Protein Products - Textured protein products are being prepared commercially by thermoplastic extrusion of flours, grits and protein concentrates under heat and pressure to form chips, chunks, flakes, and a variety of other shapes. These products can be flavored to resemble or extend meats, such as hamburger, stew meats, and beef chili, and are widely used as meat extenders. Their structure and texture can be modified by varying extrusion parameters and by the addition of salts to the mix before extrusion. They also absorb water, and to some extent fat, so they can be regarded as having physical functions, in addition to their main role as extenders.

Structured concentrates are extruded products made to have a fibrous or laminar rather than a spongy structure. In general, structured concentrates also have higher water absorption and hydration rates (2-5 minutes vs. 30-60 minutes) than those of textured flours and granular concentrates of ten years ago, and their structure and texture stands up to retorting much better.

Hulya Akdogan (1999) **Review. High moisture food extrusion**. *International Journal of Food Science and Technology, 34:195-207* (Allegato A.4.3)

Extrusion at higher moisture contents (> 40%). also known as wet extrusion, is relatively less investigated compared to low and intermediate moisture extrusion. Literature on high moisture food extrusion has been reviewed. Wet extrusion applications utilise twinscrew extruders due to their efficient conveying capabilities. Extruders can be used as bioreactors for starch hydrolysis using thermally stable enzymes. This process is usually followed by saccharification inside or outside an extruder to produce a high DE (dextrose equivalent) syrup. Starch-based high moisture extrusion research also reports a few modelling studies. The rheological properties, torque and energy requirements of high moisture extrusion systems are different from those of low and intermediate systems. Other research reviewed includes the extrusion of low-cost plant and animal proteins to manufacture nutritious food products that imitate the texture, flavour, and mouthfeel of meat.

K. S. Ronai, et al. (1978) **Process for production of textured protein flakes.** *US Patent Mo 4,103,034* (Allegato A.4.4)

A method for preparing dried flaked textured high vegetable protein which instantly hydrates a portion content of 30 percent or more, and has an improved flavor. The process includes texturizing vegetable protein material by subjecting such vegetable protein material containing moisture to a pressure of at least 1.800 pounds per square inch for a time and at a temperature sufficient to convert said moisture into steam whereby such vegetable protein material is partially disembittered, toasted without scorching and is compacted into a hard and substantially fused mass having textured characteristics. The fused mass is fragmented into particles.

A. I. Nelson, et al. (1983) **Extrusion texturization of full-fat soybean and product thereof**. *US Patent No 4,369,193* (Allegato A.4.5)

A textured soybean product is produced from full-fat soybean by h yd rating whole soybean by treatment with a dilute alkaline solution; mixing the hydrated soybean with full-fat soy flour and equilibrating the moisture content thereof; and passing the mixture through an extrusion cooker. The textured product has excellent flavor, color, and appearance, and can be formulated into an all-vegetable ground meat analogue or it can be used as an extender in blends with ground meat.

C. B. Pham, R. R. Del Rosario (1984) **Studies on the development of texturized vegetable products by the extrusion process. I. Effect of processing variables on protein properties**. *International Journal of Food Science & Technology, 19(5):535–547*

The effect of process temperature, screw speed, moisture content and pH on the protein properties of cowpea (CP), mung bean (MB), defatted soybean (DSB) and air classified mung bean (ACMB) were studied. At high process temperature and low moisture content, increased screw speed resulted in decreased nitrogen solubility index (NSI). Water absorption capacity (WAC) measurement reflected differences in the composition of the raw materials. WAC values increased with pH, screw speed and process temperature and with decreased moisture content for high protein containing ACMB and DSB products, while with low protein containing CP and MB products, WAC values decreased at high moisture content. The insolubilized protein of the extruded products was resolubilized by sodium dodecyl sulphate (SDS) and dithiothrcitol (DTT) reagents in a pH 7.6 buffer indicating the presence of both non-covalent interactions and disulphide bonds. During the extrusion process, the decrease in solubilities of extruded products can either be due to the formation of non-covalent interactions and of new disulphide bonds.

S. H. Holay, J. M. Harper (1982) **Influence of the Extrusion Shear Environment on Plant Protein Texturization**. *Journal of Food Science, 47(6):1869–1874*

The effects of total nominal shear strain, apparent shear rate, shear stress in the die, and an integral temperature-time history function on textured soy protein properties were studied. These variables are independent of extruder size and can potentially serve as machine independent correlating factors. Correlation models showed that increasing shear strain and temperature-time in the screw tended to enhance cross-linking between protein molecules, while increasing shear through the die tended to disrupt the linkages. Moisture probably increases the mobility of the protein species which could improve cross-linking and reduced density while increasing water absorption.

E. M. McCabe (1990) **Method of producing simulate meat product from whole soybeans**. *US Patent No 4,943,441* (Allegato A.4.6)

A method of processing whole soybeans to produce discrete, irregularly-shaped chunks or pieces of textured proteinaceous material which are free from off-flavors and odors and have a meat-like texture and appearance. Whole soybeans are hydrated and acidified to a pH in the range of about 4.5 to 6.5 and the pH of the soybeans is maintained in this range throughout processing. I he acidified whole soybeans are ground in an aqueous medium to provide an aqueous slurry or dough of soybean particles having a pH in the range of 4.5-6.5. The aqueous acidic slurry or dough in passed through a confined treatment zone in which high temperature pressurized steam is injected directly into a confined stream of the slurry or dough under conditions which effect texturization of the soy protein in the form of discrete chunks or pieces which are discharged from the treatment zone. The texturized pieces, when discharged from the treatment zone or when dried and rehydrated are free of off-flavors and odors and have a meat-like texture, firmness and appearance.

S.R. Dahl, R. Villota (1991) **Twin-Screw Extrusion Texturization of Acid and Alkali Denatured Soy Proteins**. *Journal of Food Science, 56(4):1002–1007*

Effect of pH on functional characteristics of soy protein was investigated by modifying soy flour through acid (HCl) or alkali (NaOH) addition. Acid- and alkali-treated proteins were evaluated and texturized by twin-screw extrusion. Products were analyzed by rheological, functional, and ultrastructural methods. Acid-modified texturized protein had little expansion, increased peak force, increased work of shearing, and a nonoriented fiber arrangement. Slightly alkaline extrudates had increased rehydration but poorer texture. Stronger alkaline treatment resulted in denser products with high peak force measurements, which disintegrated when extrudates were rehydrated. The physicochemical state of soy protein, particularly conformation and protein-water interactions as affected by pH, may influence expansion of textured products and development of plexilamellar structure.

L. Ning, R. Villotta (1994) **Influenvce of 7S and 11S Globulins on the Extrusion Performance of Soy Protein Concentrates.** *Journal of Food Processing and Preservation, 18(5):431-436*

The 7S and 11S fractions of soy protein were isolated from soy flour and recombined with soy protein concentrate at various levels to modify their ratio in different formulations, the role of each fraction on the extrusion performance and texturization behavior of soy proteins was evaluated using twin-screw extrusion. Both 11S and 7S fractions were found to have significant influence on the degree of texturization of soy protein. In particular, the 11S protein appeared to favor expansion and water holding capacity of the finished product, while an 11S/7S ratio of 1.5 in the feed formulation resulted in a product with the best textural characteristics under the selected extrusion conditions investigated

D. V. Zasypkin, Tung-Ching Lee (1998) **Extrusion of Soybean and Wheat Flour as Affected by Moisture Content.** *Journal of Food Science, 63(6):1058–1061* (Allegato A.4.7)

The effect of moisture content (MC) on texture and properties of extrudates with varied ratios of soybean flour (SF) and wheat flour (WF) was studied. A single-screw extruder was used at screw speed 200 rpm. MCs of blends were 16, 17 or 18%, w.b. The properties of extrudates depended on flow rate of the material during extrusion. The flow rate revealed a nonlinear dependence on the blend composition and the MC at the same volume of filling of the screw feeding section. The expansion ratio of WF or SF extrudates increased with lowering of the MC. Unexpectedly, the expansion ratio decreased with lower MC for the composite extrudates. Optimal extrudate properties at 16% (w.b.) MC corresponded to 80, 90 or 100% (d.b.) WF and 20, 10% or no SF, respectively. At 17 and 18% MC, optimal properties were found for products containing 80 or 90% WF and 20 or 10% SF, respectively.

Hülya Akdoga (1999) **High moisture food extrusion**. *International Journal of Food Science & Technology, 34(3):195–207* (Allegato A.4.8)
Extrusion at higher moisture contents (> 40%), also known as wet extrusion, is relatively less investigated compared to low and intermediate moisture extrusion. Literature on high moisture food extrusion has been reviewed. Wet extrusion applications utilise twin screw extruders due to their efficient conveying capabilities. Extruders can be used as bioreactors for starch hydrolysis using thermally stable enzymes. This process is usually followed by saccharification inside or outside an extruder to produce a high DE (dextrose equivalent) syrup. Starch-based high moisture extrusion research also reports a few modelling studies. The rheological properties, torque and energy requirements of high moisture extrusion systems are different from those of low and intermediate systems. Other research reviewed includes the extrusion of low-cost plant and animal proteins to manufacture nutritious food products that imitate the texture, flavour, and mouthfeel of meat.

T. Sakata, et al. (1999) **Process for preparing textured soybean protein**. *US Patent No 5,858,44*8 (Allegato A.4.9)

This invention provides a process for preparing a textured soybean protein (ISP), the process having the steps of pressurizing and heating a raw material containing a soybean protein and water, quickly releasing the pressure to texturize the protein, bringing the obtained TSP into contact with steam while the TSP remains hot and is not completely dried. According to the process of this invention, a TSP having a good flavor can be produced in a simple and economical manner.

S. Lin, et al. (2000) **Texture and Chemical Characteristics of Soy Protein Meat Analog Extruded at High Moisture**. *Journal of Food Science, 65(2):264–269* (Allegato A.4.10)

The relationships among extruder responses, texture, and protein solubility of soy protein meat analogs were studied. Soy protein isolate and wheat starch at 9:1 ratio were extruded at 60%, 65%, and 70% moisture contents and 137.8, 148.9, and 160°C cooking temperatures. The results showed that moisture content was a more important factor on the overall product texture than cooking temperature. Lower moisture content resulted in higher die pressure, harder texture, and lower total protein solubility. At a fixed moisture content, a higher cooking temperature resulted in a softer and less chewy product but only slightly changed the protein solubility. According to partial least square regression, the data from Texture Profile Analysis, protein solubility, and extruder responses correlated well and could be used to predict each other.

Sanshiroh Saitoh, et al. (2000) **Antigenicity in Soybean Hypocotyls and Its Reduction by Twin-Screw Extrusion.** *JAOCS, Vol. 77(4):419-424* (Allegato A.4.11)

The purpose of the present study was to develop a simple method to make a low-antigenicity food and/or feed rich in isoflavones from soybean hypocotyls. The antigenicity of soybean hypocotyls for bovine antisoybean sera was assessed by enzyme-linked immunosorbent assay. Immunoblotting demonstrated that the antigenicity was derived from storage proteins, which were present in hypocotyls as glycinin and β-conglycinin, and from unknown proteins. Ground soybean hypocotyls (32-mesh sieve size) were passed through a twin-screw extruder to reduce the antigenicity to 1% of the original activity. The degradation of antigen proteins in soybean products was confirmed by sodium dodecyl sulfate polyacrylamide gel electrophoresis. Trypsin inhibitor and urease activity were also greatly reduced. The concentrations of isoflavones were unaffected.

T. W. Crowe, L. A. Johnson (2001) **Twin-screw extrusion texturization of extruded-expelled soybean flour**. *Journal of the American Oil Chemists' Society 78(8):781-786* (Allegato A.4.12)

Texturized soy proteins (TSP) have been produced from hexane-extracted soy flours having a narrow range of characteristics. The objective of this study was to determine the influence of protein dispersibility index (PDI) and residual oil content on extrusion texturization of partially defatted soy flours produced by extruding-expelling (E-E). Ten E-E processed soy flours having residual oil contents and PDI values of 5.5–12.7% and 35.3–69.1%, respectively, were texturized using a twin-screw extruder. Water-holding capacities were greater for TSP prepared from E-E processed soy flours with lower residual oil contents. Bulk densities were significantly lower for TSP prepared from E-E processed soy flours compared with a commercial product made from hexane-extracted soy flour. The texture characteristics of extended ground beef patties containing texturized E-E processed soy flour were similar to that of 19% fat ground beef. Flavor acceptability was directly correlated (R=0.761) with residual oil content of the E-E processed soy flours. However, lower residual oil and higher PDI flours exhibited better texturization and extrudate qualities.

J. Zhang, et al. (2001) **Mechanical and thermal properties of extruded soy protein sheets.** *Polymer 42 :2569–2578* (Allegato A.4.13)

Soy protein plastic sheets were made by extrusion. The effects of water, glycerol, methyl glucoside, ZnSO4, epichlorohydrin, and glutaric dialdehyde on the mechanical properties of soy protein plastic sheets were studied. The thermal transition temperatures and dynamic mechanical properties of soy protein plastics were also investigated. Depending on the moisture and glycerol contents, soy protein plastic sheets displayed properties from rigid to soft. The glass transition temperatures of the sheets varied from ca. -7 to 50àC with moisture contents ranging from 26 to 2.8% and 30 parts of glycerol. The soy protein plastic sheets were usually in their glassy states at room temperature unless they contained high moisture. The b-transitions of soy protein plastic sheets ranged from -33 to -72°C depending on the moisture. After being submerged in water for 20 h, the soy protein sheets absorbed up to 180% water. With the presence of two parts of ZnSO4, water absorption of the soy protein sheets decreased by 30%. Soy protein sheets absorbed or lost moisture depending on the relative humidity of the environment.

Wang Hongwu Zhou, et al. (2001) **Effect of Processing Variables of Twin-screw Extrusion to Texturization of Compound Soybean Protein.** *Chinese Cereals and Oils Association, 02*

The effect of processing variables,such as screw speed,feed moisture and barrel tcmperature of extrusion process to the property of extrudate was experimentally studied using a new co-rotating twin-screw cooking extruder. The optimum screw speed was in the range of 80 r/min - 120 r/min and the optimum feed moisture was in the range of 34% - 44% for extrusion texturization of defatted soybean flour. The optimum processing variable for extrusion texturization of soybean protein and fresh pork meat blends was as follows: screw speed 60 r/min - 80 r/min and feed moisture 60% - 65%. The optimum temperature profile of the extruder obtained from these experiments was: 30°C, 45°C, 80°C, 100°C, 130°C, 150°C, 100°C. In these processing conditions the textured soy protein and engineering meat product had distinct fiber structure.

Hou Jianshe et.al. (2002) **Effects of temperature and water on the nutrition composition of texturized soybean protein.** *Science and Technology of Food Industry, 06*

The effects of temperature and water content on the destruction of nutrition in texturized soybean protein products are studied. Results show temperature and water content had no significant effect on both protein and fat content, but affected their compositions significantly. With the processing temperature increasing, both the lysine and the total amino acid content of the products decreased quickly and the color of them became brown and dark brown and the ammonia level in products rose, indicating higher temperature quickened these reactions, causing the loss of aminoacids. The product produced in the conditions of the ratio of material to water = 20:13 and with 190°C as processing temperature mostly retain the level of protein and fat in material, with minimal loss of amino acids and fatty acids and without browning.

I. Havakawa. et al. (1989) **Texturization of whole soybean in a twin-screw extruder**. *J. Fat. Agr., Kyushu Univ., 33(3-4):213-220* (<u>Allegato A.4.14</u>)

Good meat-like extrudates were-manufactured from full fat soybean flour using a twin-screw-extruder. From the results of FT-IR analysis, no noteworthy new chemical bonds were present in the formation of the matrix, and deamidation was observed. From-the-results of' flow double refraction-analysis, viscosity measurement, FT-IR analysis and-sodium dodecyle sulfate polyacrylamide gel electrophoresis, the-S-S bond did not play an-important role on-the-formation of- the matrix, and a large number of molecules in the products had a reduction in-molecular weight and shifted to chain structure. It was considered that the matrix-was-formed-by-entanglements-of-linearized proteins and polysaccharides in soy beans by shearing into the materials molten by high temperature and high pressure in the presence of water.

S. Lin, et al. (2002) **Extrusion Process Parameters, Sensory Characteristics, and Structural Properties of a High Moisture Soy Protein Meat Analog**. *Journal of Food Science, 67(3):1066–1072* (<u>Allegato A.4.15</u>)

Soy protein isolate and wheat starch at 9:1 ratio were extruded at 60%, 65%, and 70% moisture contents and 138, 149 and 160 °C cooking temperatures. The results indicated that moisture content was a more important factor than cooking temperature for both extrusion process parameters and product sensory characteristics. <u>Extrusion at a lower moisture content resulted in a higher product temperature and higher die pressure</u>. <u>The resultant products were tougher, chewier, and more cohesive and had a more layered and fibrous structure</u>. <u>Water absorption capacity increased with both higher extrusion moisture and higher cooking temperature</u>.

Franck P. (2002) **The Allergenicity of Soybean-Based Products Is Modified by Food Technologies.** *Int. Arch. Allergy Immunol., 128:212–219*

Three commercial products and two infant formulas were studied: Soybean flour, soy milk, texturized soy proteins, two infant formulas; the first containing total proteins and the second containing a soy protein hydrolysate. Sera from 9 patients allergic to soy protein were tested by immunoblotting (IB). Immunoblotting revealed a lack of allergenicity in infant formula. Sera recognizing the 38- and 50-kD proteins in texturized soy protein also recognized the 37- and 49-kD proteins in soybean flour and in soy milk, suggesting a protein glycation by texturization processes. The 30- to 34-kD band in texturized proteins was devoid of any allergenicity. This study seems to indicate that the 30-kD allergen (Gly m Bd 30) disappears during the production of texturized soy protein. Texturized protein could lack the major allergen Gly m Bd 30. Further studies or texturization might generate modified technologies in order to create hypoallergenic texturized proteins.

Shannon Wilson, et al. (2005) **Allergenic Proteins in Soybean: Processing and Reduction of P34 Allergenicity**. *Nutrition Reviews, 63(2):47–58* (Allegato A.4.16)

Soybean ranks among the "big 8" of the most allergenic foods, and with increasing consumption of soybean products, the incidence of soycaused allergies is expected to escalate. Soybean and its derivatives have become ubiquitous in vegetarian and many meat-based food products, and as a result, dietary avoidance has become difficult. However, soybeans can be manipulated in a variety of ways to alter their allergenicity. Several studies have focused on reducing the allergenicity of soybeans by changing the structure of the immunodominant allergen P34 using food processing, agronomic, or genetic manipulation techniques. A review of the literature pertaining to these studies is presented here.

M. K. McMindes, et al. (2006) **Soy protein containing food product and process for preparing same**. *US Patent No 2006/0073261 Al* (Allegato A.4.17)

This invention relates lo a soy protein containing food product comprising: (A) a fibrous material containing soy protein and soy cotyledon fiber- wherein said soy cotyledon fiber is present in the fibrous material in an amount of from 1 % to 8%. by weight on a moisture free basis: (B) a humectant comprising (i) a colorant and at least one of (ii) a flavoring agent, (iii) a triglyceride oil, (iv) a food grade acid or acidic salt, (v) a food grade base or basic salt, or (vi) a food grade emulsion; and (C) water. In another embodiment, the invention is directed to a process for preparing a soy protein containing food product.

V. Tolstoguzov (2006) **Texturising by phase separation**. *Biotechnology Advances, 24:626-628* (Allegato A.4.18)

The most common food processing operations, thermal and mechanical treatments, both affect phase state and texture of foods. The phase separation threshold tor food biopolymer mixtures is usually below their concentrations characteristically found in food. Phase-separation underpins texturization processes during food processing and digestion. The distribution of water between the phases, the adsorption of lipids between the phases, the deformation of dispersed particles in flowing water-in-water emulsions and the gelation of the phases result in the specific morphology and texture of food. A historical experience in tcxturisation includes the development of cooked food and texturized vegetable analogues of animal foods.

M. A. Morcos, et al. (2007) **Improving the properties of the locally produced texturized soybean.** *Misr J. Ag. Eng., 24(3):611- 629* (Allegato A.4.19)

The properties of the locally produced texturized soybean were improved through the modification of the extruder's screw (its mean effective unit) and the application of some suitable treatments. The modification was concentrated on changing the dimensions of each zone of the three screw zones (feeding, kneading, and final cooking zones). The applied treatments included two levels of fat content (7 and 1.5% fat), three levels of moisture content (15, 18, and 21%) and three types of alkaline additives (no additive, CaO 0.5% and $CaCO_3$ 1%). The tested properties of the texturized soybean included its components (protein, total carbohydrate, ash and moisture content), its physical properties (pH, bulk density, hardness, and water absorption capacity) beside the determination of its aggregate sizes distribution. The results showed obvious improvements of the properties for the locally produced texturized soybean since it were almost resemble to those of the imported texturized soybean.

A. Chiang (2007) **Protein-protein interaction of Soy Protein Isolate from extrusion processing**. *Thesis (M.S.) University of Missouri-Columbia.* (Estratto in Allegato A.4.20)

In both low moisture and high moisture extrusion, increasing product temperature from 125.3 to 140.6°C did not have significant difference on proteins that could be extracted by various solvents. The moisture content did have significant affect on the protein solubility, however no difference in protein subunit distribution was observed. In addition, there was no significant change in the molecular weight distribution of protein subunits between the control and extrudates. It appears that the effect of extrusion is to disassemble proteins and then reassemble them together by disulfide bonds, hydrogen bonds and noncovalent interactions forming fibrous structure in extrudates, Despite major difference in appearance, similar protein to protein interactions occurred in both low moisture and high moisture extrusion. Therefore, it appears that the extrusion of soy protein isolates modified very little at the molecular level and that the protein subunits did not have any structural changes.

KeShun Liu, Fu-Hung Hsieh (2008) **Protein–Protein Interactions during High-Moisture Extrusion for Fibrous Meat Analogues and Comparison of Protein Solubility Methods Using Different Solvent Systems.** *J. Agric. Food Chem.***,** *56*:2681–2687 (Allegato A.4.21)

Soy protein, mixed with gluten and starch, was extruded into fibrous meat analogues under highmoisture and high-temperature conditions. Protein solubility by most extractants showed decreasing patterns as the material passed through the extruder, but the solution containing all 6 reagents, known as isoelectric focus (IEF) buffer, solubilized the highest levels and equal amounts of proteins in all samples, indicating that there are no other covalent bonds involved besides disulfide bonds. Using the IEF buffer system with omission of one or more selective reagents is considered to be the right methodology to conduct protein solubility study and thus recommended. Results obtained with this system indicate that disulfide bonding plays a more important role than non-covalent bonds in not only holding the rigid structure of extrudates but also forming fibrous texture. The sharpest decrease in protein solubility occurred when the mix passed through the intermediate section of the extruder barrel, indicating formation of new disulfide bonds during the stage of dramatic increase in both temperature and moisture. After this stage, although the physical form of the product might undergo change and fiber formation might occur as it passed through the cooling die, the chemical nature of the product did not change significantly.

M. Katayama, L. A. Wilson (2008) **Utilization of Soybeans and Their Components through the Development of Textured Soy Protein Foods**. *J. of Food Science, 73(3):S158-S164* (Allegato A.4.22)

The objective of this study was to develop the best formulation of TSP and vegetable-based flavors to produce consumer acceptable "chicken" or "shrimp" flavoured TSP using heat application processes. Four different types of commercial TSP (containing an average of 51% protein) strip-shaped extruded with a narrow die (STRIP-N) or with a wider die (STRIP-W), shred-shaped (SHRED) strips, and 1-cm crouton-shaped bits (BITs) were used. The TSPs were baked or deep-fat fried after soaking in 5 different commercial vegetable-based powered, liquid, or oil-based flavors ranged from 0% to 22.3% concentrations. Four descriptive analyses with a minimum of 14 trained panelists were utilized to evaluate the attributes of the finished TSP. Proximate, color, and texture analyses were performed on each TSP product. All treatments were statistically analyzed. Both instrumental and sensory tests demonstrated that BIT had a significantly higher crispness than other TSP. The powder type of chicken flavor used for a consumer panel had a more intense flavor than others with the optimum hydration time, 15min. A consumer test with 125 people was performed with the highest chicken flavored (22.3%) fried and baked BIT. Overall, 66% of the total consumers preferred the fried BIT to the baked BIT, and 31% preferred the baked BIT.

R. S. MacDonald, (2009) **Soy Protein Isolate Extruded with High Moisture Retains High Nutritional Quality**. *J. Agric. Food Chem. 57:3550–3555* (Allegato A.4.23)

High-moisture extrusion of soy protein isolate generates a highly palatable meat substitute. No systematic evaluation of the nutritional quality of soy processed in this manner has been performed. This study compared the growth rate of male and female mice fed diets containing soy protein isolate without extrusion or with high-moisture extrusion. Other measures of overall growth and animal health were examined. Minor differences in the parameters were observed. Overall, the extruded soy protein was equally nutritious as the unextruded soy protein for the animals. Hence, high-moisture extrusion may be considered a useful method to generate high-quality protein foods. A longer term feeding trial may be recommended to further define the nutritional adequacy of this protein.

Feng Liang Chen, et al. (2010) **System parameters and product properties response of soybean protein extruded at wide moisture range**. *Journal of Food Engineering, 96:208–213* (Allegato A.4.24)

In order to explore the effect of water during extrusion process, soybean protein isolate (SPI) was extruded using a pilot-scale twin-screw extruder at 28%, 36%, 44%, 52% and 60% moisture content and 140, 150 and 160 °C cooking temperature. The extrusion system parameters like in-line viscosity at die, mean residence time and specific mechanical energy (SME), product textural properties including tensile strength, hardness, chewiness and degree of texturization, and the molecular weight distribution characterized by SDS–PAGE were investigated. And the interrelationship between system parameters and product properties were analyzed. The results showed that moisture content was a more important factor on system parameters and product properties than cooking temperature. Higher moisture content resulted in lower viscosity of dough in the extruder, shorter residence time and lower conversion ratio of extruder mechanical energy into heat energy, finally reducing significantly the tensile strength, hardness, chewiness and the degree of aggregation. The data from extrusion system parameters and product properties correlate well and could be used to explain and control the characteristics of extrudate.

Haiqin Ge (2011) **Texture optimization of soy protein isolate post high-moisture extrusion as an alternative dietary protein source**. *Thesis MS University of Maryland*. (Estratto in Allegato A.4.25)

Twin-screw high-moisture extrusion was capable of texturing and shaping SPI into fibrous slabs similar to that of cooked skinless chicken breast yet harder and more rubbery due to significant post-extrusion moisture loss. The texture of extruded SPI was further optimized in the present study to reduce hardness and rubberiness. The combination of acetic acid treatment under pH 4.5 at 65°C for 50 min with addition of 0.1% (w/v) mixture of cornstarch and xanthan gum at a 3:2 (w/w) ratio yielded a tender SPI meat analog with desirable color closest to that of cooked skinless chicken breast. A novel vegetarian nugget based on the modified SPI meat analog was formulated and received consumer acceptance superior to commercial counterparts in its texture without detectable soy flavor.

P. Guerrero, et al. (2012) **Extrusion of soy protein with gelatin and sugars at low moisture content**. *Journal of Food Engineering, 110:53–59* (Allegato A.4.26)

Soy protein-based materials modified with gelatin, lactose and sucrose were prepared by extrusion at low moisture content. The effect of composition on the extrusion parameters was investigated and specific mechanical energy (SME) was measured as an indication of extrusion processability, thus providing good characterization of the extrusion process in order to make it highly energy efficient and cost effective. Water content was the most important factor on the extrusion parameters and product properties. The incorporation of gelatin increased SME and the product obtained at the extruder die was not continuous. However, when lactose was added, SME decreased and the color of the product changed due to Maillard reaction. This reaction could be analyzed by Fourier transformed infrared spectroscopy (FTIR) where the changes of the amide I and amide II bands reflected that hydroxyl groups in sugars and amino groups in soy protein isolate (SPI) were consumed during extrusion. These results are in good agreement with total soluble matter (TSM) values, which were lower for mixtures with lactose than sucrose due to a higher degree of Maillard reaction. Moreover, X-ray diffraction (XRD) and scanning electron microscopy (SEM) results also showed the influence of Maillard reaction, which lead to more ordered and compact structures, respectively.

Z.M. Nazareth, et al. (2009) **Functional properties of Soy Protein Isolates prepared from gas-supported screw-pressed soybean meal**. *J. Am. Oil Che. Soc,, 86:315-321* (Allegato A.4.27)

White flakes (WFs) are obtained from dehulled flaked soybeans by extracting oil with hexane and flash- or downdraft-desolventizing the defatted flakes, and WFs are the normal feedstock used to produce soy protein ingredients. Gas-supported screw pressing (GSSP) is a new oilseed crushing technology in which traditional screw pressing is combined with injecting high-pressure CO2, thereby producing hexane-free, low-fat, high-PDI soybean meal. GSSP meals produced SPIs in significantly higher yields (59.7–63.1% vs. 51.6–61.1%), with greater free (0.05–0.40%) and bound fat (3.70–4.92%) contents than did WFs. There were no significant differences in protein contents of the SPI; all exceeded 90% protein content (db). SPIs prepared from GSSP meals had similar or slightly lower water-solubilities compared to SPIs prepared from WFs. SPIs prepared from GSSP meals had higher water-holding capacities and viscosities, and significantly better emulsifying and fat-binding properties compared to SPIs prepared from WFs. SPIs prepared from WFs had significantly better foaming properties compared to SPIs prepared from GSSP meals, which were attributed to the lower fat contents of SPIs prepared from WFs.
Hexane is the current solvent of choice used to extract crude oil, and the (defatted) flakes are desolventized by means of flash- or downdraft-desolventizing to minimize protein denaturation. To dale, only hot screw pressing and extruding-expelling (EE) have gained commercial acceptance as alternative processes, but these processes cause extensive protein denaturation thereby reducing SPI yield. Despite engineering challenges in making supercritical CO_2 (SC-$C0_2$) a continuous process. SC-CO; has long been promoted as a means of extracting oil from soybeans to produce DSF. SC-CO_2 extraction produces DSFs with higher PDls and less off-flavor in comparison to solvent-extracted DSF; but. the high capital cost associated with SC-CO_2 has prevented adoption by the soybean processing industry. A new gas-supported screw press (GSSP) process developed by Crown Iron Works (Minneapolis. MN. USA) injects CO_2 under high pressure into a screw press to act as a cooling and oil-displacement fluid thereby producing a unique soybean meal with high PDI and low residual fat content. The use of CO_2 as an extraction aid in the new GSSP process may provide similar advantages as is achieved with SC-CO_2

Crown Iron Works Co, Roseville, MN, USA

High Pressure Liquid Extraction (HIPLEX®)
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The HIPLEX® system is a mechanical screw press modified to inject liquid or gases into the internals of the press cage. Currently, liquid CO_2 is used in the press, resulting in increased oil removal and a corresponding increase in cake protein.

Crown has been advancing the CO_2 pressing technology since acquiring it in 1998. In 2005, Crown entered into an agreement with Harburg-Freudenberger (HF) for joint development of the HIPLEX® technology. The HIPLEX® process is a licensed technology that uses HF presses exclusively.

The HIPLEX® process injects CO_2 into the press to increase oil removal from the seed. The process can maintain a cooler temperature throughout the press reducing discoloration of the meal and oil. A natural and/or organic meal and oil are produced with lower residual oil than conventional mechanical pressing.

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- Produces a natural and/or organic meal and oil
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- Produces meal with lower residual oil

Harburg-Freudenberger Maschinenbau GmbH, Hamburg, Germany
HF Press+LipidTech
http://www.hf-press-lipidtech.com/downloads/docs/c67c3db1e104327fdcc096d3fe3e595d

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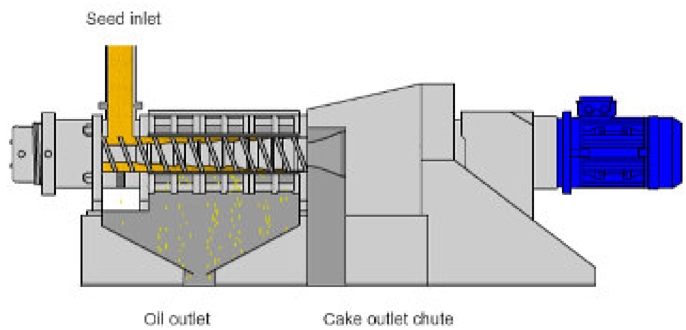

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J. Buseman (2012) **Mechanical Oil Pressing.** *INSTA-PRO International*
(NB in generale si fa riferimento alla produzione di mangimi per alimentazione animale)
Mechanical Oil Pressing
http://blog.insta-pro.com/2012/11/01/mechanical-oil-pressing/

The typical oil press features three important parts: the cage, screw, and cage bars.
Cage: This assembly houses the screw and cage bars. As seeds pass through this section, oil seeps out into the oil reservoir below. Some solids pass through as well and are pumped out with the crude oil.
Screw: This conveys the seeds through the press cage and against the cage bars. The action of the seeds being conveyed against the cage bars squeezes the oil out of the meal. When the meal reaches the end, the cake falls out and is conveyed to the next process. A motor is used to drive this screw.
Cage bars: These bars are spaced very closely together and form a ring around the screw. When the cage is closed, these encircle the screw. As mentioned above, these work with the screw to help shear and press the oil out of the seeds.

There are other ways to expand oil processing as well. Extrusion may be able to increase press efficiency and yields by allowing oil cells to rupture, making the oil easier to access and remove. A great example of this is the **Insta-Pro ExPress® process**. In the case of soybeans, this process is able to extract up to 66% of the available oil out of the seed.

Extruder Screw Design and Purpose
http://blog.insta-pro.com/2012/10/
At its core, the extruder is a very simple machine. The various configurations of shaft speed, number of chambers and types of screws/steamlocks enables the operator to create a multitude of products. Different products usually require different configurations and run parameters. An important parameter to consider is retention time in the barrel. Depending on what your product requires, you may have to increase or decrease the amount of time product stays in the barrel. A common way to do this is vary the screws inside each chamber.
Definitions
The screws inside each chamber serve two purposes:
1) Convey product through the barrel
2) Create shear and heat to perform necessary treatment to the product

There are two main factors that affect how the screw performs: pitch and flighting (see diagram).
Pitch: The distance between adjacent flights
Flights: Raised, helical sections of the screw (similar to threads on a machine bolt)

Flights

Flights can vary in design and are commonly either single or double (triple and quadruple are possible, but not very common). In the picture of the two screws, the one on the left is a single flight while the one on the right is double. Notice how the double appears to have two lobes on the end while the single only has one.

You can think of this like wrapping a string around a pencil: Single flighting is the same as wrapping one string around while double is like wrapping two strings around (anchored on opposite ends of each other). Double flights increase retention time and work since the product has to travel further in the same amount of space. This is good when the product must be heat treated to create proper chemical reactions.

Application

Altering these geometries will affect how your product cooks and conveys. Very tall flighting at a steep angle and large pitch will convey a lot of product very quickly, but will not apply very much work to it. On the other hand, short flighting with narrow pitch will convey less product but potentially do more work. Single flights are generally used at the beginning of an extruder to move product away from the intake quickly and double flights are used in the middle section to cook the product. A combination of these in your extruder will help you make the product you want.

Important Parameters for Pressing Soybean

http://blog.insta-pro.com/2012/08/28/important-parameters-for-pressing-soybeans/

The pressing of oil from soybeans appears at first glance to be a pretty simple process: you extrude the soybeans and run it through an oil press. However, there are many parameters that affect the efficiency of the process.

The goal is to extract as much oil as possible from the soybeans, which leaves you with two sellable products – oil and soybean meal. The oil is the target product, and if the equipment is not run properly and other parameters are ignored, it will cut into your profits pretty quickly. In this blog post, I'm going to discuss two important parameters to monitor to maximize oil yield (moisture and steam removal).

Soybeans – Parameters to monitor:

Moisture- the moisture level in the pre-extruded soybean can vary widely. New crop beans can be 15% to 16% moisture, while old crops can be 7% to 8%. The oil press works best with dryer product, typically 5% moisture or less is desired. Additional moisture, combined with the oil that has been freed up by cell rupture during extrusion, acts as a lubricant in the oil press. This in turn reduces the pressure the meal is exposed to in the press, which results in reduced oil yield. The extrusion process is used to rupture the oil cell, making for easier extraction. It also partially dehydrates the soy, which enhances the process. Extrusion will drop the moisture content by 45% to 50%. So what this all means is that the raw soy going into the extruder should be 9% to 10% moisture to optimize the oil yield.

Steam removal- extrusion of soy is a violent thing. The soy is put under tremendous press and friction. When it exits the extruder and is exposed to ambient atmosphere, there is an explosion, down to the molecular scale. Oil cells are ruptured, and the moisture and the bean is released in the form of steam. Since moisture is bad for pressing, it's a good idea to remove as much steam as possible before the extrudate enters the press. This starts at the extruder outlet. Some kind of exhaust should be used to separate steam from meal as it exits the extruder.

Next, the conveyor from the extruder to the press should at the very least, be vented to allow steam to escape. The best case is to have a small plenum over the top of the conveyor with a fan that can produce negative pressure, removing as much steam as possible, without cooling the meal before it enters the press.

http://blog.insta-pro.com/2012/09/

Temperature- The higher the temperature the soy is extruded at, the better the process seems to work. Higher temperature results in a higher percentage of cell rupture. This is good for removal of moisture and also for oil recovery. We recommend ExPress® Systems extruder at a minimum temperature of 310˚F and maximum of 320˚F. Because of short dwell time in the extruder, little or no nutritional damage is evident, even at temperatures of 330˚F. As long as the temperature is maintained at the extruder, the press will do its job. That is unless the press has severely worn parts, a topic we'll discuss in the near future.

Feed Rate- The oil press is like a grain combine in that it works most efficiently when it's full. That's full, not overfull. It can be hard to judge some presses as to when they are full. With our 1 ton/hour press, the press will never pull the full load amperage, even when it's full. Our 2 ton/hour press can come close and also go over the full load capacity of the main drive. In most ExPress® Systems, the production capacity of the extruders is higher than that of the oil press or presses.

Determining the proper feed rate for the extruders will require some testing of the finished meal, in the first few weeks of operation. You can figure your production rates by catching product from the extruders one minute, determining your hourly rate and recording the extruder amperage and temperature. The results of these tests should be matched with a sample from the outlet of the oil press. The press samples are then tested for residual oil content. Compare samples at different feed rates to determine where the most oil is recovered.

One thing to note about this kind of testing is the raw soybean. There can also be a variation in the oil content from one variety to the next. It may be wise to add a sample of the raw beans to compare against the finished soy cake, or meal. Modern day soybeans are being bred for higher oil content. Also, some parts of the country grow soy that consistently produce higher oil content due to weather and soil conditions. Couple high oil soy with high moisture and you will have high residual oil content.

The oil press will tell you if you're overfeeding it. A large amount of fines (often called foots) coming from between the cage bars is a good indication of overfeeding the press. Excessive foots can also be an indication of high moisture. Movement or oscillation of the vertical feed screw is also an indication of overfeeding. The overfeeding has an adverse effect because it shortens the dwell time of the meal in the press and results in higher residuals

In Feed Formulation, the Input Determines the Output

http://blog.insta-pro.com/2012/09/

Ingredient	Dry Matter %	Crude Protein %	Crude Fat %	TMEn Kcal/Kg
Soybeans, Heat processed seeds (NRC)	90	37	18	2990
Extruded whole soybeans (Insta-Pro high shear)	93	38	18	3850*
Partially defatted soybean meal (Insta-Pro ExPress®)	93	46	7	3265*

INSTA-PRO International – USA, http://www.insta-pro.com/

Insta-Pro presses mechanically extract oil from all oil-bearing seeds, such as soybean, cotton, canola, sunflower and others. Presses are commonly paired with Insta-Pro High Shear Extruders to form an automatic and continuous oil extraction system, called **ExPress®**.

Model 1000 Series Press
• Durable, compact construction
• 7.2 to 1 cage length to cage diameter ratio
• Scalable to 24 TPD capacity
CAPACITY: 750 - 1,000 lbs. (341 - 454 kg)

Insta-Pro preconditioners incorporate steam and water to pre-heat and condition products before they enter the extruder. Preconditioning expands the extruder capacity, enhances the shaping and quality of the product and ultimately reduces machine wear and operating costs. All preconditioners feature stainless steel construction and are easy to operate.

Model 2001 Preconditioners
Used in ingredient processing (full fat soy)
- Steam conditioning valve
- 2-port steam manifold

Insta-Pro Extruders
High Shear Extruders generate heat through friction to accomplish numerous processes — cooking, expansion, sterilizing, dehydrating and **texturizing**. The temperatures and pressures created in the extrusion process allow for a HTST (High Temperature, Short Time) process resulting in quality nutritional feed and food.

600 Series Extruder
- Ideal for community or village-based processing
- Affordable solution for low volume output
- Volumetric feeder with agitator

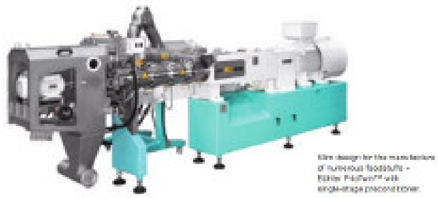
CAPACITY: 600 - 800 pounds (272 - 365 kg)

Insta-Pro **coolers** remove heat and vapor from extruded meal products prior to storage. Utilizing Insta-Pro coolers prevents heat buildup which can cause adverse effect on meal quality.

Model 400 Cooler:
CAPACITY: 1,000 lbs (455 kg) 100º F ambient maximum

Bühler S.p.A. - Segrate (Milano

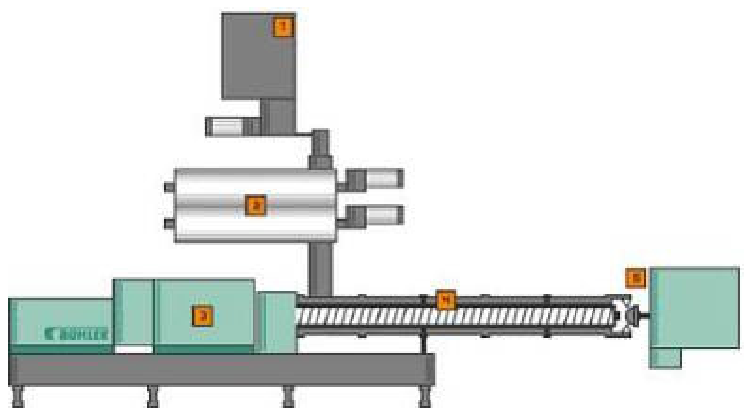
http://www.buhlergroup.com/global/downloads/Brochure_Extrusion_technology_EN.pdf



Brochures: http://www.buhlergroup.com/19886EN.htm

An extruder might be compared to a meat grinder: Inside, it cuts and heats the ingredients and kneads them into the required end product. For example, when you introduce dough ingredients, what you get at the outlet are shaped noodles, snack foods, or breakfast cereals.

In an extrusion line, the dry raw materials first enter the **feeder (1)** and are then mixed inside the **preconditioner (2)** with liquids or heated with steam. Finally, they reach the heart of the extruder system, the **processing section (4)**. Here, one or two screws rotate in a barrel, propelling the contents toward the end of the barrel. The screws are powered by a drive unit equipped with an **electric motor (3)**.



Depending on the rotational energy introduced, the screw will intermix and heat the materials to a greater or lesser extent as a result of mechanical shearing and friction. This produces a pumpable mass, which is forced through the die openings and cut into the required form by a cutting device **(5)**. The extruded strands can either be cut into pellets of any required length, or into forms such as stars, hearts, bones, little bears, or dinos – if required even in several colors.

The composition and nature of the raw materials processed makes no difference to this machine, as long as they are present in the form of a free-flowing material: shreds, flakes, granules, powders, or meals and flours. Plastics, glass fibers, wood, offals, corn (maize), rice, or **soy** can be treated in this manner. Animal and vegetable proteins, for example, can be processed into shaped cat and dog foods or into fish feeds.

Grain flours are mixed with sugar, salt, or other additives, then gravimetrically proportioned. This is followed by moisture addition in a **preconditioner** using direct steam, then extrusion in a Buhler extruder. Here, the component substances are intimately mixed, kneaded, and cooked, then shaped and cut at the die face.

Depending on the particular geometry of the die holes, this will produce **little stars, little flowers, rings** or a multitude of other shapes. To produce cornflakes, lentil-like **pellets** are cut. They are pneumatically conveyed to a **predryer** followed by a **flaking roller mill**. The flakes are toasted to obtain the typical golden-yellow color, taste, and crunchiness that is aimed at.

The following product groups can be made using our single-screw and twin-screw extruders or batch cookers:

Flakes
Cornflakes, wheat or multigrain flakes produced by the extrusion process or by traditional cooking methods. If required also colored or coated.

Direct-expanded cereals
Standard products or individually designed, customized forms made from grain flours. If required also colored or coated.

Indirect-expanded cereals
Puffed products made from extruded pellets or whole grain such as corn (maize), wheat, and rice. If required also colored or coated.

Co-extruded cereals
Water- or fat-based fillings with direct-expanded cereal envelope in a wide variety of shapes.

Wenger extrusion systems
http://www.wenger.com/new-development.php#Thermal-Twin-Extrusion-Systems

Wenger Hygienic System Components

Offerings include Waste Recycling Systems to capture emissions and/or under-processed material to prevent recontamination; a new, closed-loop Pneumatic Conveying System; on-line measurement and control systems to decouple personnel from direct product contact; new, stainless-steel hygienic machine frames that can be retrofitted to pre-existing extruders, and a new preconditioner slide gate and dust-tight downspout. Under-processed material and "fugitive" dust, which can act as a host for pathogens that can survive for up to 300 days, are the greatest sources of contamination. Stopping them in their tracks is one of Wenger's primary goals.

Wenger Enhanced Sanitary Dryer

From its inception, the Wenger Enhanced Sanitary Dryer was designed for more than impressive drying and cooling performance. As the name implies, it was also engineered for greater sanitation; less potential for cross-contamination and bacteria build-up, and a reduction in the amount of production time lost to downtime.

Initial design criteria stipulated that no internal horizontal surface could be larger than five by five millimeters unless absolutely necessary (i.e. pans, floors, etc.). The standards also called for a minimum 30-degree slope on all internal ledges, as well as the elimination of cracks and crevices in which fines and material could collect. Of course, less accumulation of material also means quicker, easier cleaning.

However, that's just the beginning. We've also made it faster and easier to clean out the Wenger Enhanced Sanitary Dryer by increasing clearances, eliminating potential spillage and adding seals. Polyester air filters even filter room air as it enters the system … putting the Enhanced Sanitary Dryer in a class of its own.

Jinan Eagle Food Machinery Co., Ltd. [Shandong, China (Mainland)]

Extruded soya bean protein machine

Extruded soya bean protein machine

1 Twrin screw extruder

2 High temperature and presser

3 Different shapes

Soya protein food process line is the newest botanical protein food process line which is developed independently according to our national conditions on the requirement of market and on the base of advanced machinery in Switzerland and America.

This processing line uses soybean powder and peanut powder to break spherical protein molecule to form chain protein molecule thus creating slice-like fiber structure, by powder-grinding, stirring, high-temperature, high-pressure and high-cutting. The product is nutritious without cholesterol or animal fat .but it looks like and tastes like meal with the quality of absorbing soil .water .and flavor.

Product development of full fat soy flour to produce healthy protein and snack food for small-scale industry

http://anchan.lib.ku.ac.th/agnet/bitstream/001/5126/1/Product%20development%20of%20full%20fat%20soy%20flour%20to%20produce%20healthy%20protein%20and%20snack%20food%20for%20small-scale%20industry.pdf

The village texturizer has been constructed in this research for developing healthy protein and snack food products from full fat soy flour. Owing to uncomplicated technology, lower production and maintenance cost, this machine which operating with optimum pressure and temperature to make the food products cook and puff is suitable for application in smallscale industry. The construction has developed into 2 categories ; 1) use stainless steel in stead of mild steel for safety of food and 2) modify the machine from manual operation to automatic with pneumatic system for the convenient and easy operation at constant time and pressure. In the experiment, full fat soy flour was produced with low heat treatment and use as raw material in the production of healthy protein and snack food. For protein food, it was varying with mixture (full fat soy four : sesame residue = 100: 0, 90: 10%), temperature (180, 200, 220oC) and pressure (5, 7 bar), meanwhile the experiment of snack food was varying with mixture (full fat soy flour : tapioca flour = 20 : 80, 30 : 70%), temperature (150, 170oC) and pressure (3, 5, 7 bar).

The village texturizer as shown in Figure 1 had been constructed at the Institute of Food Research and Product Development, Kasetsart University. The construction had modified from the prior into two categories ; one for using stainless steel instead of mild steel for safety to food and the another for modifying the design of the machine from manual operation to automatic by using pneumatic system, so the operation would be convenience and held at constant time and pressure

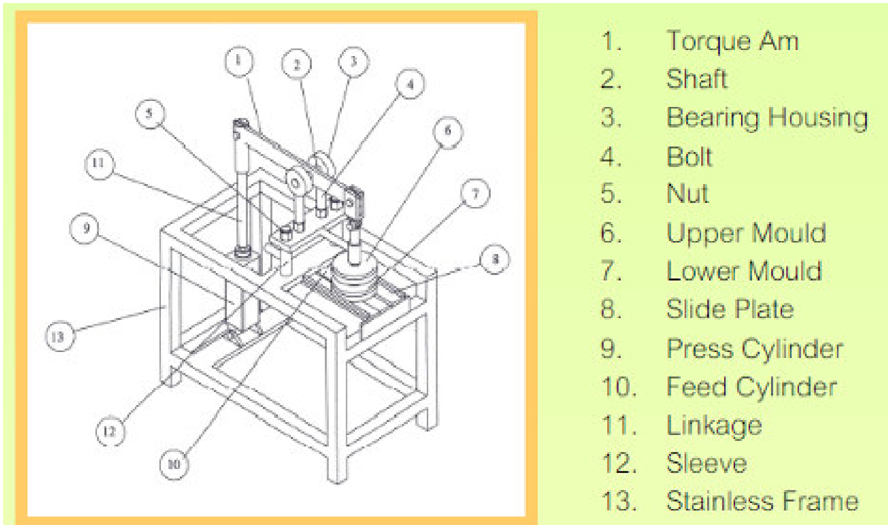


Figure 1 The modified "Village Texturizer"

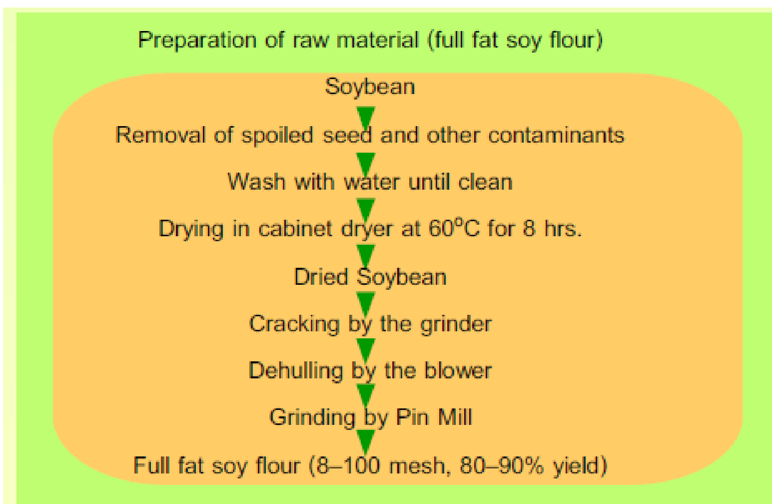


Figure 2 The processing line of full fat soy flour by low heat treatment

Production of protein food (texturized product)

For the production of protein food, full fat soy flour was mixed with water and kneading slowly in Kenwood Mixer to make dough, after that split into small ball (10 grams per each) and press by hand into flat shape. Put each flat shape in the cup (lower mould) of village texturizer, center the lid (upper mould) over the cup and press the lid with the setting temperature and pressure at holding time (8 seconds). Released the lid from the cup to get the puffed and texturized product and dried in cabinet dryer at 80oC for 30 minutes. The finished product can be used to substitute as meat by soaking in water and prepared for the various dishes as required.