EVALUATION OF WHOLE SOYBEANS IN SWINE DIETS

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A Thesis

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ABSTRACT

A laboratory assessment and three *in vivo* trials were conducted to measure the nutritive value of whole soybeans subjected to various methods of heat treatment. The laboratory assessment evaluated whole soybeans, which were either raw, extruded, micronized, jetsploded or roasted. It was found that there was a high degree of variability in proximate composition from source to source and treatment to treatment. The first *in vivo* trial compared the effect of soybean meal (CONTROL) or whole soybeans from the four different heat treatments in barley based diets on the performance of weanling piglets (28 days). No significant differences were found for ADG and feed conversion ratio. In the second trial the same whole soybean products were evaluated in growing and finishing pigs (20 kg to market). Dietary levels of whole soybeans were up to 25%. No significant differences were found for the above mentioned performance parameters. However there was a significant reduced proportion of saturated-to unsaturated fatty acids in the loin eye area of pigs fed whole soybean products, when compared to soybean meal control ($p<.05$). Extruded whole soybeans resulted in a lower degree of unsaturation than the other heat treated whole soybeans ($p<.05$). In the final trial, the same whole soybean products were evaluated for their digestibility in weanling (21 days) piglets. Feces were collected daily during two 5-day periods. Proximate analysis was conducted on the feed and the feces. It was found that the ether extractable portion of extruded whole soybeans has a higher digestibility ($p<.05$) than that of the remaining four soybean treatments. It was also found that CP is more digestible ($p<.05$) in animals at 6 weeks of age than in animals at 4 weeks of age. In conclusion: heat treated whole soybeans do not adversly affect the performance of weaners nor that of growing and finishing pigs, even at high dietary levels (25%). Feeding whole soybeans results in a higher degree of unsaturation in the carcass. The EE fraction of extruded whole soybeans is more digestible than whole soybeans of other heat treatments.

RÉSUMÉ

Une analyse en laboratoire et trois essais *in vivo* ont été conduits afin de mesurer la valeur nutritive de la fève de soya entière lorsque soumise à différents traitements de chauffage. L'analyse en laboratoire a évalué la fève de soya entière qui était soit crue, extrudée, micronisée, jet sploded ou rotie. Il a été observé qu'il y a un haut degré de variation dans la composition chimique de la fève d'une source à l'autre et d'un traitement à l'autre. Le premier essai *in vivo* a comparé l'effet du tourteau de soya (CONTROLE) avec les produits de la fève de soya des quatre differents traitements de chauffage, dans une diète à base d'orge, sur la performance de porcelets sevrés (28 jours). Aucune différence significative n'a été observée en terme de gain moyen quotidien et d'efficacité alimentaire. Dans le deuxième essai, les mêmes produits de fève de soya ont été évalués sur des porcs en croissance et en finition (20 Kg au marché). Les rations contenaient jusqu'à 25% de fève de soya entière. Aucune différence significative n'a été observée sur les paramètres de performances ci-haut mentionnés. Toutefois, il y avait une réduction significative de la proportion d'acides gras saturés sur les non-saturés, dans l'oeil de longe, pour les porcs nourris aux produits de fève de soya entière comparé au control: tourteau de soya ($p<.05$). La fève de soya extrudée a démontré une proportion d'acides gras insaturés plus petite que les autres traitement de chauffage ($p<.05$). Dans le dernier essai, les même produits de fève de soya ont été évalués pour leur digestibilité chez les porcelets sevrés (21 jours). Une collection quotidienne des fèces a été faite pour deux période de cinq jours. La composition chimique a été analysée sur les diètes et les fèces. Il a été observé que l'extractif étheré de la fève soya extrudée a une digestibilité plus élevée ($p<.05$) que les quatre autres traitements de chauffage. Il a aussi été observé que les protéines brutes sont plus digestibles ($p<.05$) chez les animaux de 6 semaines que chez ceux de 4 semaines d'âge. En conclusion: les fèves de soya traitées n'affectent pas négativement la performance de porcelets sevrés ni de ceux en croissance et en finition, même avec des rations à haute pro- portion de fèves de soya (25%). Nourrir avec de la fève soya entière résulte avec une proportion d'acides gras insaturés plus élevés dans la carcasse. L'extractif étheré de la fève de soya extrudée est plus digestible que celui la fève soumise à d'autres traitements de chauffage.

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I INTRODUCTION

1.1. Legumes as a source of protein

Soybean (*Glycine max*) is the single most important plant protein source for food and feed, supplying the greatest quantity in the Americas and Asia. Soybeans are going to be important in contributing to solving the dilemma of protein shortage worldwide (Sinha, 1977).

Liener (1980) referred to all antinutritive factors as toxic constituents. This is somewhat of a misnomer, when referring to protease inhibitors, since even at high levels they are not lethal. Thus, this is contrary to the definition of a toxin.

Antinutritive factors in untreated legumes	
1)Protease inhibitors	
2) Hemagglutinins and lectins	
3) Phytic acid	
4) Lathyrogens	
5) Glucosinolates	
6) Cyanogens	
7) Saponins	
8) Gossypol	(Liener, 1980)

In order to destroy or rather *minimize* the content of *antinutritive factors*, while maintaining the *nutritional quality* of the beans at it's *maximum* several different processing techniques have been devised.

Soybeans have experienced a tremendous increase in world production over the last 50 years. In the period from 1935-39, annual production was 12 million tons world wide. This constituted about 1/4 of oil crop production. In the 2 year period from 1984-86, annual production was 94.98 million tons, constituting over 50 % of oil crop production (Roebbelen, 1989). Over 1/3 of this is produced in the United States and Canada (Roebbelen, 1989). Soybeans have therefore gained very much importance, playing a big role in the edible oil industry as well as being an important source of protein supplement.

Why should one consider using whole soybeans in swine rations?

By adding whole soybeans, one can increase the energy density of a ration, due to the high oil content of the beans.

The wasteful process of extracting oil and adding fat back to the composed diet, which may be in the form of oil, can be avoided.

The volume of soybeans produced world wide and especially in North America, is evidently much too large for the edible oil market. Hence the feeding of whole soybeans to swine would make efficient use of the extra soybeans.

The initial problem to be studied, and the focus of the research conducted here, is the inactivation of antinutritional factors, in particular the trypsin inhibitors. The four most important processing techniques for full-fat soybeans in Québec were chosen, to be evaluated and compared in their effect on performance of weaners and growing-finishing pigs, as well as on the digestibility of selected componenets in weanling pigs.

Feeding whole soybeans to pigs may also have possible negative effects on performance-, carcass- and product quality. Due to the high amount of oil in whole soybeans (FFSB) one may find a decrease in lean yield, when comparing with animals having been fed a soybeanmeal control diet.

One also may end up with an oily carcass, due to the high degree of unsaturation of the soybean oil. This higher level of unsaturation may also precipitate a decrease in shelf life. Possibly there also may be an alteration of taste, which may be perceived negatively by the consumer.

The decision, whether to feed or not to feed FFSB is based not only on the above effects, but also on the economical situation. From an economical point of view there are several contributing factors to the decision making process. The difference in protein content between FFSB and soybeanmeal, the delivered price of soybeanmeal, the oil content of FFSB (minus the residual), a factor for the extra biological value of soybean oil over feed grade fat, the delivered price of FFSB as well as the price of processing are all taken into account, when looking at the economic feasibility of feeding FFSB.

1.2. Objectives

Therefore the objectives of this study were:

1.) To determine the chemical composition of whole soybeans subjected to different heating processes over the period of one year.

2.) To obtain an appreciation of variability of a product from the same company over a period of time.

3.) To evaluate the nutritive value of whole soybeans from different processes in young pigs.

4.) To evaluate the nutritive value of whole soybeans from different processes in growing and finishing pigs.

5.) To evaluate the digestibility of several major nutrients of whole soybeans from different heat treatments in weanling pigs.

II. LITERATURE REVIEW

2.1. The protease inhibitors:

Protease inhibitors are ubiquitous in nature, and are found in plants, animals and microorganisms (Peace, 1991), but particularly in legumes. The adaptive value of having protease inhibitors appears to be a) the prevention of autodigestion, such as is the case in the pancreas (Green and Work, 1953) and the lung (Erikson, 1965); b) the protective value against potential animal consumers (Janzen,1986, Rothman, 1986); c) inhibit microbial proteases, which may stem from potential pathogens (Wilson 1980); d) protease inhibitors may also act in controlling time of germination in seeds, which again is of adaptive value (Nielsen and Liener, 1988). The structure and properties of protease inhibitors, which are proteins in nature themselves, have been studied most extensively of all the above mentioned factors. The major class, and subject to most studies, are the trypsin inhibitors (TI) (Liener, 1980, Alli 1989), which are part of the serine proteinase inhibitors, referring to the active site of the enzyme's molecule (Peace 1991). In soybeans these inhibitors were found at levels as high as 655 mg% (Robbins,1989). The TI of soybean (i.e. Liener, 1962), and kidney bean (i.e. Alli, 1989) were chosen for studies, due to their predominance in animal and human nutrition.

2.1.1. The Soybean Trypsin Inhibitors

In the 1940's 2 classes of TI were isolated in soybeans (*Glycine max*). The first class, the Kunitz inhibitors, have a molecular weight of approximately 21,500 daltons (Kunitz, 1947). It is a single polypeptide chain, with 181 amino acid residues. The four cysteine residues are crucial in the conformation of the protein (Xavier-Filho and Campos, 1989) There are several variants, which will all be referred to as Kunitz TI (Kim et al., 1985). The trypsin is inhibited in a stoichiometric fashion- on a mole/mole basis (Liener, 1980).

The second class, the Bowman Birk TI, have a molecular weight of about 8000 daltons, and can inhibit chymotrypsin and trypsin with independent binding sites. According to Liener (1980), these inhibitors are much more stable than Kunitz TI. He hypothesized that this is due to the lesser amount of disulfide bridges of the protein. These findings hold true if the proteins are heated in an aqueous solution at 100^0C (DiPietro and Liener, 1989). In cases, where the proteins are heated under other conditions, Bowman-Birk inhibitors have been shown to be more labile (DiPietro and Liener, 1989). In other cases (Sessa, 1986), residual activities from both inhibitor classes were found. An interesting aspect is the fact that Kunitz TI has been shown to catalytically bind to inactive trypsinogen and anhydro-chymotrypsin (Liener, 1980).

Peace (1991) recently found that even infant formulas, which presumably have been prepared under much more stringent conditions than animal feedstuffs, had TI activities ranging from 3.2% to 28% of Maple arrow raw soybean samples. He also found that there was variation of TI levels from the same manufacturer, for different samples.

TI have been found and identified in many other plant food sources, such as the kidney bean (*Phaseolus vulgaris*). Bean inhibitors have a molecular weight of 10-15 000 dalton and a high level of S-containing bonds, that have been identified (Liener, 1980). The extent of their inhibitory effect on tryptic hydrolysis was demonstrated by Alli(1989).

In peanut (*Arachis hypogaea)* an inhibitor of trypsin, chymotrypsin and plasmin has been identified. It has a molecular weight of around 17 000 and probably is a tetramer. Another small TI has been identified, with actions similar to the Kunitz TI. Nine TI have been identified in peas (*Pisum sativum*), all of which possess similar inhibitory activities (Liener, 1980).

2.2. Treatments of legumes in preparation for human or animal consumption

Many treatments are available for the detoxification of legumes or isolates of their proteins. The ones of importance are listed below: 1) boiling 2) extrusion 3) alkali treatment 4) germination 5) fermentation 6) micronization 7) ultrafiltration 8) infrared 9) thiols 10) jetsplosion.

The most widely used technique, from an animal feed industry point of view, is the **extrusion** technique. The beans are forced by a screw pump through a cylinder, which has a small die hole at the end. The heat of friction, produced when the beans are forced along the cylinder by a tapering screw inside the barrel, denatures some proteins. There are two main types of extrusion: 1) *cold extrusion* 2) *hot extrusion*. The type of extrusion discussed above, is considered to be *cold extrusion*. *Hot extrusion* is based on the same principal as cold extrusion, with the difference, that the steel barrel is usually steam jacketed, but may also be electrically heated (Fellows, 1988). The sudden decrease in pressure causes the cells to rupture upon exit through the die hole, giving extruded soybeans their characteristic oily, *meal-like* appearance. Extrusion of protein-based foods (such as defatted soybeans) results in a destruction of the quarternary structure of the particular proteins, due to the heat and vapour. At the same time they repolymerize and form a viscous mass, this is why the nitrogen solubility index actually decreases during extrusion (Fellow, 1988). The factors, determining the composition of the final product, depend on several features of the extruder: a) temperature b) pressure c) diameter of the die hole and d) the shear rate (Fellow, 1988). They also depend on the material to be processed: a) moisture content b) physical properties, such as i.e. paricle size and c) their composition in terms of macronutrients (Fellow, 1988). Measurable nutritional losses are limited to some micronutrients and some labile amino acids. It was measured (Harper, 1979) that B-vitamins, with the exception of thiamin, were virtually undestroyed (95% retention) and only Vitamin C and A were lost at rates of up to 50% in different food products. Seiler (1984) found losses of 50 -90% of lysine, cystine and methionine in extruded rice.

" **Infrared** energy is electromagnetic radiation, which is emitted by hot objects " (Fellow, 1988), such as ceramic tiles. The transfer of heat to heat materials, depends on a) the surface temperature of the two materials b) the surface properties of the two materials and c) their shapes (Fellow, 1988). Any changes in nutritional value would be due to the transfer of heat and not to the radiation per se, since it is non-penetrating, and hence the same effects apply, as is discussed below for the roasting process. It should be added that the extent of uncontrolled transfer of heat is less likely, since extent of radiation is more easily controlled, than in the roasting process.

Micronization is a fairly recent process, which relies on infrared radiation. Beans are moved along a vibrating conveyor belt, to pass underneath ceramic tiles, which are heated directly by gas burners, and in turn emit infrared radiation. This radiation heats the beans and denatures proteins, amongst them TI.

Roasting is principally based on the application of heated air to the food or feed product (Fellow, 1988). The heat may also contact the product through conduction by the walls of the roaster or convection by vapour in the chamber. The infrared is converted to heat by the particles, following absorption. Since the heat is converted from convective to conductive heat at the surface of the particles, the particle size, as well as roaster surface area are very crucial in the process (Fellow, 1988). This is important, because feed particles have a low thermal conductivity rate, and therefore the roasting of the inside vs the outside of the particles is different. There aslo is removal of moisture from the outer layer, thereby forming a crust. This means that the vapour usually prevents the inside of the product to exceed 100^0C (Fellow, 1988). Roasting is the most popular technique of treating soybeans on-farm, due to it's low capital investment. On farms the basic feature is a rotating chamber through which the beans pass. Temperature and time are variable and depend on operator and equipment.

Jetsplosion is a roasting technique, which relies on super-heated air rather than direct heat. The beans travel through a chamber, into which air at temperatures up to 600^0F is blown. The travelling speed of the beans is timed so that the beans exit the chamber, when the temperature inside the beans reaches 100^0F. Upon exit the beans are fed through a roller. Due to the build up of pressure from the heat the beans "explode", much like popcorn "explodes", when heated.

Another process, which has recently been evaluated in terms of it's effect on nutritional quality of the product, is ethanol extraction, which may or may not be followed by heat treatment (Hancock, 1990 a&b). In this particular case, the soybeans were percolated with an ethanol/ water solution. Following extraction, the excess water and ethanol were drained and the soybeans were dried and in some cases autoclaved. It was found that the destruction of lysine by the heat treatment was minimized by previous ethanol extraction. This is presumed to be due to the removal of reducing sugars, minimizing the occurence of Maillard reactions and Strecker degradation. There also appears to be some inactivation of antinutritive factors by the ethanol extraction itself (Hancock, 1990 a). What Hancock however failed to discuss, was the cost of the process. It appears that it would be rather high, since feedstuffs would have to be ethanol extracted and subsequently heat treated to some extent (Hancock, 1990 a&b). Therefore from an economical point of view, this treatment is unsatisfactory. This may change with the coming energy crisis (Lewis, 1990), because ethanol will spare fossil fuel or electricity utilization to some extent.

2.3. The effect of processing on trypsin inhibitor activity

Soaking and boiling are the processing methods, which have been used throughout history to render legumes edible (Liener, 1980). Roasting also has been used, but received more attention with the advent of modern industrial food and feed production and processing (Mathews, 1989). Whether it is soaking and boiling or roasting, the overall effect is the direct application of heat. Early on Liener (1962) noted that soybeans roasted at 230 - 300 °F with dry heat were less nutritive than beans cooked in water. This indicated that not only temperature and exposure time are essential, but also moisture.

According to Alli (1989) a) there are different concentrations of TI in different varieties of *Phaseolus vulgaris* b)the activity of the TI depends on the microstructure of the protein, they are associated with - for example: when protein was amorphous vs crystalline , the degree of inhibition was lower in the latter case. This is an important aspect, because it relates to the efficiency of treatment.

DiPietro and Liener (1989) evaluated the heat inactivation of Kunitz- and Bowman-Birk TI. It is generally assumed that Kunitz TI is more heat labile than Bowman -Birk TI. From this study it appeared that Bowman-Birk TI is denatured by moist heat at similar rates as the Kunitz TI. The remaining activity is of Bowman-Birk- and Kunitz TI origin. Friedman (1982) experimented with a new way of inactivating TI. He used thiols. His reasoning was that the application of heat destroyed more of the already deficient cysteine. The destruction by heat causes cysteine to become the first limiting aa. The inactivation of TI with thiols resulted in a remarkable conservation of cysteine. Aspects to be clarified are potential hazards and cost of process.

Another process by which nutritive value is increased, and which is used widely, is fermentation. In SE Asia, the Near East and Africa, soybeans are fermented with *Rhizopus oligosporus* to make tempeh (Zamora,1987). Soybeans were fermented with *Aspergillus oryzae* and *Rhizopus oligosporus*. The amount of TI was measured in TI units inhibited /mg. It turned out that although fermentation decreased inhibition to about a fifth of the level of raw soybeans, compared to heated soybeans, the level was approx. 3 times as high.

2.4. Composition of soybean meal and Whole soybeans

Table 2.1 and 2.2 list the composition of either SBM, raw whole soybeans (WSb) or heat treated WSb, as listed by the different sources. Augustin (1989) took averages of seven sources for proximate composition of raw soybeans and indicated the variabilities associated with the particular measure. Surprisingly the greatest variability; following crude fibre (CF) (41.3%),which is to high to be of any significance; was found for dry matter (DM) (16.9%). This is surprising, since DM values usually are fairly consistant (+/- 1 %) for soybeans of the same categorie. From the same sources he also obtained another unexpectedly high variability for ash (16.3%). Ash is fairly easy to measure and usually consistant. However this variability may in part be attributed to soybeans analyzed from different sources, from different regions and different fertilization techniques (Augustin, 1989). Another factor may be the fact that ash is of a low numerical value and therefore slight differences appear as large varibilities, i.e. experimental error is magnified. On the other hand energy, protein and fat had variabilities all below 10%. Phosphorus (P) values were taken from eleven different sources, and a tremendous amount of variability (38.2%) was found. It may also be due to different analytical techniques, since for the same sources, calcium (Ca) was found to only have a variability of 14.5%. Total P in soybeans is of analytical interest, but of little nutritional significance for monogastrics, since soybeans contain significant amounts of phytate and therefore render a large and not easily definable part of the total P unavailable (Augustin, 1989 and Liener, 1980).

Table 2.1.a Proximate composition of Soybean meal and Full-Fat soybeans from different sources

	Soybean meal			
Source	NRC[1]	NRC[2]	NRC[3]	Janssen
DM	90	90.0	89.0	87.5
GE	-	-	-	-
DE	3680	-	3700	-
ME	3385	2440	3290	2310
CP	48.5	48.5	49.9	48.8
EE	.9	1.0	1.5	1.8
CF	3.4	3.9	7.0	3.2
NDF	-	-	-	-
Ash	-	-	7.3	-
Ca	.26	0.27	0.29	-
P	.64	0.62	0.68	-

Table 2.1.b Proximate composition of Soybean meal and Full-Fat soybeans from different sources

	Full Fat Soybeans					
Source	NRC^1_a	NRC^2_a	NRC^3_a	NRC^3_b	Janssen[1]	Augustin[2]
DM	90	90.0	92.0	90	89.0	91.4
GE	-	-	-	-	-	4130
DE	4035	-	4010	4140	-	-
ME	3625	3300	3600	3740	3310	-
CP	36.7	37.0	42.8	42.2	36.5	34.3
EE	18.8	18.0	18.8	20.0	19.0	18.7
CF	5.2	5.5	5.8	5.6	5.5	3.8
NDF	-	-	-	-	-	12.0
Ash	-	-	5.5	5.1	-	5.1
Ca	.26	0.25	0.27	0.28	-	0.22
P	.61	0.58	0.65	0.66	-	0.48

NRC^3_a and [1] = raw full-fat soybeans NRC^3_b and [2] = heat- processed full-fat soybeans
NRC^1_a = cooked whole soybeans NRC^2_a = heat treated whole soybeans

Table 2.2.a Amino acid composition of Soybean meal and Full-Fat soybeans from different sources

	Soybean meal		
Source	NRC[1]	NRC[2]	Janssen
Arg	3.20	3.68	3.51
Cys	0.66	0.73	0.73
Gly	-	2.29	2.05
Ser	-	2.89	2.73
His	1.12	1.32	1.22
Ile	2.00	2.57	2.39
Leu	3.37	3.82	3.71
Lys	2.90	3.18	3.12
Met	0.52	0.72	0.68
Phe	2.10	2.11	2.39
Tyr	1.50	2.01	1.71
Thr	1.70	1.91	2.05
Trp	0.64	0.67	0.63
Val	2.02	2.72	2.44

Table 2.2.b Amino acid composition of Soybean meal and Full-Fat soybeans from different sources

	Full Fat Soybeans			
Source	NRC_1	NRC_2	Wolf	Janssen
Arg	2.54	2.80	-	2.63
Cys	0.55	0.64	-	0.55
Gly	-	2.00	-	1.53
Ser	-	2.17	-	2.04
His	0.87	0.89	2.6	0.91
Ile	1.60	2.00	5.1	1.79
Leu	2.64	2.80	7.7	2.77
Lys	2.25	2.40	6.9	2.34
Met	0.46	0.51	1.6	0.51
Phe	1.80	1.80	5.0	1.79
Tyr	1.26	1.20	-	1.28
Thr	1.42	1.50	4.3	1.53
Trp	0.54	0.55	1.3	0.47
Val	1.62	1.80	5.4	1.82

NRC_1 = cooked whole soybeans NRC_2 = heat treated whole soybeans

2.5. Physiological effects of soybeans

2.5.1.General

The first researchers to be concerned with the subject where Osborne and Mendel in 1917. They stated that raw soybeans did not support growth in rats, but that the same soybeans did support growth in rats, when cooked.(Osborne and Mendel 1917)
Over the years several researchers established that the addition of sulphur-containing amino acids to uncooked SBM improved the efficiency of utilization, but did not equalize cooking(Hayward & Hafner 1941, Evans & McGinnis 1948, Barnes et al 1962,Borcher 1962a).

2.5.2. Physiological effects of Trypsin inhibitors

Sessa (1986) compared the residual activity of TI in toasted or overtoasted soybeans. Whether soybeans were fed raw or commercially toasted to rats as or overtoasted soybeans flour or raw and heated soy protein isolates, the incidence of pancreatic lesions followed a TI dose response curve. The different slopes of the curves led to the conclusion, that although at a much reduced level, TI is still present in sufficient amounts, following roasting, to cause pancreatic lesions.

According to Robbins et al (1989), the rat is not a good model for evaluating the physiological effects of soybean TI in humans. In some animal species, prolonged exposure has the following effects:
a) pancreatic lesions b) poor growth c) hypersecretion of enzymes d) pancreatic nodules e) adenocarcinoma f) general carcinogen.
To be able to apply data to the human situation, this group fed raw soy protein isolate to

the chacma baboon. The raw protein contained 655 mg% and the toasted control 42mg%. To measure pancreatic exocrine function, PABA was administered intragastrically and it's appearance rate was measured in the blood. There was no significant difference between treatment in terms of PABA appearance rate during the 22 week trial. There also was no significant difference in a) pancreatic mass b) protein content c) trypsin or chymotrypsin activity. It seems that there is no adverse effect of raw SB protein on the primate pancreas. Whether this is true in the human, remains to be seen.

Liener (1989) conducted a study on the secretory activity of the human pancreas. Pancreatic juice was collected by endoscopic retrograde cannulation of the pancreatic duct. Either buffered saline, active - or heat inactivated Bowman-Birk TI were added to the juice before infusion into the duodenum. The measurement of trypsin activity showed less than 10%, when Bowman-Birk TI was infused in the active form. Trypsin, chymotrypsin, elastase and amylase increased 2-3 times in the pancreatic juice. It was concluded that a feedback mechanism exists in humans, which regulates pancreatic output, depending on free active enzyme. The effect of longterm exposure to TI on pancreatic function still remains unsolved.

The rate of pancreatic excretion is important, because pancreatic juice , especially trypsin and chymotrypsin, for which soybean inhibitors are specific, is high in sulfur amino-acid content (Liener, 1990). Legumes are particularly notorious for their lack of sulfur amino acids (Anderson et al, 1982). Whether raw soybeans in the diet have the effect of causing hypertrophy or hyperplasia of the pancreas, depends on the the substance controlling pancreatic feedback regulation. In animals where CCK is the mediator, such as in rats

(Grant, 1990) and chicks (Peace, 1991), raw soybeans cause pancreatic enlargement. In animals where secretin is the mediator such as pigs and dogs, this enlargement is absent (Grant, 1990). In humans pancreatic secretion was increased by soybean TI (Grant, 1990), which is presumably due to the fact that pancreatic secretion in the human is regulated by CCK as well a secretin (Shils and Young, 1988). In swine there appears to be a reduction of duodenal trypsin and chymotrypsin activities, indicating that the inhibitors cause loss of these paricular enzymes (Yen et al, 1977). Whether enzymes are lost in the feces or secreted at an exaggerated rate, amino acid balance is particularly affected because of the combination of above mentioned factors: a)soybeans are typically low in sulfur containing amino acids and b) trypsin and chymotrypsin are high in sulfur amino acid content (Bondi, 1987).

2.6. Protein quality

The effect of processing on protein quality is measured indirectly in feeding trials. The feeding trials mentioned above, particularly those that measure parameters such as BV or NPU are the best and most abundant measures of quality. Chemical methods involve measures such as FDNB (Friedman, 1976) or the formation of lysino-alanine (Dietz, 1989), which measure availability of lysine. It was found for example that increasing processing heat by 40°C, from 170-210 °C, resulted in a 37 % decrease of FDNB reactive lysine in extruded products.

When soy protein isolate is treated with alkali at pH 12 (Friedman, 1976) or if beans are overheated during processing (Dietz, 1989), lysino-alanine is formed. This compound is carcinogenic and nephrotoxic (Friedman, 1976).

2.7. Whole Soybeans as livestock feed ingredient

2.7.1. Whole raw or heat treated soybeans in poultry diets

Moran et al (1973 a&b) fed raw and extruded soybeans at rates of up to 40%, complemented with corn, to broiler turkeys. Two controls differed in the source of supplemental fat: a)soy oil or b) tallow. Raw soybeans significantly reduced ($p<.05$) performance in terms of body weight gain and feed conversion. Toms receiving diets containing extruded soybeans or SBM plus soy oil, outperformed those receiving SBM plus tallow. Final bodyweights were significantly increased ($p<.05$), by extruded soybeans and SBM plus soy oil. The feed to gain ratio was significantly improved by these to treatments over the SBM plus tallow control, during the finishing period ($p<.05$), however, there was no overall effect on feed to gain ratio. Carcass yield was not affected by any treatment. Iodine number of carcass fat (back skin, breast muscle and gastroenemius) was significantly increased ($p<.05$) by diets containing WSb or soybean oil, when compared to tallow. This was due to a significant decrease in oleic (34% to an average of 25.8%) and a significant increase in linoleic acid (29% to an average of 41.5%). Organoleptic changes correlated with the fatty acid composition changes. Flavour was positively affected by higher degrees of unsaturates ($p<.05$), but juiciness was negatively affected ($p<.05$). In conclusion one may say that there appears to be no problem feeding heat treated WSb to broiler turkeys from an organoleptic point of view, and that plant oils (polyunsaturated FA) seem to be better utilized energetically than animal fats (saturated FA) (Atteh and Leeson, 1984).

Waldroup et al (1974) compared the effect of roasting, cold extrusion and hot extrusion on the nutritive value of WSb in all-mash broiler diets. WSb were incorporated into corn based diets from 0-40%, with 5% intervals, resulting in 9 experimental diets. SBM served as a control. There was no significant difference found for body weight gain and efficiency of feed utilization, when comparing the three types of full-fat soybeans. Feeding WSb of any type at levels higher than 25% significantly ($p<.05$) reduced body weight gain. Evaluating effects of pelleting and particle size of roasted soybeans by broilers, Mitchell et al (1972) found that particle size negatively affected digestibility of fat of roasted soybeans. With decreasing particle size (480 mm screen to 20 mm screen) the fat digestibility increased from 57.7% to 90.0%. Nitrogen retention was lower for all diets containing roasted WSb, than for diets containing SBM. There was no difference, when roasted soybeans were pelleted, following grinding. A similar observation was made for final body weight. Mash roasted soybeans resulted in lower ($p<.05$) final body weights than mash SBM, but there was no difference, if the diets were pelleted. Feed to gain ratio of mash roasted soybeans was significantly decreased ($p>.05$) as well, when compared to SBM control (2.26 vs 2.14, respectively); however this was reversed ($p<.05$), when the diets were pelleted (2.06 vs 2.18). The results from this trial seem to indicate that treatment of the WSb, following heat treatment is important in determining the utilization by broiler chicken, or possibly other growing monogastrics.

Latshaw et al (1976) fed raw and heated full-fat soybeans to laying hens. Graded levels of raw WSb (up to 20%) decreased egg production from 78.2 to 71.8% ($p>05$). Egg weight as well as hen body weight were significantly decreased by the addition of raw soybeans to the laying diet, and pancreas weight linearly increased with level of raw soybeans ($p<.05$). In a second experiment, egg production was not affected by corn based diets containing either roasted WSb, extruded WSb, SBM, SBM plus soy oil, SBM plus 10% raw soybeans, all at 14.8% protein or a SBM diet containing 17% protein. Egg weight was siginificantly increased by diets containing SBM plus soy oil or roasted soybeans ($p<.05$). Overall the performances of heated soybeans was comparable to the SBM control diet. Rogler et al (1963) also found that raw WSb reduced egg production, if fed at a level of 28%, to laying hens. Heat treated WSb did support a similar level of performance as SBM based diets. They also observed an increase of linoleic (13.6% to 21.2%) and linolenic (0.4% to 1.0%) concurrent with a decrease of oleic form 41.8% to 38.0% in the yolk.

Waldroup et al (1969) found that raw soybeans, with or without lysine and methionine supplementation significantly ($p<.05$) decreased egg production and feed consumed/dozen of eggs, when compared to either diets containing SBM or extruded WSb.

In a second experiment, extruded WSb and SBM containing corn-based diets not supplemented with amino acids ,were compared and it was found that there was no significant difference between diets containing whole extruded soybeans and diets containing SBM for hen-day production, kg.feed/doz eggs and egg weight. In conclusion it appears that extruded soybeans are as good a protein source as SBM, and that if the economic conditions are favourable, it may be more profitable to feed WSb to layers than SBM.

2.7.2. Raw whole soybeans in swine diets

A study (Vandergrift, 1982), involving pigs being fed raw and heated soybean flakes with cannulation near the terminal ileum had the following results: N -, amino acids - and energy digestibility, N retention and overall performance were improved by heating the flakes for 25 min. The adverse effects in raw soybeans were shown to be mediated by TI as well as lectins.

Jimenez et al (1963) fed 3 different diets at 2 levels of protein to growing and finishing pigs from 40 - 210 lbs. The 16% protein diet was fed up to 100 lbs of liveweight, the 13% protein diet was fed to market weight. The 16% control diet contained 75% corn and 21.1% SBM (44% protein) as the main ingredients. One of the experimental diets contained 69% corn and 27.1% heated soybeans. The other experimental diet contained 69% corn and 27.1% raw soybeans. The diets were isonitrogenous. Performance parameters measured were: 1) ADG, 2)FC, 3)chilled carcass weight, 4)backfat and 5) lean cuts. When comparing the diet containing heated soybeans and the control diet, no significant differences were found for any of the parameters.

The pigs receiving the diet containing raw soybeans were taken off the trial after 12 weeks, due to a drastic reduction in performance, when compared to the other two diets. This leads to the conclusion that raw soybeans are unsuited for growing and finishing pigs, whereas heated soybeans are as useful as SBM as a protein and energy supplement. However it should be noted that the 12 week weight of pigs having received the diet containing raw soybeans ranged from 31-77 kg, indicating a definite genetic component to the ability to deal with antinutritive factors in raw soybeans.

Crenshaw and Danielson (1985) evaluated age related- and dietary nitrogen effects of the feeding of raw soybeans to growing-finishing swine. There were 3 weight groups : 23, 45 and 68 kg initial weight. Pigs within each weight group were fed 1 of 3 dietary treatments: a control-SBM diet, a raw ground soybeans diet, replacing SBM on an equal weight basis and raw ground soybeans replacing SBM on an isonitrogenous basis, respectively. The dietary protein levels were 17, 15 and 13% for the three weight groups, respectively.

All performance parameters measured were decreased significantly in the youngest and smallest group, when fed diets containing raw soybeans at both levels. The trial period was terminated, when the control group reached market weight. Final weight, ADFI and F/G ratio were decreased by over 30%, whereas ADG was decreased by 50% .

The same was found in the second and third group, with the difference that the actual decrease in performance, although significant, was not as drastic in older animals. This indicates a greater, although not total tolerance to the antinutritive factors in raw soybeans with progressing age. This study also gave an indication of the genetic differences for the ability to digest raw soybeans, since the final weight ranged from 31-88 kg in the group being fed raw soybeans for the longest timespan.

Pontif et al (1987) investigated the effect of feeding raw soybeans to finishing swine on gain, feed efficiency and carcass quality. Two experiments were conducted with a total of 136 crossbred pigs, with initial weight of 62 and 59 kg, respectively. Experimental diets were formulated such that raw soybeans provided 0, 33, 66 and 100% of dietary protein.

The control and "filler" for the intermediate diets was 44% SBM. The measured amount of mg of TI/g of diet, was 0 for the control, 1.18, 2.4 and 3.67 for the diets containing 33,66 and 100 % raw soybeans, respectively.

There was a linear effect of raw soybeans on ADG and a quadratic effect on the gain to feed ratio.

Carcass characteristics were not significantly affected by the level of raw soybeans although carcass weight and loin eye area tended to decrease with increasing levels of raw soybeans, whereas backfat tended to increase, presumably due to the higher level of oil with increasing levels of raw soybeans.

In conclusion we can say that there is potential for feeding raw soybeans at older ages,i.e. toward the end of the finishing period or thereafter to the breeding stock, but that through most of the growing-finishing period it is detrimental to feed raw soybeans. Also we can conclude that there is a definite genetic component that make the difference in the ability to digest raw soybeans, which may be exploited in the future.

2.7.3. Heat treated whole soybeans in swine diets

DeSchutter (1989) conducted several trials evaluating WSb in swine diets. In the first series of trials growing and finishing pigs were fed a corn-SBM control diet and 3 experimental diets, where the SBM was replaced on an isonitrogenous basis by either roasted, micronized or extruded WSb, as well as an isocaloric diet containing an equal amount of oil as was found in the diets containing FFSB. Pigs were grown from 27-100 kg of liveweight. No significant difference was found for any of the growth parameters measured (ADG,ADF and feed to gain ratio).

A similar trial (DeSchutter, 1989) was conducted with starter pigs from 8-26 kg. The control diet was a corn-SBM diet. The experimental diets contained roasted, extruded, micronized and infra-red heated FFSB on an isonitrogenous basis.

No significant differences were found. The trial was repeated, eliminating the micronized treatment. This time the objective was to adjust for soybean variety, since previously, soybeans were obtained from different sources. In this experiment, one big batch of the *Maple Leaf* cultivar was bought and treated with the different techniques. Animals were grown from 8.9 kg to 27 kg. It appeared that extruded FFSB were superior in terms of feed to gain ratio to the other diets, with no significant differences amongst them.

Another growing and finishing trial was conducted, using extruded soybeans at 4 levels. The control diet was a corn-SBM diet, with 0% extruded SB (ESB). The three experimental diets contained ESB at 8.5, 17.5 and 25.5% . Animals were taken on these diets from 24.5 kg to market weight. There seemed to be an apparent decrease in ADF at the intermediate level of ESB. The only other significant difference was found for carcass weights, with carcasses from the 2 higher levels of ESB being significantly heavier than the control diet's. An analysis of the backfat composition was done. Myristic, palmitic and palmitoleic acids were significantly decreased with increasing levels of ESB. However numerically these decreases were not that significant. The striking change was achieved at the level of oleic and linoleic acid. The level of oleic acid decreased by 9.5%, from 47.9 to 38.4% and at the same time the level of linoleic rose from 14.7 to 24.6% . These changes may have a significant impact on the shelf life of the product. The table of the results from a taste test conducted, evaluating tenderness, juiciness, flavour and overall acceptability is difficult to interpret, due to mistakes in the table. Generally, no significant differences were found.

Overall one can conclude that although FFSB have not improved pig performance significantly, no adverse effects have been shown.

2.7.4. Grain sources and whole soybeans in swine diets

McConnell et al (1975) compared different grain sources in combination with FFSB as a protein and energy source. They fed hogs in two phases, from 21-57 kg and from 57-101 kg. The control diet for the first phase was a corn-SBM diet, with 78.3% corn and 18.6% SBM as well as 83.6% corn and 13.3% SBM for the second phase. In the experimental diets, roasted soybeans (RSB) replaced SBM on an isonitrogenous basis. Corn was replaced by barley on an equal weight basis in both diets. When comparing the 4 diets: corn-SBM,corn-RSB,barley-SBM and barley-RSB, it was found that only the pigs being fed barley-SBM performed significantly ($p > .05$) below the level achieved with the other three diets. From this we have concluded that barley is a much better grain source to use, if one wishes to detect advantages of feeding FFSB instead of SBM. This is due to the lower digestible energy content of barley versus corn and the high oil content of full-fat soybeans versus SBM.

2.8. Fats and oils in swine diets

It is generally thought that the addition of fats or oils to the diets of weanling pigs facilitates the transition from liquid to solid feed (Farnsworth, 1987). Sows milk is high in fat and therefore the switch to the typically low fat/ high carbohydrate weaner diet would be easier for the piglet, if fat was to be added (Farnworth, 1987). However, Frobish (1970) found that animals, weaned at relatively young ages (15-21 days), performed relatively poorly in the 4 weeks following weaning, when fed diets containing various fats and oils at up to 20% . On the other hand, it was found later on (Aherne, 1982) that possibly the disregard for protein to calorie ratio may have been the problem. When the level of protein, vitamins and minerals were increased concurrently to fat levels
the animals made good use of the nutrients (Aherne, 1982).

In growing and finishing pigs it has been shown, that the backfat usually reflects the composition of dietary fatty acids the animal was exposed to during the growing and finshing phase.

2.9. Digestibility of raw and heated soybean meal

Vandergrift et al (1983) compared the digestion of various nutrients in raw and heated soybean flakes by pigs. Soybeans where exposed to water in order to achieve moisture contents of 23%. Subsequently they were exposed to steam cooking for various lenghts of time. Nitrogen-, amino acid-, energy digestibility, as well as nitrogen retention were measured at the level of the terminal ileum of barrows, with initial weights between 25 and 45 kg. Heating for either 25, 35, 45 65 or 105 minutes equally improved ($p<.01$) the ileal digestibility of the above mentioned nutrients. Pigs fed raw soybeans excreted more ($p<.01$) nitrogen in the feces and urine than pigs fed any of the heat treated SBM. This results in a reduced nitrogen absorption and retention. Pigs fed raw soybeans absorbed nitrogen to a greater extent from the large intestine, than pigs fed heat treated SBM. However this absorbed nitrogen is excreted in the urine (Vandergrift, 1983) and therefore explains the significantly higher ($p<.01$) urinary nitrogen loss by pigs receiving raw SBM. Fecal nitrogen was also significantly higher in raw SBM than from heat treated soybeans. Ileal DM digestibilities were 78.9% for the 5 heat treated SBM diets on average and 68.9% for the diet containing raw SBM. The average DM digestibility over the entire digestive tract was 88.4% for all six treatments. The difference between ileal and total tract digestibility was significant ($p<.01$), when raw vs all heat treatments was compared. Similar results were found for GE digestibilities.

Jorgensen et al (1984) found that apparent fecal availabilities of essential amino acids in SBM may overestimate ileal apparent availabilities ,in growing pigs, by up to 19% (threonine). The difference in crude protein apparent availability (between fecal app.av. and ileal app. av.) was calculated to be overestimated by 15%. Organic matter apparent digestibility was overestimated as well by the fecal values (ileal 85.5% vs 96.2% fecal). However, DM apparent digestibility values for both measurements were very close (83.6% ileal vs 84.6% fecal). Tanksley et al (1981) conducted a similar experiment with finishing pigs; they also collected urine. The difference between ileal apparent digestibility and total tract digestibility was smaller, but nevertheless sizeable. Total N digestibility was overestimated by 6.9%, whereas the largest overestimation of the digestibility of an essential amino acid was for tryptophan (9.3%). Surprisingly the difference in DM apparent digestibilities was 10.9%. It appears that fecal apparent digestibilities or total digestive tract apparent digestibilities are only a reasonable indicator of DM and energy; but do not correlate to true digestibilities of organic matter, amino acids and CP.

Leibholz (1981) determined apparent fecal DM digestibilities of a SBM-lactose diet (CP 28.1%) in early weaned (3-4 days) piglets, from the age of 7-28 days. The results she obtained were fairly high (89.6 for the period from 9-14 days and 91.4% for the period from 23-28 days of age). Nitrogen fecal apparent digestibilities were 86.4 and 89.3% for the two periods, respectively.

Walker et al (1986) did not find any significant difference in performance and nitrogen digestibility, comparing isolated soy protein (ISP), ethanol extracted SBM (ESOY) and SBM in early weaned (21 days) piglets. There was a significant difference in DM digestibility between ISP and SBM ($p<.05$), but not with ESOY.

Hancock et al (1990) evaluated the effect of ethanol extraction of defatted raw soybean flakes on rate of gain as well as on N digestibility and retention, as well as on the biological value. Marginally protein deficient diets (15% CP) were fed to young pigs (initial body weight 8.9 kg) for 24 days. The 9 experimental diets, contained raw defatted soybeans, which were autoclaved for 5, 20 or 60 minutes, which was combined with either a previous ethanol extraction, an ethanol extraction following autoclaving or no ethanol extraction at all. In this particular experiment, it was found that 20 minutes of autoclaving produced the best rates of gain ($p<.001$). Pigs fed diets with beans which had been ethanol extracted prior to autoclaving (A-OH) (20 min) had the highest rates of gain ($p<.06$). This is not attributable to the TI content of the diet, since these diets had intermediate TI levels between diets that were autoclaved without ethanol extraction(W/O-OH) and diets that were autoclaved before ethanol extraction (B-OH). It is assumed that this was due to a reduction in Maillard reaction, because of the previous ethanol extraction. This is further confirmed by similar results obtained with bean flakes having been autoclaved for 60 minutes. A-OH bean-fed pigs also had a higher rate of gain ($p<.001$). Feed:gain ratio responded the same way as growth rate to the above mentioned variables. In the underprocessed beans (autoclaved for 5 minutes) either ethanol extraction (A-OH or B-OH) improved the apparent N retention significantly ($p<.009$). This effect was reduced with increasing processing time, indicating that the severity of the autoclaving treatment did override the beneficial effect of ethanol extraction. Apparent biological value (N retention/N digested) was only affected by ethanol extraction for the excessive heat treatment. Beans autoclaved following ethanol extraction (A-OH) produced a higher apparent biological value than B-OH or W/O-OH ($p<.04$). Again this indicates that the removal of reducing sugars protected lysine from Maillard reactions.

III. CHEMICAL COMPOSITION OF WHOLE SOYBEANS

3.1.Introduction

Whole soybeans (WSb) are becoming more attractive as animal feeds, with steadily improving treatment methods, which are geared to optimize the preservation of nutrients, as well as energy inputs, while maximizing the destruction of antinutritve factors. The group of antinutritive factors of main concern, and a primary target of processing are the trypsin inhibitors (TI). In Québec and eastern Ontario several techniques for the processing of WSb are being used. The most frequently used processing technique, by feed manufacturers, is extrusion. The beans are forced by a srew pump through a cylinder, which has a small die hole at the end. The heat of friction, produced when the beans are forced along the cylinder by a tapering screw inside the barrel, denatures some proteins.The sudden decrease in pressure causes the cells to rupture upon exit through the die hole, giving **extruded** soybeans their characteristic oily, *meallike* appearance.

Micronization is a fairly recent process, which relies on infrared radiation. Beans are moved along a vibrating conveyor belt, to pass underneath ceramic tiles, which are heated directly by gas burners, and in turn emit infrared radiation. This radiation heats the beans and denatures proteins, amongst them TI. There are only two locations in Québec where this process is used, and both belong to *Prograin*.

Roasting is principally based on the application of heated air to the food or feed product (Fellow, 1988). The heat may also contact the product through conduction by the walls of the roaster or convection by vapour in the chamber. The infrared is converted to heat by the particles, following absorption. Since the heat is converted from convective to conductive heat at the surface of the paricles, the particle size, as well as roaster surface area are very crucial in the process (Fellow, 1988). This process is the most commonly used by small scale soybean producers, which generally use the beans produced to feed their own animals.

Jetsplosion is a roasting technique, which relies on super-heated air rather than direct heat. The beans travel through a chamber, into which air at temperatures up to 600^0F is blown. The travelling speed of the beans is timed so that the beans exit the chamber, when the temperature inside the beans reaches 100^0F. Upon exit the beans are fed through a roller. Due to the build up of pressure from the heat the beans "explode", much like popcorn "explodes", when heated. There is no processing plant in Québec. The only one we could find was in Hanover Ont., owned by New Life Mills. However, even this processing plant is not using the technique at this time.

3.2.Materials and Methods

Monthly samples of either processed WSb or raw WSb, were sent, by different producers, to the Crampton Nutrition Laboratory. Proximate analysis as well as a complete mineral profile was analyzed on all samples received. Proximate analysis includes: dry matter (DM), crude protein (CP), ether extract (EE), acid detergent fibre (ADF), neutral detergent fibre (NDF), cellulose, gross energy (GE) , calcium (Ca) and phosphorus (P). Other minerals analyzed were : Mg, Cu, Zn, Fe, Mn, Na, K.

All procedures were conducted according to AOAC (AOAC, 1975), except CP, which was analyzed using a *LECO FP-428 Nitrogen Analyzer*, 3000 Lakeview Ave. St.Joseph, Mi 49085-2396, USA . Calcium, Mg, Cu, Zn, Fe, Mn, Na and K were determined on a *Perkin Elmer 2380 Atomic Absorption Spectrophotometer*, Beaconsfield, Buckingshamshire HP9 1 QA, England. P was determined by the *AOAC* method on a *Beckmann* , 5758 Royalmount Ave. Montreal P.Q. H4P 1K5, spectrophotometer.

In addition, trypsin inhibitor activity (TIA) (della Gatta,1988) lysine availability availability (Hurrell, 1981) and pepsin digestibility (AOAC, 1975) assays were conducted. TIA was measured on all samples, whereas lysine availability and pepsin digestibility only on selected samples including samples from each processing method.

A profile of the major fatty acids in the EE fraction was measured by means Gas Liquid Chromatography, using *Hewlett Packard*, 6877 Goreway Drive, Missisauga, Ontario L4V 1M8, instrument. A complete amino acid profile (with the exception of tryptophan) was measured as well. The instrument used for this purpose was a *Varian High Pressure Liquid Chromatograph (HPLC)*, 24201 Frampton Ave., Harbor City CA 90710 USA.

1) DETERMINATION OF TI LEVELS IN LEGUMES (della Gatta et al. 1988)

Expression of activity:

One trypsin unit (TU) is arbitrarily defined as an increase of 0.01 absorbance units at 410 nm. TIA is expressed in terms of trypsin units inhibited (TIU).

calculation: $$\text{TIU/mg CP} = \frac{A_0 - A}{0.01*(s*1000*(CP/100)*v)/100\ \text{ml}}$$

$$= \frac{A_0 - A}{10*s*CP*v}$$

where:

A_0	absorbance of standard at 2 ml of trypsin
A	absorbance of sample against the sample blank
s	weight in gram of ether extracteded (EE) soybeans used
CP	% of CP in EE soybeans
v	volume in ml of suspension used for incubation

Observations

- always take an aliquot of the suspension immediately after the 2h shaking. TI extraction is not completed after 2h and therefore prolonged exposures of the soybeans to the glycine buffer will yield higher TIU values
- percentage of inhibition $(100-(A*100/A_0)$ should be between 20 and 70%. If the inhibition is >70%, the absorbance of the sample (A) will be very low. At inhibitions of <20% the absorbance of A is in a range were the standard curve is not linear any more. The standard curve appears to be linear up to 1.4 ml trypsin. With more trypsin the substrate (BAPA) appears to be limiting

2) DYE-BINDING LYSINE: (Hurrell, 1981)

This method is a modification of the procedure published by Hurrell, Lerman & Carpenter (1979), J.Food Sci, 44, 1211. Dye-binding lysine is the difference between the dye-binding capacity of the protein before and after acetylation of the ϵ-amino lysine groups with acetic anhydride. The modifications contained in the new method are largely designed to overcome the influence of the equilibrium dye concentration on the dye-binding capacity. The main changes are:

(a)The Foss buffer system has been replaced by the Udy system.

(b)The concentration of sodium acetate used during the acylation stage has been reduced from 16.4% to 5%.

(c)Propionic anhydride is replaced by acetic anhydride.

(d)The Foss dye-binding meter is considered to be much too imprecise and it is recommended to use normal laboratory equipment (Flask-shaker, spectrophotometer).

(e)The dye should be purified before use and stored in a desicator.

Calculation of dye-binding lysine

The equilibrium dye concentration for DBC (A) and (B) should be between 1 and 2.5 mmol/1. For more precise results, it is preferable that the difference between the (A) and (B) values should not exceed 0.3 mmol/1.

Dye-binding lysine (mmoles/16 g N)= [mean DBC (A) - mean DBC (B)] x (.1462 for DBL in g/16 gN)

3.3. Results and Discussion

3.3.1.Proximate Analysis

Average values of whole soybeans, by treatment, obtained for proximate analysis as well as TI levels and a complete mineral profile are listed in Table 3.1. The major focus of discussion will be the parameters of greatest consequence to our purpose: 1) DM-, 2) EE-, 3) CP-, 4) TI content.

Raw soybeans had an average DM content of 88.83%, as measured in the Crampton Nutrition Laboratory over the sampling period of one year (Table 3.1). The mean level of TI was 139.89 TIU/mg CP. **Jetsploded soybeans** had the highest DM content (93.43%) with a standard deviation of the mean of 0.49. These beans also had the lowest amount of TI (14.62 TIU/mg CP) with a standard deviation for this measurement (2.48) (Table 3.1). There are 2 possible explanations for these results: A) Since only 1 company is involved, the source of soybeans (cultivar, cultivator etc) may have been much more consistent, the soil or storage facilities may have promoted higher DM contents. B)Jetsplosion is a fairly severe process, always removing the maximum amount of moisture from the seed.

The data supports the second hypothesis, due to the fact that DM content is high and TI levels are low, indicating severe heat treatment. On the other hand, some doubt is cast on this conclusion by the fact that **jetsploded** soybeans also had the highest amount of CP (43.36%), which suggests that this is probably a cultivar effect.

The values obtained for **roasted soybeans** were found to be at the opposite side of the spectrum (Table 3.1). As expected, they had the highest degree of variability. Here the mean value for DM composition is relatively low (90.71%), with a standard deviation of 2.76.

Table 3.1. Variability of Full Fat Soybean samples, by treatment, as analyzed in the Crampton Nutrition Laboratorium

Treatment	Raw	Extruded	Micronized	Jetsploded	Roasted	Overall mean & C.V.
Dry Matter %	88.83c	90.85b	92.04ab	93.43a	90.71b	90.67
Std. Error Mean	0.40	0.40	0.56	0.69	0.40	2.52
N	33	33	17	11	33	127
Ether extract %	20.71ab	19.18c	21.51a	20.42b	21.32a	20.55
Std. Error Mean	0.24	0.24	0.33	0.41	0.24	6.65
N	33	33	17	11	33	127
Crude protein %	40.11b	40.16b	40.65b	43.37a	40.25b	40.51
Std. Error Mean	0.56	0.56	0.78	0.96	.56	7.89
N	33	33	17	11	33	127
NDF %	10.83b	10.47b	11.20ab	12.31a	10.73b	10.88
Std. Error Mean	0.35	0.35	0.49	0.64	0.35	18.63
N	33	33	17	10	33	126
ADF %	11.94b	9.42c	11.34b	13.38a	11.93b	11.32
Std. Error Mean	0.36	0.36	0.49	0.61	0.36	17.91
N	33	33	17	11	32	126
Cellulose %	6.85ab	7.02a	5.64c	5.87cb	7.29a	6.76
Std. Error Mean	0.31	0.31	0.43	0.54	0.31	26.31
N	33	33	17	11	33	127
GE kcal/g	5790.02	5655.23	5832.79	5670.05	5748.65	5739.58
Std. Error Mean	56.68	56.68	78.97	98.17	56.68	5.67
N	33	33	17	11	33	127
TIU/mg CP	149.22	15.71	15.048	14.62	16.82	-
Std. Error Mean	5.59	5.69	7.66	11.58	6.53	-
N	30	29	16	7	22	104
Ash	5.57a	5.61a	5.72a	5.24b	5.55a	5.57
Std. Error Mean	0.05	0.05	0.07	0.09	0.05	5.22
N	33	33	17	11	33	127
Ca ppm	2128.39cd	2365.15a	2153.29cb	1984.27d	2294.41ab	2222.78
Std. Error Mean	43.90	43.90	61.16	76.03	45.29	11.34
N	33	33	17	11	31	125
P ppm	6379.24	6441.73	6334.76	5848.27	6597.23	6397.02
Std. Error Mean	82.24	82.24	114.58	142.45	84.85	7.39
N	33	33	17	11	31	125
Mg ppm	2613.58a	2602.55ab	2732.71a	2479.73b	2607.10ab	2613.48
Std. Error Mean	34.44	34.44	47.98	59.64	35.53	7.57
N	33	33	17	11	31	125
Cu ppm	16.29a	16.39a	16.09a	12.72b	16.06a	15.92
Std. Error Mean	0.27	0.27	0.38	0.47	0.28	9.82
N	33	33	17	11	31	125

Table 3.1. Variability of Full Fat Soybean samples, by treatment, as analyzed in the Crampton Nutrition Laboratorium

Treatment	Raw	Extruded	Micronized	Jetexploded	Roasted	Overall mean & C.V.
Zn ppm	54.61	55.65	66.41	49.45	56.25	56.44
Std. Error Mean	4.44	4.44	6.18	7.69	4.58	45.16
N	33	33	17	11	31	125
Fe ppm	122.35b	169.90a	172.80a	103.39b	134.39b	143.08
Std. Error Mean	9.07	9.07	12.63	15.70	9.36	36.40
N	33	33	17	11	31	125
Mn ppm	23.68	25.05	25.26	25.07	23.58	24.36
Std. Error Mean	0.46	0.46	0.64	0.79	0.47	10.80
N	33	33	17	11	31	125
Na ppm	8.41b	78.73a	7.76a	25.19a	12.45a	29.38
Std. Error Mean	6.80	6.80	9.48	11.77	7.02	133.11
N	33	33	17	11	31	125
K ppm	6939.10a	6221.94cb	6500.10ab	5809.98c	7142.52a	6641.15
Std. Error Mean	179.37	179.37	249.91	310.67	185.06	15.51
N	33	33	17	11	31	125

Values in the same row, with different subscripts are significantly different ($p<.05$)

The average TIA was 16.82 TIU/mg CP, with a tremendous variability of 17.65 standard deviation (Table 3.1). This appears to be proof of the limitations of this procedure, because application of heat is limited to avoid burning of the outside, which is reflected in the fact that TI levels are the highest of all four treatments. **Extrusion** as well did not remove a lot of moisture, but this was expected due to the nature of the process. The mean level was (90.85%), with a variability similar to that of the **roasted** treatment. TI levels were 15.71 TIU/mg CP (Table 3.1). **Micronization** removed a lot of moisture with an average DM content of 92.04%. TI levels were intermediate (15.05 TIU/mg CP) (Table 3.1).

Several of the differences observed, between samples from different heat treatments, were significant. **Raw** WSb had the lowest DM ($p>.05$) content. **Jetsploded** WSb had a significantly higher DM content than **extruded** or **roasted** WSb, with **micronized** WSb being intermediate.

Ether extraction resulted in some unexpected results. **Micronized** and **roasted** WSb had a significantly higher ($p<.05$) EE content than **extruded** or **jetsploded** WSb, with **raw** soybeans being intermediate. It is surprising that the **extruded** soybeans had the lowest level of EE (19.18%), since it was expected to be highest, because intracellular as well as structural (i.e. phospholipids) lipids are much more accessible than with other treatments. **Jetsploded** WSb had significantly higher ($p<.05$) CP content than all other WSb. The same was true for ADF content ($p<.05$) and the reverse for ash content ($p<.05$) (Table 3.1).

The overall average DM content of the 33 **raw** WSb samples analyzed was 2.57% and 3.17% lower than values listed by Augustin and the three NRC references (1984, 1988, 1989), respectively. There are marked differences between EE values and CP values, between these three sources. The EE obtained in our laboratorium are approximately 2 % higher, than from the above mentioned sources. CP values range from 34.3% to 42.8%, with our findings (40.11%) being somewhat intermediate. The gross energy values obtained by bomb calorimetry do not compare to the values found by Augustin (5790 kcal/g vs 4130 kcal/g). This must be due to the higher EE of the soybeans collected in Québec. Most of the sources used by Augustin are from the 1970's and 1960's. Considerable amount of progress in soybean breeding and management has been achieved since that period (Snyder, 1987), which may account for these differences.

Average DM content for all 4 heat treatments was 90.67%. This corresponds with the DM value indicated for raw WSb, but not heat - processed WSb, by Augustin (91.4%). This may be an indication that processors are more nutritionally and energetically conscious. The values for DM ,taken from nutrient requirements of poultry (NRC, 1984) , dairy cattle (NRC, 1989), and swine (NRC, 1988) as well as Janssen (1979) are 90% or lower. Again the EE values found were considerably higher. An average EE content for all 4 heat treatments of 20.50% was found. The values obtained from the literature give an average of 18.9% EE. Only the NRC tables for the nutrient requirements of cattle give a value of 20.0% (NRC, 1989). Protein content as well was higher than values in the literature. An average CP content for all 4 heat treatments was 40.66%. The mean value , calculated from the literature, for CP content of WSb was 38.1%. Again the only value close to our findings was the one given by NRC nutrient requirements for dairy cattle (NRC, 1989).

The validity of comparing the numbers, obtained from periodic samples for proximate analysis, with analyses obtained from the literature seems inapropiate. Too many unknowns are involved, especially when dealing with **heat treated** soybeans, such as strain or strains used, growing conditions, farm practices, such as fertilizer used etc.. It is more useful to compare samples in a time and space restricted setting, like the one in which the present experiment was conducted. Several variables are hereby eliminated or minimized. Restricting the sampling period to one year and the area to Québec and Eastern Ontario, somewhat levels the growing season variability and the type of soils as well as some general agricultural practices. However there is no doubt that several factors can not be accounted for and have to be accepted as unknowns. It is for example impossible to obtain information on the strain of soybeans processed in different processing plants, since they receive soybeans from many different producers, which are subsequently mixed in the storage bins (Personal communication).

3.3.1.1. DM- and CP pepsin digestibility, trypsin inhibitor activity and lysine availability

One set of whole soybeans with at least 5 samples per treatment was analyzed for lysine availability, pepsin DM digestibility, pepsin CP digestibility (Appendix, Tables 8.7.1-5). Lysine availability in micronized WSb was higher than for all other treatments, but not significantly, with 6.12% of total CP. Mean CP value was 49.54% (Appendix, Table 8.7.6), with no significant difference amongst treatments. There was no significant difference in TIA between different heat treatments, with raw soybeans having about a ten-fold level of activity (Appendix, Table 8.7.6). The mean DM pepsin digestibility was 77.48% (Appendix, Table 8.7.6), with no significant difference amongst treatments. The mean CP pepsin digestibility was 71.99% (Appendix, Table 8.7.6), with raw soybeans having a significantly higher ($p<.05$) *in vitro* digestibility (75.59%) (Appendix, Table 8.7.6) than the heat treated soybeans. There was no significant difference in *in vitro* digestibility amongst heat treated soybeans. These results were analyzed for correlations (Appendix, Tables 8.8.1-7) amongst each other, as well as correlations with TIA and CP content. All treatments were analyzed statistically, considering individual treatments, all treatments and all heat treatments together. CP content on an EE basis appears to be affected by TIA. There was a significant ($p<.1$) large ($r>-0.69$) negative correlation for extruded, jetsploded and for all sources excluding raw WSb and a negative correlation approaching significance for raw soybeans ($p=0.13$). In contrast in micronized WSb, these two factors seem to be positively correlated ($p=.08$). In jetsploded WSb, there also was a positive correlation between CP content and lysine availability ($p=.08$). When all sources excluding raw WSb were analyzed, several correlations were significant or were approaching significance. There was a significant negative correlation (r= -0.52, p=.01) between CP content and TIA. Lysine availability had low correlation coefficients with all three other factors (CP on EE, TI and CP digestibility) (>.33), but all three were approaching significance (Appendix, Table 8.8.7). CP pepsin digestibility does not seem to be correlated to CP content or TIA.

3.3.2. Proximate analysis by company within each treatment

A separate analysis (Appendix, Tables 8.3.1-5) was conducted in order to determine the variability of soybean composition stemming from individual sources. Only sources, which submitted 4 samples or more will be considered here. In the **extruded** categorie three sources met this criterion (Appendix, Table 8.3.2). Bazinet Lacoste had the greatest variability for DM (std. dev. 2.27) content, as well as the highest content of DM (93.39%). It was followed by LB products (std.dev. and DM content 1.49 and 91.42%) and Nutribec (std.dev. and DM content 1.22 and 87.70%). For all Proximate analysis parameters, except ash and Ca, Bazinet Lacoste had the highest degree of variability. Surprisingly it showed the lowest degree of variability for TIA. One would expect this kind of result, if heat was excessively applied, especially in regard of the high DM content. Contrary to this, the TIA was the highest of all three sources. There are two possible explanations: a) the source of soybeans used had very high TI contents or b) the variability is due to a factor other than heat. The first hypothesis seems to be true, based on the high level of TIA (TIU/mgCP 173.94) of the **raw** soybeans supplied by this company. Overall the data supports the hypothesis that different processors receive batches of soybeans, which differ noticeably depending on cultivar and producer.

There were two sources of **micronized** soybeans: a) Semences Prograin and b)Micrograin

(90) (Appendix, Table 8.3.3). The only mentionable differences were found in DM content, which was higher (93.48%) and more variable (2.49) in the samples received from Micrograin, as well as TIA (20.09 TIU/mgCP, 8.44 std.dev.). Otherwise the results are fairly close. The explanation for these results, may lie in the fact that both companies have the same owner. However, Micrograin is a relatively new acquisition, and therefore the operators may not be as experienced as the operators in the mother plant.The raw soybeans received from the two sources differ somewhat, but this may be due to the fact that we received only two **raw** samples from Micrograin. For both sources the TIA is high.

For the **jetsploded** soybeans, the discussion of individual treatments applies, since there was only one company involved (Appendix, Table 8.8.4). There were two sources, which sent more than four or more samples of **roasted** soybeans: a) Meunerie Fremeth and b) M.Roland Simard (Appendix, Table 3.1.2.e). It appears that M.Simard used a more severe heat treatment than Meunerie Fremeth, since the DM content was higher (92.33vs 91.05, respectively) and the TIA was much lower (8.61 TIU/mgCP, which is very low vs 12.31 TIU/mgCP, respectively). This is particularly supported by the fact that the opposite was true, when looking at the **raw** soybeans (Appendix, Table 3.1.2.d) supplied by both sources. DM content was higher in the samples received from the Meunerie Fremeth, but TIA was lower. It may be advisable for M.Simard to either reduce processing temperature or decrease processing time. As an overall conclusion it can be said that the quality of the final product from a nutritional point of view depends to a great extent on the source of soybeans as well as processing practices.

3.3.3. Macro- and trace mineral profiles

The overall average Ca content, for all treatments, was 0.22 %, P 0.64 %, Mg 0.26 %, Cu 15.92 ppm, 56.44 ppm, Fe 143 ppm, Mn 24.36 ppm, Na 29.38 ppm and K 6641.15 ppm (Table 3.1). WSb from the jetsploded treatment had significantly lower levels of Ca, Cu and Fe than extruded soybeans; significantly lower levels of Ca, Mg,Cu, Fe and K than micronized soybeans; significantly lower levels of Ca, Cu, and K than raw WSb. This is attributed to the fact that jetsploded WSb had significantly lower ash content than all other sources of WSb. Raw WSb had low levels of Ca, Fe and Na. It is difficult to perceive a relationship between mineral profile and heat treatment, which would override the well established effects of soil type on mineral profile (Snyder, 1988).

3.3.4. Amino acid profile

Amino acid composition of WSb are expressed on a DM basis and as percentage of amino acids analyzed and listed in Table 3.2.a&b andTables 8.4.a-e (Appendix). The overall average alanine content for all treatments, was 4.51%, aspartic acid 11.08%, 11.29% arginine, 18.53% glutamic acid, 5.62% serine, 4.76 glycine, 2.26% histidine, 3.82% isoleucine, 7.43% leucine, 6.26% lysine, 0.98% methionine, 3.92% phenylalanine, 4.48% proline, 7.74% threonine, 3.60% tyrosine and 3.72% valine.

It is difficult to compare these compositions to values obtained from the literature, since a) only 16 amino acids were analyzed and b) they therefore can not be expressed on a CP percentage basis. A significant difference between treatments was found for lysine content, where jetsploded soybeans had the lowest ($p<.05$) level and micronized soybeans an intermediate level, between jetsploded vs extruded, raw and roasted WSb. This contrary to

Treatment averages		Table 3.2.a Average amino acid composition , by treatment On D.M. Basis															
Treatment	N	Asp	Glu	Ser	Gly	His	Arg	Thr	Ala	Pro	T,r	Val	Met	Ile	Leu	Phe	Lys
Raw	31	4.33	6.94	2.17	1.65	0.86	3.94	2.68	1.72	1.67	1.33	1.44	0.38	1.49	2.79	1.48	2.34
Std.error		0.61	0.67	0.28	0.23	0.12	1.04	0.75	0.30	0.32	0.13	0.14	0.08	0.21	0.28	0.20	0.24
Extruded	33	4.14	6.95	2.11	1.79	0.86	4.43	3.34	1.69	1.76	1.38	1.38	0.38	1.41	2.77	1.50	2.36
Std.error		0.50	0.65	0.21	0.22	0.13	0.97	3.62	0.34	0.48	0.18	0.12	0.10	0.20	0.25	0.38	0.25
Micronized	17	4.30	7.15	2.11	2.34	0.90	4.26	2.67	1.65	1.65	1.37	1.42	0.40	1.48	2.89	1.61	2.36
Std.error		0.36	0.52	0.23	2.25	0.13	0.83	0.67	0.18	0.33	00.10	0.12	00.08	00.16	0.25	0.40	0.25
Jetsploded	7	4.01	6.67	2.07	1.72	0.78	4.42	2.98	1.76	1.82	1.31	1.34	0.36	1.40	2.86	1.43	2.14
Std. error		0.49	0.16	0.10	0.09	0.08	0.64	0.63	0.15	0.11	0.12	0.07	0.06	0.12	0.15	0.10	0.16
Roasted	32	3.92	6.89	2.04	1.70	0.80	4.35	3.05	1.70	1.61	1.35	1.37	0.32	1.36	2.71	1.36	2.38
Std. error		0.51	0.61	0.16	0.20	0.14	1.16	0.81	0.26	0.28	0.24	0.21	0.07	0.24	0.31	0.23	0.24
Average	120	4.14	6.92	2.10	1.84	0.84	4.28	2.94	1.70	1.70	1.35	1.39	0.37	1.43	2.81	1.47	2.32
Std.error		00.49	0.52	0.20	0.60	0.12	0.93	1.29	0.25	0.31	0.15	0.13	0.08	0.19	0.25	0.26	0.23

Treatment averages		Table 3.2.b Average amino acid composition , by treatment as percentage of total amino acids analyzed On D.M. Basis															
Treatment	N	Asp	Glu	Ser	Gly	His	Arg	Thr	Ala	Pro	Tyr	Val	Met	Ile	Leu	Phe	Lys
Raw	31	11.67	18.65	5.85	4.42b	2.31	10.57	7.20	4.62	4.74	3.57	3.87	1.04	4.01	7.51	3.97	6.31a
Std. error		0.28	0.25	0.11	0.33	0.06	0.43	0.63	0.11	0.16	0.07	0.08	0.04	0.11	0.12	0.15	0.10
Extruded	33	10.91	18.33	5.56	4.70ab	2.27	11.58	8.17	4.42	4.62	3.62	3.63	1.00	3.73	7.30	3.98	6.19a
Std.error		0.27	0.24	0.11	0.32	0.06	0.42	0.61	0.11	0.16	0.07	0.08	0.04	0.10	0.12	0.14	0.10
Micronized	17	11.19	18.63	5.50	5.82a	2.35	11.06	6.95	4.27	4.28	3.56	3.69	1.05	3.87	7.51	4.17	6.12ab
Std.error		0.37	0.34	0.15	0.45	0.08	0.59	0.85	0.15	0.22	0.09	0.08	0.06	0.15	0.16	0.20	0.14
Jetsploded	7	10.86	18.00	5.59	4.63ab	2.11	11.93	8.01	4.74	4.91	3.50	3.60	0.97	3.79	7.71	3.86	5.76b
Std. error		0.58	0.53	0.24	0.70	0.13	0.91	0.24	0.34	0.34	0.14	0.17	0.09	0.23	0.26	0.31	0.21
Roasted	32	10.68	18.68	5.57	4.60ab	2.18	11.67	8.19	4.59	4.36	3.65	3.72	0.88	3.70	7.37	3.68	6.48a
Std. error		0.27	0.25	0.11	0.33	0.06	0.43	0.62	0.11	0.16	0.07	0.08	0.04	0.11	0.12	0.14	0.10
Average	120	11.08	18.53	5.62	4.76	2.26	11.29	7.74	4.51	4.48	3.60	3.72	0.98	3.82	7.43	3.92	6.26
Std.error		1.59	1.40	0.62	1.85	0.34	2.42	3.50	0.63	0.90	0.38	0.45	0.24	0.60	0.68	0.82	0.56

Treatment averages		Table 3.3 Average Fatty acid composition as percentage of Fatty acids analyzed On D.M. Basis						
Treatment	N	14:0	16:0	18:0	18:1	18:2	18:3	22:0
Raw	27	0.10	11.24	3.67	22.15	54.27ab	8.44b	0.15
Std. error		0.01	0.12	0.06	0.26	0.30	0.13	0.03
Extruded	31	0.12	11.18	3.71	22.25	54.41ab	8.17b	0.17
Std. error		0.01	0.11	0.05	0.24	0.28	0.12	0.03
Micronized	16	0.10	11.39	3.71	21.91	54.56ab	8.23b	0.12
Std. error		0.02	0.16	0.07	0.33	0.39	0.16	0.04
Jetsploded	8	0.10	10.96	3.73	22.36	53.59b	9.13a	0.13
Std. error		0.02	0.22	0.11	0.47	0.56	0.23	0.06
Roasted	28	0.09	11.02	3.65	21.64	55.11a	8.21b	0.32
Std. error		0.01	0.12	0.06	0.25	0.30	0.12	0.03
Average	110	0.10	11.17	3.69	22.03	54.52	8.33	0.19
Std.error		0.06	0.62	0.30	1.33	1.57	0.65	0.17

Table 3.4 Vitamin A & E content of full-fat soybeans by treatment

Treatment average	N	Vitamin A µg/g	Vitamin E µg/g
Raw	27	0.120	20.67cb
Std. error		0.01	0.52
Extruded	26	0.16	21.82ab
Std.error		0.01	0.53
Micronized	17	0.133	22.85a
Std. error		0.02	0.65
Jetsploded	7	0.109	18.68c
Std. error		0.03	1.01
Roasted	22	0.125	20.03bc
Std. error		0.02	0.57
Average	99	0.133	21.07
C.V.		53.63	12.74

the findings on lysine availability, where **micronized** had the highest level of available lysine and was followed by **jetsploded** soybeans, with **raw** soybeans surprisingly having the lowest availability. The differences were not significant, which is probably due to the small sample size of **jetsploded** soybeans.

3.3.5. Fatty Acid Profile

Fatty acid compositions are listed by treatment in Tables 8.5.1-5 and 3.3. The overall average eicosanoic acid content, for all treatments, was 0.19%, linoleic 54.52%, linolenic 8.33%, myristic 0.10%, oleic 22.03%, palmitic 11.17% and stearic 3.69%. No significant difference was found for oleic acid between treatments. However, **roasted** WSb had a significantly higher ($p<.05$) level of linoleic acid than **jetsploded** soybeans, with all other treatments being intermediate. Therefore **jetsploded** soybeans had a significantly higher ($p<.05$) content of linolenic acid than all other treatments.

3.3.6. Vitamin A & E

The average values by treatment obtained for vitamin A and E levels are listed in Table 3.1.c. Individual values are listed in Appendix Tables 8.6.1-5. No significant differences in Vitamin A levels was found for any of the treatments. The average value was 0.133 μg/g. This lack of significance may be due to the very high C.V. (53.63%). A significant difference was found for Vitamin E levels. **micronized** WSb had the highest level (22.85 μg/g), which was significantly different ($p<.05$) from **jetsploded** soybeans, which had a level of 18.68 μg/g. There are at least three possible explanations for this fact: a) different strains with significantly different levels of Vitamin E were used, b)different levels of oil content or composition affect Vitamin E content or c)treatment oxidizes Vitamin E at different rates.

A combination of the latter two possibilities seems to be the case. **jetsploded** soybeans have significantly higher levels of linolenic acid. Jetsplosion also appears to be a more severe heat treatment. (see above) It is therefore likely, that this combination results in a significantly greater rate of Vitamin E oxidation.

IV. WHOLE SOYBEAN PRODUCTS EVALUATED WITH WEANLING PIGS

4.1.Introduction

Young pigs undergo a severe change of the nutritional environment at weaning. They are being taken from a liquid, high protein, high fat, no fibre diet, which is the sow's milk, to a solid diet, which is usually significantly lower in fat and protein content and usually contains significant amounts of fibre. Soybean meal (SBM), the byproduct of oil extraction from whole soybeans (WSb), is the major protein source of these diets. In order to facilitate the transition, it has been proposed to add high energy feedstuffs to the weaner diet (Farnsworth, 1987). Animal fat or plant oil could both be used, since they have the highest concentration of energy/weight unit (Lehninger, 1980). Most weaner diets are formulated to contain 20 to 22% protein, and therefore SBM usually is used in significant amounts. This is why adding fat back into the ration to raise the energy level, could be an unnecessary process, since oil has been previously extracted from that very SBM component of the feed being supplemented. Weaner diets based on cereals other than corn, in this case barley, need to be supplemented with fat to an even larger extent, due to the higher digestible energy (DE) content of corn compared to these cereals. Raw soybeans not only contain about 18% of oil, but also antinutrititive factors (Liener, 1980), particularly trypsin inhibitors, which have to be destroyed by thermal treatment (Liener, 1980). Young animals are more susceptible to these factors (Crenshaw and Danielson, 1985), and one would therefore expect to see more pronounced differences in performance from one heat treatment to the other, than in older animals. Knowing that there are several fundamentally different processing techniques in use (deSchutter, 1989), it is assumed that they will have measurably different effects on the WSb product. The balance between maximum destruction of antinutritive factors and the optimum conservation of labile nutrients, such as lysine, are the most important criteria for identifying a good processing technique. Currently, processes that are in use include: **extrusion, micronization, jetsplosion** and **roasting.**

4.2. Objective

The objective of this study was to evaluate the effects of different processing techniques on the nutritional value of full-fat soybeans for piglets, in terms of their effect on performance from weaning to 20 kg liveweight.

4.3. Materials and Methods

Animals:105 purebred **Landrace** animals were used in this trial.

The standard management procedures administered at birth include teeth and tails clipping and intraperitoneal injection of 1 cc of iron supplement.

All males were castrated at approx. 1 week of age.

Overall 60 females and 45 male castrates were used in this experiment, with 35 animals per block.

The animals used in this trial were born and raised in the Maternity and Weaning unit of the MacDonald College Farm. They were weaned at approx. 4 weeks (28 days) of age. The weaner diet is a corn- SBM based diet with skim milk powder (SMP) as a protein supplement.

The first block was put on experimental feed the 30th of August 1990, the second and third block on the 20th of September and the fourth on the 11th of February 1991.

One female animal was removed from each pen in the fourth block, due to complete lack or negative growth response after 2 weeks.

Feed: Tables 4.1 & 4.2 show the composition of experimental ingredients and experimental diets respectively. The four sources of WSb are an average of 8% lower in CP than SBM, but contain up to 21% EE.

Facilities: Animals were kept at the Maternity and Weaning Unit of MacDonald College. One waterer is fixed at the front of the pen at a height of approx 20 cm. The dimension of the pens is 5.0 m^2. The feeder was set in the back of the pen. Some wood-shaving bedding was used throughout most of the trial.

P4SR feeders ,from *J.P.Soubry Limited*, were used, with a capacity of 100 lbs and 4 holes, framed by corrugated steel.

Measurements:

Throughout the duration of the trial, body weight was taken every week as well as feed consumption.

A Toledo push scale with a maximum capacity of 500 lbs and a 1/2 lb graduation was used.

Analyses: See Section 3.

4.3.1. Experimental design

Animals were selected from 28 litters. A completely randomized block design was used, with 3 blocks and 5 pens/block. Average initial weight was approx. 6.1 kg. Number of males and females was equal in each pen within a block, and care was taken to distribute animals such that overall average initial weight was similar between pens, within a block.

In **Block** 1 there were 3 males and 4 females/pen.

In **Block** 2 there were 3 males and 4 females/pen.

In **Block** 3 there were 3 males and 4 females/pen.

All body weight, feed consumption and feed conversion data were analyzed by the GLM procedure, using SAS (1985) .

4.4. Results and Discussion

The differences in soybean composition for different treatments are mainly attributable to the fact, that the individual processing plants used soybeans of different varieties produced in different regions (Section 3). There were no significant differences in body weight, weight gain, ADG and feed conversion (Tables 4.3 and 4.6 respectively). However, the performance of animals being fed extruded soybeans tended to be the most favourable in feed conversion. Body weights and weight gains also were not significantly different (Table 5). The average weekly body weight gain and the average daily gain per pen/week were 2.73 kg and .390 kg, respectively (Table 3). Generally it can be concluded that there were no significant differences between treatments for either parameter and that the coefficient of variability is very high. This is presumably due to the different pre-weaning environments

Table 4.1 Composition of Experimental Ingredients

Ingredient	DM	CP	EE	Ash	ADF	NDF	Ca	P
Barley	85.08	11.6	1.7	2.26	10.78	11.84	.44	.30
Soybean Meal	88.62	47.46	.89	6.24	6.72	7.69	.39	.51
Extruded Soybeans	90.54	41.25	19.53	5.35	10.45	10.2	.20	.66
Micronized Soybeans	92.03	40.71	20.48	5.61	11.40	14.85	.18	.62
Jetsploded Soybeans	94.06	37.8	18.51	5.35	16.36	12.30	.23	.56
Roasted Soybeans	91.05	40.29	21.37	4.8	12.07	11.53	.19	.55

DM= dry matter, CP = crude protein, EE = ether extract,
ADF = acid detergent fibre, NDF =neutral detergent fibre.

Table 4.2 Composition of Experimental Diets

Ingredient	Soybean Meal	Extruded	Micronized	Jetsploded	Roasted
Barley	74.25	69.25	68.75	65.75	68.50
Soybean Meal	21.75	-	-	-	-
Fullfat Soybeans	-	26.75	27.25	30.25	27.50
Limestone[1]	0.5	0.5	0.5	0.5	0.5
Calcium Phosphate[2]	2.8	2.8	2.8	2.8	2.8
Vitamin-Mineral Premix[3]	0.3	0.3	0.3	0.3	0.3
CholineCl[4]	0.1	0.1	0.1	0.1	0.1
NaClI	0.3	0.3	0.3	0.3	0.3
Calculated CP, %	19.05	19.06	19.07	19.06	19.03

1)Limestone: Ca min: 37%, Mg min: .3%;
2)Biophos: P min 21%; Ca max 18%; Ca min 15%; F max 2100 mg/kg;
Fe 1500 max mg/kg
3)Fortamix:Fe 36 000 mq/kg, Zn 50 000 mg/kg, Mn 12 000 mg/kg,
Cu 40 000 mg/kg, I 100 mg/kg, Vit. A min 2 800 000 IU/kg, Vit. D min 280 000 IU/kg,
Vit.E min 10 000 IU/kg.
4)Choline Cl: 600 000 mg/kg, DM min 97.5% .

Table 4.3 Average Body Weight (kg) per Pig in each Treatment

Weeks	C	ESB	MSB	JSB	RSB	C.V.	P
Initial	6.36	6.30	6.27	6.30	6.39		
1	8.200	8.414	8.410	8.252	8.290	9.05	.718
2	10.39	10.85	10.94	10.77	10.58	13.8	.596
3	13.29	13.86	13.70	13.80	13.30	13.9	.707
4	16.29	16.75	16.34	16.75	16.04	16.2	.801
5	19.80	20.27	20.36	20.48	19.28	16.1	.592
N	20	20	20	20	20		

Table 4.4 Weekly Body Weight gain (kg) per Pig in each Treatment

Weeks	C	ESB	MSB	JSB	RSB	C.V.	P
0-1	1.857	2.124	2.086	2.005	1.919	37.65	.715
1-2	2.190	2.433	2.533	2.519	2.286	32.20	.466
2-3	2.76	2.58	2.53	2.77	2.48	38.06	.831
3-4	3.005	3.16	2.635	2.95	2.74	36.89	.54
4-5	3.51	3.52	4.03	3.73	3.24	33.80	.291
N	20	20	20	20	20		
Total weight gain							
Total	13.46	13.97	14.09	14.18	12.89	23.42	.601
N	20	20	20	20	20		

Table 4.5 Average daily gain (kg) per Pig in each Treatment

0-1	.2653	.3034	.2980	.2864	.2741	37.65	.715
1-2	.3129	.3476	.3619	.3599	.3265	32.20	.466
2-3	.3943	.3686	.3614	.3957	.3543	38.06	.831
3-4	.4293	.4514	.3764	.4214	.3914	36.89	.54
4-5	.5007	.5029	.5750	.5329	.4621	33.80	.291
N	20	20	20	20	20		

Table 4.6 Feed Conversion (kg of feed/ kg of gain)of Pigs per Period by Treatment

Weeks	C	ESB	MSB	JSB	RSB	C.V.	P
2	1.873	1.617	1.750	2.033	2.153	16.35	.301
3	1.880	2.063	2.480	2.083	2.350	15.88	.300
4	1.810	1.607	1.963	1.970	1.687	21.57	.723
5	1.630	1.650	1.680	1.783	1.890	10.62	.438
Average	1.80	1.73	1.97	1.97	2.02		
N	20	20	20	20	20		

these piglets experienced. Looking at the numerical values of these parameters, the control along with the diet containing roasted soybeans showed the poorest results. The other three diets, containing extruded, micronized and jetsploded WSb all performed well, with no clear trends in favour of either. All diets showed a steady increase in weekly and daily weight gain, throughout the five week experimental period.

The average initial body weight was 6.32 kg and the final average weight, after 5 weeks, was 20.04 kg (Table 4.4).The feed conversion data for all five treatments is shown in Table 4.4. The best, although not significantly better, is the diet containing extruded soybeans, with an average feed conversion ratio of 1.73. This is followed by the control diet, which showed an average feed conversion ratio of 1.80. The remaining three dietary treatments, i.e. micronized, jetsploded and roasted performed rather poorly, with average feed conversion ratios of 1.97, 1.97 and 2.02, respectively. Coefficients of variability were considerably lower, because feed consumption was measured on a per pen basis, rather than with individual animals.

The average weight gain was 13.72 kg (Table 4.4). Neither of these total differences was significant ($p>.05$). The group receiving roasted soybeans as a dietary treatment started out with the highest initial weight, but ended up with the lowest final weight (difference >800 g). The control diet also started out with an average weight, which was greater than the remaining three dietary treatments, but finished with a lower weight (difference >300 g). The remaining three diets started and finished with similar weights. Overall the gains were good with gains of approx. 14 kg in 5 weeks for the groups receiving extruded, micronized and jetsploded soybeans in their diets.

As a general conclusion it can be said, that, although not significantly better, extruded WSb seem to promote a better performance than any other WSb product in weanling pigs. This is presumably due to the fact that extrusion is a process, by which the structure of the cells is disrupted and the intracellular oil coats the resulting meal. This results in an increased palatability to the piglets. Palatability is of greater importance in smaller pigs, since the feed intake is highly variable following weaning.

4.4.1. General Discussion

The results reported herein consolidate those found in an earlier trial at the Ridgetown College of Agricultural Technology (deSchutter 1989). Two trials were conducted there. In the first trial feeding 4 different sources of WSb (extruded, micronized,roasted and infrared treated) resulted in no significant improvement, when compared to a SBM-control diet. Although not statistically significant, extruded soybeans produced measurable improvements in ADG, feed intake and feed/gain ratio. The differences in the experimental design, when comparing this trial and the one we conducted are nevertheless important. DeSchutter used diets which were corn-based as opposed to barley-based diets in our trial. She also used diets which were formulated to contain 18% protein. Therefore these diets had a) a lower protein content and b) a lower oil content. However, the pigs used also were 2 kg heavier, at the beginning of the trial, than the ones we used. This implies that these pigs had been on solid feed for at least 1 week and therefore may have reacted differently to the experimental diets than the pigs we used, since our experimental pigs were switched onto the experimental diets right at weaning. Also the fact that the experimental diets contained barley as a cereal source may have been of great importance in terms of digestion.

The two factors of greatest importance are the relatively high fibre content of barley, as well as the presence of ß-glucans. In a second trial, which was designed to adjust for soybean variety, only roasted, extruded and infra red treated WSb were compared to a SBM-control. Here it was found that F/G ratio was significantly improved (<.03) by using whole extruded soybeans in the starter diet. All other parameters were not significantly different from the control for any of the treatments. The average total weight gains in both these trials were greater, when compared to the trial reported herein. This is attributed to a) a six rather than a five week trial period and b) the greater initial weight of piglets.

4.5. Conclusion

The results obtained demonstrate that piglets perform well on barley-based diets, containing either SBM or WSb. There seems to be no significant difference between individual processing techniques, in terms of their effect on nutritional value. Extruded soybeans seem to be slightly, but consistantly more beneficial than other WSb products or the standard SBM control, whether fed with corn or barley. Therefore economic considerations and availability are going to be the two determining factors, when deciding whether or not to use WSb in diets for weanling pigs.

V. EVALUATION OF DIFFERENT WHOLE SOYBEAN HEAT PROCESSED PRODUCTS IN THE DIET OF GROWING AND FINISHING PIGS

5.1. Introduction

Soybean meal (SBM), the byproduct of oil extraction from whole soybeans (WSb), is the major protein source in swine diets. The supplementation of most commercial grower- or finisher diets with a substance of high caloric density is essential, in order to achieve the required levels of energy. Fat or oil would be the substances of choice, since they have the highest concentration of energy/weight unit (Lehninger, 1980). However, adding fat in one form or another back into the ration to raise the energy level, is a futile cycle, since oil has been previously extracted from that very SBM component of the feed being supplemented. Swine diets based on cereals other than corn, in this case barley, need to be supplemented with fat to an even larger extent, due to the higher digestible energy (DE) content of corn compared to these cereals. Raw soybeans contain not only about 18% of oil, but also antinutrititive factors (Liener, 1980), particularly trypsin inhibitors, which have to be destroyed by thermal treatment (Liener, 1980). Several different processing techniques involving heat are currently in use (deSchutter, 1989). The types of radiation or heat the beans are exposed to are fundamentally different in these techniques (Fellows 1988). It is assumed that they will have measurably different effects on the WSb product. The balance between maximum destruction of antinutritive factors and the optimum conservation of labile nutrients, such as lysine, are the most important criteria for identifying a good processing technique. Currently, processes that are in use include: **extrusion, micronization, jetsplosion** and **roasting**.

5.2. Objective

The main objective of this study was to compare the animal performance of growing- and finishing pigs in response to the nutritive value of differently processed WSb included in a barley-based diet. The second objective was to evaluate the final product, the animal carcass, that reaches the consumer.

5.3. Materials and Methods

Animals: 75 purebred **Landrace** pigs were obtained from the Maternity unit of MacDonald College.They were selected from 18 litters. The standard management procedures administered at birth include teeth and tails clipping and intraperitoneal injection of 1 cc of iron supplement.

All males were castrated at approx. 1 week of age. Animals were born and raised (up to initial weight) in the Maternity and Weaning unit of the MacDonald College Farm. They were weaned at approx. 4 weeks (28 days) of age. The weaner diet is a corn- SBM based diet with skim milk powder (SMP) as a protein supplement. Several days before initial weight was attained, animals were moved from the Maternity and Weaning unit to the Nutrition Barn and put in group pens, so that animals would have adjusted at commencement of the trial. Three blocks of 25 animals each were started in this experiment. The fiist block (i.e. group of 25 animals) reached the initial weight of 20 kg on the 23rd of May 1990, at which time the five pens of five animals each were switched onto their respective experimental diets. The second group was put on the experiment 5 days later, on the 28th of May. The last group followed 9 days later on the 6th of June.

In Table 5.3 a&b the proximate composition of the growing diets, which were fed from an average of 20 kg to average of 60 kg is shown. All diets were compared to a barley-SBM control, with SBM at 19% in the growing diet and 13.5% in the finishing diet. Diets were formulated to be isonitrogenous during each of the 2 periods until market. The growing diets were formulated to contain 18% protein, based on the analysis of the components. Barley was the cereal of choice. During the growing phase, the minimum content of barley was 69.75% and the maximum content of WSb was 26.25%. A 4% Mineral-Vitamin Premix was common to all diets. Choline-Cl was added, because of the additional fat contributed by the WSb. The finishing diets (Table 5.2b) only differed in the balance of barley and soybean product, in order to achieve 16 % protein levels. Here the minimum level of barley was 77.25% and the maximum level of WSb was 18.75%. The calculated EE content for the growing control-SBM diet was 1.47% and for the finishing diet 1.52% . The average EE content for the diets containing WSb was 6.15% for the growing diets and 4.80% for the finishing diets. Pens were switched from the growing diet to the finishing diet when the average pen weight was as close to 60 kg as possible. The switch was done on the week day, which corresponded to the normal weighing day, or the same day during the week between two weighings, in order to keep weekly intervals. A minimum weight of 58 kg average/pen and a maximum of 62 kg average/pen was set.

Facilities: Animals were kept at the Nutrition Barn of MacDonald College. Four waterers are fixed at the back of the pen. Two waterer were at a height of approx. 25 cm and two at a height of approx. 65 cm. The area of the pens is 5.4 m^2. The feeder was fixed in the front of the pen, onto one of the gates, which made up the walls of the pen. Some wood-shaving bedding was used throughout most of the trial. Metal grates served as a cover for the manure chain. Five 4H feeders were purchased from *J.P.Soubry Limited*, with a capacity of 200 lbs and 4 holes, framed by corrugated steel. The ten remaining pens were fitted with standard 4 hole plastic feeders, with about the same capacity as the 4H feeders.

Parameters recorded: Throughout the duration of the trial, body weight was taken at least every 2 weeks and feed consumption was measured weekly.

A Toledo scale with a maximum capacity of 500 lbs and a 1/2 lb graduation was used.

Feedconsumption was calculated by substracting weekly weigh back from feed added during that period. Backfat thickness was measured at approximately 60 kg of body- weight, 140 days of age and at market weight. Pigs were weighed several times during the timespan, in which they were assumed to reach 60 kg of body weight. A Scanmatic SM-1 (by Medimatic, Denmark) machine was used to measure.

Prior to shipping animals were weighed again. This weight was taken as live market weight. The criterion for shipping, was a minimum live weight of 90 kg.

All animals were shipped to *Abbatoir Laurentide* in *St. Esprit, Québec*.

They were killed the morning following the shipping. At the slaughter facility, the warm carcass weight, backfat thickness, lean thickness and calculated lean yield were recorded. A backfat sample was taken at the neck level of each left carcass half. These samples were frozen upon return to the College.

One animal per pen was chosen, from which the right carcass half was bought back completely from the slaughterhouse. These halves were also frozen upon return to the College. Cross sections were taken from these halves at the level of the loin eye and the level at which the backfat thickness was measured in the slaughterhouse (i.e. between the

3rd and 4th rib).

Analyses: Proximate analysis of the diet is described in Section 3. The cross section of the 3rd and 4th rib was used to manually measure the backfat thickness.

The total lean area of the cross section as well as the loin eye area was measured by means of a planimeter. The weight of the cross section and the loin eye area were recorded.

The muscle in the cross section was separated from adipose and connective tissue, weighed, freeze dried and analyzed for ether extract (EE) content in a standard *AOAC Soxhleth* procedure. The fatty acid analysis was conducted on a *5710A Hewlett Packard GLC.* For this the fat had been extracted on a *Soxtech* extractor, using chloroform methanol (2:1) at 100^0C for 1 hour. The fatty acids were methylated for GLC analysis, using a method described by Morrison, 1964.

5.3.1. Experimental Design

A 3x5 completely randomized block design was used.

Five animals were distributed to one of 5 pens within each block. Number of males and females was equal in each pen within a block, and care was taken to distribute animals such that overall average initial weight was similar between pens, within a block.

Overall 50 females and 25 male castrates were used in this experiment, with 25 animals per block.

In **Block** 1 there were 2 males and 3 females/pen.

In **Block** 2 there were 5 females/pen.

In **Block** 3 there were 3 males and 2 females/pen.

Initial weight was approx. 20 kg. Five experimental diets were used. A barley-based, SBM containing, was used as a control. The experimental treatments were diets containing WSb, which had undergone the following treatments: 1) extrusion 2) micronization 3) jetsplosion 4) roasted. All body weight, feed consumption and feed conversion data, as well as data obtained from the slaughter house and the Laboratory were analyzed by the GLM procedure, using SAS (1985).

5.4. Results and Discussion

Table 5.1 lists the composition of the experimental ingredients.

Tables 5.2 a& b list the composition of the experimental diets. The overall body weight gains during the 6-7 week growing period were good with an overall average body weight gain of 40.24 kg for the whole period (Table 5.4) and an ADG of .774 kg (Table 5.5). Treatments did not differ significantly in total body weight gains and average daily gain (ADG) for either the growing or the finishing period (Table 5.4 and 5.5 respectively). Average daily feedconsumption also was not significantly different (Table 5.6). Feed consumption consistently increased over time, until market, with an overall average total daily feed consumption of 2.54 kg. There was however a significant difference in feed consumption at weeks 3-4. Diets containing micronized and jetsploded WSb were consumed at a lesser rate than the remaining 3 treatments; presumably this effect was not dietary, but rather related to the experimental procedure (i.e. environmental stress of some sort etc.), since subsequently the difference, although consistently lower, was not significantly different (Table 5.6). There was no significant difference in feed conversion ratios, which ranged from 3.24 to 3.44 kg of feed/ kg of gain (Table 5.7). Significant differences were found between

Table 5.1 Composition of Experimental Ingredients

Ingredient	DM	CP	EE	Ash	ADF	NDF	Ca	P
Barley	85.08	11.6	1.7	2.26	10.78	11.84	.44	.30
Soybean Meal	88.62	47.46	.89	6.24	6.72	7.69	.39	.51
Extruded Soybeans	90.54	41.25	19.53	5.35	10.45	10.2	.20	.66
Micronized Soybeans	92.03	40.71	20.48	5.61	11.40	14.85	.18	.62
Jetsploded Soybeans	94.06	37.8	18.51	5.35	16.36	12.30	.23	.56
Roasted Soybeans	91.05	40.29	21.37	4.8	12.07	11.53	.19	.55

DM= dry matter, CP = crude protein, EE = ether extract, ADF = acid detergent fibre, NDF = neutral detergent fibre.

Table 5.2 Composition of Experimental Diets

Table 5.2a Growing Pigs from Initial to 60 kg Liveweight

Ingredient	Soybeanmeal	Extruded	Micronized	Jetsploded	Roasted
Barley	77.00	72.75	72.25	69.75	72.00
Soybean Meal	19.00	-	-	-	-
Fullfat Soybeans		23.25	23.75	26.25	24.00
Limestone	0.5	0.5	0.5	0.5	0.5
Calcium Phosphate	2.8	2.8	2.8	2.8	2.8
Vitamin-Mineral Premix	0.3	0.3	0.3	0.3	0.3
CholineCl	0.1	0.1	0.1	0.1	0.1
NaClI	0.3	0.3	0.3	0.3	0.3
Calculated CP, %	18.05	18.02	18.05	18.01	18.02

Table 5.2b Finishing Pigs from 60 kg to Market Weight

Ingredient	Soybeanmeal	Extruded	Micronized	Jetsploded	Roasted
Barley	82.50	79.50	79.00	77.25	79.00
Soybean Meal	13.5	-	-	-	-
Fullfat Soybeans	-	16.50	17.00	18.75	17.00
Limestone	0.5	0.5	0.5	0.5	0.5
Calcium Phosphate	2.8	2.8	2.8	2.8	2.8
Vitamin-Mineral Premix	0.3	0.3	0.3	0.3	0.3
CholineCl	0.1	0.1	0.1	0.1	0.1
Nacl	0.3	0.3	0.3	0.3	0.3
Calculated CP, %	16.05	16.02	16.08	16.05	16.01

5.3 Proximate Analysis

Table 5.3.a Composition of Grower diets (On D.M. basis)

Item	DM	EE	Ash	CP as fed	ADF	GE	Ca	P
SBM	91.70	1.48	6.14	18.01	7.13	3.89	.68	.84
Extruded	92.33	5.40	7.21	18.34	7.34	3.97	.94	1.06
Micronized	92.13	5.10	7.84	17.52	6.89	4.10	1.00	1.17
Jetsploded	92.26	5.54	6.69	18.05	7.34	4.10	.85	.94
Roasted	92.27	5.21	6.79	17.36	6.69	4.13	.85	.97

Table 5.3.b Finisher diets On D.M. basis

Item	DM	EE	Ash	CP as fed	ADF	GE	Ca	P
SBM	91.87	1.67	7.06	17.84	7.32	3.92	.85	.95
Extruded	91.87	3.87	6.19	16.49	6.75	4.10	.73	.87
Micronized	92.11	4.71	6.83	16.81	7.40	4.13	.84	.97
Jetsploded	91.99	4.48	6.50	17.50	7.03	4.03	.75	.93
Roasted	92.21	4.55	7.38	17.44	7.27	4.07	.98	1.08

Table 5.4 Average body weights and gain (kg) per pig in each Treatment

Weeks	N	SBM	ESB	MSB	JSB	RSB	SEM	P
Init.	15	20.0	20.2	20.2	20.1	20.2	5.8	.9988
2	15	29.3	29.1	28.8	27.8	28.2	7.0	.4941
4	15	39.7	41.4	39.0	39.0	40.3	14	.3915
6	15	53.3	54.3	51.4	51.5	51.3	26	.3791
7	15	57.2	59.2	57.0	57.7	57.2	33	.8534
8	15	62.8	64.7	61.0	62.1	62.9	29	.4275
10	15	73.3	75.6	73.0	73.1	74.8	39	.7620
final	15	90.6	92.4	90.8	91.9	90.8	12	.5518
GP	15	41.1	40.7	39.8	39.8	39.8	26	.9096
FP	15	29.4	31.5	30.8	31.1	30.9	22	.8027

Values with a different subscript are significantly different.
Period:
GP = growing period (up to an average of approx.60 kg bwt)
FP = finishing period (from GP to market)

Table 5.5 Average daily gain (g/day) per Treatment

Weeks	N	SBM	ESB	MSB	JSB	RSB	SEM	P
0-2	15	660	627	613	567	573	35	.6206
2-4	15	773	887	733	807	820	17	.0284
4-6	15	920	913	880	887	840	29	.7105
6-7	15	560	687	807	887	833	18	.2206
7-8	15	793	780	853	627	813	12	.4469
6-8	15	677	733	830	757	823	58	.3822
8-10	15	747	760	847	780	833	37	.5367
10-12	10	690	870	620	710	700	34	.0524
final	15	720	680	873	920	720	43	.0056
GP	15	773	807	733	767	793	114	.3886
FP	15	733	780	773	807	780	13	.5205

Period:
10-12 = 50 observations (i.e. 10 observations/treatment)
GP = growing period (up to an average of approx.60 kg bwt)
FP = finishing period (from GP to market)

Table 5.6. Cummulative average daily feed consumption per pig (kg/day) in each Treatment

Weeks	N	SBM	ESB	MSB	JSB	RSB	SD	P
0-2	15	1.601	1.535	1.391	1.342	1.287	.20	.327
0-4	15	1.853	1.903	1.608	1.654	1.718	.12	.076
0-6	15	2.079	2.154	1.827	1.905	1.948	.18	.272
0-8	15	2.270	2.310	1.993	2.068	2.136	.16	.178
0-10	15	2.417	2.394	2.167	2.237	2.281	.12	.140
TOTAL	15	2.590	2.636	2.502	2.498	2.539	.21	.903

Values with a different subscript are significantly different.

5.7. Average overall feed conversion of growing and finishing pigs, for both periods

Treatment	SBM	ESB	MSB	JSB	RSB	SE
Feedconversion	3.44	3.32	3.34	3.24	3.30	.2
Number of animals	15	15	15	15	15	

No significant differences were found.

Table 5.8.a Carcass values obtained at the slaughterhouse by block						
	Market Weight (kg)	Backfat Thick-ness (mm)	Lean Thick-ness (mm)	Lean Yield (%)	Carcass weight (kg)	Dressing Percent-age
Block 1	92.4	20.2	41.8 b	49.6 b	69.8	75.6
Block 2	91.9	18.3	48.3 a	50.6 a	69.7	75.8
Block 3	91.0	18.6	45.0 ab	50.2 ab	68.3	75.1

Values in the same column with different subscripts are signicantly different at (p<.05). Block 1: 2 males 3 females Block 2: 5 females Block 3: 3 males 2 females

Table 5.8b Carcass values obtained at the slaughterhouse by treatment						
	Market Weight (kg)	Backfat Thick-ness (mm)	Lean Thick-ness (mm)	Lean Yield (%)	Carcass weight (kg)	Dressing Percent-age
Control	90.9	17.4	46.7	50.9	68.6	75.5
ESB	92.8	20.2	43.0	49.7	70.6	76.1
MSB	92.1	19.3	45.3	50.1	69.1	75.0
JSB	91.9	19.8	47.2	50.0	69.9	76.1
RSB	91.1	18.4	42.9	50.1	68.2	74.9

No significant differences were found

Table 5.9 Effect of dietary supplementation with whole soybeans on loin eye area and backfat of carcasses taken from the slaughterhouse					
Item	N	Back-fat	Total loin area	Loin eye area	Loin eye as % of total
Units		mm	mm^2	mm^2	%
SBM	2	14.50	113.63ab	33.44ab	30.24ab
Esb	3	17.67	95.83b	30.60b	32.06ab
Msb	3	15.00	109.28ab	30.89b	28.38ab
Jsb	2	14.50	138.89a	38.25a	27.55b
Rsb	3	18.67	94.19b	35.60ab	37.67a
S.E.		3.57	13.72	3.26	4.41
N	13	values with different subscripts are significantly different (p<.05)			

Table 5.10 Backfat measurements (mm) for different periods per treatment								
Measure	**N**	**SBM**	**ESB**	**MSB**	**JSB**	**RSB**	**C.V**	**P**
Average 60 kg body wt								
1st layer	15	5.5	5.4	5.6	5.6	5.3	11	.4828
2nd layer	15	3.0	3.6	3.5	3.4	3.1	27	.3517
3rd layer	15	3.1	3.7	3.4	4.5	3.7	49	.3057
Total	15	11.6	12.7	12.5	13.5	12.1	18	.3577
Ave.age 140 days								
1st layer	15	6.3	6.1	6.1	6.5	5.9	18	.6201
2nd layer	15	3.8	4.3	3.7	4.0	3.5	33	.5341
3rd layer	15	4.1	4.1	4.5	3.7	3.5	49	.6616
Total	15	14.3	14.5	14.3	14.2	12.9	24	.6700
Backfat at Market wt.								
1st layer	15	6.9	6.2	6.8	6.9	6.5	15	.1350
2nd layer	15	4.7	4.6	4.7	4.8	4.5	26	.9349
3rd layer	15	4.5	3.8	4.2	4.6	4.5	39	.6947
Total	15	16.2	14.7	15.7	16.3	15.4	19	.4298

No sign. differences were found at any time.
Totals: # of Females : 50; # of Males : 25;

Table 5.11 Days to market			
Treatment	Days to market	Days in finishing period	N
Block 1	92.96ab	51.80b	25
Block 2	95.24a	54.60a	25
Block 3	90.60b	51.80b	25
Soybean meal	90.60b	52.73	15
Extruded	96.00a	52.73	15
Micronized	94.47ab	52.73	15
Jetsploded	90.20b	52.73	15
Roasted	93.40ab	52.73	15

Values in the same column with different subscripts are signifcantly different (p<.05)

Table 5.12 Fatty acid composition of Loin eye area of samples taken at the slaughterhouse

Fatty acid	Myristic	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic	Eicosanoic	Arachidonic	N
Soybean meal	1.44	26.61	3.59a	12.70	47.11a	5.80c	1.15c	1.46	0.55	3
Extruded	1.52	27.49	2.81b	14.29	41.08b	9.87c	1.92b	0.59	0.66	3
Micronized	1.29	24.09	2.54b	11.89	36.75c	18.97a	2.44a	0.66	0.99	2
Jetsploded	1.28	24.46	2.82b	11.80	37.86bc	17.68ab	2.23ab	0.48	1.41	2
Roasted	1.56	27.19	2.83b	14.22	38.58c	11.80bc	1.94b	0.57	0.87	3

Fatty acids expressed as percent of methylesters

Values in the same column with different subscripts are signifcantly different (p<.05) blocks in the amount of lean yield and lean thickness (Table 5.8a), as measured at the slaughter-house. These differences are attributable to the fact that the block with the lowest yield and thickness was composed only of females. There were no differences found (Table 5.8b), for treatments. The measurements taken at the slaughterhouse, which determine the grade, do not correlate at all with the backfat data collected on the live animals. These measurements are taken on the warm carcass, as it passes down the chain, at the level of the 3rd and 4th rib. Only one measure is taken here, whereas the live measure is the average between 2 readings taken at the height of the last rib. The numerical values as well as the ranking are very different. The average thickness was 19.02 mm at the slaughterhouse (Table 5.8) and 15.7 mm on the live animal(Table 5.10). At the slaughterhouse (Table 5.8) the ranking was as follows, from the highest, 1) extruded 2) jetsploded 3) micronized 4) roasted and 5) control, whereas on the live animals the ranking was, from the highest, 1) roasted 2) extruded 3) micronized 4) jetsploded 5) roasted.The three backfat measurements are listed in Table 5.10. There was no significant difference in backfat thickness at any time and for any of the three layers. The increase in backfat thickness from 60 kg to market weight are markedly different. At 60 kg the control-SBM dietary treatment had produced the least amount of backfat thickness (average 11.6 mm) (Table 5.10), but at market weight it had the second thickest backfat layer (16.2 mm). The increases for SBM, extruded, micronized, jetsploded, SBM and roasted WSb were 4.6, 2.0, 3.2, 2.8, and 3.3 mm, respectively. It appears that the control-SBM diet had a greater propensity towards producing fat than the 4 treatments of WSb, since the weight gain during the finishing period was 1.5 kg less than the average weight gain (Table 5.4) for the 4 treatments (29.4 vs 31.1

kg). The opposite seemed to be true for the growing period (Table 5.4), where the control diet gained 1.1 kg more than the average for all 4 treatments (41.1kg vs 40.9 kg), but the backfat thickness was 1.1 mm less than the average for the 4 treatments (11.6 vs 12.7 mm). During the finishing period, which was of highly variable length (Table 5.11), since the body weight was the criterion for market, the average total gains were also .774 kg. Total average days to mark t were 92.9 days (Table 5.11) from an average of 20.14 kg to 91.3 kg (Table 5.4). The fatty acid compositions of the loin eye area are listed in Table 5.12. Oleic acid decreased from 47.1% for the SBM control to 38.44% average for all 4 WSb treatments and linoleic from 5.92 for SBM control to 14.41% average for all 4 WSb treatments.

Gains observed in this experiment , which were .780 kg, as an average for all 4 experimental treatments, and .740 kg for the SBM-control diet, were slightly lower than in gains found by other researchers (Jimenez, 1963). These averages were not significantly different ($p<.05$). Final body weight averages at market were 91.5 kg for the 4 dietary treatments and 90.6 kg for the control diet, with no significant difference between them. Jimenez (1963) found that heated WSb (27% of diet) improved ADG of growing-finishing pigs significantly ($p<.05$) when comparing to corn-SBM control (21%) diet. ADG's were .841 kg and .773 kg, respectively. Although the animals in the trial by Jimenez started out with very similar weights, (average 15.7 kg) and the final weights were markedly different (4.7 kg), where the animals on the control diet weighed 91.6 kg at market and the animals receiving WSb 96.3 kg, no significant difference was found. All other parameters measured were not significantly different as well, such as carcass weight, - length, backfat thickness and % lean cuts). Jimenez et al. (1963) measured backfat thickness at market and found it to be 4.17

cm and 4.32 cm for the control diet and the diet containing whole SB, respectively.Backfat measured in a trial by McConnell et al (1975) on pigs at market time was 2.66 and 2.80 cm for the 2 barley- based dietary treatments, which contained either SBM or whole roasted soybeans. The marked discrepancy between the numerical values of these 2 results is explained by the fact that backfat used to be measured at 2 points on the animal (around the shoulder and around the lumbar region) and then these measurements were added up. McConnell however measured backfat at the level of the last rib on both sides and took the average. This was also the procedure used in this trial, therefore the markedly thicker backfat found by McConnell is not so easily explained. In our trial the average backfat thickness was 1.62 cm and 1.55 cm for the control-SBM diet and the average for the 4 dietary treatments, respectively. The apparent reason for this discrepancy is the fact that the final weights in the trial by Wahlstrom were considerably higher (100.7 kg and 102.4 kg, control and roasted soybeans, respectively), whereas in our trial the final weights for the corresponding treatments was 90.6 kg and 90.8 kg, respectively.

DeSchutter (1989) conducted 2 trials with growing and finishing pigs. The first one did not show any significant effect of any of the experimental treatments; which were SBM +oil, roasted WSb, extruded WSb and micronized WSb, on parameters of performance such as ADG, ADF and feed/gain ratio. In the second trial, which had exactly the same dietary treatments, feed/gain ratio was significantly improved by all dietary treatments, when compared to the SBM-control diet (2.96 average of 4 treatments vs 3.23 kg of feed/kg of gain, SBM-control). Carcass weight and lean yield were not significantly affected by treatment (81.8 kg, whole soybean average vs 81.2 kg, control, carcass weights and 50.1%

vs 50.7% lean yield, respectively).

McConnell et al (1975) again found that roasted WSb significantly improved the feed/gain ratio in barley-based diets. The amount of feed/kg gain required was 3.22 kg and 3.00 kg ($p<.05$) for the diets containing SBM and roasted WSb, respectively. ADG was improved as well by the addition of roasted WSb, namely from .68 kg (control) to .77 kg. The carcass measurements did not show any improvement or negative effect of adding roasted WSb to barley- based diets. Of interest and as expected, the percentage of lean cuts for corn-based diets of the same trial were significantly different. The control-SBM diet resulted in lean yields of 51.51%, whereas the diet containing roasted WSb yielded only 49.01%, which was significantly ($p<.05$) lower. McConnell et al also found, for the same diets, that the *Longissimus dorsi* area was significantly affected in the same way. The control-SBM diet yielded areas of 30.84 cm^2 and the diet containing roasted WSb 27.74 cm^2. Wahlstrom (1971) did not find any significant difference in *Longissimus dorsi* area, when he compared data collected from market pigs, which had been fed either a control diet based on corn and SBM or WSb, which had been heated by the infra-red method. *Longissimus dorsi* areas were 28.69 and 29.61 cm^2, respectively. Interestingly he found a significant improvement of dressing percentage in animals fed WSb, although there was no significant difference for measures of lean yields found (*L.dorsi* and ham and loin%).

Surprisingly and in contrast to findings by deSchutter, extruded WSb did not result in greater fatty acid composition changes, but rather the opposite. The extruded treatment most closely paralleled the profile of loin eye areas from pigs having received the control treatment (Table 5.12). Wahlstrom (1971) also analyzed FA composition. As expected the percentage of oleic acid decreased significantly in pigs having received WSb (49.3% vs 45.0%), whereas the percentage of linoleic acid increased from 8.6% to 14.1%. DeSchutter (1989) observed similar trends in an experiment, where WSb were fed at levels of 25.5%, the changes in composition were even more dramatic. Oleic acid decreased f[illegible]8% to 37.08% of total fat in the loin eye area, whereas linoleic acid increased at the same rate from 12.49% to 2 3.83% and there was also a marked increase in linolenic acid observed, from .56% to 2.19%). The absolute percentage of these FA are dependant on the level of WSb in the diet. There also were significant differences amongst WSb dietary treatments in terms of FA composition. The extruded WSb treatment produced significantly higher levels of linoleic acid than the micronized WSb treatment (27.45% vs 21.21%, respectively), as well as significantly higher levels of linolenic acid than the control or all other treatments. It is well established that monogastric adipose tissue reflects the fatty acid composition of the dietary components (Shils and Young, 1988). Therefore the results obtained here come as no surprise. Despite these significant changes in fatty acid composition, grading of the animals was not affected (Tables 5.8 a&b). According to deSchutter, palatability is not affected either (deSchutter, 1989).

5.5 Conclusion

In conclusion we can say that levels of 25% or more of WSb in swine growing and finishing diets do not adversely affect either the performance or carcass quality of the pigs.

VI. DIGESTIBILITY OF WHOLE SOYBEANS IN THE DIET OF WEANLING PIGS

6.1 Introduction

Heat treated whole soybeans (WSb) were previously evaluated in weanling pigs, and no significant differences in overall performance was detected. It may however be of interest to determine whether there are measurable differences in digestibility, which are attributable to a particular heat treatment. Young pigs undergo a severe change of the nutritional environment at weaning. They are being switched from a liquid, high protein, high fat, no fibre diet, which is the sow's milk, to a solid diet, which is usually significantly lower in fat and protein content and usually contains significant amounts of fibre. In order to facilitate this transition, it has been proposed to add high energy feedstuffs to the weaner diet (Farnsworth, 1987). Weaner diets based on cereals other than corn, in this case barley, need to be supplemented with fat to an even larger extent, due to the higher digestible energy (DE) content of corn compared to these cereals. Young animals are more susceptible to these factors (Crenshaw and Danielson, 1985), and one would therefore expect to see more pronounced differences in performance response from one heat treatment to the other of whole soybeans, than in older animals. Knowing that there are several fundamentally different processing techniques in use (deSchutter, 1989), it is assumed that they will have measurably different effects on the WSb product. The balance between maximum destruction of antinutritive factors and the optimum conservation of nutritive value, is the most important criteria for identifying a good processing technique. Currently, processes that are in use include: extrusion, micronization, jetsplosion and roasting.

6.2.Materials and Methods:

Twenty purebred Landrace piglets were taken from 4 different litters. Five animals of the same sex, from the same litter constituted one of 4 blocks. Altogether there were 3 blocks of females (15 animals) and 1 block (5 animals) of castrate males. The standard management procedures administered at birth include teeth and tails clipping and intraperitoneal injection of 1 cc of iron supplement. All males were castrated at approx. 1 week of age.

The animals were weaned at 3 weeks (21 days) of age. They were moved from the Maternity unit to the Nutrition Barn of MacDonald College. There they were housed individually in 2 tiered rows of wire cages, with an area of approx. 1,2 m^2 for each individual cage. After a 3 day adaptation period, during which they were fed a typical corn-SBM-SMP starter diet, they were switched onto the experimental diets.

There were five experimental diets; four diets containing WSb products and a SBM containing control. All diets were barley based. They contained at least 55.5% barley and 4% Vitamin -Mineral Mix. The WSb products tested were as follows: 1)extruded 2)micronized 3)jetsploded 4)roasted. All diets were formulated to contain 21 % protein. Feces were collected daily in two 5-day periods: the first one at 4 weeks of age and the second one at 6 weeks of age. Animals were weighed at 3 weeks of age (weaning), 4 weeks of age (beginning of first 5-day collection period), at the end of the first 5-day collection period, at 6 weeks of age (beginning of second 5-day collection period) and at the end of that period. Feed consumption was measured daily, after the animals started receiving the experimental diets, that is three days after they had been transferred to individual metabolic cages. After 4 days (at 4 weeks of age) the first 5 day collection period was initiated. After 5 days, the collection was interrupted for 9 days (until 6 weeks of age) and a second 5 day collection period was begun. Twenty-four hours were allowed after feeding a weighed amount of feed, for the digesta to pass through the tract, therefore collection was actually only started at 29 days and 43 days of age. The total excreta for one 24 hour period was collected into individual aluminum trays. Feces contaminated with urine, water or feed was weighed, but discarded. The remaining feces was freeze-dried. Proximate analysis was conducted on the freeze-dried samples.

Feed: Tables 1 and 2 show the composition of experimental ingredients and experimental diets respectively. The four sources of WSb are an average of 8% lower in crude protein (CP), but contain up to 21% ether extract (EE).

Analyses: Proximate analysis was conducted on dietary samples. EE, CP, ash and total dry matter (DM) was conducted on the fecal samples. For methodology see Section 3.

6.2.1. Experimental design

Animals were selected from 4 litters. A completely randomized block design was used, with 4 blocks and 5 animals/block. Average initial weight was approx. 6.7 kg. Number of males and females was equal in each pen within a block, and care was taken to distribute animals such that overall average initial weight was similar within a block. There were three blocks with females only and one block with males only.

All body weight, feed consumption and fecal composition data were analyzed by the GLM procedure, using SAS (1985).

6.3.Results and Discussion

Table 6.1 lists the formulation of the experimental diets. The maximum level of WSb used was very high in these diets (from 36.5% to 40.5%), because of the high CP level (22%), the diets were formulated for. In Table 6.2 the proximate composition of the actual experimental diets is listed. CP values were satisfactorily close (22.39 -22.96%) for all experimental diets. The diet containing extruded soybeans, was surprisingly low in EE, compared to the other three diets containing WSb. Overall average bodyeight of piglets at three weeks of age was 6.72 kg (Table 6.4). There were no significant differences between treatments. This however had changed by the beginning of the first collection period (Table 6.4). Pigs starting out on diets containing micronized WSb were significantly ($p<.05$) heavier than in the four other experimental groups. This difference diminished over the experimental period, and by the end of the second collection period, there were no significant differences between treatments. There was a significant difference ($p<.05$) in gain, during the timespan between the two periods, between pigs receiving diets containing extruded and roasted WSb. The extruded soybeans precipitated the best gain during this period (3.65 kg) as well as the best performance over the whole period. There was a significant difference ($p<.05$) of initial body weights between Block 2 and 4. This was presumably due to the fact that Block 2 contained only males and Block 4 only females. This difference remained significant throughout the whole experimental period (Table 6.4). Block 4 did experience a significantly lower weight gain during the two collection periods (Table 6.4). Tables 6.5-8 lists digestibilities of several nutrients, as well as total fecal excretion, DM excretion and feed consumption data. These averages represent cumulative

Table 6.1. Composition of Experimental Diets

Ingredient	SBM	Extruded	Micronized	Jetsploded	Roasted
Barley	68.5	59.5	58.5	55.5	56.5
Soybean	27.5	36.5	37.5	40.5	39.5
Limestone	0.5	0.5	0.5	0.5	0.5
Biophos	2.8	2.8	2.8	2.8	2.8
Fortamix	0.3	0.3	0.3	0.3	0.3
Chol Cl	0.1	0.1	0.1	0.1	0.1
NaCLI	0.3	0.3	0.3	0.3	0.3
% Protein	21.00	20.95	20.91	20.90	20.94

Table 6.2. Proximate Analysis of Experimental diets

Diet	DM	EE	CP	Ash	ADF	GE	Ca	P
SBM	88.50	2.31	22.96	7.43	8.72	3.87	1.15	1.15
Extruded	88.74	7.83	22.59	7.67	8.83	4.20	.97	1.02
Micronized	89.26	9.09	22.39	7.15	9.94	4.21	.92	1.01
Jetsploded	90.23	10.20	22.85	7.28	11.38	4.43	1.02	1.06
Roasted	89.26	9.58	22.76	7.68	11.52	4.32	1.07	1.13

Table 6.3. Average Body Weight of Piglets (kg) per Block

Period	Block 1	Block 2	Block 3	Block 4	Overall mean
Initial weight	6.88ab	7.45a	6.42ab	6.11b	6.72
Beginning of first collection period	7.54a	7.78a	7.03b	6.49c	7.21
End of first collection period	9.55ab	9.83a	8.95b	7.55c	8.97
Beginning of second collection period	13.38a	12.88a	12.26a	10.14b	12.16
End of second collection period	15.87a	15.83a	14.85a	12.48b	14.76
Average total Body Weight Gains per Piglet (kg) during different experimental periods					
Initial to first collection period	0.66	0.33	0.61	0.37	0.49
First collection period	2.01a	2.06a	1.92a	1.06b	1.76
Between 1st and 2nd collection period	3.83a	3.05ab	3.31ab	2.59b	3.19
Second collection period	2.49ab	2.95a	2.60ab	2.35b	2.59

Values in the same row with different subscripts are significantly different ($p<.05$)
Blocks 1,3 and 4 contained 4 females per pen; Block 2 contained 4 castrates

Table 6.4. Average Body Weight of Piglets(kg) per Treatment

Period	SBM	ESB	MSB	JSB	RSB	Overall mean
Initial weight (weaning)	6.76	6.58	7.21	6.35	6.69	6.72
Beginning of first collection period	7.29b	7.10b	7.74a	6.92b	7.00b	7.21
End of first collection period	8.99ab	8.99ab	9.87a	8.51b	8.50b	8.97
Beginning of second collection period	12.59ab	12.64b	13.12a	11.68ab	10.79b	12.16
End of second collection period	15.07a	15.23a	15.52a	14.25a	13.73a	14.76
Average total Body Weight Gains per Piglet (kg) during different experimental periods						
Initial to first collection period	0.53	0.51	0.53	0.57	0.31	0.49
First collection period	1.70	1.90	2.13	1.59	1.50	1.76
Between 1^{st} and 2^{nd} collection period	3.60ab	3.65a	3.25ab	3.17ab	2.30b	3.19
Second collection period	2.48	2.59	2.40	2.57	2.93	2.59
Overall gain (28 days)	8.31	8.65	8.31	7.90	7.04	8.04

Values in the same row with different subscripts are suignificantly different (p<.05)
3 females and 1 castrate/ treatment.

Table 6.5.a Digestibilities of DM, CP, EE, OM and CHO, as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Day 1 and 2 of first collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM exctreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	236.34	62.07	0.37	83.59	84.75	80.28b	80.56	86.62
Extruded	162..61	52.46	0.36	85.50	86.78	81.95a	83.16	88.76
Micronized	219.63	57.67	0.30	80.98	82.46	80.05b	78.70	84.91
Jetsoloded	221.26	59.72	0.29	79.56	80.61	80.38ab	75.48	85.06
Roasted	151.79	47.29	0.29	83.12	84.26	81.95ab	80.68	87.14
Average	188.86	54.76	0.33	83.17	84.40	81.86	80.46	86.98
C.V.	22.8	14.7	14.7	3.5	3.2	1.44	5.2	2.7

Table 6.5.b Digestibilities of DM, CP, EE, OM and CHO, as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Days 1 to 3 of first collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM exctreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	248.59a	62.79	0.38a	83.77	84.94	80.43b	80.67	86.69
Extruded	172.17ab	55.26	0.36ab	84.40	85.70	83.40a	82.06	87.64
Micronized	241.06ab	65.42	0.32ab	79.46	80.98	80.05b	78.09	83.03
Jetsploded	217.25ab	60.10	0.29bc	79.19	80.29	81.67ab	74.75	84.82
Roasted	159.82b	50.89	0.26c	80.36	81.70	81.37ab	77.05	85.05
Average	198.26	57.76	0.32	81.98	83.27	81.79	79.19	85.90
C.V.	17.4	12.9	10.8	3.6	3.2	1.2	5.2	2.9

Values in the same column with different subscripts are significantly different ($p<.05$).

Table 6.5.c Digestibilities of DM, CP, EE, OM and CHO, as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Days 1 to 4 of first collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM excreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	247.46a	57.73	0.34	82.79	84.01	80.40b	79.14	85.87
Extruded	186.60ab	57.63	0.36	83.72	85.04	83.36a	81.59	86.90
Micronized	258.75a	62.62	0.32	80.24	81.62	80.07b	78.80	83.89
Jetsploded	226.00ab	61.86	0.29	78.87	80.01	81.60ab	74.38	84.39
Roasted	163.95b	49.95	0.28	81.51	82.71	81.07ab	78.72	85.78
Average	207.93	57.49	0.32	81.89	83.15	81.70	79.18	85.70
C.V.	16.0	14.7	15.1	3.8	3.5	1.3	4.6	3.2

Table 6.5.d Digestibilities of DM, CP, EE, OM and CHO, as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Day 1 to 5 of first collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM excreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	253.27	57.61	0.34	82.67	83.93	80.45b	79.18	85.76
Extruded	207.67	61.34	0.37	83.55	84.87	83.51a	81.46	86.76
Micronized	287.57	69.03	0.35	80.40	81.71	80.06b	78.97	84.24
Jetsploded	237.02	62.93	0.31	79.48	80.64	81.54b	75.73	84.67
Roasted	194.83	55.63	0.30	81.69	82.86	80.73b	79.01	86.01
Average	228.33	61.03	0.34	81.96	83.22	81.68	79.39	85.77
C.V.	23.0	19.5	12.0	3.4	3.1	0.9	4.2	2.8

Values in the same column with different subscripts are significantly different ($p<.05$).

Table 6.6.a Digestibilities of DM, CP, EE, OM and CHO, as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Day 1 to 2 of second collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM excreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	483.35	114.65	0.70a	83.62	84.84	80.02	81.27	86.61
Extruded	370.89	94.57	0.70a	86.66	87.84	84.28	85.89	89.21
Micronized	431.85	104.45	0.57b	81.98	83.56	79.94	80.41	85.85
Jetsploded	500.85	126.42	0.67ab	81.23	82.39	81.40	78.98	85.17
Roasted	412.06	110.59	0.64ab	82.18	83.58	80.02	80.69	86.19
Average	424.63	107.05	0.67	83.79	85.08	81.71	82.30	87.11
C.V.	22.3	16.5	6.2	3.5	3.2	3.0	4.4	2.8

Table 6.6.b Digestibilities of DM, CP, EE, OM and CHO, as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Day 1 to 3 of second collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM excreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	491.46	117.86ab	0.72a	83.66	84.97	80.06	80.56ab	87.09
Extruded	371.73	94.96b	0.70a	86.47	87.64	84.20	85.51a	89.11
Micronized	426.68	101.92ab	0.60b	83.23	84.66	79.97	81.93ab	86.91
Jetsploded	501.23	126.55a	0.69a	81.80	82.95	81.40	79.61b	85.70
Roasted	443.51	116.95ab	0.67ab	82.45	83.81	79.73	81.28ab	86.42
Average	431.71	108.58	0.68	84.06	85.32	81.63	82.50	87.43
C.V.	19.2	11.9	4.4	2.8	2.6	2.4	2.9	2.4

Values in the same column with different subscripts are significantly different (p<.05).

able 6.6.c Digestibilities of DM, CP, EE, OM and CHO,as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Day 1 to 4 of second collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM exctreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	525.18	126.03	0.72	82.56	83.95	80.12	79.75	85.95
Extruded	402.47	102.55	0.70	85.36	86.57	84.33	84.07	88.18
Micronized	472.26	113.86	0.63	81.90	83.46	79.98	80.33	86.03
Jetsploded	533.93	133.27	0.71	81.44	82.62	81.35	78.93	85.57
Roasted	501.49	126.37	0.71	82.06	83.25	79.40	80.61	86.06
Average	470.87	117.14	0.70	83.17	84.45	81.61	81.40	86.71
C.V.	23.9	17.4	6.6	4.2	3.8	2.9	5.1	3.2

Table 6.6.d Digestibilities of DM, CP, EE, OM and CHO,as well as total weight of excreta, DM excreted and feed consumed for different periods, by treatment.

Period: Day 1 to 5 of second collection period	On DM basis							
Treatment	Total weight of excreta (g)	DM exctreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	500.61	122.06	0.74	83.35	84.64	83.77bc	81.09	86.63
Extruded	406.02	106.69	0.72	85.09	86.31	80.16a	83.78	88.07
Micronized	480.01	121.75	0.66	81.39	82.96	79.05bc	80.19	85.61
Jetsploded	518.41	134.44	0.74	81.85	82.99	81.34b	79.93	85.78
Roasted	493.38	125.89	0.73	82.66	83.76	79.05c	81.20	86.63
Average	465.64	119.26	0.72	83.30	84.55	81.35	81.75	86.83
C.V.	23.3	18.2	6.1	4.1	3.7	1.1	5.1	2.8

Values in the same column with different subscripts are significantly different ($p<.05$).

Table 6.7 Digestibilities of DM, CP, EE, OM and CHO,as well as total weight of excreta, DM excreted and feed consumed for different periods, y treatment.

Period: Day 1 to 10. Total of both collection periods	On DM basis							
Treatment	Total weight of excreta (g)	DM exctreted (g)	Feed consumed (kg)	DM digestibility (%)	OM digestibility (%)	EE digestibility (%)	CP digestibility (%)	CHO digestibility (%)
SBM	376.94	89.83	0.54	83.01	84.28	80.31b	80.14	86.12
Extruded	306.85	84.02	0.55	84.32	82.33	83.64a	82.61	87.41
Micronized	383.79	98.69	0.51	80.90	82.33	80.00b	79.56	84.93
Jetsploded	377.71	95.39	0.52	80.66	81.81	81.44b	77.83	85.23
Roasted	344.11	90.76	0.52	82.17	83.31	79.89b	80.11	86.32
Average	346.99	90.14	0.53	82.63	83.88	81.52	80.57	86.30
C.V.	21.1	16.3	5.0	2.5	2.4	0.8	3.2	2.0

Values in the same column with different subscripts are significantly different ($p<.05$)

Table 6.8 Digestibilities of DM, CP, EE, OM and CHO,as well as total weight of excreta, DM excreted and feed consumed for different periods, y treatment.

Collection Period 1 and 2	On DM basis									
	DM digestibility		OM digestibility		EE digestibility		CP digestibility		CHO digestibility	
Treatment	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Average	81.96	83.30	83.22	84.55	81.68	81.35	79.39$_a$	81.75$_b$	85.77	86.83
Pr > F	0.12		0.93		0.40		0.04		0.16	

Values in the same row with different subscripts are significantly different ($p<.05$).

averages of at least two days, in order to adjust for daily variability, which was large for certain animals. Over the first collection pericd (Table 6.6.d), the only significant treatment effect was that for EE digestibility. Diets containing extruded soybeans were superior 9p<.05) to all other treatments. Animals of this group had an average of 83.51% EE digestibility, while the second highest (jetslploded treatment) was 2 percentage points lower. These differences were amplified during the second collection period (Table 6.6.i), where again the extruded treatment was superior to all other treatments (p <.05). During this period, the jetsploded treatment had also a significantly higher EE digestibility than roasted soybeans, with micronized soybeans being intermediate. When cumulative averages over the two collection periods were computed (Table 6.6.j), EE digestibility was again the only parameter significantly affected by treatment. Overall, the digestibility of the Ether extractable portion of the extruded diet had a digestibility of 83.64%, which is significantly higher (p<.05) than for all other dietary treatments (average digestibility for all other treatments was 80.16 %). The overall average fecal excretion was 346.99 g; DM excretion 90.14 g; feed consumption 0.53 kg; DM digestibility, 82.63%; OM digestibility, 83.88%; CP digestibility, 80.57% and CHO digestibility 86.30%. When the overall average apparent digestibilities for the 2 individual periods were compared, it was found that only CP apparent digestibility was significantly dependant on age. CP digestibility was significantly lower (p<.05) (79.39%) for all diets at 4 weeks of age (79.39%), than at 6 weeks of age (81.75%). The apparent CP and DM digestibilities measured in this experiment were lower than in the experiment conducted by Tanksley et al (1983). He found apparent N digestibilities of 89.7% and DM digestibilities of 87% for SBM vs 80.14% and 83.01% in our trial, respectively. However, Tanksley was using diets based on corn starch while the diet used here was based on barley and subsequently contained much higher levels of fibre, as well as less digestible CHO portion. Jorgensen et al (1984) found apparent fecal DM digestibilities of 84.6% which is close to the values reported herein. CP and OM apparent digestibilities found by this group were much higher than in our experiment. OM apparent digestibilities were found to be 96.2%. This does not correspond with the value of 84.3%, which we found. CP values also are much higher at 91.5%. Vandergrift et al (1983) also found DM apparent digestibilities in the order of > 85%. The consistantly lower digestibilities found in this trial are therefore attributed to the high barley content. Therefore the results can not be compared with values from the literature, but rather within the experimental setting.

6.4 Conclusion

From this experiment we can conclude that the ether extractable fraction of extruded soybeans is more accessible to the digestive process, than the equivalent fraction of the other processed forms of whole soybeans as well as the smaller lipid fraction in SBM.

We also conclude that the apparent CP digestibility is age dependant, being lower in animals at 4 weeks of age than in older animals (6 weeks of age).

VII. GENERAL CONCLUSIONS

Soybean composition over time and location is highly variable. Improvements in soybean breeding accounts for a greater part of the variability than location. Jetsplosion is the harshest of the treatments involving heat. Contrary to expectations this does not affect lysine availability. Roasting is the most highly variable treatment. This was expected. Soybean meal and the 4 heat treated whole soybean sources are not significantly different in their effect on performance of pigs following weaning to 20 kg liveweight.

In barley-based diets levels of whole soybeans of up to 26% in grower-, and up to 18.75% in finisher-, barley-based diets do nc adversely affect performance of pigs from 20 kg liveweight to market, compared to isonitrogenous barley-based soybean meal diets. Carcass composition is significantly affected by whole soybeans vs soybean meal, whereas there are smaller but nevertheless significant differences amongst heat treated soybeans. The loin eye areas of pigs having received barley and whole soybeans have adipose tissue which is more unsaturated than that from pigs having received barley and soybean meal.

Barley appears to lower overall digestibilities of diets containing soybean meal as a protein source, when compared to corn-based diets. The ether extractable fraction of extruded soybeans is significantly more digestible than the equivalent fraction of micronized, jetsploded and roasted whole soybeans. This is attributed to the fact that the extrusion process ruptures the cells of the soybeans and therefore renders the intracellular oil more accessible to the actions of lipases and bile.

VIII.APPENDIX

1) List of Sources of Whole Soybeans

2) Tables

Table 8.1. Identification of the Sources of Whole Soybeans

#1 LB Products
1361 Graham Bell
Boucherville, P.Q.
J4B 6A1

#2 Shurgain

#3 Nutribec Lteé.
C.P. 278, Succ. St.Sauveur
P.Q. G1K 6W3

#4 Semences Prograin Inc.
145, Bas Rivière Nord
St. Césaire, P.Q. J0L 1T0

#5 New Life Mills
252 14th Street
Hanover, Ontario

#6 Coop Féderé
Ste Clet P.Q.

#7 Food Science Departement
MacDonald College of McGill University, 21111 Lakeshore Blvd., Ste Anne de Bellevue, P.Q. H9X 1C0

#8 Meunerie Fremeth inc.
435, Route 158
New Glagow, P.Q.
J0R 1J0

#9 Ferme Robert Coriveau enr.
316, Route 122, C.P. 283
St. Edmond, P.Q.
J0C 1K0

#10 M.Pierre Normandeau
220, Rang St.Antoine
St. Etienne-de-Beauharnois, P.Q.
J0S 1S0

#11 M.Jean-Marie Goerig
310, Riviére Sud-Ouest
Maskinongé, P.Q.
J0K 1N0

#12 M.Hérvé Martin
810, 5iéme Rang Ouest
Sainte-Cécile-de-Milton
J0E 2C0

#13 Bazinet Lacoste inc.
652, Route Principale
St. Hugues, P.Q.
J0H 1N0

#14 M.Roland Simard
2816, Felton
Rock Forest
J1N 1A4

#15 Blythe-Brae farms

#16 Grains Bécancour
19025 Boul. Bécancour
St.Grégoire, P.Q.
G0X 2T0

#17 Micrograin (90) inc.
235, chemin St.Robert
St.Robert, P.Q.
J0G 1S0

#18 M.Raymond Messier
1158 Rang Brodeur
St.Eugène, P.Q.
J0C 1J0

#19 Ferme J.Chartier &Fils inc.
741 Nôtre-Dame
Champlain, P.Q.
G0X 1C0

#20 Régie des Marché Agricole
St.Sauveur, P.Q.

#21 Comax, Coopérative Agricole
M.Gilles Cardinal
174, Rang 3 Case Postale 60
Ste rosalie, P.Q.

#22 Michel Robidoux
125, 12e Rang Sud
Saint Nazaire, P.Q.
J0H 1V0

Table 8.2.1.a Proximate Analysis of Raw Whole soybeans			On D.M. Basis							
Source	Sample	D.M.	EE	CP	NDF	ADF	Cellulose	GE Kcal/g	TIU/mg CP	Ash
4	167-0	86.88	21.84	39.84	9.57	8.67	4.79	5850.6	99.13	5.35
4	181-0	87.68	20.37	43.07	11.55	8.91	3.90	5850.8	119.09	5.16
6	186-0	86.06	21.69	41.37	8.92	8.18	5.14	5984.2	120.91	5.47
4	273-0	87.02	20.28	42.22	10.20	9.52	4.35	5572.3	123.05	5.60
7	495-0	86.68	20.50	39.77	11.85	10.82	4.54	5644.9	162.74	5.66
7	498-0	93.44	19.35	41.49	11.06	11.47	4.90	5681.7	58.56	5.21
4	573-0	87.32	20.14	37.00	10.36	10.14	4.84	7730.2	186.59	5.86
9	619-0	91.66	22.76	35.95	10.45	14.19	7.09	5760.4	185.82	5.85
10	620-0	90.75	21.12	38.71	10.58	12.78	7.06	5730.0	176.13	5.83
17	706-0	87.73	20.73	39.95	10.87	11.59	9.26	5653.7	144.09	5.53
17	707-0	91.64	21.95	38.99	11.71	14.73	8.22	5684.3	123.55	5.62
13	708-0	86.07	20.82	38.97	10.73	10.85	10.97	5634.9	188.91	5.58
13	709-0	91.87	21.14	38.79	9.95	7.43	10.80	5747.3	98.11	5.46
14	710-0	88.13	20.17	43.91	11.26	13.26	9.02	5673.4	103.38	5.28
14	711-0	93.97	20.75	43.58	12.07	11.43	9.59	5725.2	71.63	5.60
9	791-0	87.46	22.3	38.25	9.56	12.62	6.00	5728.3	201.18	5.66
8	803-0	88.62	18.91	41.96	10.76	11.14	7.09	5540.5	156.38	5.77
12	879-0	87.29	20.47	38.82	11.10	13.04	6.31	5579.1	169.67	5.90
4	889-0	88.41	19.85	42.18	10.77	12.39	6.04	5576.3	173.9	5.06
4	1003-0	87.66	20.38	40.95	12.12	15.95	7.44	5806.5	147.13	5.35
10	1005-0	91.39	22.7	31.75	13.25	14.62	7.47	6729.4	129.39	6.29
9	1054-0	88.65	19.81	37.92	10.47	14.03	7.48	5674.0	166.63	5.84
4	1086-0	87.93	19.53	41.06	10.72	11.70	6.54	5709.1	140.04	5.31
10	1093-0	90.38	23.05	30.42	13.30	13.22	7.53	5731.4	119.66	6.13
4	1124-0	85.43	21.22	43.31	8.43	10.09	9.17	5630.3	187.35	5.37
10	1700-0	88.75	19.54	41.13	9.09	12.21	5.97	5678.9	168.12	5.36
4	1748-0	86.25	20.14	43.08	8.57	12.42	0.00	5850.6	290.31	5.35
12	9-1	88.9	19.32	44.08	10.54	13.32	8.20	5691.8	101.2	5.78
12	10-1	87.7	20.91	39.43	11.27	10.70	8.46	5096.9	111.44	5.46
8	11-1	87.38	20.53	43.58	10.44	12.12	6.87	5928.1	99.69	5.47
10	12-1	87.42	19.24	44.22	10.64	9.95	6.22	5673.8		5.48
	Average	88.83	20.71	40.11	10.83	11.94	6.85	5790.03	139.89	5.57
	Std. Dev.	2.29	1.08	3.20	1.20	2.15	2.13	411.81	62.94	0.27

Table 8.2.1.b Mineral Analysis of Raw Whole soybeans		On D.M. Basis								
Source	Sample	Ca	P	Mg	Cu	Zn	Fe	Mn	Na	K
4	167-0	2107	6913	2548	15.4	53.6	99.3	24.5	6.6	5072.6
4	181-0	1939	5479	2349	16.7	52.2	100.4	21.7	6.6	5645.8
6	186-0	2320	6158	2631	15.1	50.2	104.8	23.2	13.8	5646.2
4	273-0	2203	6369	2689	15.9	52.4	113.2	24.5	12.6	8067
7	495-0	1917	7372	2665	18.0	55.6	134.2	24.8	6.6	7401
7	498-0	1680	5986	2330	14.5	50.0	84.4	24.9	11.1	6753
4	573-0	1984	6793	2720	16.6	54.5	126.0	27.6	17.3	6639
9	619-0	1982	6435	2558	15.9	47.6	124.0	23.7	15.4	7639
10	620-0	1848	5566	2744	13.4	54.0	161.2	22.8	13.4	6718
17	706-0	1906	6144	2479	17.1	56.2	119.3	22.8	17.0	7626
17	707-0	1912	6620	2570	17.0	53.4	118.6	24.9	6.7	7953
13	708-0	1989	5986	2405	18.0	56.0	112.1	26.4	7.6	6878
13	709-0	1989	5848	2346	17.7	53.9	121.0	25.7	12.1	6547
14	710-0	1937	6538	2377	19.9	50.4	95.1	21.6	17.0	6734
14	711-0	2228	6402	2495	20.7	50.6	185.9	22.2	12.8	7098
15	730-0	1939	6438	2439	18.6	52.3	122.8	25.0	11.4	6444
9	791-0	2353	6654	2841	17.1	55.3	206.3	24.5	6.9	7764
9	792-0	2409	6560	2928	18.6	60.8	146.5	24.2	4.2	8306
8	803-0	2503	6167	2900	15.4	52.2	124.7	26.6	3.9	7521
12	879-0	2257	6396	2790	16.2	51.3	108.8	24.3	1.4	7618
4	889-0	2012	5991	2477	17.2	50.9	103.0	24.7	5.7	7177
4	1003-0	2474	5658	2601	13.14	42.7	102.7	21.7	4.1	6993
10	1005-0	1804	7353	2528	16.5	55.5	110.0	19.0	11.1	6609
9	1054-0	2099	6768	2448	14.8	52.5	143.9	20.2	8.1	5539
4	1086-0	1924	6073	2275	16.0	48.4	115.8	22.6	3.1	7028
10	1093-0	2007	7258	2611	16.8	58.6	137.0	20.4	3.4	6926
4	1124-0	2095	6767	2423	17.6	51.5	158.0	26.9	3.3	8155
10	1700-0	2231	6475	3110	14.5	67.6	91.3	19.2	0.0	6028
4	1748-0	2296	6638	2713	16.3	60.3	111.3	26.7	0.0	5159
12	9-1	2677	6208	2772	15.1	56.2	150.7	22.5	0.0	8547
12	10-1	2512	5755	2685	12.2	61.6	123.1	26.2	0.0	07024
8	11-1	2356	6116	2615	14.1	64.1	99.6	24.0	0.0	07082
10	12-1	2348	6631	3186	15.7	69.8	83.5	21.7	10.5	6653
	Average	2128.5	6379.3	2613.6	16.3	54.6	122.4	23.7	8.4	6939.1
	Std. Dev.	235.6	469.4	214.1	1.8	5.5	27.0	2.2	4.8	863.4

Table 8.2.2.a Proximate Analysis of Extruded Whole soybeans			On D.M. Basis							
Source	Sample	DM	EE	CP	NDF	ADF	Cellulose	GE kcal/g	TIU/mg CP	Ash
1	11-0	92.40	20.17	36.55	18.00	13.31	8.49	5718.6	8.95	6.09
3	135-0	93.50	19.73	37.18	13.72	14.75	5.59	5688.9	7.29	5.91
2	148-0	91.78	21.13	31.34	15.60	10.05	8.21	5637.4	23.32	5.40
2	149-0	92.28	19.98	37.77	10.94	8.14	5.70	5683.8	13.41	5.58
3	155-0	86.93	20.07	36.47	10.01	9.44	5.47	5754.1	12.67	6.12
1	165-0	92.31	19.24	41.62	11.73	9.01	5.32	5789.2	9.04	5.10
2	178-0	92.47	20.05	38.63	9.98	8.67	6.04	5700.2	16.91	5.32
3	182-0	85.87	18.04	43.08	10.52	12.44	4.79	5792.5	16.37	5.08
1	267-0	93.40	19.03	40.71	8.65	7.60	5.72	5618.8	6.01	5.46
7	497-0	94.35	17.55	42.55	9.53	7.46	5.47	5549.5	5.70	5.41
1	518-0	90.54	19.53	41.25	10.20	10.45	5.44	5638.4	16.87	5.35
1	520-0	90.40	19.61	40.13	8.84	10.48	5.62	5679.2	17.33	5.24
3	544-0	88.05	15.43	44.26	8.26	8.42	5.58	6629.2	16.53	5.99
1	602-0	89.81	18.95	39.01	9.42	9.19	7.26	6035.0	17.98	6.45
3	731-0	89.57	18.37	42.92	10.37	9.72	7.46	5671.5	8.79	6.08
1	752-0	91.67	18.51	39.05	10.94	9.87	7.05	5399.8	12.15	5.19
13	793-0	94.44	19.69	39.37	10.60	7.12	6.79	5749.7	14.39	5.02
1	918-0	90.48	18.51	41.46	9.68	10.02	7.56	5702.9	11.28	5.46
1	1048-0	90.87	18.01	43.18	11.06	9.44	7.20	5403.3	8.99	5.96
13	1055-0	95.41	21.92	33.06	9.93	8.26	7.96	5670.3	19.79	5.98
3	1106-0	87.6	20.91	34.20	12.88	10.03	7.57	5787.7	13.73	6.26
1	1107-0	90.89	17.96	42.08	11.36	9.45	10.02	5611.2	8.84	5.51
13	1126-0	94.28	19.56	39.56	13.22	9.39	13.62	5557.9	14.80	5.55
3	1483-0	88.72	21.75	38.37	12.45	8.04	6.99		20.40	5.68
1	1430-0	93.37	18.41	42.48	9.12	10.56	6.85	5590.7	13.65	5.55
1	1750-0	88.78	19.7	38.50	11.19	9.29	5.90	5789.2	15.54	5.10
13	1749-0	93.25	18.4	41.89	9.80	8.13	7.88	5930.3	12.36	5.88
3	1-1	87.19	16	45.01	11.29	7.80	8.06	5310.2	9.69	6.33
21	2-1	90.01	18.71	42.48	8.86	8.42	6.87	4221.8	16.1	5.43
21	3-1	87.95	20.52	43.35	9.27	9.49	7.08	5969.3	29.4	5.42
22	110-1	90.37	19.94	41.09	8.70	8.73	7.20	5488.5		5.34
13	158-1	89.57	18.54	44.44		6.34	6.54	5403.6		5.72
22	324-1	89.68	18.86	42.31	9.37		8.50	5374.7		5.33
	Average	90.87	19.18	40.12	10.71	9.43	7.22	5655.6	14.67	5.63
	Std. Dev.	2.34	1.37	3.15	2.89	1.76	1.80	340.04	6.16	0.39

Table 8.2.2.b Mineral Analysis of Extruded Whole soybeans		On a D.M. Basis								
Source	Sample	Ca	P	Mg	Cu	Zn	Fe	Mn	Na	K
1	11-0	2497	6545	2539	16.5	48.6	141.5	22.8	57.2	4858
1	135-0	2801	6542	2561	16.2	49.5	126.9	22.5	57.2	6068.4
2	148-0	2658	4967	2548	17.0	53.2	136.1	22.9	31.5	6037
2	149-0	2764	5460	2585	16.0	63.9	208.7	24.5	59.3	5313
3	155-0	2389	6501	2462	18.1	54.6	291.0	24.0	69.7	6074.7
1	165-0	2126	6164	2407	15.9	51.8	130.9	24.5	181.7	5581
2	178-0	2542	5625	2526	16.3	56.3	174.1	25.7	73.2	5533
3	182-0	2374	6545	2721	14.1	63.8	244.2	27.8	71.3	5881
1	267-0	2231	6247	2429	16.6	53.4	139.3	24.1	210.5	5401
7	497-0	1716	6197	2397	15.7	50.3	88.6	24.4	22.2	5906
1	518-0	1974	6608	2441	17.4	54.2	161.9	25.0	102.7	7660
1	520-0	1772	6711	2423	16.7	52.7	170.2	24.3	134.8	6341
3	544-0	2126	6929	2785	15.5	57.6	349.7	32.2	68.7	7740
1	602-0	2012	6926	2644	17.2	53.5	203.4	26.5	140.7	6499
3	731-0	2464	6773	2819	17.2	54.1	264.9	30.4	48.8	7352
1	752-0	2357	6900	2776	17.6	52.4	176.6	26.3	220.7	6491
13	793-0	2259	5734	2690	15.2	72.5	122.0	24.5	7.0	7560
1	918-0	3150	6407	2973	13.7	43.1	135.9	27.6	66.3	7700
1	1048-0	2048	7571	2443	17.0	52.9	226.3	24.0	232.8	6086
13	1055-0	2344	6435	2453	18.1	54.2	127.6	25.6	1.9	0.0
3	1106-0	2749	6050	2580	16.4	57.1	183.0	23.1	218.6	5514
1	1107-0	2184	6776	2762	17.9	63.8	128.7	27.0	148.5	6326
13	1126-0	2556	6045	2482	14.5	48.8	142.1	23.3	8.5	7125
3	1483-0	2057	6774	2232	16.6	51.8	119.5	25.9	69.2	6951
1	1430-0	2056	6664	2410	17.5	49.3	109.2	24.6	92.1	6284
1	1750-0	2653	6883	2410	19.0	54.1	136.3	20.3	16.9	5688
13	1749-0	2525	6588	2713	16.4	57.9	290.6	25.7	11.8	5362
3	1-1	2733	7091	3137	17.9	64.2	342.9	32.1	22.8	7434
21	2-1	2303	6482	2539	15.2	55.5	116.7	25.6	21.8	6684
21	3-1	2391	6692	2541	15.2	54.6	112.8	25.0	22.3	7177
22	110-1	2225	5875	2894	14.6	64.2	70.8	18.8	0.9	6670
3	158-1	2554	6551	2886	16.3	63.6	117.2	20.1	64.5	7049
22	324-1	2460	6319	2676	15.5	59.1	107.0	25.6	42.0	6978
	Average	2365.14	6441.8	2602.5	16.4	55.6	169.9	25.1	70.73	6221.87
	Std. Dev.	307.72	502.08	194.67	1.22	5.93	70.00	2.85	68.23	1362.6

Table 8.2.3.a Proximate Analysis of Micronized Whole soybeans			On D.M. Basis							
Source	Sample	D.M.	EE	CP	NDF	ADF	Cellulose	GE Kcal/g	TIU/mg CP	Ash
4	128-0	92.10	21.98	39.20	9.61	7.26	6.83	5742.7	10.40	5.99
4	156-0	91.42	21.68	39.72	9.95	10.52	4.31	5754.8	12.37	5.82
4	166-0	91.62	22.19	40.24	10.59	11.54	4.75	5778.2	10.92	5.58
4	180-0	91.92	20.92	42.39	12.55	10.67	5.03	5739.8	17.12	5.58
4	274-0	91.97	21.03	41.39	9.79	9.85	4.82	5724.7	8.86	5.84
7	496-0	90.67	21.01	41.66	11.85	10.50	4.54	5610.5	13.50	5.86
4	545-0	92.03	20.48	40.71	14.85	11.40	4.95	6342.5	16.90	5.61
4	574-0	91.61	21.30	36.04	14.54	13.80	4.92	5643.5	14.04	6.18
17	794-0	94.42	23.42	39.29	8.84	12.37	5.34	5772.1	16.62	5.80
4	890-0	92.3	21.11	41.84	9.19	11.81	6.90	5568.8	14.29	5.83
4	1004-0	91.61	21.53	41.24	13.16	12.99	6.92	6986.1	11.28	5.39
17	1056-0	95.69	22.92	39.91	10.10	9.58	4.48	5779.1	10.8	5.78
4	1085-0	92.03	21.3	40.64	10.66	10.57	7.27	5672.1	14.96	5.67
4	1125-0	89.42	21.31	40.71	10.78	11.97	10.52	5748.2	13.68	5.69
17	1127-0	93.85	22.55	42.45	10.44	10.76	7.20	5743.2	22.3	5.72
17	1744-0	89.91	20.44	41.06	12.61	12.99	7.04	5772.4	30.62	5.32
4	1747-0	92.09	20.48	42.51	10.83	14.17	0.00	5778.2	11.68	5.58
	Average	92.04	21.49	40.65	11.20	11.34	5.64	5832.75	15.05	5.72
	Std. Dev.	1.47	0.76	1.53	1.73	1.64	2.10	328.70	5.90	0.20

Table 8.2.3.a Mineral Analysis of Micronized Whole soybeans			On D.M. Basis							
Source	Sample	Ca	P	Mg	Cu	Zn	Fe	Mn	Na	K
4	128-0	2122	5770	2660	13.7	44.6	89.7	23.6	6.2	5317
4	156-0	2510	5895	2569	14.9	52.2	180.5	25.1	10.6	5748.7
4	166-0	2225	6316	2731	15.9	54.1	176.4	26.4	13.0	5971.9
4	180-0	2158	5680	2720	15.5	50.6	232.7	26.7	5.7	4721.1
4	274-0	2144	6376	2860	15.7	50.3	217.5	28.2	10.8	8209
7	496-0	1912	6990	2840	17.7	52.5	186.2	26.6	9.4	6502
4	545-0	1828	6243	2695	16.4	51.8	144.6	22.3	8.7	6373
4	574-0	1962	6734	2844	17.0	53.5	178.5	29.0	22.3	5913
17	794-0	1985	7075	2706	18.2	325.5	85.3	24.9	3.4	8256
4	890-0	2119	6360	2795	16.7	47.4	218.9	24.7	3.3	7086
4	1004-0	2444	5261	2936	14.4	38.2	191.0	21.1	9.9	8765
17	1056-0	2204	5978	2623	17.1	49.5	79.7	20.1	6.4	8047
4	1085-0	2067	5933	2651	15.6	52.7	216.5	24.4	4.3	5487
4	1125-0	2214	6665	2785	16.6	50.3	268.4	29.1	10.3	5555
17	1127-0	1897	7874	2323	17.7	43.7	76.7	23.4	7.6	6997
17	1744-0	2274	5975	2591	15.0	52.3	129.0	23.4	0.0	6395
4	1747-0	2541	6566	3127	15.4	59.7	266.0	30.4	0.0	5158
	Average	2153.3	6334.8	2732.8	16.1	66.4	172.81	25.3	7.8	6500.1
	Std. dev.	201.9	603.5	168.9	1.2	64.93	60.99	2.8	5.1	1178.7

Table 8.2.4.a Proximate Analysis of Jetsploded Whole soybeans			On a D.M. Basis							
Source	Sample	D.M.	EE	CP	NDF	ADF	Cellulose	GE Kcal/g	TIU/mg CP	Ash
5	153-0	93.03	20.70	41.20	11.74	15.59	5.24	5725.0	11.84	5.40
5	154-0	93.34	21.07	41.17	10.55	14.26	4.81	5755.6	10.87	5.40
5	168-0	93.39	20.63	41.93	13.73	13.90	5.87	5774.3	10.21	4.84
5	268-0	93.69	21.03	40.68	8.99	10.31	4.88	5437.1	6.97	5.44
5	546-0	94.06	18.51	37.80	12.30	16.36	7.90	5616.6	18.65	5.35
5	549-0	92.83	21.29	40.78	11.39	13.59	4.67	5811.7	14.04	5.07
5	550-0	93.06	20.40	39.53	13.84	12.64	5.53	5751.1	17.26	5.32
5	559-0	92.54	21.09	40.43	11.79	12.26	6.89	5889.3	14.24	5.58
5	327-1	93.91	20.25	50.79			6.02	5558.5		5.04
5	328-1	94.04	19.97	51.77	15.17		6.10	5540.2		5.09
5	329-1	93.81	19.7	50.95	13.63		6.66	5511.1		5.06
	Average	93.43	20.62	43.36	12.31	13.61	5.87	5670.06	14.62	5.24
	Std. Dev.	0.49	0.97	4.89	1.73	1.79	10.95	137.39	2.48	0.21

Table 8.2.4.b Mineral Analysis of Jetsploded Whole soybeans			On D.M. Basis							
Source	Sample	Ca	P	Mg	Cu	Zn	Fe	Mn	Na	K
5	153-0	1899	5956	2403	10.6	45.4	9.1	23.9	6.3	5404.3
5	154-0	1918	5696	2368	11.7	44.2	86.3	23.9	7.7	5643.5
5	168-0	2016	5831	2365	12.1	43.0	104.4	23.0	7.5	5623.4
5	268-0	2266	5582	2416	12.8	47.9	90.2	24.9	7.0	5164.6
5	546-0	2283	5568	2445	14.4	57.3	173.4	31.7	163.2	5927
5	549-0	1763	6043	2445	12.6	46.5	110.3	24.6	17.5	5641
5	550-0	1893	5955	2439	12.5	46.1	141.5	28.9	12.8	6249
5	595-0	1926	5769	2437	13.1	46.4	122.9	24.6	17.2	6338
5	327-1	1959	6036	2662	13.8	69.2	102.2	23.4	15.8	6087
5	328-1	1968	5923	2653	13.3	50.0	105.3	23.4	12.1	6346
5	329-1	1936	5972	2644	13.0	48.0	91.7	23.5	10.0	5486
	Average	1984.3	5848.2	2479.8	12.7	49.4	103.4	25.1	25.2	5809.9
	Std. Dev.	149.1	164.9	82.1	1.8	4.1	45.8	2.9	44.5	384.5

Table 8.2.5.a Proximate Analysis of Roasted Whole soybeans		On D.M. Basis							
Source	Sample	D.M.	EE	CP	NDF	ADF	Cellulose	GE Kcal/g	TIU/mg CP	Ash
0	1088-9	90.58	20.62	40.20	16.80	12.96	11.42	5659.1	10.82	6.24
0	1188-9	91.52	19.25	38.65	12.65	8.24	9.62	5664.3	11.25	5.46
0	551-0	91.02	21.37	40.29	11.53	13.26	4.72	5767.2	14.26	5.27
8	618-0	94.59	23.51	34.44	9.08	11.60	7.03	5793.4	19.22	6.12
11	656-0	91.28	25.87	32.36	13.24	12.32	7.57	5718.7	20.10	5.52
12	657-0	90.83	22.26	39.13	14.30	14.63	7.10	5714.0	20.52	5.61
15	730-0	92.67	19.8	41.05	13.13	16.95	7.90	5740.8	11.36	5.57
16	753-0	95.79	20.55	39.66	12.74	14.11	5.53	5710.4	32.13	5.57
8	804-0	90.83	20.07	41.63	12.40	14.30	[illegible].21	5636.9	8.75	5.43
9	792-0	92.04	22.21	36.74	12.07	13.56	7.05	5780.1	9.28	5.48
12	880-0	89.96	21.54	37.15	9.69	14.47	7.23	5535.8	12.09	5.71
14	968-0	94.42	22.14	36.89	8.94	11.43	6.62	5719.1	7.94	5.76
8	1057-0	93.23	20.79	39.83	10.71	13.19	6.79	5545.4	7.54	5.58
18	1128-0	88.25	20.5	43.73	10.65	12.45	10.12	5597.7	18.54	5.85
9	1129-0	89.83	21.34	42.60	8.44	12.35	8.16	5666.3	10.9	5.66
10	1133-0	85.49	19.51	43.92	9.18	10.33	8.75	5684.9	22.54	5.51
20	1173-0	91.47	22	40.16	11.54	10.80	9.33	5848.9	7.96	5.84
19	1238-0	90.12	21.97	40.86	9.39	14.14	6.98	5703.5	10.76	5.53
19	1239-0	95.88	26.36	36.91	9.44	14.71	6.81	5694.6	10.16	5.21
19	1240-0	91.79	25.1	41.75	8.39	9.87	5.60	5545.3	8.64	5.49
8	1699-0	90.68	21.53	43.21	14.04	14.63	7.44	5822.7	9.55	5.44
9	1742-0	90.16	20.07	41.32		14.09	6.72	5933 9	9.77	5.60
18	1743-0	86.47	20.12	42.35		13.26	6.22	5967.4	10.08	5.53
22	4-1	88.5	20.94	42.92		12.67	8.03	6474.6	29.55	5.16
22	5-1	88.41	21.01	42.65		11.64	6.62	5994.8	21.33	5.41
14	6-1	89.32	20.1	41.04		15.51	7.85	5721.0	17.05	5.30
14	7-1	91.43	23.72	35.32		10.92	7.62	6146.8	13.34	5.44
14	8-1	91.94	20.44	41.75		13.69	7.42	5797.3	10.91	5.17
10	13-1	85.75	19.71	42.82		8.34	5.97	5842.6		5.38
14	111-1	88.33	19.88	40.89		8.34	7.53	5570.0		5.67
14	112-1	88.27	19.81	36.94		8.34	6.62	5437.9		5.53
12	113-1	91.2	21.53	39.67		8.34	6.03	5592.1		5.75
9	156-1	91.37	21.07	44.02		8.34	6.60	5581.7		5.51
18	157-1	88.1	20.98	42.77		8.34	5.68	5822.9		5.57
16	385-1	96.65	17.96	40.55			6.58	5794.1		5.32
	Average	90.69	20.83	40.30	10.81	12.01	7.08	5754.25	16.97	5.53
	Std. Dev.	2.76	4.17	2.94	1.90	2.29	1.11	199.11	17.65	0.21

Table 8.2.5.b Mineral Analysis of Roasted Whole soybeans			On D.M. Basis							
Source	Sample	Ca	P	Mg	Cu	Zn	Fe	Mn	Na	K
0	551-0	1864	5510	2389	13.6	43.5	128.0	27.2	14.4	6735
8	618-0	2175	7167	2722	16.0	55.1	122.9	26.1	11.4	8275
11	656-0	2286	6926	2618	20.5	58.0	303.5	20.7	14.2	6652
12	657-0	2278	6586	2593	18.8	47.7	172.0	22.1	20.9	7393
16	753-0	1923	7167	2599	18.7	54.1	111.8	25.2	1.1	7798
8	804-0	2214	6203	2450	15.0	52.7	136.6	26.8	2.9	8824
12	880-0	2601	6375	2829	16.7	48.9	114.2	21.5	4.4	7648
14	968-0	2473	7004	2743	18.0	103.8	197.0	26.5	6.6	7061
8	1057-0	2069	6350	2392	15.6	52.9	115.3	21.3	5.3	6253
18	1128-0	2300	7124	2436	13.8	48.7	82.7	26.1	4.4	6648
9	1129-0	2427	6744	2405	17.5	44.5	126.9	24.5	4.3	6865
10	1133-0	2246	6801	2854	16.6	58.5	83.1	21.1	5.4	6629
20	1173-0	2187	6873	2635	17.5	54.7	174.9	25.1	7.0	6961
19	1238-0	1642	6415	2153	16.9	47.7	95.4	23.3	8.4	7842
19	1239-0	1888	6932	2169	17.5	51.1	81.4	21.9	4.7	7058
19	1240-0	2119	6546	2201	12.0	42.5	89.3	17.4	8.2	6719
8	1699-0	2062	6774	2669	15.7	62.9	120.2	25.4	67.7	6801
9	1742-0	2423	6475	2662	14.1	56.6	176.4	28.8	0.0	6045
18	1743-0	2440	6157	2671	16.7	49.7	183.9	20.8	0.0	6071
22	4-1	2281	6416	2525	15.9	57.6	122.0	21.5	9.9	8102
22	5-1	2345	6677	2573	13.8	56.6	158.4	26.0	9.7	7621
14	6-1	2312	6551	2637	15.6	57.1	127.6	25.8	6.5	7009
14	7-1	2459	6934	2740	16.6	52.5	96.2	23.0	9.6	8446
14	8-1	2396	5983	2605	15.8	56.6	105.5	22.8	5.9	7174
10	13-1	2615	6477	2840	14.5	65.3	142.3	23.3	15.9	8420
14	111-1	2435	6248	2723	15.3	61.1	173.2	26.0	25.0	6501
14	112-1	2629	7301	2849	18.4	66.8	105.4	23.8	13.5	7407
12	113-1	2487	6741	2560	15.1	61.4	109.6	23.0	22.6	6886
9	156-1	2471	6079	2654	15.1	50.3	162.0	20.8	4.8	6882
18	157-1	2597	6661	2934	16.6	64.7	119.2	20.4	65.6	7167
16	385-1	2548	6317	2990	14.1	60.0	129.3	22.8	5.8	5525
	Average	2294.4	6597.2	2607.1	16.1	56.2	134.39	23.6	12.5	7142.5
	Std. Dev.	238.7	389.8	206.1	1.8	10.69	44.1	2.5	15.5	752.5

Table 8.3.1 Means and Variability by Company of Raw Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	4	6	7	8	9	10
Dry Matter %	87.18	86.06	90.06	88.00	89.95	85.62
Std. Deviation	0.91		4.78	0.88	2.25	1.103
N	9	1	2	2	4	5
Ether extract %	20.42	21.69	19.93	19.72	21.77	19.61
Std.Deviation	0.70		0.81	1.15	1.33	1.01
N	9	1	2	2	4	5
Crude protein %	41.41	41.37	40.63	42.77	37.22	43.37
Std. Deviation	2.02		1.22	1.15	1.06	3.79
N	9	1	2		4	5
NDF %	10.25	8.92	11.46	10.60	10.64	9.886
Std. Deviation	1.23		0.56	0.23	1.05	1.21
N	9	1	2	2	4	5
ADF %	11.09	8.18	11.15	11.63	13.60	9.35
Std. Deviation	2.30		0.46	0.69	0.71	1.17
N	9	1	2	2	4	5
Cellulose %	5.23	5.14	4.72	6.98	6.91	7.36
Std. Deviation	2.57		0.25	0.16	0.63	0.77
N	9	1	2	2	4	5
GE kcal/g	5952.97	5984.20	5663.30	5734.30	5735.70	5763.75
Std. Deviation	676.55		26.02	274.07	46.34	292.80
N	9	1	2	2	4	5
TIU/mg CP	173.87	70.68	140.19	128.04	131.29	155.95
Std. Deviation	53.33		73.73	40.09	108.74	39.74
N	9	1	2	2	3	4
Ash	5.38	5.47	5.44	5.62	5.71	5.44
Std. Deviation	0.23		0.32	0.21	0.18	0.23
N	9	1	2	2	4	5
Ca ppm	2114.89	2320.00	1798.50	2429.50	2210.75	2430.50
Std. Deviation	182.03		167.58	103.94	203.59	171.11
N	9	1	2	2	4	5
P ppm	6297.89	6158.00	6679.00	6141.50	6604.25	6639.00
Std. Deviation	523.10		980.05	36.06	141.29	460.67
N	9	1	2	2	4	5
Mg ppm	2532.78	2631.00	2497.50	2757.50	2693.75	2847.00
Std. Deviation	162.87		236.88	201.52	227.58	187.52
N	9	1	2	2	3	5
Cu ppm	16.09	15.10	16.25	14.75	16.60	15.55
Std. Deviation	1.31		2.47	0.91	1.63	1.01
N	9	1	2	2	4	5

Table 8.3.1 Means and Variability by Company of Raw Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	4	6	7	8	9	10
Zn ppm	51.83	50.20	52.80	58.15	54.05	61.90
Std. Deviation	4.72		3.96	8.41	5.51	4.79
N	9	1	2	2	4	5
Fe ppm	114.41	104.80	109.30	112.15	155.18	112.70
Std. Deviation	18.05		35.21	17.75	35.53	24.37
N	9	1	2	2	4	5
Mn ppm	24.54	23.20	24.85	25.30	23.15	22.20
Std. Deviation	2.22		0.07	1.84	1.99	1.14
N	9	1	2	2	4	5
Na ppm	6.59	13.80	8.85	4.65	8.65	10.65
Std. Deviation	5.29		3.18	1.06	4.79	4.29
N	9	1	2	2	4	5
K ppm	6659.60	5646.20	7077.00	7301.50	7312.00	7524.50
Std. Deviation	1147.29		458.20	310.42	1216.94	453.13
N	9	1	2	2	4	5

Table 8.3.1 Means and Variability by Company of Raw Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	12	13	14	15	17
Dry Matter %	87.96	88.97	91.05	92.67	89.69
Std. Deviation	0.84	4.10	4.13		2.77
N	3	2	2	1	2
Ether extract %	20.23	20.98	20.46	19.8	21.34
Std.Deviation	0.82	0.23	0.41		0.86
N	3	2	2	1	2
Crude protein %	40.78	38.88	43.75	41.05	39.47
Std. Deviation	2.88	0.13	0.23		0.68
N	3	2	2	1	2
NDF %	10.97	10.34	11.67	13.13	11.29
Std. Deviation	0.38	0.55	0.57		0.59
N	3	2	2	1	2
ADF %	12.35	9.14	12.35	16.95	13.16
Std. Deviation	1.44	2.42	1.29		2.22
N	3	3	2	1	2
Cellulose %	7.66	10.89	9.31	7.90	8.74
Std. Deviation	1.17	0.12	0.40		0.73
N	3	2	2	1	2
GE kcal/g	5455.93	5691.10	5699.30	5740.80	5669.50
Std. Deviation	316.00	79.48	36.62		22.34
N	3	2	2	1	2
TIU/mg CP	127.43	173.94	114.72		163.65
Std. Deviation	36.93	64.18	22.47		14.35
N	3	2	2		2
Ash	5.71	5.52	5.44	5.57	5.58
Std. Deviation	0.23	0.08	0.23		0.06
N	3	2	2	1	2
Ca ppm	2482.00	1989.00	2082.50	19.39	1909.00
Std. Deviation	211.60	0	205.77		4.24
N	3	2	2	1	2
P ppm	6119.67	5917.00	6470.00	6438.00	6382.00
Std. Deviation	329.50	97.58	96.17		336.58
N	3	2	2	1	2
Mg ppm	2749.00	2375.50	2436.00	2439.00	2524.50
Std. Deviation	56.15	41.72	83.44		64.35
N	3	2	2	1	2
Cu ppm	14.50	17.85	20.30	18.6	17.05
Std. Deviation	2.07	0.21	0.57		0.07
N	3	2	2	1	2

Table 8.3.1 Means and Variability by Company of Raw Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	12	13	14	15	17
Zn ppm	56.37	54.95	50.50	52.30	54.80
Std. Deviation	5.15	1.48	0.14		1.98
N	3	2	2	1	2
Fe ppm	127.27	116.55	140.50	122.80	118.95
Std. Deviation	21.65	6.29	64.20		0.50
N	3	2	2	1	2
Mn ppm	24.33	26.05	21.90	25.00	23.85
Std. Deviation	1.85	0.49	0.42		1.49
N	3	2	2	1	2
Na ppm	6.67	9.85	14.90	11.40	11.85
Std. Deviation	4.56	3.18	2.97		7.28
N	3	2	2	1	2
K ppm	7729.67	6712.50	6916.00	6444.00	7789.50
Std. Deviation	767.61	234.05	257 39		231.22
N	3	2	2	1	2

Table 8.3.2 Means and Variability by Company of Extruded Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	1	2	3	7	13	21	22
Dry Matter %	91.42	92.18	87.70	94.35	93.39	88.98	90.02
Std. Deviation	1.49	0.36	1.22		2.27	1.03	0.25
N	13	3	7	1	5	2	2
Ether extract %	19.03	20.39	18.65	17.55	19.62	19.61	19.40
Std.Deviation	0.71	0.64	0.44		1.41	0.91	0.38
N	13	3	7	1	5	2	2
Crude protein %	40.24	35.91	40.62	42.55	39.66	42.91	41.70
Std. Deviation	2.05	3.98	4.23		4.23	0.44	0.44
N	13	3	7	1	5	2	2
NDF %	11.07	12.17	10.83	9.53	8.71	9.07	9.04
Std. Deviation	2.51	3.00	1.56		5.06	0.21	0.24
N	13	3	7	1	5	2	2
ADF %	10.26	8.95	9.41	7.46	7.85	8.95	9.994
Std. Deviation	1.87	0.99	1.59		5.06	0.54	0.96
N	13	3	7	1	5	2	2
Cellulose %	6.77	6.65	6.56	5.47	8.56	6.98	7.85
Std. Deviation	1.39	1.36	1.26		2.90	0.11	0.68
N	13	3	7	1	5	2	2
GE kcal/g	5666.55	5673.8	5860.07	5549.50	5662.36	5095.55	5431.60
Std. Deviation	164.03	32.57	407.60		198.34	873.75	174.34
N	13	3	7	1	5	2	2
TIU/mg CP	14.13	21.19	15.30	8.57	15.34	22.75	
Std. Deviation	4.40	5.38	3.90		3.16	6.65	
N	12	3	7		4	2	
Ash	5.57	5.43	5.93	5.41	5.63	5.43	5.33
Std. Deviation	0.42	0.13	0.43		0.38	0.01	0.89
N	13	3	7	1	5	2	2
Ca ppm	2297.00	2654.67	2413.14	1716.00	2447.60	2347.00	2343.50
Std. Deviation	385.10	111.04	267.43		137.26	44.00	86.11
N	13	3	7	1	5	2	2
P ppm	6688.00	5350.67	6666.14	6197.00	6270.60	6587.00	6097.00
Std. Deviation	356.41	342.35	340.15		369.20	105.00	182.09
N	13	3	7	1	5	2	2
Mg ppm	255.23	2553.00	2676.57	2397.00	2644.80	2540.00	2785.00
Std. Deviation	181.98	29.82	288.39		178.99	1.00	78.92
N	13	3	7	1	5	2	2
Cu ppm	16.86	16.43	16.54	15.70	16.10	15.20	15.05
Std. Deviation	1.24	0.51	1.40		1.37	0.00	0.81
N	13	3	7	1	5	2	2

Table 8.3.2 Means and Variability by Company of Extruded Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	1	2	3	7	13	21	22
Zn ppm	52.25	57.80	57.60	50.30	59.40	55.05	61.65
Std. Deviation	4.63	5.50	4.78		9.10	0.45	1.84
N	13	3	7	1	5	2	2
Fe ppm	152.85	172.97	256.46	88.60	159.90	119.75	88.90
Std. Deviation	33.43	36.31	83.40		73.66	25.30	18.15
N	13	3	7	1	5	2	2
Mn ppm	24.58	24.37	27.93	24.40	23.84	25.30	22.20
Std. Deviation	2.01	1.40	3.76		2.30	0.25	2.88
N	13	3	7	1	5	2	2
Na ppm	127.85	54.67	81.30	22.20	18.74	22.05	21.45
Std. Deviation	69.52	21.23	63.07		25.83	0.251	14.53
N	13	3	7	1	5	2	2
K ppm	6229.49	5627.67	6706.67	5906.00	5419.20	6930.00	6824.00
Std. Deviation	801.15	371.17	873.36		3143.25	246.50	201.93
N	13	3	7	1	5	2	2

Table 8.3.3 Means and Variability by Company of Micronized Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium		
Company	4	17
Dry Matter %	91.59	93.48
Std. Deviation	0.78	2.49
N	13	4
Ether extract %	21.26	22.33
Std.Deviation	0.51	1.31
N	13	4
Crude protein %	40.64	40.68
Std. Deviation	1.69	1.39
N	13	4
NDF %	11.41	10.50
Std. Deviation	1.85	1.57
N	13	4
ADF %	11.31	11.42
Std. Deviation	1.80	1.55
N	13	4
Cellulose %	5.52	6.01
Std. Deviation	2.39	1.32
N	13	4
GE kcal/g	5853.08	5766.70
Std. Deviation	388.69	16.00
N	13	4
TIU/mg CP	13.37	20.09
Std. Deviation	4.33	8.44
N	12	4
Ash	5.74	5.66
Std. Deviation	0.21	0.23
N	13	4
Ca ppm	2172.77	2090.00
Std. Deviation	219.15	178.06
N	13	4
P ppm	6214.54	6725.50
Std. Deviation	485.62	924.34
N	13	4
Mg ppm	2785.62	2560.75
Std. Deviation	143.61	165.74
N	13	4
Cu ppm	15.81	17.00
Std. Deviation	1.09	1.41
N	13	4

Table 8.3.4 Means and Variability by Company of Jetsploded Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium	
Company	5
Dry Matter %	93.42
Std. Deviation	0.52
N	11
Ether extract %	20.42
Std.Deviation	0.81
N	11
Crude protein %	43.36
Std. Deviation	5.13
N	11
NDF %	12.31
Std. Deviation	1.82
N	10
ADF %	13.38
Std. Deviation	1.76
N	11
Cellulose %	5.87
Std. Deviation	1.00
N	11
GE kcal/g	5670.05
Std. Deviation	144
N	11
TIU/mg CP	14.62
Std. Deviation	2.68
N	7
Ash	5.24
Std. Deviation	0.23
N	11
Ca ppm	1984.27
Std. Deviation	156.59
N	11
P ppm	5848.27
Std. Deviation	172.13
N	11
Mg ppm	2479.73
Std. Deviation	114.77
N	11
Cu ppm	12.72
Std. Deviation	1.03
N	11

Table 8.3.3 Means and Variability by Company of Micronized Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	4	17
Zn ppm	50.61	117.75
Std. Deviation	5.13	138.55
N	13	4
Fe ppm	197.45	92.68
Std. Deviation	48.18	24.48
N	13	4
Mn ppm	25.97	22.95
Std. Deviation	2.77	2.03
N	13	4
Na ppm	8.81	4.35
Std. Deviation	5.44	3.40
N	13	4
K ppm	6215.90	7423.75
Std. Deviation	1184.38	879.68
N	13	4

Table 8.3.4 Means and Variability by Company of Jetsploded Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	5
Zn ppm	49.45
Std. Deviation	7.56
N	3
Fe ppm	103.39
Std. Deviation	40.35
N	11
Mn ppm	25.07
Std. Deviation	2.72
N	11
Na ppm	25.19
Std. Deviation	45.96
N	11
K ppm	5809.98
Std. Deviation	403.29
N	11

Table 8.3.5 Means and Variability by Company of Roasted Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium

Company	0	8	9	10	11	12
Dry Matter %	91.05	92.33	90.45	85.6	91.28	90.66
Std. Deviation	0.47	1.90	0.81	0.18		0.64
N	3	4	3	2	1	3
Ether extract %	20.41	21.48	20.83	19.61	25.87	21.78
Std.Deviation	1.07	1.48	0.67	0.14		0.42
N	3	4	3	2	1	3
Crude protein %	39.71	39.78	42.65	43.37	32.36	38.65
Std. Deviation	0.92	3.82	1.35	0.78		1.33
N	3	4	3	2	1	3
NDF %	13.66	11.58	8.75	9.88	13.24	11.13
Std. Deviation	2.78	2.14	0.30	0.99		2.75
N	3	4	3	2	1	3
ADF %	11.49	13.43	11.59	9.33	12.32	12.48
Std. Deviation	2.82	1.37	2.95	1.41		3.59
N	3	4	3	2	1	3
Cellulose %	8.60	7.38	7.16	7.36	7.57	6.79
Std. Deviation	3.45	0.62	0.87	1.97		0.66
N	3	4	3	2	1	3
GE kcal/g	5696.87	5699.6	5727.30	5763.75	5718.70	5613.97
Std. Deviation	60.97	131.22	183.85	111.51		91.09
N	3	4	3	2	1	3
TIU/mg CP	15.47	8.61	10.33	22.54		12.09
Std. Deviation	2.41	1.01	0.80			
N	3	3	2	1		1
Ash	5.66	5.64	5.59	5.45	5.52	5.69
Std. Deviation	0.51	0.33	0.08	0.09		0.07
N	3	4	3	2	1	3
Ca ppm	1864.00	2130.00	2440.33	2430.50	2286.00	2455.33
Std. Deviation		76.21	26.63	260.92		163.81
N	1	4	3	2	1	3
P ppm	5510.00	6623.50	6432.67	6639.00	6926.00	6567.33
Std. Deviation		435.76	334.51	229.10		183.71
N	1	4	3	2	1	3
Mg ppm	2389.00	2558.25	2573.67	2847.00	2618.00	2660.67
Std. Deviation		161.70	146.12	9.90		146.71
N	1	4	3	2	1	3
Cu ppm	13.60	15.58	15.57	15.55	20.50	16.87
Std. Deviation		0.42	1.75	1.49		1.86
N	1	4	3	2	1	3

Table 8.3.5 Means and Variability by Company of Roasted Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium						
Company	**0**	**8**	**9**	**10**	**11**	**12**
Zn ppm	43.50	55.90	50.47	61.90	58.00	52.67
Std. Deviation		4.79	6.05	4.81		7.59
N	1	4	3	2	1	3
Fe ppm	128.00	123.75	155.10	112.70	303.50	131.93
Std. Deviation		9.13	25.46	41.86		34.77
N	1	4	3	2	1	3
Mn ppm	27.20	24.90	24.70	22.20	20.70	22.20
Std. Deviation		2.47	4.00	1.56		0.75
N	1	4	3	2	1	3
Na ppm	14.40	21.83	3.03	10.65	14.20	15.97
Std. Deviation		30.79	2.64	7.42		10.05
N	1	4	3	2	1	3
K ppm	6735.00	7538.25	6597.33	7524.50	6652.00	7309.00
Std. Deviation		1209.87	478.41	1266.43		387.88
N	1	4	3	2	1	3

Table 8.3.5 Means and Variability by Company of Roasted Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium					
Company	14	16	18	19	20
Dry Matter %	91.05	96.22	87.61	92.60	91.47
Std. Deviation	1.96	0.61	0.99	2.96	
N	6	2	3	3	1
Ether extract %	21.01	19.26	20.53	24.48	22.00
Std.Deviation	0.59	1.83	0.43	2.26	
N	6	2	3	3	1
Crude protein %	38.80	40.11	42.95	39.84	40.16
Std. Deviation	1.02	0.63	0.71	2.58	
N	6	2	3	3	1
NDF %	10.16	12.47	10.17	9.07	11.54
Std. Deviation	0.0.26	0.38	0.71	0.59	
N	6	2	3	3	1
ADF %	11.37	14.11	11.35	12.91	10.80
Std. Deviation	1.09		2.64	2.65	
N	6	1	3	3	1
Cellulose %	7.28	6.06	7.34	6.46	9.33
Std. Deviation	0.0.21	0.74	2.42	0.75	
N	6	2	3	3	1
GE kcal/g	5732.02	5752.25	5796.00	5647.80	5848.90
Std. Deviation	89.869	59.18	186.31	88.88	
N	6	2	3	3	1
TIU/mg CP	12.31	91.77	14.31	9.85	7.96
Std. Deviation	3.85		5.98	1.09	
N	4	1	2		1
Ash	5.48	5.45	5.65	5.41	5.84
Std. Deviation	0.09	0.18	0.17	0.17	
N	6	2	3	3	1
Ca ppm	2450.67	2203.00	2445.67	1883.00	2187.00
Std. Deviation	51.95	395.98	148.58	238.54	
N	6	2	3	3	1
P ppm	6670.17	6742.00	6647.33	6631.00	6873.00
Std. Deviation	186.55	601.04	483.64	268.78	
N	6	2	3	3	1
Mg ppm	2716.17	2794.50	2680.33	2174.33	2635.00
Std. Deviation	35.18	276.48	249.13	24.44	
N	6	2	3	3	1
Cu ppm	16.61	16.40	15.70	15.47	17.50
Std. Deviation	0.50	3.25	1.64	3.02	
N	6	2	3	3	1

Table 8.3.5 Means and Variability by Company of Roasted Full Fat Soybean samples, as analyzed in the Crampton Nutrition Laboratorium					
Company	14	16	18	19	20
Zn ppm	66.32	57.05	54.37	47.10	54.70
Std. Deviation	7.07	4.17	8.96	4.33	
N	6	2	3	3	1
Fe ppm	134.15	120.55	128.60	88.70	174.90
Std. Deviation	18.80	12.37	51.25	7.01	
N	6	2	3	20.87	1
Mn ppm	24.65	24.00	22.43	3.08	25.10
Std. Deviation	0.61	1.70	3.18	3	
N	6	2	3	7.10	1
Na ppm	11.18	3.45	23.33	2.08	7.00
Std. Deviation	2.78	3.32	36.67	3	
N	6	2	3	7206.33	1
K ppm	7266.33	6661.50	6628.67	576.01	6961.00
Std. Deviation	246.10	1607.25	548.26	3	
N	6	2	3		1

Table 8.4. Amino Acid Profile of Whole Soybeans, expressed as percentage of total amino acids analyzed																		
Company	Sample	Total	Asp	Glu	Ser	Gly	His	Arg	Thr	Ala	Pro	Tyr	Val	Met	Ile	Leu	Phe	Lys
Raw N = 31 Table 8.4.d																		
4	167	36.03	11.7	18.2	5.8	4.4	2.4	13.5	6.7	3.8	3.8	3.4	3.9	1.3	4.5	7.4	3.7	5.6
4	181	43.1	11.4	17.9	5.8	4.9	2.6	13.2	6.5	4.4	4.9	3.5	3.2	1.2	3.7	7.2	3.7	6.0
6	186	37.73	11.3	17.9	5.6	5.0	2.3	12.2	8.4	4.3	5.0	3.4	3.4	1.1	3.9	7.4	3.5	5.2
4	273	38.09	11.7	18.6	6.0	4.7	2.4	13.2	6.6	4.3	3.7	3.1	3.5	1.1	3.9	7.5	3.9	5.8
7	495	36.01	12.1	19.2	6.1	5.1	2.4	11.3	6.2	4.6	3.5	3.1	3.7	1.3	4.2	7.8	4.1	5.3
7	498	37.74	11.3	18.3	6.0	5.6	2.1	12.9	6.5	4.4	4.8	3.5	3.5	1.2	4.2	7.2	3.6	5.0
4	573	34.71	11.8	17.8	5.8	4.4	2.1	10.3	6.9	4.6	4.2	3.4	3.6	1.3	4.0	7.7	5.0	7.0
9	619	32.91	13.0	18.7	6.7	4.2	2.5	7.5	6.1	4.7	4.1	3.6	4.2	1.2	4.9	8.2	4.0	6.3
10	620	36.13	13.1	19.0	6.8	4.2	2.4	7.5	6.1	4.5	4.3	3.6	4.0	1.2	4.5	8.0	4.0	6.7
17	706	37.09	13.3	18.8	6.7	4.2	2.3	7.0	5.8	4.4	3.9	3.8	4.7	1.3	4.7	8.2	4.6	6.3
17	707	36.29	13.2	18.4	6.7	4.3	2.4	7.6	6.1	5.1	4.5	3.6	4.0	1.2	4.5	8.1	4.1	6.3
13	708	36.21	13.3	18.8	6.6	4.3	2.4	7.6	5.9	4.9	4.3	3.5	4.0	1.2	4.5	8.3	4.1	6.4
13	709	36.11	13.0	17.5	6.8	5.0	2.5	7.4	6.2	5.5	4.7	3.6	3.9	1.2	4.4	8.1	4.1	6.2
14	710	39.9	13.6	19.5	6.5	4.1	2.4	7.5	5.2	4.2	5.1	3.7	4.4	1.1	4.7	7.2	4.4	6.6
14	711	39.82	13.2	18.8	6.5	4.5	2.3	7.4	6.2	5.4	4.6	3.5	3.8	1.2	4.4	8.0	4.2	6.0
9	791	35.91	13.3	18.9	6.7	4.1	2.4	7.9	4.8	4.4	5.2	3.7	4.4	1.2	4.7	7.3	4.5	6.6
8	803	38.01	13.5	19.5	6.3	4.1	2.7	8.5	4.4	4.2	5.3	3.7	4.3	1.2	4.6	7.3	4.3	6.3
12	879	36.01	13.5	19.1	6.6	4.2	2.2	8.5	4.3	4.2	5.6	3.7	4.2	1.1	4.6	7.3	3.9	7.1
4	889	38.97	12.1	21.4	5.5	4.5	1.5	9.5	5.3	4.3	4.8	3.2	3.6	0.9	3.8	8.0	4.5	7.0
4	1003	37.67	11.2	20.2	5.9	4.9	2.3	7.2	5.1	5.2	5.3	3.7	4.4	1.1	4.3	8.8	4.5	5.9
10	1005	29.8	11.1	18.8	5.0	3.9	2.7	12.5	9.1	3.8	3.8	3.9	3.8	0.8	3.4	6.7	3.5	7.3
9	1054	36.9	10.8	18.1	4.8	3.7	2.6	12.1	8.8	4.7	4.7	3.7	3.8	0.8	3.5	7.0	3.6	7.3
4	1086	38.26	11.4	19.7	5.0	3.7	2.6	12.8	8.8	4.4	3.5	3.3	3.6	0.6	3.2	6.9	3.4	6.8
10	1093	28.07	11.2	18.5	5.1	3.9	2.5	12.5	9.4	3.9	3.3	3.6	3.9	1.0	3.4	7.1	3.3	7.4
4	1124	40.14	11.8	20.2	5.2	3.9	2.6	12.9	9.2	4.6	3.9	3.2	3.6	0.6	3.1	6.6	3.1	5.3
10	1700	38.14	10.1	18.5	5.4	4.6	2.4	12.9	9.1	3.8	3.6	3.8	3.9	0.7	3.7	7.7	4.0	5.8
4	1748	39.51	10.1	19.1	5.3	4.7	2.6	12.4	9.3	3.8	3.4	3.8	3.9	0.7	3.6	7.5	3.1	6.8
12	9	40.99	8.7	17.5	5.0	4.5	1.7	13.3	10.3	5.1	4.9	3.7	3.7	0.8	3.4	7.0	4.1	6.3
12	10	36.21	8.5	16.7	4.9	4.4	.7	12.9	10.1	6.2	5.5	3.8	3.7	0.9	3.4	7.1	3.9	6.5
8	11	40.22	8.9	17.5	5.2	4.4	2.0	11.8	9.9	6.2	5.6	3.8	3.6	0.7	3.2	6.9	4.4	5.9
10	12	41.11	8.6	16.9	4.9	4.5	1.7	13.7	9.9	5.3	4.9	3.7	3.7	0.9	3.4	7.2	3.9	6.6
	Aver.	37.22	11.67	18.65	5.85	4.42	2.31	10.57	7.20	4.62	4.74	3.57	3.87	1.04	4.01	7.51	3.97	6.31
	Std. error	0.62	0.28	0.25	0.11	0.33	0.06	0.43	0.63	0.11	0.16	0.07	0.08	0.04	0.11	0.12	0.15	0.10

Table 8.4. Amino Acid Profile of Whole Soybeans, expressed as percentage of total amino acids analyzed

Company	Sample	Total	Asp	Glu	Ser	Gly	His	Arg	Thr	Ala	Pro	Tyr	Val	Met	Ile	Leu	Phe	Lys
Extruded	N= 33 Table 8.4.a																	
1	11	36.4	12.1	19.8	6.0	5.8	2.7	8.0	3.6	4.9	4.7	3.8	4.1	1.4	4.1	8.2	3.8	6.9
1	135	37.1	11.3	18.9	5.9	5.7	2.4	8.6	4.6	4.9	5.7	3.8	3.8	1.3	5.1	8.1	3.8	6.2
2	148	31.5	11.1	18.1	6.0	5.7	2.5	9.2	4.4	4.4	4.8	3.8	3.8	1.3	3.8	7.6	7.3	6.0
2	149	37.7	11.1	18.8	5.8	5.6	2.7	8.5	3.7	4.2	5.6	3.7	3.4	1.1	3.7	8.0	8.0	6.1
3	155	36.5	10.4	15.9	5.5	5.5	2.2	12.1	6.0	4.9	9.9	4.1	3.0	1.4	3.3	6.8	3.3	5.8
1	165	41.6	11.3	18.0	5.8	5.0	2.2	13.0	6.7	4.3	4.8	3.4	3.1	1.2	3.8	7.2	4.1	6.0
2	178	38.8	11.3	17.5	5.7	4.9	2.3	12.6	6.7	4.4	4.9	3.6	3.1	1.3	3.9	7.2	4.4	6.2
3	182	43.2	11.3	18.1	5.6	4.9	2.5	13.2	6.3	4.6	4.9	3.5	3.5	1.4	3.7	7.2	3.7	5.8
1	267	37.06	11.1	17.8	5.6	4.9	2.4	12.4	8.1	4.3	4.6	3.2	3.2	1.3	3.8	7.3	4.0	5.9
7	497	38.63	11.4	18.7	5.7	4.8	2.3	12.9	6.7	4.7	3.4	3.4	3.6	1.0	4.1	7.5	4.1	5.7
1	518	37.09	11.3	18.1	5.8	4.8	2.5	13.2	6.5	4.4	4.0	3.3	3.6	1.2	4.0	7.4	4.1	5.6
1	520	36.66	11.3	18.4	5.7	5.2	2.7	13.0	6.7	4.2	3.2	3.3	3.7	1.2	4.2	7.5	4.1	5.9
3	544	40.12	12.0	18.3	5.9	4.7	2.4	10.9	6.7	4.6	5.2	3.7	3.5	1.1	3.9	7.7	3.2	6.3
1	602	35.91	12.3	18.2	6.9	4.2	2.3	9.7	6.3	4.5	4.4	3.6	3.9	1.1	4.4	7.8	3.9	6.7
3	731	35.97	13.3	19.4	6.5	4.1	2.4	8.3	5.3	4.3	4.8	3.6	4.4	1.1	4.6	7.1	4.4	6.4
1	752	36.82	13.4	19.3	6.4	4.1	2.6	8.2	4.6	4.2	5.2	3.9	4.3	1.1	4.7	7.1	4.4	6.5
13	793	36.07	13.3	19.2	6.6	4.1	2.4	8.1	4.9	4.2	5.3	3.9	4.3	1.1	4.6	7.2	4.4	6.4
1	918	38.24	12.6	22.1	5.6	4.8	1.6	8.5	5.4	3.9	4.5	3.3	3.8	1.1	4.1	8.4	4.5	6.0
1	1048	40.78	11.1	19.7	5.0	3.7	2.7	12.3	8.7	4.0	4.0	3.6	3.8	0.7	3.4	6.9	3.6	6.9
13	1055	30.04	10.6	18.3	4.7	3.7	2.5	12.0	8.8	5.2	4.9	3.5	4.0	0.7	3.6	7.3	3.7	6.7
3	1106	31.87	13.0	22.0	5.9	5.4	1.8	12.3	9.4	1.6	1.5	3.4	4.0	0.7	3.3	7.3	2.2	6.2
1	1107	38.85	11.5	19.7	5.3	4.0	2.4	13.1	9.0	4.4	4.0	3.1	3.6	0.6	3.2	6.9	3.5	5.8
13	1126	35.5	10.4	18.9	4.9	4.6	2.8	11.4	8.5	4.3	4.5	3.7	3.8	0.9	3.5	7.6	3.0	7.2
3	1430	59.08	6.6	10.0	3.3	3.2	1.6	7.8	39.5	4.2	3.8	3.5	2.3	0.4	2.0	4.7	1.7	5.3
3	1483	35.92	9.4	17.2	5.2	4.8	1.9	14.6	9.1	4.6	4.5	3.5	3.9	0.6	3.3	7.2	2.8	7.2
13	1749	38.8	10.2	18.7	5.3	4.7	2.3	12.7	9.1	3.8	3.7	3.7	3.8	0.9	3.7	7.7	4.0	5.8
1	1750	36.12	9.9	18.8	5.4	4.7	1.6	12.5	9.1	3.9	3.8	3.8	3.7	1.0	3.7	7.8	4.1	6.0
3	1	41.61	9.9	18.6	5.3	4.7	2.1	12.5	8.9	4.2	4.1	3.9	3.8	0.7	3.6	7.7	4.1	6.0
21	2	39.13	9.8	18.6	5.3	4.6	2.1	12.7	9.1	4.0	3.8	3.9	3.7	0.9	3.6	7.7	4.1	6.1
21	3	40.11	9.8	18.5	5.3	4.7	2.5	12.8	9.1	4.1	3.7	3.7	3.7	0.8	3.6	7.7	3.9	6.0
22	110	39.08	8.1	16.8	5.3	4.6	1.8	15.1	9.8	6.0	5.4	4.1	3.1	0.6	2.7	6.2	3.8	6.5
13	158	41.19	9.0	17.3	5.1	4.4	1.9	14.3	9.0	5.9	5.5	3.5	3.3	0.9	3.1	6.6	3.8	6.6
22	324	39.49	8.8	17.3	5.2	4.6	1.8	15.5	9.4	5.6	5.3	3.6	3.3	0.9	3.0	6.4	3.5	5.6
	Aver.	38.27	10.91	18.33	5.56	4.70	2.27	11.58	8.17	4.42	4.62	3.62	3.63	1.00	3.73	7.30	3.98	6.19
	Std. error	0.60	0.27	0.24	0.11	0.32	0.06	0.42	0.61	0.11	0.16	0.07	0.08	0.04	0.10	0.12	0.14	0.10

Table 8.4. Amino Acid Profile of Whole Soybeans, expressed as percentage of total amino acids analyzed

Company	Sample	Total	Asp	Glu	Ser	Gly	His	Arg	Thr	Ala	Pro	Tyr	Val	Met	Ile	Leu	Phe	Lys
Micronized N = 17 Table 8.4.b																		
4	128	39.3	11.2	19.6	5.9	5.6	2.8	8.1	3.1	4.3	5.3	3.8	3.8	1.0	4.1	8.1	7.1	6.1
4	156	39.7	11.3	17.6	5.8	4.8	2.3	12.3	6.8	4.0	4.5	3.8	3.0	1.3	3.8	7.3	5.3	6.0
4	166	40.3	11.4	17.6	5.7	4.7	2.5	12.9	6.5	4.2	5.0	3.5	3.2	1.2	4.0	7.2	4.2	6.2
4	180	42.4	11.3	17.9	5.7	5.0	2.4	12.7	6.6	4.5	5.2	3.3	3.1	1.2	3.8	7.3	4.2	5.9
4	274	37.98	11.6	18.5	5.9	4.9	2.4	13.3	6.7	4.1	3.2	3.5	3.9	1.3	4.3	7.4	3.9	5.1
7	496	37.18	11.5	18.6	5.8	5.0	2.6	13.1	6.7	4.4	3.4	3.4	3.8	1.3	4.2	7.7	4.0	4.5
4	545	37.09	12.5	18.5	6.1	4.4	2.4	10.1	6.7	4.4	4.6	3.3	3.7	1.1	4.1	7.8	4.2	6.2
4	574	34.08	11.3	17.7	4.8	4.4	2.1	10.8	7.5	4.8	4.1	3.4	3.6	1.3	3.9	7.2	5.5	7.6
17	794	36.28	13.3	19.2	6.6	3.9	2.4	8.0	4.8	4.3	5.3	3.9	4.2	1.1	4.7	7.3	4.4	6.5
4	890	38.31	12.5	21.9	5.5	4.4	1.6	8.4	5.4	3.8	4.6	3.3	3.9	1.3	4.2	8.4	4.6	6.4
4	1004	38.05	11.2	20.3	5.9	5.0	2.3	7.3	4.9	5.2	5.3	3.7	4.5	1.0	4.4	8.9	3.9	6.3
17	1056	46.42	8.0	13.9	3.6	24.4	2.1	8.9	6.7	4.4	4.1	3.0	3.0	0.6	2.8	5.7	2.8	6.1
4	1085	38.14	11.7	19.8	5.2	3.8	2.8	13.0	9.1	4.5	4.1	3.3	3.5	0.8	2.9	6.2	3.0	6.3
4	1125	35.59	10.9	19.3	5.1	4.6	2.7	12.3	8.9	4.0	3.1	3.8	3.9	0.8	3.5	7.8	2.9	6.3
17	1127	37.24	10.6	19.0	5.0	4.6	2.5	11.7	9.0	3.9	3.5	3.9	3.9	0.9	3.7	8.0	3.1	6.8
17	1744	38.06	10.0	18.4	5.4	4.7	2.5	12.7	9.2	3.9	3.7	3.8	3.9	0.9	3.7	7.6	3.8	5.7
4	1747	39.25	10.0	18.9	5.5	4.7	1.6	12.4	9.5	3.8	3.7	3.8	3.8	0.7	3.7	7.7	4.0	6.1
	Aver.	38.55	11.19	18.63	5.50	5.82	2.35	11.06	6.95	4.27	4.28	3.56	3.69	1.05	3.87	7.51	4.17	6.12
	Std. error	0.83	0.37	0.34	0.15	0.45	0.08	0.59	0.85	0.15	0.22	0.09	0.08	0.06	0.15	0.16	0.20	0.14
Jetsploded N = 7 Table 8.4.c																		
5	268	36.5	11.5	18.2	5.8	4.8	2.4	13.0	6.6	4.2	4.6	3.3	3.6	1.2	4.2	7.3	3.8	5.5
5	546	35.17	12.3	18.1	6.0	4.5	2.2	10.1	6.8	4.4	5.6	3.2	3.7	1.1	4.1	7.8	3.8	6.1
5	549	37.58	12.3	18.0	6.0	4.3	2.3	11.0	6.6	4.6	4.8	3.2	3.5	1.1	4.0	7.6	4.4	6.1
5	550	36.53	12.4	18.0	5.5	4.5	2.3	9.7	6.7	5.3	5.3	3.5	3.4	1.1	4.1	8.2	4.0	6.0
5	327	37.48	9.5	18.5	5.6	5.0	1.7	13.0	10.0	5.1	5.0	3.7	3.4	0.7	3.1	7.2	3.7	4.8
5	328	38.29	9.1	17.7	5.1	4.7	1.9	13.1	9.7	4.7	4.4	3.9	3.9	0.8	3.5	8.0	3.6	6.0
5	329	37.91	8.9	17.5	5.1	4.6	2.0	13.6	9.7	4.9	4.7	3.7	3.7	0.8	3.5	7.9	3.7	5.8
	Aver.	37.07	10.86	18.00	5.59	4.63	2.11	11.93	8.01	4.74	4.91	3.50	3.60	0.97	3.79	7.71	3.86	5.76
	Std. error	1.30	0.58	0.53	0.24	0.70	0.13	0.91	0.24	0.34	0.34	0.14	0.17	0.09	0.23	0.26	0.31	0.21

Table 8.4. Amino Acid Profile of Whole Soybeans, expressed as percentage of total amino acids analyzed

Company	Sample	Total	Asp	Glu	Ser	Gly	His	Arg	Thr	Ala	Pro	Tyr	Val	Met	Ile	Leu	Phe	Lys
Roasted	N = 32	Table 8.4.e																
0	551	36.84	12.8	18.6	5.3	4.7	2.2	8.5	7.9	4.7	4.8	3.4	3.6	1.1	4.1	8.0	4.0	6.2
8	618	31.99	13.1	18.4	6.6	4.2	2.4	7.3	5.9	5.0	4.2	3.7	4.2	1.3	4.7	8.0	3.9	7.1
11	656	30.13	13.0	18.0	6.8	4.4	2.4	7.6	6.1	4.3	3.6	3.8	4.3	1.4	4.8	8.5	3.9	6.9
12	657	35.92	13.4	19.3	6.6	4.2	2.4	7.0	5.5	4.7	4.2	3.5	4.2	1.3	4.7	8.2	4.1	6.5
15	730	30.36	13.4	19.3	6.6	4.1	2.4	8.3	4.7	4.3	4.4	3.8	4.5	1.0	4.8	7.2	4.5	6.6
16	753	36.05	13.5	19.1	6.6	4 0	2.4	8.2	4.7	4.2	5.2	3.9	4.3	1.2	4.7	7.2	4.4	6.4
8	804	38.23	13.7	19.7	6.4	4.0	2.2	8.6	4.2	4.2	5.3	3.7	4.3	1.2	4.6	7.2	4.2	6.4
12	880	35.16	12.5	21.5	5.7	4.3	1.7	7.7	5.5	4.5	5.3	3.3	3.8	1.0	3.8	7.8	4.5	7.1
14	968	34.19	11.2	20.1	6.1	5.0	2.4	7.4	5.1	5.4	5.2	3.8	4.6	1.0	4.4	9.0	4.0	5.2
8	1057	36.71	10.8	19.0	5.0	3.9	2.5	12.5	9.1	4.4	4.0	3.8	3.8	0.6	3.3	6.7	3.4	7.1
18	1128	38.43	10.5	18.8	4.9	5.0	2.8	11.8	8.9	4.1	3.6	3.9	3.9	0.9	3.5	7.8	3.0	6.7
9	1129	37.29	10.6	19.1	5.1	4.6	2.7	11.6	8.8	4.0	3.3	3.9	3.9	0.6	3.6	7.9	2.9	7.3
10	1133	38.74	10.6	19.2	5.0	4.6	2.7	12.0	8.9	4.6	4.0	3.7	3.8	1.0	3.4	7.5	2.9	6.0
20	1173	36.16	10.6	20.4	5.2	5.1	2.6	14.9	8.9	4.4	4.2	0.7	3.5	0.6	3.0	6.5	2.1	7.4
19	1238	38.07	10.8	18.7	5.2	5.1	2.4	12.5	8.7	4.6	4.0	3.7	3.9	0.6	3.5	7.5	2.8	6.0
19	1239	34.35	11.0	16.7	5.4	5.2	2.6	13.4	9.0	5.1	4.5	3.6	3.8	0.7	3.2	7.1	2.8	6.0
19	1240	38.59	10.5	18.8	5.2	5.0	2.4	12.5	8.3	4.8	4.5	3.5	3.8	0.6	3.3	7.5	2.8	6.5
8	1699	40.14	9.9	18.2	5.2	4.6	2.4	12.4	10.2	3.8	3.6	3.5	3.5	0.7	5.3	7.6	3.5	5.7
9	1742	38.07	10.3	19.2	5.5	4.8	1.8	12.1	8.9	3.7	3.7	3.8	3.9	0.9	3.7	7.8	4.1	6.0
18	1743	39.17	10.0	18.9	5.4	4.7	2.0	12.3	8.9	3.3	3.1	3.7	3.8	0.6	3.7	7.8	4.1	7.7
22	4	39.58	9.9	19.0	5.4	4.6	2.0	12.2	8.9	4.3	3.9	3.9	3.8	0.9	3.6	7.7	4.0	6.0
22	5	39.22	10.1	19.2	5.4	4.7	1.7	12.2	8.9	4.1	3.6	3.8	3.8	0.7	3.6	7.9	4.2	6.0
14	6	38.56	10.2	19.2	5.5	4.8	1.9	12.5	9.3	4.3	4.0	4.0	1.3	0.9	3.8	8.0	4.1	6.2
14	7	32.76	10.0	18.2	5.6	4.9	1.8	12.0	9.2	4.0	3.6	4.0	3.8	1.0	3.7	7.9	4.1	6.4
14	8	38.15	8.7	17.5	4.9	4.5	1.8	12.6	10.8	5.6	5.4	3.9	3.7	1.0	3.3	6.5	4.0	5.8
10	13	38.5	8.9	17.9	5.2	4.9	2.1	14.5	7.5	5.1	4.6	3.9	3.7	0.9	3.4	7.5	3.7	6.3
14	111	38.05	8.5	17.8	5.5	4.8	1.8	12.6	10.0	6.3	5.7	4.1	3.2	0.8	2.7	5.7	3.7	6.8
14	112	34.16	8.5	17.2	5.3	4.6	1.8	15.1	9.9	5.4	5.1	4.0	3.2	0.7	2.8	6.2	3.6	6.6
12	113	36.46	8.4	17.0	5.4	4.7	1.7	15.0	9.5	5.7	5.5	4.1	3.2	0.8	2.8	6.1	3.3	6.8
9	156	40.9	8.1	16.9	5.5	4.8	1.7	15.2	9.7	5.4	5.2	4.2	3.9	0.6	2.6	5.8	3.7	6.6
18	157	39.58	8.9	18.8	5.3	3.8	1.6	16.2	10.6	4.9	4.7	3.3	2.7	0.8	2.7	5.9	3.0	6.8
16	385	40.06	9.3	17.9	5.3	4.7	2.5	14.8	9.6	3.8	3.6	2.8	3.4	0.8	3.3	7.8	4.3	6.1
	Aver.	36.89	10.68	18.68	5.57	4.60	2.18	11.67	8.19	4.59	4.36	3.65	3.72	0.88	3.70	7.37	3.68	6.48
	Std. error	0.61	0.27	0.25	0.11	0.33	0.06	0.43	0.62	0.11	0.16	0.07	0.08	0.04	0.11	0.12	0.14	0.10

Raw		Table 8.5.1 Fatty acids as percentage of Fatty acids analyzed On D.M. Basis						
Source	Sample	14:0	16:0	18:0	18:1	18:2	18:3	22:0
4	167-0	0.1	10.8	3.4	22	55.4	8.3	
17	706-0	0.12	10.9	3.89	22.3	53.1	9.58	
4	181-0	0.1	10.6	3.9	23.5	54.5	7.4	
6	186-0	0.1	11.8	4	22.5	54.6	7	
4	273-0	0.1	12.1	3.7	21.3	54.6	8.2	
7	495-0	0.1	11.4	3.3	21.1	55.2	8.9	
7	498-0	0.1	11.2	3.7	20.9	55.8	8.2	
4	573-0	0.06	11.5	3.72	22.0	53.6	8.5	
9	619-0	0.05	10.8	3.95	21.8	55.2	7.47	
10	620-0	0.05	11.6	4.05	22.0	54.1	7.59	
17	707-0	0.15	11.1	3.52	20.7	55	8.88	
13	708-0	0.06	10.7	3.57	22.5	53.8	9.19	
14	710-0	0.05	9.67	2.82	21.9	56.9	8.52	
14	711-0	0.06	9.98	3.15	22.1	56.2	8.37	
9	791-0	0.05	10.5	3.47	19.8	57.1	8.87	
4	1003-0	0.05	12.00	3.94	25.20	49.50	8.10	0.20
10	1005-0	0.05	13.10	4.10	22.27	50.65	9.45	0.23
9	1054-0	0.04	12.02	4.09	23.20	52.51	7.63	0.20
4	1086-0	0.05	11.00	3.52	21.24	52.33	9.03	0.31
10	1093-0	0.07	12.07	3.94	20.32	52.95	10.25	0.35
4	1124-0	0.05	11.00	3.32	22.10	55.40	7.81	0.20
10	1700-0	0.12	11.83	3.83	23.88	50.59	8.29	0.53
4	1748-0	0.06	11.04	3.77	22.59	54.49	6.88	0.54
12	9-1	0.07	11.30	3.48	22.44	53.10	8.56	0.36
12	10-1	0.05	10.17	3.31	19.33	56.72	9.53	0.38
8	11-1	0.06	10.78	3.85	22.65	53.65	8.08	0.40
10	12-1	0.06	11.16	3.50	24.14	52.08	8.21	0.36
	Average	0.10	11.24	3.67	22.15	54.27	8.44	0.15
	Std. error	0.01	0.12	0.06	0.26	0.30	0.13	0.03

Extruded		Table 8.5.2 Fatty acids as percentage of Fatty acids analyzed On D.M. Basis						
Source	Sample	14:0	16:0	18:0	18:1	18:2	18:3	22:0
1	11-0	0.1	11.9	4.7	21.7	52.4	8.2	
1	135-0	0.1	11.5	3.9	21.7	54.7	8.1	
2	148-0	0.1	11	3.7	19	56.9	9	
2	149-0	0.1	11.5	3.9	20.9	55.4	8	
3	155-0	0.1	10.7	3.3	20.0	57.3	8.6	
1	165-0	0.1	11.2	3.5	22.7	54	8.5	
2	178-0	0.1	11.1	3.9	21.6	55.4	7.9	
3	182-0	0.1	11.8	3.7	24.7	51.7	7.5	
1	267-0	0.1	11.2	3.5	22.9	53.6	8.6	
7	497-0	0.1	11.2	3.7	21.6	54.6	8.2	
1	518-0	0.1	11.7	3.7	22.2	53	8.6	
1	520-0	0.1	11.4	3.5	22.6	53.5	8.6	
3	544-0	0.1	12.1	3.6	24.7	52.1	7.4	
1	602-0	0.7	10.8	3.63	22.5	53.4	8.83	
1	752-0	0.05	10.8	3.35	22.0	54.6	9.02	
13	793-0	0.05	10.7	3.22	20.1	57.1	8.67	
1	1048-0	0.05	11.45	4.13	25.37	51.08	7.60	0.20
13	1055-0	0.04	11.02	3.70	22.40	54.30	7.95	0.21
3	1106-0	0.06	12.00	4.25	20.30	54.30	8.35	0.25
1	1107-0	0.06	11.24	3.85	24.12	52.30	8.10	0.20
13	1126-0	0.05	11.45	3.75	22.10	55.00	7.25	0.20
3	1430-0	0.06	10.72	3.93	24.60	51.71	8.03	0.45
3	1483-0	0.05	10.11	3.40	22.00	54.95	8.56	0.45
13	1749-0	0.07	10.93	3.72	20.86	55.48	7.91	0.40
1	1750-0	0.08	10.13	3.56	22.66	54.15	8.41	0.37
3	1-1	0.11	11.43	3.72	22.79	52.48	8.45	0.36
21	2-1	0.07	10.66	3.66	21.52	55.51	7.65	0.38
21	3-1	0.07	10.82	3.82	22.67	54.45	7.23	0.42
22	110-1	0.05	10.67	3.67	22.10	55.47	7.17	0.39
13	158-1	0.05	11.23	3.29	20.64	54.00	8.68	0.40
22	324-1	0.05	10.59	3.70	22.11	55.34	7.33	0.41
	Average	0.12	11.18	3.71	22.25	54.41	8.17	0.17
	Std. error	0.01	0.11	0.05	0.24	0.28	0.12	0.03

Micronized		Table 8.5.3 Fatty acids as percentage of Fatty acids analyzed On D.M. Basis						
Source	Sample	14:0	16:0	18:0	18:1	18:2	18:3	22:0
4	128-0	0.1	11.4	3.8	21.3	55.6	7.8	
4	156-0	0.1	12	3.6	20.2	55.7	8.4	
4	166-0	0.1	10.9	3.3	21.8	55.4	8.5	
4	180-0	0.1	10.9	3.8	22.8	54.5	7.8	
4	274-0	0.1	12.1	3.8	21.1	54.3	8.5	
4	496-0	0.1	11.6	3.4	21.8	54.2	8.9	
4	545-0	0.1	12	3.9	21.9	54.7	7.4	
4	574-0	0.07	11.5	3.69	21.4	54.0	8.68	
17	794-0	0.05	10.7	3.3	20.2	56.9	8.79	
4	1004-0	0.04	12.10	4.10	25.20	49.31	8.20	0.21
17	1056-0	0.05	11.70	3.81	22.73	53.77	7.68	0.20
4	1085-0	0.05	10.93	3.76	22.00	54.50	8.41	0.20
4	1125-0	0.05	10.90	3.34	21.70	55.50	8.04	0.20
17	1127-0	0.05	10.50	3.62	22.70	54.65	8.10	0.30
17	1744-0	0.09	10.82	3.76	19.27	56.04	9.00	0.37
4	1747-0	0.15	11.83	4.24	23.64	51.58	7.17	0.38
	Average	0.10	11.39	3.71	21.91	54.56	8.23	0.12
	Std. error	0.02	0.16	0.07	0.33	0.39	0.16	0.04

Jetsploded		Table 8.5.4 Fatty acids as percentage of Fatty acids analyzed On D.M. Basis						
Source	Sample	14:0	16:0	18:0	18:1	18:2	18:3	22:0
5	268-0	0.1	11.4	3.8	21.9	53.3	9.1	
5	546-0	0.1	12	3.8	23	52.1	8.4	
5	549-0	0.07	10.9	3.91	22.8	52.7	8.86	
5	550-0	0.07	10.8	3.89	22.8	52.8	8.93	
5	595-0	0.07	10.5	3.9	23.6	52.3	8.77	
5	327-1	0.05	10.54	3.51	21.29	54.27	9.56	0.34
5	328-1	0.05	10.57	3.50	21.11	54.38	9.60	0.36
5	329-1	0.05	10.50	3.50	21.32	54.36	9.49	0.34
	Average	0.10	10.96	3.73	22.36	53.59	9.13	0.13
	Std. error	0.02	0.22	0.11	0.47	0.56	0.23	0.06

Roasted		Table 8.5.5 Fatty acids as percentage of Fatty acids analyzed On D.W. Basis						
Source	Sample	14:0	16:0	18:0	18:1	18:2	18:3	
9	792-0	0.05	10.8	3.63	20.1	56.8	8.53	
8	618-0	0.06	11.3	3.99	20.9	55.8	7.22	
12	657-0	0.11	10.7	3.54	21.2	55.5	8.59	
16	753-0	0.04	10.3	3.45	21.3	56.3	8.5	
14	968-0	0.05	11.60	3.98	22.48	54.60	6.90	0.20
8	1057-0	0.04	11.60	4.00	20.43	55.21	8.40	0.20
18	1128-0	0.06	11.50	3.35	20.25	56.15	8.30	0.30
9	1129-0	0.04	11.40	3.42	21.10	56.45	7.12	0.35
10	1133-0	0.06	11.75	3.31	23.15	53.10	8.25	0.25
20	1173-0	0.05	11.40	3.69	20.95	55.15	8.26	0.25
19	1238-0	0.05	10.50	3.10	20.05	57.00	8.85	0.30
19	1239-0	0.05	9.87	3.03	20.40	54.10	8.75	0.31
19	1240-0	0.06	10.67	4.00	23.80	53.55	6.95	0.45
8	1699-0	0.07	10.86	3.56	21.78	54.56	7.69	0.42
9	1742-0	0.10	11.51	3.81	22.22	52.88	8.38	0.35
18	1743-0	0.06	12.80	4.23	20.91	49.69	8.35	0.35
22	4-1	0.06	10.45	3.66	23.23	53.85	7.66	0.43
22	5-1	0.07	10.91	3.50	20.20	55.63	8.60	0.38
14	6-1	0.06	10.46	3.58	21.81	54.52	8.44	0.40
14	7-1	0.06	10.80	3.74	19.78	55.27	9.21	0.43
14	8-1	0.06	10.55	3.62	21.96	54.68	8.06	0.40
10	13-1	0.07	11.36	3.51	23.15	52.40	8.66	0.37
14	111-1	0.06	11.12	3.29	19.47	55.98	9.30	0.35
14	112-1	0.05	10.43	3.15	21.96	55.00	8.30	0.35
12	113-1	0.04	10.87	3.54	21.35	55.65	7.67	0.36
9	156-1	0.05	10.51	3.86	22.40	55.04	7.27	0.40
18	157-1	0.05	10.80	3.82	22.20	54.61	7.41	0.45
16	385-1	0.06	9.92	3.70	23.33	53.28	8.80	0.40
	Average	0.09	11.02	3.65	21.64	55.11	8.21	0.32
	Std. error	0.01	0.12	0.06	0.25	0.30	0.12	0.03

Table 8.6.1 Vitamin A & E content of full-fat soybeans Raw

Source	Sample	Vitamin A μg/g	Vitamin E μg/g
4	167-0	0.08	16.18
4	181-0	0.12	25.34
6	186-0	0.12	17.64
4	273-0	0.16	23.10
7	495-0	0.16	24.35
7	498-0	0.18	21.95
4	573-0	0.08	22.58
9	619-0	0.10	21.82
10	620-0	0.12	20.99
17	706-0	0.10	21.08
17	707-0	0.12	20.57
13	708-0	0.12	19.63
13	709-0	0.12	19.82
14	710-0	0.10	21.68
14	711-0	0.14	21.20
9	791-0	0.10	19.49
8	803-0	0.12	20.33
12	879-0	0.16	19.93
4	889-0	0.12	19.59
4	1003-0	0.10	19.55
10	1005-0	0.12	21.13
9	1054-0	0.12	19.46
4	1086-0	0.15	19.28
10	1093-0	0.08	19.19
4	1124-0	0.08	19.67
10	1700-0	0.16	20.81
4	1748-0	0.10	21.70
	Average	0.120	20.67
	Std. error	0.01	0.52

Table 8.6.2 Vitamin A & E content of full-fat soybeans Extruded			
Source	Sample	Vitamin A μg/g	Vitamin E μg/g
2	148-0	0.26	23.50
2	149-0	0.30	26.70
3	155-0	0.13	26.52
1	165-0	0.12	22.91
2	178-0	0.61	24.81
3	182-0	0.10	26.99
1	267-0	0.06	23.53
7	497-0	0.22	24.80
1	518-0	0.14	23.17
1	520-0	0.12	22.79
3	544-0	0.10	19.46
1	602-0	0.12	22.93
3	731-0	0.12	19.28
1	752-0	0.14	20.40
13	793-0	0.14	19.69
1	918-0	0.10	22.14
1	1048-0	0.14	19.46
13	1055-0	0.12	19.42
3	1106-0	0.10	19.52
1	1107-0	0.08	19.63
13	1126-0	0.08	20.16
3	1430-0	0.10	19.47
3	1483-0	0.10	20.79
13	1749-0	0.10	22.12
1	1750-0	0.12	22.05
	Average	0.161	21.82
	Std. error	0.01	0.53

Table 8.6.3 Vitamin A & E content of full-fat soybeans Micronized			
Source	Sample	Vitamin A μg/g	Vitamin E μg/g
4	156-0	0.10	27.72
4	166-0	0.18	28.58
4	180-0	0.12	27.38
4	274-0	0.20	24.86
4	496-0	0.24	25.58
4	545-0	0.08	19.52
4	574-0	0.14	21.36
17	794-0	0.12	20.76
4	890-0	0.12	21.47
4	1004-0	0.10	19.50
17	1056-0	0.10	19.93
4	1085-0	0.14	19.89
4	1125-0	0.08	20.17
17	1127-0	0.12	20.45
17	1744-0	0.12	21.03
4	1747-0	0.12	21.56
	Average	0.133	22.85
	Std.error	0.02	0.65

	Std.error	0.02	0.65

Table 8.6.4 Vitamin A & E content of full-fat soybeans Jetsploded

Source	Sample	Vitamin A μg/g	Vitamin E μg/g
5	154-0	0.10	13.16
5	168-0	0.12	20.74
5	268-0	0.08	26.42
5	546-0	0.12	19.03
5	549-0	0.12	19.42
5	550-0	0.12	19.85
	Average	0.109	18.68
	Std. error	0.03	1.01

Table 8.5.5 Vitamin A & E content of full-fat soybeans Roasted

Source	Sample	Vitamin A μg/g	Vitamin E μg/g
0	1188-0	0.30	18.74
0	551-0	0.12	19.57
8	618-0	0.14	20.61
11	656-0	0.12	21.07
12	657-0	0.10	20.32
15	730-0	0.12	19.47
16	753-0	0.12	20.35
9	792-0	0.10	19.35
12	880-0	0.14	19.68
14	968-0	0.12	19.46
8	1057-0	0.10	20.01
18	1128-0	0.10	20.10
9	1129-0	0.14	20.54
10	1133-0	0.10	22.73
20	1173-0	0.10	21.69
19	1238-0	0.14	20.32
19	1239-0	0.12	20.27
19	1240-0	0.10	19.92
8	1699-0	0.10	20.54
9	1742-0	0.12	21.38
18	1743-0	0.12	20.97
	Average	0.125	20.03
	Std. error	0.02	0.57

Table 8.7.1 Raw Soybeans						
					Pepsin digestibility	
Sample #	% CP on EE	TIU/mg sample	TIU/mg CP	Lysine avail.	% DM	% Protein
495	50.03	81.42	162.74	5.24	76.16	73.57
498	51.44	30.12	58.56	5.27	77.45	77.27
573	46.33	86.45	186.59	6.54	79.11	74.62
620	49.08	86.44	176.13	6.66	77.06	73.04
706	50.4	72.62	144.09	4.54	78.62	79.40
1003	51.43	75.67	147.13	5.48	78.84	75.64
Averages	49.46	71.41	145.62	5.65	77.68	75.58

Table 8.7.2 Extruded Soybeans						
					Pepsin digestibility	
Sample #	% CP on EE	TIU/mg sample	TIU/mg CP	Lysine avail.	% DM	% Protein
135	46.32	3.37	7.28	5.76	76.70	60.35
148	39.74	9.27	23.32	5.86	74.00	76.47
149	47.2	6.33	13.41	5.39	76.33	77.28
165	51.54	4.66	9.04	5.81	78.75	72.93
178	48.32	8.17	16.91	5.52	75.56	76.58
918	50.88	5.74	11.28	5.94	78.77	69.32
Averages	47.33	6.26	13.54	5.71	76.69	72.16

Table 8.7.3 Micronized Soybeans						
					Pepsin digestibility	
Sample #	% CP on EE	TIU/mg sample	TIU/mg CP	Lysine avail.	% DM	% Protein
128	50.24	5.22	10.40	6.58	78.15	72.53
156	50.72	6.28	12.37	5.53	78.73	72.32
166	51.72	5.65	10.92	5.84	79.70	74.04
180	53.61	9.18	17.12	5.98	77.37	71.90
1085	51.64	7.73	14.96	6.68	79.60	67.12
Averages	51.59	6.81	13.15	6.12	78.71	71.58

Table 8.7.4 Jetsploded Soybeans						
					Pepsin digestibility	
Sample #	% CP on EE	TIU/mg sample	TIU/mg CP	Lysine avail.	% DM	% Protein
153	51.95	6.15	11.84	5.72	76.00	72.45
154	52.16	5.67	10.87	6.27	78.09	71.71
168	52.83	5.40	10.21	6.13	76.18	67.55
546	46.38	8.65	18.65	5.28	71.84	71.09
1056	51.78	5.59	10.80	6.33	81.44	64.17
Averages	51.02	6.29	12.47	5.95	76.71	69.39

Table 8.7.5 Roasted Soybeans

Sample #	% CP on EE	TIU/mg sample	TIU/mg CP	Lysine avail.	Pepsin digestibility % DM	Pepsin digestibility % Protein
551	51.24	7.31	14.26	5.41	75.64	72.42
618	45.03	5.34	11.87	6.14	77.24	68.27
619	45.03	8.65	19.22	6.12	75.54	71.98
656	43.82	13.00	29.68	5.28	76.58	66.57
730	51.18	5.82	11.36	5.74	80.05	75.07
1128	55.01	10.20	18.54	6.11	80.15	70.03
Averages	48.55	8.39	17.49	5.80	77.53	70.72

8.7.6 Average of All Sources

Sample #	% CP on EE	TIU/mg CP	Lysine avail.	Pepsin digestibility % DM	Pepsin digestibility % Protein
Raw	49.46	145.62a	5.65	77.68	75.58a
Extruded	47.33	13.54b	5.71	76.69	72.16ab
Micronized	51.59	13.15b	6.12	78.71	71.58ab
Jetsploded	51.02	12.47b	5.95	76.71	69.39b
Roasted	48.55	17.49b	5.80	77.53	70.72ab
Average	49.54	-	5.83	77.48	71.99

8.8.1 Raw Soybeans

Correlation coefficients for different parameters	% CP on EE	TIU/mg CP	Lysine avail.	% Crude Protein Pepsin digest.
% CP on EE	-	-0.69	-0.70	0.43
Probability	-	0.13	0.12	0.40
TIU/mg CP	-	-	0.50	-0.55
Probability	-	-	0.31	0.26
Lysine availability	-	-	-	-0.76
Probability	-	-	-	0.08

8.8.2 Extruded Soybeans

Correlation coefficients for different parameters	% CP on EE	TIU/mg CP	Lysine avail.	% Crude Protein Pepsin digest.
% CP on EE	-	-0.74	-0.02	-0.17
Probability	-	C.095	0.97	0.74
TIU/mg CP	-	-	-0.07	0.70
Probability	-	-	0.90	0.12
Lysine availability	-	-	-	-0.43
Probability	-	-	-	0.39

8.8.3 Micronized Soybeans

Correlation coefficients for different parameters	% CP on EE	TIU/mg CP	Lysine avail.	% Crude Protein Pepsin digest.
% CP on EE	-	0.83	-0.16	-0.09
Probability	-	0.08	0.80	0.89
TIU/mg CP	-	-	0.05	-0.52
Probaility	-	-	0.94	0.37
Lysine availability	-	-	-	-0.63
Probability	-	-	-	0.26

8.8.4 Jetsploded Soybeans

Correlation coefficients for different parameters	% CP on EE	TIU/mg CP	Lysine avail.	% Crude Protein Pepsin digest.
CP on EE	-	-0.99	0.84	-0.27
Probability	-	0.001	0.08	0.67
TIU/mg CP	-	-	-0.90	0.36
Probability	-	-	0.39	0.55
Lysine availability	-	-	-	-0.56
Probability	-	-	-	0.33

8.8.5 Roasted Soybeans

Correlation coefficients for different parameters	% CP on EE	TIU/mg CP	Lysine avail.	% Crude Protein Pepsin digest.
% CP on EE	-	-0.40	0.11	0.51
Probability	-	0.43	0.84	0.30
TIU/mg CP	-	-	-0.44	-0.65
Probability	-	-	0.39	0.17
Lysine availability	-	-	-	0.10
Probability	-	-	-	0.85

8.8.6 All Sources

Correlation coefficients for different parameters	% CP on EE	TIU/mg CP	Lysine avail.	% Crude Protein Pepsin digest.
% CP on EE	-	-0.06	0.09	-0.01
Probability	-	0.77	0.66	0.97
TIU/mg CP	-	-	-0.10	0.39
Probability	-	-	0.61	0.04
Lysine availability	-	-	-	-0.40
Probability	-	-	-	0.037

8.8.7 All Sources except raw whole soybeans

Correlation coefficients for different parameters	% CP on EE	TIU/mg CP	Lysine avail.	% Crude Protein Pepsin digest.
% CP on EE	-	-0.52	0.32	-0.06
Probability	-	0.01	0.14	0.80
TIU/mg CP	-	-	-0.33	0.15
Probability	-	-	0.13	0.50
Lysine availability	-	-	-	-0.29
Probability	-	-	-	0.19

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