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PROCESSED SOYBEANS FOR YOUNG CALVES

by

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BVSc., Univ. of Khartoum, 1979

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Animal Nutrition

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1983

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ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. J. L. Morrill for his constant guidance and help in conducting research and in writing this thesis.

I would like to thank Dr. C. L. Norton and Dr. R. K. Burkhard for being on my supervisory committee.

I am deeply indebted to the African-American institute for their financial support throughout my program of study. I would also like to express gratitude to California Pellet Mill Co. for partial financial support for research. I would like to thank Dr. D. E. Johnson and Mr. Bruce Morrill for their effective help in the statistical analysis of research data. This thesis is dedicated to the University of Gezira-Wadmedani, Sudan with my best wishes for advancements and achievements.

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INTRODUCTION

Soybeans have a high protein and energy content. However, raw unheated soybeans contain several compounds which may lower the feed value of the beans. These include trypsin inhibitors, urease, lipase, and hemagglutinins which may cause gastrointestinal disturbances initiated by immunological mechanisms (Stead et al., 1966; Sissons, 1982).

Controlled heating decreased nitrogen solubility in grains and forages (Tagari et al., 1962; Glimp et al., 1967). Heat also increased protein bypassing the rumen (Hudson et al., 1970) and increased nitrogen retention (Nishimuta et al., 1973). The process of heating soybeans should minimize the activity of the antinutritional factors and at the same time achieve adequate rumen bypass for maximum protein utilization. Heat-treated soybeans were beneficial when fed to cows in early lactation (Schingoethe, 1982). Heating beyond a certain level will render protein simultaneously unavailable in both the rumen and the small intestine (Ørskov, 1982).

Young calves require a high protein, high energy, palatable feed (NRC, 1978). Soybean meal has been used as a source of protein in calf starters for many years in most parts of the United States. Limited amounts of full-fat soybeans have been used due to the economics of feeding whole soybeans and fear of poor utilization of whole soybeans

by the young calf because of the growth inhibitors contained in whole soybeans. Many processing methods are now available which may improve soybean utilization. These include expansion extrusion, popping, and roasting.

The benefit of rumen bypass was shown in calves (Hedde et al., 1974). Morrill et al. (1981) reported a beneficial effect when extruded soybeans were fed to young calves. Nitrogen retention was higher for calves fed roasted soybeans compared to that of calves fed microwave-cooked soybeans (Prasad and Morrill, 1976). Extruded soybeans were equal to soybean meal as a source of protein for dairy calves (Daniels et al., 1973b; Stutts, 1982). Calves fed expanded-extruded soybeans utilized feed more efficiently than those on soybean meal + fat (Daniels and Flynn, 1976).

In a preliminary study (Stutts, 1982), soybeans processed at different temperatures were evaluated for protein solubility, urease activity, and utilization by the calf in a N-balance study. N-retention was less when calves consumed raw soybeans compared to the heat-treated soybeans which were all similar in N-retention. Based on these results, three processing temperatures were selected and used in this experiment to further evaluate heated soybeans as a feed for young pre-weaned and weaned calves.

The correlation between plasma protein or immunoglobulin level of neonatal calves and susceptibility to infection has been well established (Gay et al., 1965). Normal calves had higher plasma protein concentration than those that died or needed assistance (Thornton et al., 1972; Cassidy et al., 1981). Warner et al. (1981) suggested a target plasma

protein of > 5.5% for satisfactory performance. Another objective of this study was to evaluate the effect of plasma protein level at 24 hrs of age on the subsequent performance of young Holstein calves.

LITERATURE REVIEW

Protein Nutrition in Ruminants

Utilization and Sources

Protein utilization by ruminants is distinctively different from other mammals. The principal differences are associated with the digestive processes, and in particular with the symbiotic relationship between the ruminant (host) animal and the microbial flora of the rumen and the hind-gut (Ørskov, 1982).

Ruminants are distinguished from monogastric animals by the development of a series of pouches anterior to their true gastric stomach--the abomasum. This forestomach is composed of the rumen, the reticulum, and the omasum (Harfoot, 1978).

The rumen is an ideal fermentation site. Comprising one seventh of the mass of most ruminants, the rumen is maintained at a relatively constant temperature (39°C), and is buffered by salivary secretions. Also, the rumen environment is one of extreme anaerobiosis; consequently, inhabitable microorganisms are strict anaerobes (James and Hespell, 1981).

Dietary protein can be classified into two categories: (1) undegradable dietary protein, which escapes the action of the rumen microorganisms and passes into the abomasum, and (2) rumen degradable

protein, which is hydrolyzed by proteolytic enzymes of microbial origin into its constituent amino acids. These amino acids are then deaminated, forming ammonia and carbon skeletons, both of which can be incorporated into microbial protein (Webster, 1980).

Microbial protein supply is a function of the quantity of organic matter fermented in the rumen, i.e. the energy available to the microbes, and the extent to which the available energy is used (Owens and Bergen, 1983).

Depending on a sufficient source of fermentable energy and other essential substrates, nonprotein nitrogen (NPN) such as urea can also be converted to ammonia and incorporated into microbial protein (Webster, 1980). Sources of ammonia in the rumen include: (1) degradation of dietary protein and NPN; (2) hydrolysis of urea recycled to the rumen and (3) degradation of microbial protoplasm. Destinations for ruminal ammonia include: (1) uptake by microbes; (2) absorption through the rumen wall, and (3) flushing to the omasum (Owens and Bergen, 1983). The ammonia absorbed through the ruminal wall will be carried to the liver where it is converted to urea, which can be recycled to the rumen as NPN via the blood and saliva, or excreted into the urine. The quantity of urea returned to the rumen appears to be negatively related to ruminal ammonia concentration and positively related to plasma urea concentration and to organic matter digestion in the rumen (Nolan and Leng, 1972; Kennedy and Milligan, 1980).

Postruminal protein digestion and absorption is similar to that of monogastric animals. Microbial protein and undegraded dietary protein pass from the reticulorumen into the omasum, where much of the water is

removed, then into the abomasum where gastric juice containing hydrochloric acid is secreted giving the abomasal contents the low pH necessary for the abomasal enzymes pepsin and rennin that hydrolyze proteins to simpler compounds. Rennin is important in curdling and digesting milk protein in the young ruminant (Miller, 1979). Principal enzymes acting on nitrogenous compounds in the small intestine appear to be similar to those of monogastric animals (Armstrong and Hutton, 1975). Trypsin, chymotrypsin and carboxypeptidase, the three major enzymes in the pancreatic juice, are involved in the further breakdown of partially-digested proteins to amino acids for absorption and utilization by the animal (Miller, 1979). Amino acids absorbed from the small intestine of ruminants are supplied by ruminal microbial protein, undegraded or protected feed proteins, amino acids which bypass the rumen, and endogenous secretions (Chalupa, 1975; Smith, 1975).

Tissues of ruminants, like those of other animals, cannot synthesize the carbon chain of certain amino acids (essential amino acids) which appear to be qualitatively the same as in monogastrics (Black et al., 1952; Black et al., 1957; Downes, 1961). The ruminant must depend on microbial protein synthesized in the rumen plus dietary protein and amino acids that escape degradation in the rumen for supply of essential amino acids. The difficulty of assessing quantitative essential amino acid requirements is due to ruminal fermentation and variation in requirements with age and type of function, i.e. wool growth, body growth, and lactation. Estimates of requirements were based on whole body protein synthesis or net protein deposition coupled with an ideal essential amino acids pattern (Hutton and Annison, 1972; Armstrong and

Annison, 1973; Owens et al., 1973; Bergen, 1980). Different workers reported different requirements of sulfur-containing amino acids, which appear to be the most limiting. However, after adjusting for factors like growth rate and apparent digestibility of nitrogen fed, requirements of ruminants and non-ruminants, expressed as grams per day per kg of metabolic body size ($\text{kg}^{0.75}$), were similar (Williams and Smith, 1974; Foldager et al., 1977; Tzeng and Davis, 1980).

Microbial protein, a major protein source for the ruminant, has a biological value between 66 and 87 (Johnson et al., 1944; Reed et al., 1949; Williams and Moir, 1951; McNanght et al., 1954; Chalupa, 1972). Bergen et al. (1968a,b) found the biological value, true digestibility, and net protein utilization of microbial protein to be similar to casein. Requirements of high producing ruminants will exceed the microbial protein supply of amino acids both in quality and quantity. In such a case, a supply of undegraded dietary protein (rumen bypass) is important for good performance.

Rumen Bypass and Degradability

The patterns and levels of the essential amino acids at the absorption sites may be a major limiting factor in ruminant nitrogen nutrition. The proportion of protein in natural feeds that escapes rumen degradation varies but under most conditions is between 20 and 60% (McDonald, 1954; Little et al., 1968; Chalupa, 1975; Mertens, 1977). Factors influencing the amount of protein bypassing degradation in the rumen include:

- (1) retention time in the rumen, which is determined by rate of passage which in turn is a function of feed intake, specific gravity, particle

size of diet, concentrate to roughage ratio, and rate of rumen digestion (Balch and Campling, 1965); and (2) protein solubility in rumen liquid, which is an inherent characteristic of proteins. Feedstuffs composed largely of albumins and globulins are normally more soluble than those composed primarily of prolamins and glutelins (Wholt et al., 1973). The maturity of plants at harvest affects the type of protein present in the total plant, and this influences the solubility of the plant protein (Waldo, 1968).

There is a variation in the rate by which individual amino acids are degraded in the rumen, with arginine and threonine rapidly degraded and valine and methionine least rapidly degraded (Lewis and Emery, 1962; Chalupa, 1974).

Protein Degradability Estimates

Due to the complexity of measuring protein bypass or degradability in animals, many in vitro systems have been used to predict ruminal proteolysis for various protein sources (Broderick, 1982). These include measurement of solubility in various solvents, loss of protein or accumulation of ammonia or amino acids in vitro, and loss of protein upon incubation with various proteolytic enzymes. In vivo measurements and animal response are the only applicable methods to evaluate these screening methods and directly determine bypass. Solubility plus in situ measurements may correlate with bypass values when adjusted with some reference protein (Owens and Bergen, 1983; Zinn and Owens, 1983).

Several test solutions have been used to estimate solubility of protein. These include Wise Burroughs mineral mixture (Burroughs et al.,

1950), diluted NaOH (Lyman et al., 1953), 0.15M NaCl (Krishnamoorthy et al., 1982), artificial saliva (Tagari et al., 1962; Wholt et al., 1973), autoclaved rumen fluid (Wholt et al., 1973), diluted solution of pepsin in 0.1N HCl (Beever et al., 1977), and water at various temperatures (Mertens, 1977). Disagreement between the results of different solvents may be explained by factors such as temperature, degree of agitation, extraction time, and ionic strength of solvent (Wholt et al., 1973). Krishnamoorthy et al. (1982) concluded that protein solubility varies with type of solvent and feedstuff.

Although solubility is important in estimating degradability, recent evidence questions the assumption of total degradation of all sources of soluble protein. Certain proteins, though soluble, appear to resist protease in vitro. Soluble proteins from soybean meal, rapeseed meal, and casein were hydrolyzed at different rates (Mahadevan et al., 1980).

In vivo methods involve the use of postruminal cannulae in the abomasum or small intestine. Undegraded dietary protein can be estimated as the difference between total protein and microbial protein entering the abomasum or small intestine, after estimating the microbial protein. The latter can be estimated by markers (Clarke, 1977; Broderick, 1982; Stern et al., 1982). Another technique involves the use of polyester bags containing substrate incubated in the rumen (Mehrez and Ørskov, 1977; Weakley et al., 1983). A drawback of this method is that soluble protein may be washed out without actually being degraded, weakening the assumption that rate of disappearance of protein from the bag represents rate of degradation (Mohamed and Smith, 1977).

Improving Protein Utilization in Ruminants

Several workers have demonstrated the beneficial effect of supplying a bypass protein source in ruminants. Work by Wholt (1973) and Sniffen (1974) indicated that as solubility of dietary protein decreased, protein degradation in the rumen and urinary nitrogen excretion decreased, and nitrogen retention increased in sheep and growing cattle. Provided that microbial requirement for nitrogen is adequate, supplying ruminants with high quality protein with the ability to bypass rumen degradation and thus provide and improve the pattern and quantity of amino acids at the absorption sites may be beneficial, especially for high producers and growing ruminants.

Protection of Proteins to Improve Utilization

Processing methods used in feed manufacturing can either increase or decrease ruminal degradation of proteins. Increased degradation may be the result of disruption of the protein matrix whereas heat applied or generated during processing can decrease ruminal degradation of protein (Hale, 1973). Heating will result in crosslinking within and between protein molecules, mainly because of reactions between free amino acid groups and other reactive groups on amino acid residues (Finely and Friedman, 1973). Most feed proteins, particularly those in grains and oilseed meals, are present in the diet with large amounts of carbohydrates. Heating of proteins in the presence of carbohydrate results in Schiff base formation between free amino acids and aldehyde groups as well as many other reactions (Broderic, 1974). As a result, controlled heating decreased nitrogen solubility in grains and forages

(Tagari et al., 1962; Glimp et al., 1967; Nishimuta et al., 1974; Beever et al., 1975). It also increased protein bypassing the rumen (Hudson et al., 1970) and increased nitrogen retention (Nishimuta et al., 1973). However, heating beyond a certain level will render the protein simultaneously unavailable in both the rumen and small intestine (Ørskov, 1982).

Certain chemical agents form reversible cross linkages with amino acids and amide groups which decrease solubility of proteins at the pH of the rumen. Chemically-treated proteins are subsequently made available to the host animal by destruction of these linkages in the acidic abomasum (Chalupa, 1974).

Formaldehyde treatment of casein generally has resulted in increased nitrogen retention, wool growth and muscle growth (Barry, 1972; Faichney, 1971; Wright, 1971). On the other hand, treatment of plant proteins has not yielded consistent responses. Faichney (1971) and Tamminga (1979) reported improvement in weight gain in young ruminants and milk production in dairy cows when fed formaldehyde-treated proteins. Wachira et al. (1974) reported no benefit from formaldehyde-treated rations for lambs and lactating cows and concluded that formaldehyde treatment may be of benefit if younger lambs and high producing cows in early lactation are used. Steers fed formaldehyde-treated soybean meal gained significantly less than those fed soybean meal; a digestion trial indicated that the soy protein had been over-treated, lowering its apparent digestibility (Schmidt et al., 1973). Broderic et al. (1978) reported a slight trend toward greater milk production, true protein and total protein in milk when a ration supplemented with formaldehyde-treated casein was fed to cows.

Tannins have also been used to protect proteins. They decrease protein degradability in the rumen by forming cross linkages between proteins and other molecules (Huber and Kung, Jr., 1981). Addition of 10% tannin to soybean meal decreased in vitro deamination 90% and when fed to lambs increased gain, feed efficiency, and nitrogen retention (Driedger and Hatfield, 1972). However, Nishimuta et al. (1974) found no benefit from feeding soybean meal treated with 9% tannic acid to steers.

Another technique used to reduce ruminal protein degradation and thus improve utilization was the use of fat, which resulted in reduction in ruminal ammonia concentration when added to groundnut or coconut meals fed to sheep (Jayasinghe, 1961). Volatile fatty acids were used by Atwal et al. (1974) to protect a mixture of soybean meal and promine protein.¹ The result was reduction in ruminal ammonia release in vivo. It was suggested that the presence of propionic acid (contained within the volatile fatty acids) in close proximity to the proteins had a bacteriostatic effect on ruminal microbes.

The natural rumen bypass method is closure of the esophageal groove to provide an extension of the esophagus from cardia to the reticulo-omasal orifice. Esophageal groove closure is a normal function in young ruminants, but occurs rarely in mature animals (Chalupa, 1975). Factors influencing closure include age, temperature of the liquid, posture of the animal while drinking, site of delivery in the esophagus and chemical composition of the liquid (Ørskov, 1972). With respect to the

¹Isolated soya protein.

latter, there are reports that the groove is activated by presence in the mouth of salts of sodium (Reik, 1954), copper (Watson and Jarret, 1941) and zinc (Mönning and Quin, 1935). Rumen bypass of nutrients by closure of the esophageal groove has resulted in significant improvements in growth rate and feed efficiency (Ørskov, 1972); however, practical methods for stimulating the reflex have not been established.

Other methods for improving protein utilization by ruminants include use of amino acid analogs, encapsulated amino acids, and alteration of rumen metabolism (Clark, 1974).

Soybean Meal and Processed Soybeans for Ruminants

Soybean meal (SBM) has been the major protein supplement in many parts of the United States for many years. SBM is prepared by crushing the beans and removing fat, either mechanically with hydraulic or expeller extraction, or by solvent extraction. Most SBM produced is solvent extracted with hexane being the organic solvent normally used. The hexane-laden flakes are then passed through a desolventizer-toaster. This equipment recovers the hexane as it toasts. The amount of moisture, heat and time involved in this process can affect the quality of the resulting SBM (Schingoethe, 1982).

Raw soybeans contain several compounds which lower their nutritive value and feed quality. These include trypsin inhibitors, urease, and lipase (Schingoethe, 1982). While Kakade et al. (1976) concluded that soybeans trypsin inhibitors play a minor role and failed to exert deleterious effects in calves, heating raw soybeans may help to destroy urease activity and thus prevent conversion of urea to ammonia by urease

and also limit lipase activity and thus control rancidity. This will result in increasing the storage life of soybeans and also decrease protein solubility to provide rumen bypass which is beneficial to high producing dairy cows and growing animals (Schingoethe, 1982).

Several methods have been used to improve utilization of SBM and whole soybeans by ruminants. The optimal treatment should reduce protein degradability to provide high quality protein past the rumen for postruminal degradation, yet it should allow adequate nitrogen to become available for optimal rumen microbial growth (Nishimuta et al., 1973).

Treating SBM with formaldehyde has received wide attention. Schmidt et al. (1974) failed to observe any benefit from feeding formaldehyde-treated SBM to steers and lambs; using several formaldehyde levels, they suggested that this was due to the reduction of ruminal NH_3 below the desirable levels necessary for optimal microbial synthesis, which was caused by overprotection of the soyprotein. Similar results were reported by Clark et al. (1974) using lactating cows. Nishimuta et al. (1974) concluded that heat and formalin treatment significantly increased the amount of total protein presented to the abomasum, but formalin treatment may cause the SBM protein to be resistant to postruminal enzymatic degradation. Comparing formalin to heat treatment, nitrogen retention in lambs was highest for heat-treated rations. This indicated resistance to postruminal degradation of the formalin-treated protein.

Tannic acid treatment of SBM increased nitrogen retention in lambs (Driedger et al., 1969).

Decreasing protein solubility of SBM by heat improved nitrogen retention in lambs (Sherrod and Tillman, 1962; Glimp et al., 1967;

Hudson et al., 1970). Tagari et al. (1962) reported similar results. Heat-treated SBM, when compared to solvent-extracted SBM, resulted in slightly more milk production during the first 8 weeks of lactation but no change during the later part of lactation (Ahrar and Schingoethe, 1979).

Utilization of Full-fat Soybeans

Several methods are available for processing whole soybeans. These include expansion extrusion, roasting, and popping (Daniels and Flynn, 1976) and dry hot air (Stutts, 1982). Moisture is used in the form of steam for some processes during roasting, cooking, or extruding (Schingoethe, 1982).

Different workers have reported different results on the use of full-fat soybeans for lactating cows. Heat-treated soybeans were beneficial when fed to cows in early lactation. There was no real advantage for the heat-treated products for cows in mid to late lactation (Schingoethe, 1982). Yu (1978) concluded that treating soybeans with dry heat at 140°C for 4 hours or formaldehyde (3.5g/100g soybean protein) reduced nitrogen digestibility markedly in the rumen but not in the small intestine. Mielk and Schingoethe (1981) observed no differences in milk production, milk fat, or total solids when they compared SBM, heat-treated soybeans, and unheated soybeans in concentrate mixtures for lactating cows in their first 7 weeks postpartum. Roasting soybeans at 118°C for 3.5 minutes increased their acceptability; however, this process did not alter coefficients of apparent digestibility for crude protein, crude fiber, ether extract or dry matter; fat-corrected milk production was

not affected (Rakes et al., 1972). Satter (1981) reported a beneficial effect from feeding extruded soybeans to lactating cows. This agrees with results reported by Smith et al. (1980), where cows in early lactation produced significantly more milk on extruded soybean diets.

Although whole soybeans can provide extra energy, limited amounts of full-fat soybeans have been used as a source of protein in calf starters. This is because of: (1) the economics of feeding whole soybeans compared to SBM or other protein sources and (2) the fear of poor utilization by the young calf due to the antinutritional factors contained in soybeans (Daniels and Flynn, 1976). Kakade et al. (1976) fed raw soybeans and heated soybeans with trypsin inhibitor added as a control to young calves and concluded that soybean trypsin inhibitor plays a minor role, if any, in calf nutrition. However, Daniels et al. (1973a) using raw, expanded extruded and roasted soybeans, suggested that the trypsin inhibitor in raw soybeans was not completely destroyed in the rumen of young cattle. This was postulated to be the reason for the lower digestible protein, energy, and dry matter for the raw soybeans fed to heifers averaging 157 kg. However, there was no significant difference in gains. In another report, Daniels et al. (1973b) concluded that extruded soybeans were equal to SBM as a source of protein for dairy calves. Morrill et al. (1981) reported a beneficial effect when extruded soybeans were fed to young calves. Stutts (1982) found no significant difference between SBM and extruded soybeans fed to calves up to 8 weeks of age.

Prasad and Morrill (1976) reported no significant differences in the digestibilities of dry matter, ether extract, or nitrogen-free

extract, but nitrogen retention was higher for roasted compared to microwave-cooked soybeans. Using calves from 3 to 112 days of age, Daniels and Flynn (1976) compared soybeans roasted in an infra-red cooker for 2 minutes at 121°C, extruded soybeans at 135°C and SBM plus 2% fat, and reported a significantly lower growth rate with the roasted soybeans compared to the other two. Calves fed expanded-extruded soybeans utilized feed more efficiently than SBM + fat. Sudweeks et al. (1978) observed no benefit from feeding roasted soybeans - 138°C exit temperature - to beef calves.

Dairy Calf Management

Colostrum Feeding and Immunity

The blood of the newborn calf contains no antibodies until it has received colostrum. The calf should have colostrum within 3-4 hours of birth (Logan et al., 1978) and for the first 4 days of life (Roy, 1980a), to get protection with immunoglobulins. The correlation between serum protein or immunoglobulin levels of neonatal animal and susceptibility to infection has been well established in the calf, lamb, and pig (Gay et al., 1965). Normal calves had significantly higher serum protein concentration than those calves that died or needed assistance (Thornton et al., 1972; Cassidy et al., 1981). Warner et al. (1981) confirmed the significance of colostrum feeding as soon as possible after birth and suggested a target plasma protein of > 5.5 for satisfactory performance.

Calf Feeding

Young calves do not consume dry feed readily and depend on milk or liquid replacement for nutrients (Appleman et al., 1975).

Grains and plant proteins are of much lower cost than milk or ingredients suitable for use in milk replacers. Thus it is recommended to utilize those nutrients from cheaper sources as early as feasible by offering the calf a high quality dry feed as soon as possible (Miller, 1979). The majority of calves can be weaned by the 5th week of age, the main exceptions being those which have suffered a severe setback from diarrhea. As a rough guide, calves should not be weaned unless they are eating at least 0.34 kg concentrate per day and preferably not under a live weight of 50 kg (Roy, 1980b).

Quality calf starters that are consumed readily are essential to dairy herd replacement rearing and early weaning programs (Otterby and Linn, 1981). Recommended nutrient content for starters has been published (NRC, 1978). Simple well-balanced preparations have supported growth as well as more complicated formulations (Miller et al., 1969). Various sources of protein such as soybean, linseed, cottonseed, rapeseed, peanut, sunflower, meat and fish meals were satisfactory in starters and dried skim milk was not superior to vegetable proteins (Otterby and Linn, 1981).

MATERIALS AND METHODS

Six calf starters (table 1) were compared to evaluate heat-processed whole soybeans as the major protein source for young calves. Whole soybeans used in starters 4-138, 5-171 and 6-191 were processed using a Model-2 Jet-sploder.¹ The flow diagram of the process is shown in figure 1. The process consisted mainly of feeding raw whole soybeans by gravity into the Jet-sploder's heat exchanger. Super hot air was then pumped through jets in the exchanger, quickly heating the soybeans and also transporting them through the unit to the outlet where they were rolled. The air flow system, electronic controllers, and variable speed feeder ahead of the rolls resulted in the desired residence time for soybeans (35, 65, or 110 seconds) and thus the desired exit temperature (138, 171, or 191 respectively).

All the starters were formulated to be iso-nitrogenous, with starter 2-SBM+fat made iso-caloric to the whole soybean-containing starters by the addition of animal fat.

One hundred and twenty-one male and female Holstein calves were used. Blood was sampled at approximately 24 hours of age to determine plasma protein (PP) % and packed cell volume (PCV) by use of a refractometer²

¹California Pellet Mill Co., 1800 Folsom St., San Francisco 94103.

²American Optical, Scientific Instrument Division, Buffalo, New York 14215.

and a microhematocrit centrifuge, respectively. The first six calves were randomly assigned to the six starters and calves in each subsequent group of six were assigned in the same way at 24-48 hours of age. Two types of housing were used. Some males were housed in a mechanically-ventilated building having 0.8m x 1.2m individual pens bedded with wood shavings. The temperature was maintained between 13 and 20°C. Other calves, both male and female, were housed in 1.2m x 1.2m wood hutches bedded with straw.

The calves were fed 2 quarts of colostrum as soon as possible after birth, and for the following three days colostrum, divided into two feedings, was also fed at the rate of 8% of body weight at birth per day. Afterwards milk was fed at the rate of 8% of body weight at birth per day in two feedings, until weaning at 5 weeks of age, provided that they were eating ≥ 0.45 kg of starter per day. Each calf was fed starter individually from the first week of life and had access to the starter all the time. The starters were fed in small amounts and changed as necessary to ensure freshness. The calves were fed the same starter ad lib until the end of the trial when the calves were eight weeks of age. Water was available all the time except during cold nights. The calves were observed twice daily for general appearance, sickness, and scours (Larson et al., 1977). Weights and starter consumption were recorded weekly.

The starters, soybean meal, and raw and processed soybeans were sampled and analyzed for crude protein, ether extract, crude fiber, and nitrogen free extract (AOAC, 1980). Soybean meal and raw and processed soybeans were also analyzed for acid detergent unavailable protein

(Goering and Van Soest, 1970) and protein dispersibility index (PDI) (AACC, 1969). Processed soybeans were also analyzed for trypsin inhibitor activity (AOAC, 1980 and AOCS, 1982).

The data were analyzed using factorial analysis of variance with repeated measures (week) and multivariate analysis for PP and PCV. Treatment means were tested by least significant difference where appropriate.

RESULTS

Results of chemical analysis of starters are in table 2. Trypsin inhibitor activity, protein dispersibility index (PDI), and acid detergent unavailable protein (ADUP) for SBM and whole soybeans are in table 3. As the processing temperature increased, trypsin inhibitor and PDI decreased and ADUP increased. In a preliminary evaluation, Stutts (1982) reported no detectable urease activity in soybeans processed at 138, 171, or 191°C, the same temperatures used in this study. These results indicate that more heat is required to completely suppress trypsin inhibitor activity than urease activity. McNaughtan et al. (1981) reported similar results.

From 121 calves originally assigned to the experiment, 20 calves did not complete the 8-week period (either due to death or sickness). The distribution of these calves among the six starters is shown in table 4. Even though the differences between 5-171 and 6-191 and the other four starters were large, they were not significant ($P > 0.05$).

In this trial PP and PCV (measured at approximately 24 hours of age) had no significant effect during the 8-week period on feed consumption, weight gain, or scours score (table 5). PP values were available for 120 calves; of these 72 (60%) had $PP > 6\%$, of which 3 calves were sick and removed and 7 more (9.7%) died. Of the 48 calves having $PP \leq 6\%$, one was sick and removed and 9 more (18.7%)

died. Naylor et al. (1977) reported that, during a trial, all calves that died up to 5 weeks of age had a PP < 6%. Based on these results and work by Cassidy et al. (1981) and Warner et al. (1981), feeding and management systems for neonatal calves should aim to produce plasma protein in excess of 6% by feeding adequate amounts of colostrum as soon as possible after birth.

Average weekly gains, starter consumption, and scours scores for calves housed in hutches and those housed in pens are presented in appendix tables II - VII. All calves lost weight during the second week except those on starter 5-171 housed in hutches (appendix table II). The incidence of scours tended to be lower when the calves were weaned and were fed only dry feed.

Calves Housed in Hutches. Analyses of variance and probabilities for starter consumption, weight gain, and scours score are in table 6. Weight gains were different between starters ($P=0.02$) but not between sexes ($P=0.48$). Least square means for weekly gains (table 7) were higher ($P<0.05$) for calves on 5-171 than all the other starters except those on 6-191, while gains for calves on 6-191, 4-138, 3-Raw, and 1-SBM were not statistically different ($P>0.05$) from each other.

Feed consumption was different ($P=0.07$) between starters but not between sexes ($P=0.73$). Least square means for weekly starter consumption (table 7) were not significantly different ($P>0.07$) between calves on starters 5-171, 6-191, 4-138, and 3-Raw. Calves on 1-SBM and 2-SBM+fat had the lowest feed consumption, significantly lower than those on 5-171 and 6-191.

Scours score was different ($P=0.01$) between starters but not between sexes ($P=0.30$). Least square means for weekly scours score are in table 7. The lowest score (least scours) was for calves on starter 5-171 which was significantly lower ($P<0.05$) than all the others except those on 6-191. Scours scores for calves on 6-191, 2-SBM+fat, 3-Raw, 4-138 and 1-SBM were not different ($P>0.05$).

Calves Housed in Pens. The analysis of variance is in table 8. Weight gains were not different between starters ($P=0.31$) nor were feed consumption ($P=0.37$) and scours score ($P=0.14$). However, performance in almost all measurements favored starters 5-171 and 6-191. Least square means for weekly weight gain, starter consumption, and scours score are in table 7. Inability to detect a significant starter effect on the performance of these calves may be explained by the fact that a small number was used in pens, which did not provide sufficient data to detect a statistically significant effect.

Discussion

Whole soybeans processed at 171°C as the major protein supplement resulted in superior calf performance up to 8 weeks of age compared to the other supplements used in this experiment. Processing at this temperature sufficiently suppressed antinutritional factors contained in raw soybeans and reduced protein solubility (PDI of 13.8%) and thus probably provided rumen protein bypass for a better protein utilization. Processing at 191°C , resulting in a PDI of 9.7% and ADUP of approximately 3% of dry matter (table 3), might have resulted in overheating the soy protein. Processing at 138°C did not sufficiently

suppress antinutritional factors and probably did not provide enough rumen bypass (PDI of 34.1) for efficient protein utilization.

The performance of calves on 3-Raw was unexpectedly good; antinutritional factors of raw soybeans apparently did not cause very severe deleterious effects on these calves. Kakade et al. (1976) concluded that trypsin inhibitor plays a minor role, if any, in calf nutrition, and work by Sissons (1982) indicated that most of the unfavorable effects of the antinutritional factors were associated with liquid feeding when preruminant calves were fed milk replacers containing soyprotein. However, utilization of the raw soybeans starter tended to improve as the calves advanced in age, a phenomenon that might be connected with palatability as well as rumen development and destruction of growth depressing agents in the rumen.

The inferior performance of calves on starter 2-SBM+fat was similar to that reported by Stutts (1982). The significantly lower starter intake, which was only comparable to that of the raw soybean starter (table 7), may indicate a palatability problem which in turn resulted in the lowest weight gain. On the other hand, the lower than expected level of performance of calves on 1-SBM may be explained by the lower energy content compared to other starters (table 9).

These results provide a guideline for processing soybeans for use as the major protein supplement in calf starters.

TABLE 1. INGREDIENT COMPOSITION OF STARTERS^a

Ingredients	%					
	1-SBM	2-SBM +Fat	3-Raw	4-138	5-171	6-191
Corn cobs, ground	9.95	9.97	9.99	10.07	10.10	10.12
Corn, rolled	40.23	40.32	40.39	40.72	40.87	40.95
Oats, rolled	20.12	20.16	20.20	20.36	20.43	20.47
Soybean meal ^b	15.29	15.85				
Animal fat		1.57				
Soybean, ground, raw			19.05			
Soybean, ground, 138 ^c				18.39		
Soybean, ground, 171 ^c					18.10	
Soybean, ground, 191 ^c						17.93
Sorghum grain, rolled	8.04	5.75	3.98	4.01	4.03	4.04
Dry molasses	4.66	4.67	4.68	4.72	4.74	4.75
Salt	0.22	0.22	0.22	0.23	0.23	0.23
Trace mineral salt	0.22	0.22	0.22	0.23	0.23	0.23
Limestone	0.97	0.97	0.97	0.98	0.98	0.98
Dicalcium phosphate	0.30	0.30	0.30	0.30	0.30	0.30
Vit. A and D	d	d	d	d	d	d

^aAs fed basis.^bFrom a single source throughout the experiment.^cIndicates processing temperature (°C).^d1,000,000 A and 50,000 D/0.5 kg; 41g added/45.5 kg starter.

TABLE 2. CHEMICAL COMPOSITION OF STARTERS

Component	1-SBM	2-SBM +Fat	3-Raw	4-138	5-171	6-191
Dry Matter (%)	87.3	87.3	87.9	88.4	86.2	87.6
	% Dry Matter					
Crude protein	17.2	15.5	14.3	15.6	15.4	16.6
Ether extract	3.1	3.8	6.2	7.4	5.9	6.5
Crude fiber	8.8	7.8	9.3	7.9	6.1	8.4
Ash	4.9	7.3	5.1	5.2	4.7	4.8
Nitrogen free extract	66.0	65.6	65.1	63.9	67.9	63.7

TABLE 3. SELECTED MEASUREMENTS OF SOYBEAN MEAL AND
WHOLE SOYBEANS USED IN STARTERS

	SBM	Raw	138	171	191
Trypsin inhibitor ^a (TIU ^b /mg)			13.8	5.0	1.2
Protein dispersibility index ^c	47.5	92.6	34.1	13.4	9.9
Crude protein ^d	41.9	37.4	38.6	38.4	39.0
Acid detergent unavailable protein ^d	1.6	1.3	1.5	2.0	2.9

^aRun on defatted sample.

^bTrypsin inhibitor units.

^cAs a percent of total protein.

^dAs a percent of dry matter.

TABLE 4. NUMBER OF CALVES ASSIGNED TO AND
REMOVED FROM THE EXPERIMENT GROUPED BY STARTER

Starter	Assigned	Removed
1-SBM	20	6
2-SBM+fat	20	5
3-Raw	21	4
4-138	20	4
5-171	20	0
6-191	<u>20</u>	<u>1</u>
Total	121	20

TABLE 5. PROBABILITY OF AN EFFECT OF PLASMA PROTEIN AND
PACKED CELL VOLUME ON FEED CONSUMPTION, WEIGHT GAIN,
AND SCOURS SCORE¹

	Feed consumption	Gain	Scours score
	Probability of > F		
Plasma protein	0.67	0.25	0.92
Packed cell volume	0.21	0.52	0.69

¹Tested by Wilk's criterion (Chatfield and Collins, 1980; Johnson et al., 1980).

TABLE 6. ANALYSES OF VARIANCE FOR STARTER CONSUMPTION,
WEIGHT GAIN, AND SCOURS SCORE FOR CALVES IN HUTCHES

Source of variation	d.f.	Starter consumption		Gain		Scours score	
		MS ^a	P ^b	MS	P	MS	P
Sex	1	0.61	0.73	1.14	0.48	0.26	0.30
Starter	5	10.86	0.07	5.95	0.02	0.81	0.01
Sex * Starter	5	4.96	0.45	2.08	0.47	0.42	0.14
Error	82	5.23		2.27		0.25	

^aMean square.

^bProbability.

TABLE 7. LEAST SQUARE MEANS FOR WEEKLY WEIGHT GAIN, STARTER CONSUMPTION, AND SCOURS SCORE BY STARTER¹

Starter	Weight gain (kg)		Starter consumption (kg)		Scours score	
	Hutches	Pens	Hutches	Pens	Hutches	Pens
5-171	3.44 ^b	2.21	5.81 ^a	4.11	1.58 ^b	1.68
6-191	2.98 ^{ab}	2.67	5.61 ^a	3.77	1.86 ^{ab}	2.00
4-138	2.33 ^{ac}	1.73	4.43 ^{ab}	4.00	1.97 ^a	2.49
3-Raw	2.16 ^{ac}	0.74	4.36 ^{ab}	1.59	2.02 ^a	2.29
1-SBM	1.96 ^{ac}	1.79	3.98 ^b	3.12	2.17 ^a	1.88
2-SBM+Fat	1.90 ^c	0.54	3.84 ^b	1.32	2.19 ^a	2.24

¹Averaged across weeks.

^{abc}Means within column with the same letter are not different ($P > 0.05$ for gain and scours score, $P > 0.07$ for starter consumption).

TABLE 8. ANALYSES OF VARIANCE FOR STARTER CONSUMPTION,
WEIGHT GAIN, AND SCOURS SCORE FOR CALVES IN PENS

Source of variation	d.f.	Starter consumption		Gain		Scours score	
		MS ^a	p ^b	MS	P	MS	P
Starter	5	6.47	0.37	2.88	0.31	0.37	0.14
Error	15	5.67		2.24		0.19	

^aMean square.

^bProbability.

TABLE 9. ENERGY TO PROTEIN RATIOS FOR STARTERS

Starter	Ratio ¹
1-SBM	44.5 : 1
2-SBM+Fat	51.1 : 1
3-Raw	55.7 : 1
4-138	50.8 : 1
5-171	51.6 : 1
6-191	47.7 : 1

¹Estimated net energy in kcal to crude protein as a percentage.

MODEL M-2 JET-SPLODER FLOW DIAGRAM

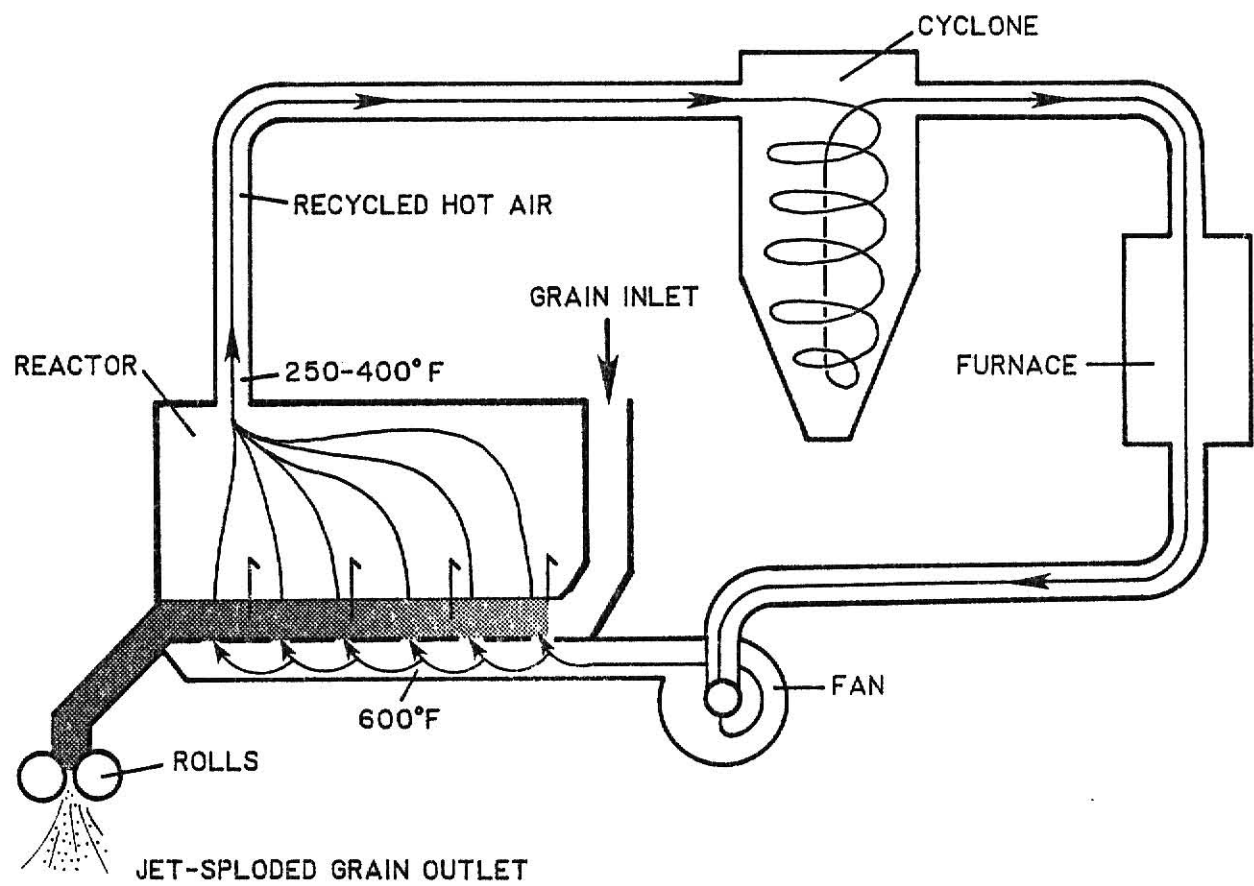


Figure 1

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APPENDIX

APPENDIX TABLE I. CHEMICAL COMPOSITION OF SOYBEAN
MEAL AND WHOLE SOYBEANS USED IN STARTERS

Component	SBM	Raw	138	171	191
Dry Matter	88.7	91.2	92.5	93.9	94.7
	————— % Dry Matter —————				
Crude fiber	9.9	5.6	5.5	5.5	4.4
Ether extract	1.2	21.4	21.7	21.6	22.7
Ash	7.4	5.1	5.2	5.3	5.6
Nitrogen free extract	37.5	31.1	30.5	29.4	30.0

APPENDIX TABLE II. WEEKLY GAIN BY STARTER FOR CALVES IN HUTCHES

	Gain (kg±SE)							
	Week							
Starter	1	2	3	4	5	6	7	8
5-171	0.96±0.47	0.59±0.45 ^c	2.04±0.59	3.71±0.67	4.05±0.55	4.34±0.56 ^a	5.44±0.51	6.38±0.49
6-191	0.06±0.47	-0.76±0.46 ^{ab}	2.16±0.59	4.28±0.69	3.58±0.57	4.23±0.58 ^a	5.60±0.52	5.44±0.51
4-138	0.00±0.47	-0.70±0.46 ^{abc}	0.99±0.61	3.58±0.72	3.06±0.62	4.51±0.64 ^a	5.77±0.58	6.91±0.56
3-Raw	0.47±0.49	-0.39±0.48 ^{bc}	1.47±0.65	3.29±0.76	4.03±0.62	2.65±0.64 ^b	4.59±0.58	4.31±0.56
1-SBM	0.08±0.49	-1.39±0.48 ^{ab}	1.64±0.67	3.03±0.78	4.22±0.66	4.69±0.68 ^a	6.14±0.61	5.56±0.60
2-SBM +Fat	0.95±0.49	-1.77±0.51 ^a	1.59±0.69	3.66±0.81	2.91±0.62	2.15±0.64 ^b	4.22±0.58	5.54±0.58

abcMeans with unlike letters within a week differ (P<0.05).

APPENDIX TABLE III. WEEKLY STARTER CONSUMPTION BY STARTER FOR CALVES IN HUTCHES

Starter	Starter Consumption (kg±SE)							
	Week							
	1	2	3	4	5	6	7	8
5-171	0.23±0.06	0.42±0.06 ^b	1.75±0.24	2.93±0.38	4.30±0.46	8.79±0.74	12.35±0.82	15.72±0.87 ^a
6-191	0.16±0.06	0.22±0.06 ^a	1.65±0.25	2.54±0.39	4.93±0.47	9.44±0.77	12.58±0.85	15.20±0.89 ^a
1-SBM	0.21±0.06	0.21±0.06 ^a	1.19±0.26	2.42±0.44	4.19±0.54	9.92±0.90	13.37±0.99	15.51±1.05 ^a
4-138	0.11±0.06	0.23±0.06 ^a	0.94±0.25	2.11±0.41	3.09±0.49	8.99±0.85	12.08±0.94	15.34±0.99 ^a
3-Raw	0.09±0.06	0.16±0.06 ^a	1.32±0.26	2.42±0.44	4.23±0.52	8.28±0.85	10.95±0.94	12.51±0.99 ^b
2-SBM +Fat	0.14±0.06	0.19±0.06 ^a	0.96±0.27	2.19±0.44	3.25±0.52	6.72±0.85	9.48±0.94	12.52±0.99 ^b

^{a,b}Means with unlike superscripts within a week differ (P<0.05).

APPENDIX TABLE IV. WEEKLY SCOURS SCORE BY STARTER FOR CALVES IN HUTCHES

Starter	Scours Score ¹ (±SE)							
	Week							
	1	2	3	4	5	6	7	8
5-171	1.9±0.2 ^a	2.6±0.2	1.9±0.2	1.6±0.2	1.4±0.1 ^b	1.1±0.1	1.1±0.1	1.0±0.03
6-191	2.3±0.2 ^{abc}	3.0±0.2	2.0±0.2	1.9±0.2	1.5±0.1 ^{bc}	1.3±0.1	1.1±0.1	1.0±0.03
2-SBM +Fat	2.3±0.2 ^{ab}	3.0±0.2	2.3±0.2	1.7±0.2	1.4±0.2 ^b	1.4±0.1	1.2±0.1	1.1±0.04
3-Raw	2.4±0.2 ^{ab}	3.1±0.2	2.2±0.2	2.1±0.2	1.6±0.2 ^{abc}	1.3±0.1	1.1±0.1	1.2±0.04
4-138	2.6±0.2 ^{bc}	2.9±0.2	2.7±0.2	2.0±0.2	1.9±0.2 ^a	1.3±0.1	1.2±0.1	1.1±0.04
1-SBM	2.8±0.2 ^c	3.2±0.2	2.5±0.2	1.9±0.2	1.8±0.2 ^{ac}	1.3±0.1	1.1±0.1	1.1±0.04

¹Larson et al., 1977.

abc Means with unlike letters within a week differ (P<0.05).

APPENDIX TABLE V. WEEKLY GAIN BY STARTER FOR CALVES IN PENS

	Gain (kg±SE)							
	Week							
Starter	1	2	3	4	5	6	7	8
5-171	2.27±0.74	-2.49±0.98	0.91±1.07	3.18±1.09	2.95±1.33	3.29±1.47 ^{abc}	3.18±1.19 ^{abc}	4.42±0.97 ^{ab}
6-191	1.59±0.74	-2.72±0.98	0.11±1.07	2.16±1.09	2.83±1.33	6.12±1.47 ^a	4.76±1.19 ^{ab}	6.46±0.98 ^a
4-138	0.91±0.74	-0.68±0.98	-1.47±1.07	0.57±1.09	2.42±1.53	5.59±1.69 ^{ab}	6.65±1.37 ^a	6.50±1.13 ^a
3-Raw	1.63±0.66	-0.63±0.87	-1.99±0.96	0.45±0.97	2.63±1.19	0.91±1.47 ^{bc}	2.27±1.19 ^{bc}	2.38±0.98 ^b
1-SBM	-0.11±0.74	-1.93±0.98	0.35±1.07	2.49±1.09	2.95±1.33	3.93±1.69 ^{abc}	6.19±1.34 ^a	4.69±1.13 ^b
2-SBM								
+Fat	1.70±0.74	-0.57±0.98	-0.11±1.07	1.51±1.26	1.51±1.53	-1.36±1.69 ^c	0.30±1.37 ^c	2.72±1.13 ^b

abc Means with unlike letters within a week differ (P<0.05).

APPENDIX TABLE VI. WEEKLY STARTER CONSUMPTION BY STARTER FOR CALVES IN PENS

	Starter Consumption (kg±SE)							
	Week							
Starter	1	2	3	4	5	6	7	8
5-171	0.00±0.04	0.15±0.19	0.65±0.37	1.33±0.63	2.62±1.21	6.69±2.19	9.65±2.51	11.81±3.00
6-191	0.09±0.04	0.51±0.19	0.87±0.37	1.33±0.63	2.03±1.21	6.04±2.19	8.47±2.51	10.78±3.00
1-SBM	0.00±0.04	0.20±0.19	0.49±0.37	1.09±0.63	1.57±1.21	5.36±2.19	9.68±2.89	11.98±3.47
4-138	0.13±0.04	0.39±0.19	0.79±0.37	1.92±0.63	3.83±1.39	8.23±2.53	11.52±2.89	14.15±3.47
3-Raw	0.00±0.04	0.18±0.17	0.18±0.33	0.34±0.56	1.32±1.08	3.87±2.19	4.22±2.51	5.37±3.00
2-SBM +Fat	0.01±0.04	0.19±0.19	0.73±0.37	0.89±0.63	1.88±1.39	2.75±2.53	2.95±2.89	3.93±3.47

APPENDIX TABLE VII. WEEKLY SCOURS SCORE BY STARTER FOR CALVES IN PENS

Starter	Scours Score ¹ ($\pm$ SE)							
	Week							
	1	2	3	4	5	6	7	8
5-171	1.4 $\pm$ 0.3	3.0 $\pm$ 0.3	2.1 $\pm$ 0.5	1.7 $\pm$ 0.4	1.8 $\pm$ 0.4	1.5 $\pm$ 0.4	1.0 $\pm$ 0.3	1.0 $\pm$ 0.2
6-191	1.5 $\pm$ 0.3	3.7 $\pm$ 0.3	3.2 $\pm$ 0.5	2.1 $\pm$ 0.4	1.6 $\pm$ 0.4	1.6 $\pm$ 0.4	1.3 $\pm$ 0.3	1.2 $\pm$ 0.2
2-SBM+Fat	1.4 $\pm$ 0.3	2.9 $\pm$ 0.3	2.9 $\pm$ 0.5	2.7 $\pm$ 0.4	2.1 $\pm$ 0.4	1.4 $\pm$ 0.4	1.8 $\pm$ 0.3	1.7 $\pm$ 0.3
4-138	1.9 $\pm$ 0.3	3.6 $\pm$ 0.3	2.8 $\pm$ 0.5	3.1 $\pm$ 0.4	3.1 $\pm$ 0.4	1.7 $\pm$ 0.4	1.2 $\pm$ 0.3	1.1 $\pm$ 0.3
1-SBM	1.9 $\pm$ 0.3	3.5 $\pm$ 0.3	2.1 $\pm$ 0.5	1.6 $\pm$ 0.4	1.7 $\pm$ 0.4	1.4 $\pm$ 0.4	1.1 $\pm$ 0.3	1.0 $\pm$ 0.3
3-Raw	1.6 $\pm$ 0.3	3.3 $\pm$ 0.3	2.8 $\pm$ 0.5	2.6 $\pm$ 0.4	2.2 $\pm$ 0.4	1.6 $\pm$ 0.4	2.1 $\pm$ 0.3	1.8 $\pm$ 0.2

¹Lawson et al., 1977.

PROCESSED SOYBEANS FOR YOUNG CALVES

by

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BVSc., Univ. of Khartoum, 1979

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Animal Nutrition

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1983

Holstein calves were used in a completely randomized repeated measure (week) design from 1-2 days to 8 weeks of age to evaluate heat processed soybeans as the major protein supplement in calf starters. The starters contained soybean meal (1-SBM), soybean meal with added animal fat (2-SBM+fat), raw soybeans (3-Raw), or soybeans processed at 138°C (4-138), 171°C (5-171) or 191°C (6-191). Some calves, both male and female, were housed in wood hutches while only males were housed in individual inside pens. They were fed milk at 8% of body weight at birth divided into two feedings until weaning at 5 weeks of age. All calves were fed starter ad lib from start to end. Scours scores were recorded twice daily, feed consumption and body weight weekly.

For calves housed in hutches, those on starter 5-171 gained more weight ($P < 0.05$) than all the others except those on starter 6-191 ($P > 0.05$). Calves on 1-SBM and 2-SBM+fat starters had the lowest gains, although not significantly lower than those on 3-Raw or 4-138 starters. Feed consumption was not different ($P > 0.07$) between calves on 5-171, 6-191, 1-SBM, or 4-138 starters. Those on 3-Raw and 2-SBM+fat starters had the lowest consumption which was significantly lower than those on 5-171 and 6-191 starters ($P < 0.07$). Calves on starter 5-171 had the lowest scours score (least scours) compared to all the others ($P < 0.05$) except those on 6-191 starter. There were no significant differences between sexes in weight gain ($P = 0.48$), starter consumption ($P = 0.73$), or scours score ($P = 0.30$).

For calves housed in pens, those on starters 5-171 and 6-191 gained more weight, consumed more starter, and had lower incidence of scours than calves in other starters. However, weight gain, starter consumption

and scours score were not significantly different between starters. This may have been due to the small number of calves used which did not provide enough data to detect statistically significant differences.

Plasma protein and packed cell volume measured at approximately 24 hrs of age for all calves did not have a significant effect ($P > 0.20$) on weight gain, starter consumption, or scours score up to 8 weeks of age.