PROCESSED SOYBEANS AND TYPES OF HOUSING FOR YOUNG CALVES

by

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INTRODUCTION

The ruminant is supplied by two protein sources which are available for utilization; they are feed and microbial protein (Veira et al., 1980). Those sources determine the amino acids available for absorption and utilization (Sniffen, 1974). Protein utilization can be improved by rumen bypass, since post ruminal digestion utilizes high quality feed more efficiently (Hedde et al., 1974). Protein solubility influences the amount of protein degraded in the rumen and thus the protein's bypass potential (Crawford et al., 1978). Several methods have been utilized to measure solubility as an estimator of protein bypass (Goering and Waldo, 1974a; Waldo and Goering, 1979).

An average of 40% of the dietary protein consumed escapes rumen degradation and 87% of the true protein that bypasses is absorbed (Satter and Roffler, 1975). Rumen bypass has been shown to be beneficial in calves (Hedde et al., 1974) and sheep (Ørskov et al., 1970).

Several methods can be implemented to increase bypass potential, such as esophageal groove closure, and heat or chemical treatment of protein. Processing methods provide a way to improve feeding value and thus a possible system for regulating rumen bypass (Chalupa, 1975).

Several researchers have evaluated soybean protein that has been processed or treated. The extrusion process has shown benefit in calves (Morrill et al., 1981) and lactating cows (Satter, 1981). Heat treatment of soybean protein has been shown to be beneficial for the ruminant (Tagari et al., 1962; Glimp et al., 1967; Hudson et al., 1970; Nishimuta et al., 1973; Netemeyer et al., 1982). Crooker et al. (1982) and Lindquist et al. (1982) noted that chemically treated protein had no effect on milk production. Mir et al. (1982) noted an increase in milk yield by feeding NaOH treated soybean meal to lactating cows.

REVIEW OF LITERATURE

Protein Utilization in the Ruminant

Protein Sources and Utilization

Dietary N utilization varies between animals that rely on a fermentation type digestion and those whose digestion is a simple hydrolytic process. This is especially true when the site of fermentation precedes the primary area for absorption of amino acids in the intestines as it does in the ruminant (Satter and Roffler, 1975).

There are two sources of protein available for digestion in the ruminant, microbial and feed protein. The small intestine is supplied with amino acids from rumen microbial protein, protected feed proteins and amino acids that bypass the rumen, and endogenous secretions (Chalupa, 1975; Veira et al., 1980; Stern, 1981; Wanapat et al., 1982). The dietary protein which bypasses the rumen along with the microbial protein determines the quantities and ratios of amino acids that will be offered for absorption and utilization (Sniffen, 1974).

Rumen bacteria extensively hydrolyze dietary proteins to their characteristic amino acids. Those amino acids are deaminated quickly and NH_3 is formed. The solubility of the protein in the rumen fluid is closely connected to the rate of proteolysis and the protein level in the diet is related to the deamination rate (McGilliard, 1972).

The synthesis of microbial protein is an energy dependent process. The quantity of dietary protein transformed into microbial protein is significant to the N management of the ruminant. It should be an important consideration in the decision of whether to reduce degradation in the rumen via artificial methods (Chalupa, 1975).

Rumen Bypass of Protein and the Effect of Solubility

Bypass of the rumen changes the location of digestion and absorption of nutrients in the digestive tract of ruminants and also furnishes a mechanism for supplementing nutrient outflow from the rumen (Chalupa, 1975). The bypass of protein has the advantage of decreasing rumen NH_3 and N excretion in the urine, thus improving N-retention. In addition, it allows high quality protein to be utilized without being converted to a lower quality protein. The value of bypass protein may lie in its capacity to complement the microbial protein's amino acid composition, instead of its biological value (Wohlt et al., 1976). Hedde et al. (1974) noted that protein utilization can be improved by rumen bypass, because post ruminal digestion utilizes high quality feed more efficiently.

True protein is degraded in or bypasses the rumen to be digested or excreted. There may be large variation in the quantity of protein that escapes rumen degradation. Satter and Roffler (1975) suggested an average of 40% as an escape rate for protein in the diet and that the other 60% is degraded to NH_3.

Hedde et al. (1974) demonstrated that rumen bypass improved feed efficiency, metabolizable energy utilization, and protein and energy digestibility in calves fed milk replacer via the abomasum versus the rumen. Lambs were fed protein supplements in dry form or liquid suspension by Ørskov et al. (1970). They observed greater N retention, higher weight gains, and lower urinary N excretion with lambs fed the liquid suspension which bypassed the rumen.

There are two basic reasons responsible for differences in protein degradation in the rumen. They are solubility and retention time in the rumen. Solubility is a natural characteristic of proteins, but it is variable among protein sources as is the degree of rumen degradation (Chalupa, 1975). Protein solubility in the rumen is considered a contributing cause of inefficient protein utilization (Pichard and Van Soest, 1977). It can be influenced by rumen pH, feeding frequency, level of intake, protein type, and feed particle size (Sniffen, 1974).

The major soluble portion of protein in feedstuffs are the protein fractions, albumins and globulins, which are soluble in rumen fluid. The insoluble portion of the protein consists of prolamins and glutelins, which have the potential for rumen bypass. Albumins and globulins are soluble in water and salt, and prolamins and glutelins are soluble in dilute alkali and alcohol (Wohlt et al., 1973; Sniffen, 1974). Protein oil seeds contain large quantities of albumins and globulins, which make them quite soluble, but high in protein quality (Sniffen, 1974).

Wohlt et al. (1976) indicated that there was a high positive correlation between ruminal NH_3 concentration and the solubility of dietary protein. The effects of solubility are possibly related to high NH_3 levels in the rumen that can result from rapid degradation of the soluble fraction of the protein. The ensuing increase in NH_3 absorption through the rumen wall would precede a decrease in the efficiency of N utilization (Crawford et al., 1978). Ruminal NH_3 concentration can be significantly influenced within minutes after feeding highly soluble protein (Sniffen, 1974).

The quantity of feed protein that bypasses the rumen depends on the amount of soluble protein in the diet, the rate of degradation, and the rate of flow for solids and liquids through the rumen (Crawford et al., 1978). Several procedures are used to reduce rumen degradation of protein and amino acids and thus increase bypass potential. They include esophageal groove closure, chemical treatment, heat treatment, use of amino acid analogs, encapsulation, and selective regulation of balances of metabolic pathways in the rumen. The methods should not hinder rumen metabolism or post ruminal digestion (Chalupa, 1975).

The protection of large proportions of proteins from high quality feeds may help increase their efficiency of utilization for milk production (Ahrar and Schingoethe, 1979). Stern (1981) concluded that when a protected protein source is required by an animal it is of value to feed heat treated protein. Protection of protein permits more amino acids to arrive at the intestine and it also furnishes more absorbable amino acids/unit absorbable energy. A positive response will be expected if the ruminant needs additional amino acids, but if the quantities of amino acids are adequate the response may be negative or nil (Chalupa, 1975).

Whitelaw and Preston (1963) discussed the significance of solubility in defining the nutritive values of protein for the young calf. The determination of the nutritive values appears to rely on the type of protein used. The value of low solubility protein appears to extensively depend on its amino acid composition. Majoub et al. (1978) noted that a low N solubility diet fed to lactating cows increased milk production, but it did not alter milk composition. Protein sources with different solubilities were fed to sheep along with low quality roughages to study the effects of protein metabolism. Sheep fed protein sources with higher solubilities had significantly higher apparent crude protein digestibilities (Wanapat et al., 1982).

Ruminants having medium or high production depend on feed protein bypassing the rumen. The quantity of dietary protein bypassing the rumen must increase as the level of production increases. Microbial protein alone is not sufficient to support high production, but it is probably adequate for the low producer (Stern, 1981). It appears that rumen bypass of protein would be advantageous in most circumstances, practically speaking (McGilliard, 1972).

Formulating diets for lactating dairy cows according to N solubility has the potential to improve protein utilization. There is substantial variation among feedstuffs in N solubility, but the use of solubility in formulation could decrease the quantity of crude protein used as well as the cost (Majoub et al., 1978).

Measurements of Protein Solubility

The techniques for measuring protein insolubility attempt to predict or estimate the digestible or absorbable feed protein that bypasses degradation in the rumen and enters the small intestine (Waldo and Goering, 1979).

Several methods and solvents have been utilized by ruminant nutritionists to estimate insolubility. They include autoclaved rumen fluid, 70% ethanol, .15M NaCl, NH_3 accumulation, in situ disappearance, boiling water, cold water, phosphate buffer, mineral solution, .02N NaOH, and salt solution of Burroughs et al. (Goering and Waldo, 1974a; Waldo and Goering, 1979). There is no generally accepted method for measuring solubility (Waldo and Goering, 1979). A uniform method is needed, but it should be easily duplicated in a laboratory and also should simulate the solubility in the rumen (Wohlt et al., 1973).

Protein solubility within feeds and between feeds has proven to be quite variable, as demonstrated by the variety of solvents and methods that have been used (Crooker et al., 1978; Waldo and Goering, 1979). There are factors related to the solvent used in a solubility determination which can influence its outcome. These include salt, temperature, pH, extraction time, degree of agitation, and ionic strength (Wohlt et al., 1973). Crooker et al. (1978) indicated that a change in ionic strength from .11 to .19 had no effect on the determination of soluble N. A comparison of autoclaved rumen fluid, modified Burroughs mineral mixture, and McDougal's artificial saliva showed a significant difference in mean soluble N values.

Nitrogen solubility in feedstuffs was determined by Krishnamoorthy et al. (1982) using .15M NaCl, autoclaved rumen fluid, borate-phosphate buffer, Burroughs mineral mixture, bicarbonate-phosphate buffer, and McDougal's artificial saliva. They concluded that N solubility varied with the solvent and the feedstuff. In addition, the borate-phosphate buffer had more stability than the other solvents.

Waldo and Goering (1979), in a comparison of four methods, concluded that autoclaved rumen fluid might be preferable to .15M NaCl, concentrated Burroughs solution, and boiling water for 1 h and 6 h at 39°C. The N insolubility determinations for the four methods ranged from 47.8% to 77.2% for soybean meal. The hot water method gave the lowest soluble N determination, and NaCl gave the highest. These results emphasized that solubility for one method is not a predictor for other methods.

An increase in pH from 5.5 to 7.5 increased soluble N of isolated soy protein in mineral buffer and autoclaved rumen fluid. The soluble N content was greater for the protein when it was determined by mineral buffer compared to when rumen fluid was the solvent (Wohlt et al., 1973).

Improving Protein Utilization in the Ruminant

Processing Methods and Their Effect on Protein

Soybean meal has been an important protein supplement for many years. Whole soybeans are also an excellent protein supplement and they are higher in energy than soybean meal. They also have anti-nutritional components that decrease their feeding value. Lipase, urease, and trypsin inhibitor are those components and they are routinely eliminated by heating during processing. Schingoethe (1982) stated that it is not a necessity to heat soybeans to alter those factors for ruminants, since lipase causes no problems when the soybeans are fed fresh, rumen bacteria destroy trypsin inhibitors, and urease is also present in the rumen.

There is growing interest in methods of processing soybean meal as a possible way to improve its feeding value (Schingoethe, 1982). Routine processing and storage of feed ingredients, like soybean meal, can affect the quantity and rate of rumen protein degradation. This can influence performance of the animal in a positive or negative manner (Goering and Waldo, 1974a; Chalupa, 1975). Processing provides a possible system for regulating rumen bypass of protein (Chalupa, 1975). Hale (1973) suggested that the disruption of the protein matrix could result in increased degradation, but heat generated or applied in processing could decrease protein degradation. The heat also aids in the destruction of anti-nutritional factors, like trypsin inhibitor in soybeans, in various protein sources, which can improve animal performance (Goering and Waldo, 1974b). There are several methods available for processing feed ingredients. They encompass extruding, roasting, pelleting, thermalizing, grinding, micronizing, popping, dry rolling or cracking, exploding, reconstitution, soaking, pressure cooking, steam processing and flaking, and steam rolling (Hale and Theurer, 1973).

There are many processing methods for heating soybeans, by generating or requiring heat they help protect the protein and decrease its degradation in the rumen. Soybeans can be cooked, roasted, pelleted, extruded, or heated at high temperatures. Moisture is used in the form of steam for some processes during roasting, cooking, or extruding (Schingoethe, 1982).

In order to obtain optimal protein protection without decreasing amino acid digestion in the intestine, it is important to know the level of processing required. Overprotection of dietary protein can occur by heating beyond optimal conditions, but often these conditions are unknown. Knowledge of the optimum heating level is necessary to accomplish the benefit of heat treatment on rumen protein utilization (Stern, 1981; Schingoethe, 1982).

Heat or Chemical Treatment of Protein

The treatment of protein by the use of heat or chemicals may make the protein unavailable to rumen microorganisms (Cummins et al., 1982). The treatment effect is influenced considerably by the protein solubility of the starting material (Goering and Waldo, 1974a). Heat or chemical treatment of protein usually causes a decrease in the albumin and globulin fractions of the protein, thus reducing its solubility (Sniffen, 1974). Nishimuta et al. (1973) indicated that treatment to reduce soybean meal protein solubility should let sufficient N be available for rumen microorganisms and also allow high quality protein to bypass the rumen.

Specific chemical agents can decrease protein solubility at rumen pH by forming reversible cross linkages with amide and amino groups. Those proteins are made available to the ruminant in the acidic abomasum, where the linkages are destroyed (Chalupa, 1975). Goering and Waldo (1974a) stated that proper use of chemicals, like tannic acid or formaldehyde, would decrease the concentration of soluble N and possibly increase N-retention.

Heat treatment of protein decreases degradation in the rumen, increases the amino acid supply to the intestine, and thus improves animal performance (Stern, 1981). Since solubility is decreased by heating, it can be advantageous for high producing cows by allowing feed protein to be used in the lower digestive tract. The quality of the protein can be diminished with too much heat and thus decrease its value to the animal (Schingoethe, 1982).

Schingoethe and Ahrar (1979) found the N solubility of soybean meal decreased 27% after heat treatment, but amino acid composition was similar for the heated and unheated meals. Heating soybean meal for 4 h at 138° to 149°C appeared to improve its usage in specific diets for cattle (Thomas et al., 1978).

Heat treating raw soybeans allows them to be fed with urea. The heat also helps prevent rancidity and decrease protein solubility. It has also been observed that heating soybeans increases their consumption by some dairy cows (Schingoethe, 1982).

The Utilization of Processed or Treated Soybean Protein for the Ruminant

Feeding Extruded Soybean Protein

Extruded soybeans were compared to ground raw soybeans for young calves. The extrusion process caused increased N balance in the calves by 13% (Morrill et al., 1981).

Satter (1981) compared raw soybeans, soybean meal, extruded soybeans, and extruded soybean meal to evaluate extruded soy protein and its resistance to degradation in the rumen. Nitrogen disappearance of extruded soybeans in the rumen was greatly affected by extrusion temperature. There was a notable difference in N disappearance between raw and extruded soybeans. Soybeans extruded with Masonex at 149°C were more resistant to ruminal degradation than those extruded with bentonite or ammoniated ligno sulfonate at the same temperature. Satter also noted that the rate of degradation did not differ between soybeans extruded at 132°, 141°, and 149°C, but extrusion at 157°C appeared to increase resistance to ruminal degradation.

An ensuing study by Satter (1981) revealed that extrusion increased a product's resistance to ruminal degradation with increasing exposure in the rumen. Lactating cows were fed diets containing either whole soybeans, soybean meal, or soybeans extruded at 149° or 132°C. The soybeans extruded at 132°C were less resistant to degradation than those extruded at 149°C. There was a greater flow of amino acids into the small intestine with extruded whole soybeans compared to raw soybeans. There appeared to be no difference in whole soybeans extruded at 149°C vs 132°C.

Feeding Heat or Chemically Treated Soybean Protein

In the first 8 wk of lactation, cows fed heated soybean meal produced slightly more milk compared to cows fed solvent extracted soybean meal. There were no differences in milk production in later lactation since protein intake was not limiting as it was at the start of lactation (Ahrar and Schingoethe, 1979).

Glimp et al. (1967) decreased the solubility of soybean meal from 72 to 35% by heating it for 4 h at 149°C. Protein utilization was evaluated for diets of 12.1 and 17.2% crude protein for early weaned lambs. Lamb performance improved by feeding heated soybean meal at

12.1% protein, but performance at 17.2% was similar for heated and unheated soybean meal. There was also an increase in N-retention from the heated meal at the 12.1% level.

Regular and heated soybean meal was fed to lambs by Hudson et al. (1970). The solubility of the soybean meal decreased from 72 to 35% after heating for 4 h at 149°C. Lambs fed heated soybean meal had slower ruminal degradation, an increase in the concentration of dry matter (DM) reaching the abomasum, and also an increase in total N in abomasal contents. Nitrogen retention did not differ between the meals.

High and low solubility diets, containing heated soybean meal and heated corn or regular soybean meal and regular corn, were fed to lambs (Little et al., 1963). Weight gains for the diets were similar. They also observed that heated soybean meal was low in soluble N, converted to NH_3 in the rumen slowly, and it appeared to be an insufficient N source for in vitro cellulose digestion, unlike solvent processed soybean meal.

Netemeyer et al. (1982) evaluated various amounts of heat in soybean meal processing. Meals with protein dispersibility indexes (PDI) of 51.4, 41.8, 30.2, 18.0, and 8.2 were used for in vitro studies. They concluded that the processing temperature was inversely related to the microbial digestibility, in vitro, of protein and DM. The PDI decreased as the temperature increased. An ensuing study compared soybean meals, with PDIs of approximately 10 and 40, at two protein levels for lactating cows. The cows fed the extensively heat treated soybean meal had a greater milk yield, but no change in milk composition.

Tagari et al. (1962) used sheep to compare toasted soybean meal, untoasted soybean meal, and soybean meal prepared by evaporating the solvent at room temperature. These meals had protein solubilities of 13.1, 40.7, and 61.2%, respectively. They observed that sheep consuming toasted soybean meal had the greatest N-retention.

Soybeans were more acceptable to lactating cows after they had been roasted at 118°C for approximately 3.5 min. Cows consumed 22% more concentrate mix when it contained roasted soybeans instead of raw soybeans (Rakes et al., 1972).

Sherrod and Tillman (1962) noted that autoclaving soybean meal for 45 min and incorporating it into semi-purified diets for growing lambs resulted in substantially improved gain and feed efficiency.

When formaldehyde treated (.3%) soybean meal was fed to lactating cows, the treatment had no effect on milk production, milk fat percentage, and milk solids-not-fat percentage. The crude protein digestibility of the treated soybean meal diet was lower than the untreated (Crooker et al., 1982). Lindquist et al. (1982) also compared .3% formaldehyde treated soybean meal to untreated meal and observed no difference in milk production, milk components, and DM consumption.

Steers were fed soybean meal treated with water, 1.5 ml, or 3.0 ml 40% formaldehyde/100g soybean protein. Formaldehyde treatment tended to increase feed consumption, but the steers consuming the soybean meal treated with 3.0 ml formaldehyde gained significantly slower than those fed meal treated with water. Gain was intermediate on the 1.5 ml formaldehyde treated meal (Schmidt et al., 1974).

Soybean meal treated with formalin, tannic acid, or heat was fed to lambs by Nishimuta et al. (1973). Heated meal supported the highest N-retention, but heat treatment greatly reduced cellulose digestion. Crude protein digestion was decreased significantly with the formalin treated soybean meal. Nishimuta et al. (1974) compared the same treatments using steers. There was no difference in abomasal total-N between the meals, but the highest level of protein-N reaching the abomasum/day was from the formalin treated meal. The quantity of amino acids introduced to the abomasum/day was increased by formalin and heat treatment. In addition, heat- and formalin-treated soybean meal increased digestible protein going to the abomasum.

A study by Mir et al. (1982) evaluated soybean meal treated with NaOH or fresh whole blood and compared them to untreated meal for lactating cows. Milk yield increased with NaOH treatment, but it did not change milk composition. The use of fresh whole blood had no real effects.

Housing for Young Calves

Good management is the key to healthy calves and low mortality (Appleman and Owen, 1975). Housing is an important part of calf management and it can make a difference in the success or failure of a calf program. Calf housing should be dry, free from drafts, provide proper temperature and humidity control, and also prevent contact between calves. Appleman and Owen (1975) recommended that housing for calves should utilize pens with solid walls to alleviate drafts, and prevent suckling among calves. Housing should also guard the calf against severe weather extremes. The calf protects itself against normal weather variability by instinct and haircoat (Hastings, 1973).

Several housing systems are available for calves. The three most distinct types used are floor pens, elevated pens, and hutches. Floor pens are inside individual pens with bedding. This type of pen requires a high labor expense, and a medium capital investment. Elevated pens are inside individual stalls that have slatted floors. These pens require no bedding, little labor, and a high capital investment. Hutches are outdoor individual houses with bedding. They are solid on three sides and the top. Hutches require a low capital investment.

Davis et al. (1954) compared outdoor pens to a conventional barn with individual solid partitioned stalls having concrete floors. The outdoor pens were portable and one-half of each pen was covered at all times. During the winter, the pens were protected on three sides, thus they could be called hutches. All the calves housed inside had respiratory problems and other symptoms of illness. The calves in outdoor pens were not adversely affected and they gained significantly more than the inside calves. It was also noted that the incidence of scours was greater for calves housed inside.

Erb and Murdock (1951) noted that the incidence of scours was similar in calves housed in a barn, described only as "conventional," and in an open shed, but scours were less severe in the open shed. Calves housed inside had a mortality rate of 24% compared to 2% outside. There was no significant difference in gain between calves housed in the open shed and the barn. A greater amount of total digestible nutrients (TDN)/unit of body weight was consumed by the open shed calves. Calves in the "conventional" barn had a slightly higher average efficiency of gain.

Another comparison evaluated conventional barns with solid partitioned box stalls, open sheds, and outdoor portable pens for calves (Murley and Culvahouse, 1958). The portable pens were like those used by Davis et al. (1954). The growth of calves in the three types of housing did not differ. There were no adverse effects to the calves outdoors in cold temperatures. An earlier study by Murley et al. (1954) suggested that there was no significant difference in average daily gain (ADG) between calves housed in an open shed with individual pens and a conventional barn. In addition, there were no differences in the health of calves in the different housing systems.

The growth rates of calves did not differ in a comparison of three housing systems by Van Horn et al. (1976). They evaluated elevated slatted floor pens, outdoor movable pens, and bedded pens in a closed barn. One-third of each outdoor pen was covered with tin and the sides with woven wire.

Willett et al. (1967) indicated that calves had similar gains in freestall barn pens, outdoor "portable" pens, and a concrete-tile conventional calf barn (cold type). There were also no differences in the health of calves between housing types.

McKnight (1978) compared hutches to inside elevated pens. The hutch calves were healthier, consumed more starter, and had similar growth to the calves raised inside. He suggested the use of hutches instead of conventional facilities to overcome the incidence of morbidity and high mortality. McKnight concluded that hutches are equal to or superior to housing methods traditionally used for calves.

In another study comparing hutches and individual pens in an insulated heated barn, the housing systems had no effect on ADG, hay consumption, pneumonia, or scours (Jorgenson et al., 1968).

EFFECT OF DIETARY EXTRUDED SOYBEANS AND TYPE OF HOUSING ON CALF PERFORMANCE

Summary

A completely randomized, repeated measures (week) design was used to assign 60 Holstein calves to experiment at 1 to 2 d of age for 8 wk. Twelve treatment combinations (3 starters x 4 types of housing) were utilized. The starters contained soybean meal (SBM), extruded whole soybeans (EXTR), or soybean meal and added fat (SBMF). Types of housing were inside floor pens, inside elevated pens, small wood hutches, and large fiberglass hutches. Each calf was fed individually and weight gains, feed consumption, and observations of health were recorded. Calves fed SBM gained more (P<.05) than those consuming SBMF. Gains were intermediate for calves consuming EXTR. Females gained more (P<.05) in wood hutches than in floor- and elevated-pens, but compared to fiberglass hutches gain was similar. Males gained similarly (P>.05) in the four types of housing. SBM starter intake was greater (P<.05) than EXTR and SBMF intake during wk 6 to 8. Calves in fiberglass hutches consumed more (P<.05) starter during wk 5 to 8.

(Key Words: Extruded Soybeans, Calves, Starter, Housing)

Introduction

Soybeans are high in protein and energy, but they contain anti-nutritional factors which can affect their feeding value. They can also become rancid after grinding in hot weather. Extruding soybeans may improve their nutritional value by destroying anti-nutritional factors and increasing rumen bypass potential. Extrusion also allows for extended storage of soybeans. The extrusion of soybeans has been shown to be beneficial for calves (Morrill et al., 1981) and lactating cows (Satter, 1981).

Three distinct types of housing are used for calves; they are floor pens, elevated pens, and hutches. Some workers (Davis et al., 1952; Davis et al., 1954; McKnight, 1978) found outdoor housing more beneficial than indoor types, and others (Murley et al., 1954; Murley and Culvahouse, 1958; Willett, 1967; Jorgenson et al., 1968; Van Horn et al., 1976) determined that there were no substantial differences in specific aspects of calf performance in indoor or outdoor housing.

The objectives of our study were to evaluate the effect of extruded soybeans for young calves and compare housing systems for calves. This study provided a comparison of the three housing types and it also allowed the opportunity to compare large fiberglass hutches and small wooden hutches.

Experimental Procedure

Sixty Holstein calves, 36 heifers and 24 bulls, were assigned to experiment at 1 to 2 d of age for 8 wk in a completely randomized, repeated measures (week) design. Three starters and four types of housing were utilized. The types of housing were .8m x 1.2m inside floor pens with wood shavings as bedding, .5m x 1.2m inside elevated metal pens, 1.2m x 1.2m wood hutches, and 1.2m x 2.4m fiberglass hutches. The hutches were bedded with straw. The building housing the floor and elevated pens had mechanical ventilation and a temperature maintained between 13° to 18°C.

The starters are shown in table 1. The soybeans used in EXTR were extruded through a Wenger Model X-25 extruder.[1] The process utilized ground soybeans that were preconditioned with moisture and steam and processed under elevated pressure, and a temperature of 156°C in the extruder.

The calves were fed milk twice daily. They were fed 8% of body weight during the first and sixth weeks, and 9% through the remaining weeks until weaning. Calves were weaned at 6 wk provided they were eating > .7 kg starter/day and had gained > 9 kg since birth.

Each calf was fed starter individually. They had access to starter at all times, water during the day, and chopped prairie hay at night. Calves were observed twice daily for general appearance and fecal score (Larson et al., 1977). Weight gains and feed consumption were recorded weekly.

Starters, hay, soybean meal, and extruded soybeans were sampled and analyzed for crude protein (Kjeldahl) and dry matter (DM) in accordance with AOAC (1970) procedures. Soybean meal and extruded soybeans were also analyzed by protein dispersibility index (PDI) (AACC, 1969).

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[1]Wenger Manufacturing Co., Sabetha, KS.

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

Results and Discussion

The analyses of variance are in table 2. Calf weight gains were different (P=.01) between diets. Gains were greater (P<.05) on SBM than on SBMF (table 3). Gains on EXTR were intermediate to the other diets. The sex x housing interaction on gain was significant (P=.02). There were no differences (P>.05) in gain among males in the four housing types, but gains of females were different (P<.05). Females gained more in wood hutches than in floor and elevated pens (table 4).

The diet x week interaction on starter consumption was significant (P=.0003). Consumption did not differ (P>.05) in wk 1 through 5, but during wk 6 calves fed SBM ate more (P<.05) than those consuming EXTR or SBMF (table 5). There were also differences (P<.05) in starter consumption during wk 7 and 8; calves consuming SBM had the greatest intake. The housing x week interaction on starter intake was significant (P<.0001). Intake did not differ (P>.05) in wk 1 through 4, but calves in fiberglass hutches consumed more starter (P<.05) than those in other housing types for wk 5 through 8 (table 6). During wk 6 through 8, starter intake by calves in the two types of hutches was different (P<.05), but starter intakes were similar (P>.05) in the floor and elevated pens. Differences in hay consumption due to sex, diet, and housing were not significant (P>.05).

There was a difference (P=.03) in scours (fecal score) between diets (table 7). Calves on SBMF had a greater scour score (P<.05) than EXTR. There were no differences (P=.65) between housing types for scour scores. Total observations of sickness in each housing type were 33-floor pens, 29-elevated pens, 13-wood hutches, and 12-fiberglass hutches. The mortality for each housing type was 0-floor pens, 3-elevated pens, 3-wood hutches, and 2-fiberglass hutches.

The analyses of starters, hay, soybean meal, and extruded soybeans are listed in table 8. Our study indicated that the growth of calves fed extruded soybeans was acceptable, but no special benefit was obtained from the extrusion process. Other workers (Morrill et al., 1981; Satter, 1981) observed additional benefit from the extrusion process. Satter noted that extrusion at 157°C appeared to increase resistance to ruminal degradation as compared to extrusion at 132°, 141°, and 149°C.

Greater growth was expected on the higher energy diets. Gain was significantly less on the diet containing soybean meal and added fat compared to soybean meal alone. Possibly, a factor of some unpalatability or an undesirable protein:energy ratio could be an explanation for the failure of calves on high fat diets to grow more. The extruded soybeans and soybean meal used had similar PDIs, indicating similar solubilities and possibly similar bypass potentials. The fact that performance was not similar with soybean meal and extruded soybeans is possibly due to protein:calorie ratio as previously noted.

In regards to housing types, calves raised in hutches had substantially fewer sickness observations than those in inside housing. In addition, females had superior gains in the hutches. This was also demonstrated by McKnight (1978). Calf performance was similar in the small and large hutches.

TABLE 1. COMPOSITION OF STARTERS[a]

Ingredient	SBM[b]	EXTR[c]	SBMF[d]
	%		
Corn, rolled	40.0	40.4	40.2
Oats, rolled	25.0	25.3	25.1
Milo, rolled	16.4	12.6	14.1
Soybean meal[e]	12.2		12.9
Extruded soybeans		15.2	
Molasses, dry	4.6	4.7	4.7
Fat, animal			1.3
Salt	0.2	0.2	0.2
Salt, trace mineral	0.2	0.2	0.2
Limestone	1.1	1.1	1.1
Dicalcium phosphate	0.2	0.2	0.2
Vitamin A and D[f]	41g	41g	41g

[a]As fed basis.

[b]Contains soybean meal.

[c]Contains extruded soybeans.

[d]Contains soybean meal and added fat.

[e]From a single source.

[f]1,000,000 IU A and 500,000 IU D/.5 kg; 41g added/45.5 kg starter.

TABLE 2. ANALYSES OF VARIANCE

Source of Variation	d.f.	Starter Consumption		Gain		Scours	
		MS[a]	P[b]	MS	P	MS	P
Diet (D)	2	67.5	.03	50.3	.01	3.3	.03
Housing (H)	3	68.9	.02	20.4	.10	.5	.65
Sex (S)	1	13.3	.38	.7	.08	4.6	.02
S x D	2	2.4	.87	4.3	.62	.1	.90
S x H	3	45.2	.06	33.0	.02	.8	.45
H x D	6	19.2	.37	16.7	.12	1.9	.07
S x H x D	6	14.0	.56	11.1	.32	.8	.47
Error (a)	31	16.9		9.1		.8	
Week (W)	7	949.0	<.0001	265.6	<.0001	26.4	<.0001
D x W	14	7.4	.0003	3.7	.62	.3	.50
H x W	21	17.8	<.0001	2.4	.95	.4	.17
S x W	7	.6	.97	7.1	.13	.3	.46
Error (b)	294	2.5		4.4		.3	

[a]Mean Square.

[b]Probability.

TABLE 3. WEEKLY GAIN BY DIET

Diet	Gain kg±SE
SBM[c]	3.5±.2[a]
EXTR[d]	3.1±.2[ab]
SBMF[e]	2.8±.2[b]

[a,b]Means with unlike subscripts differ (P<.05).

[c]Contains soybean meal.

[d]Contains extruded soybeans.

[e]Contains soybean meal and added fat.

TABLE 4. WEEKLY GAIN (SEX x HOUSING)

	Gain kg±SE	
Housing	Male	Female
Floor pens	3.2±.3	2.6±.2[a]
Elevated pens	2.9±.4	2.7±.3[a]
Wood hutches	2.9±.4	3.8±.3[b]
Fiberglass hutches	3.7±.3	3.3±.3[ab]

[a,b]Means with unlike subscripts differ (P<.05) between females.

TABLE 5. WEEKLY STARTER CONSUMPTION (DIET x WEEK)

	Starter Consumption kg±SE							
	Week							
Diet	1	2	3	4	5	6	7	8
SBM[d]	.2±.5	.3±.5	1.0±.5	2.4±.5	4.1±.5	6.9±.5[a]	11.2±.5[a]	14.4±.5[a]
EXTR[e]	.2±.5	.3±.5	.9±.5	2.0±.5	3.4±.5	5.0±.5[b]	9.5±.5[b]	12.3±.5[b]
SBMF[f]	.2±.5	.3±.5	.9±.5	1.5±.5	4.0±.5	4.5±.5[b]	8.4±.5[c]	10.8±.5[c]

[a,b,c]Means with unlike subscripts differ ($P<.05$) within week.

[d]Contains soybean meal.

[e]Contains extruded soybeans.

[f]Contains soybean meal and added fat.

TABLE 6. WEEKLY STARTER CONSUMPTION (HOUSING x WEEK)

	Starter Consumption kg±SE Week							
Diet	1	2	3	4	5	6	7	8
Floor pens	.2±.5	.3±.5	.8±.5	1.4±.5	2.5±.5[a]	4.1±.5[a]	6.9±.5[a]	10.3±.5[a]
Elevated pens	.1±.5	.4±.5	.9±.6	1.9±.6	2.9±.6[a]	3.5±.6[a]	7.5±.6[a]	10.0±.6[a]
Wood hutches	.1±.5	.1±.5	.9±.5	2.0±.6	3.6±.6[a]	6.4±.6[b]	11.2±.6[b]	13.4±.6[b]
Fiberglass hutches	.3±.6	.4±.6	1.2±.6	2.7±.6	5.0±.6[b]	7.9±.6[c]	13.2±.6[c]	16.3±.6[c]

[a,b,c]Means with unlike subscripts differ ($P<.05$) within week.

TABLE 7. SCOUR SCORE BY DIET

Diet	Scours Score*±SE
SBM[c]	2.3±.5[ab]
EXTR[d]	2.2±.5[a]
SBMF[e]	2.4±.6[b]

[a,b]Means with unlike subscripts differ (P<.05).

[c]Contains soybean meal.

[d]Contains extruded soybeans.

[e]Contains soybean meal and added fat.

*Larson et al., 1977.

TABLE 8. ANALYSES OF STARTERS, HAY, SOYBEAN MEAL, AND EXTRUDED SOYBEANS

	%		
Item	CP[a]	DM	PDI
Starter			
SBM[b]	16.17	87.40	
EXTR[c]	16.44	87.94	
SBMF[d]	15.77	87.75	
Hay, prairie	5.67	92.26	
Soybean meal	43.99	93.00	31.85
Extruded soybeans	43.59	93.25	29.74

[a]Dry matter basis.

[b]Contains soybean meal.

[c]Contains extruded soybeans.

[d]Contains soybean meal and added fat.

LABORATORY EVALUATION OF PROCESSED SOYBEANS AND THEIR NITROGEN BALANCE IN CALVES

Summary

Twenty one samples of raw and heat treated soybeans were evaluated for crude protein, dry matter (DM), protein dispersibility index (PDI), and urease activity. These analyses were used to select four soybean treatments for further evaluation. The four types of treated soybeans were incorporated into starters for evaluation in a N-balance trial. The trial utilized four male Holstein calves, 10 to 15 wk of age, and the four starters in a 4 x 4 Latin square design. One starter contained raw soybeans having a PDI of 92 and the others contained heat treated beans having PDIs of 21, 40, and 43. The four periods consisted of a 5 d collection and a change-over period of at least 7 d. N-retention was less ($P<.05$) when the calves consumed the raw soybean diet compared to the heat treated soybean diets, which were all similar in N-retention.

(Key Words: Soybeans, PDI, N-Balance, Calves)

Introduction

Rumen bypass of protein has the potential to improve feed utilization efficiency because post ruminal digestion is more efficient (Hedde et al., 1974). The benefits of bypassing the rumen have been demonstrated in calves (Hedde et al., 1974) and sheep (Ørskov et al., 1970). Processing soybeans provides a possible system for regulating rumen bypass of protein (Chalupa, 1975).

Several methods are used to improve bypass potential of protein and amino acids. They include chemical treatment, heat treatment, encapsulation, esophageal groove closure, use of amino acid analogs, and selective regulation of balances of metabolic pathways in the rumen (Chalupa, 1975).

Protein solubility is an important property affecting rumen bypass. The quantity of protein bypass depends on the amount of low solubility protein in the diet as well as degradation rate and flow rate through the rumen (Crawford et al., 1978). Various methods are used to determine protein solubility or insolubility as an estimator of bypass potential (Goering and Waldo, 1974a; Waldo and Goering, 1979).

This study utilized heat treated soybeans processed in a California Pellet Mill Jet-Sploder. The process uses hot air which quickly heats the beans and transports them through the system. The system recycles most of the air which increases heating efficiency.

The objectives of this experiment were to evaluate protein solubility of raw and processed (heat treated) soybeans, using PDI, and measure their utilization by the calf using a N-balance trial.

Experimental Procedure

In Vitro Trial

Soybeans were processed at various temperatures and times in a California Pellet Mill Jet-Sploder[1] (table 1). Selected soybean treatments were tempered by storage in a bin prior to cooling. The processed soybean samples were analyzed for crude protein (Kjeldahl), DM (AOAC, 1970), PDI, and urease activity (AACC, 1969). Processing conditions, PDI, and tempering time were used as a basis for selecting four soybean treatments for further evaluation.

N-Balance Trial

The conditions selected for further evaluation are shown in table 2. The processed soybeans were analyzed like the original samples, except for urease activity. The soybeans were incorporated into starters for evaluation in a N-balance trial (table 3).

Four male Holstein calves, 10 to 15 wk of age, and four starters were utilized in a 4 x 4 Latin square design. The calves were housed in individual elevated collection stalls. Starter was fed according to body weight and chopped prairie hay was fed at 10% of the starter intake. All calves were fed individually, twice a day, towards the upper limit of their intake. Calves 1, 3, and 4 were fed at 3% of body weight, and 2 was fed at 2.5% of body weight.

The four periods consisted of a 5 d collection period and a change-over of at least 7 d. The calves were weighed prior to each

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[1]California Pellet Mill Co., San Francisco, CA.

period. Feces and urine were collected together in a metal collection box containing 25 ml concentrated sulfuric acid and water to maintain acidity. Representative samples were obtained for each calf per period. The samples were analyzed for N and DM (AOAC, 1970).

The starters and hay were analyzed for crude protein (Kjeldahl) and DM (AOAC, 1970). The data were analyzed using analysis of variance and least significant difference where appropriate.

Results and Discussion

In Vitro Trial

The analyses of the 21 soybean samples are in table 1. In general, the soybeans showed a trend of increasing PDI and urease activity with decreasing processing time and temperature. There was also a trend of decreasing PDI by tempering the soybeans at the same processing conditions.

N-Balance Trial

The analyses of variance are in table 4. The analyses of the four soybean samples, starters, and hay utilized in the N-balance trial are in table 2.

The N-retention of calves fed raw soybeans was less ($P<.05$) than those fed processed soybeans (table 5). Calf 2 had less N-retention in the four periods than the others which had similar N-retention (table 5).

The concept that high protein solubility decreases rumen bypass potential (Crawford et al., 1978) is supported by the lower N-retention of calves fed raw soybeans. The processed soybeans, which were less soluble, gave similar N-retention in the calves. The processing of the soybeans appeared to help increase N-retention, but even though the processed soybeans varied in solubility they did not vary in N-retention. It is possible that similar rumen efficiencies and rates of bypass in the calves could explain the results of the processed soybeans.

Calf 2 had significantly less N-retention than the other calves. This is probably due to the fact that the calf consumed less N per unit of body weight and with metabolic fecal nitrogen being proportional to intake (Maynard et al., 1979), N-retention was less.

This study showed that processing was of some benefit to the calves, as indicated by N-retention. The difference between the N-retention of processed and raw soybeans was statistically significant, but small from a practical standpoint. Tempering soybeans appeared to have no special benefit on N-retention when compared to the untempered beans at the same processing conditions. Since the processed soybeans did not differ in their N-retention, further evaluation needs to be done to determine the best processing time and temperature needed to obtain optimal rumen by-pass potential and protein utilization. In addition, the possible benefit of tempering needs to be evaluated at other processing conditions to determine its usefulness in the processing of soybeans. It is probably wise to evaluate soybeans with a PDI of less than 20, preferably in a range of 10 to 15. A PDI of 10 has been shown to be beneficial for the lactating cow (Netemeyer et al., 1982).

TABLE 1. PROCESSING CONDITIONS AND ANALYSES OF SOYBEANS

Sample	Grain exit temperature (°C)	Processing time[a]	Tempering time[b]	% CP[c]	% DM	% PDI	Urease[d]
Raw				42.57	93.09	90.49	2.00
1	204°	2'05"	0	43.07	97.45	11.68	0
2	193	1'50"	10'	40.53	97.46	36.74	0
3	193	1'50"	0	40.16	97.04	22.00	0
4	188	1'35"	10'	40.93	97.34	12.43	0
5	188	1'40"	0	40.73	97.36	21.56	0
6	182	1'30"	10'	41.77	97.37	22.74	0
7	182	1'30"	0	38.70	96.89	16.16	0
8	177	1'10"	10'	40.88	97.01	14.06	0
9	177	1'15"	0	43.01	96.97	25.18	0
10	171	1'05"	10'	40.80	96.73	13.80	0
11	171	1'05"	0	40.89	96.61	14.86	0
12	160	51"	10'	40.95	96.77	13.10	0
13	160	52"	0	40.30	96.47	18.45	0
14	149	42"	10'	41.15	96.42	18.43	0
15	149	42"	0	40.98	96.61	24.09	0
16	138	35"	10'	41.57	96.30	25.03	0
17	138	35"	0	41.24	96.23	42.89	.10
18	127	27"	20"	42.13	96.12	69.83	.65
19	116	25"	20"	40.66	95.74	65.25	1.67
20	110	27"	20"	42.03	95.38	78.00	1.96

[a] ' = minutes; " = seconds.

[b] Storage time prior to cooling.

[c] Dry matter basis.

[d] Activity indicated by pH rise.

TABLE 2. PROCESSING CONDITIONS OF SOYBEANS IN STARTERS AND ANALYSES OF SOYBEANS, STARTERS, AND HAY

Item	Grain exit temperature (°C)	Processing time[a]	Tempering time[b]	%		
				CP[c]	DM	PDI
Soybeans						
Raw				44.02	87.58	91.65
B	171°	1'02"	0	44.92	95.53	20.97
C	138	35"	10'	45.71	92.51	39.22
D	138	35"	0	45.69	92.75	43.00
Starters[d]						
Raw				15.51	88.07	
B				15.90	88.80	
C				15.69	88.81	
D				16.20	88.46	
Hay						
Chopped prairie				5.09	92.12	

[a]' = minutes; " = seconds.
[b]Storage time prior to cooling.
[c]Dry matter basis.
[d]Starters contain soybeans with corresponding labels.

TABLE 3. COMPOSITION OF STARTERS[a]

Ingredient	%
Corn	55.4
Oats	16.7
Soybeans, raw or processed[b]	20.4
Molasses, liquid	5.6
Premix[c]	1267.6g

[a]Dry matter basis.

[b]Raw soybeans ground in a hammermill with a 1/8" screen.

[c]Premix consists of: salt, 110.9g; trace mineral salt, 110.9g; limestone, 430.3g; dicalcium phosphate, 146.4g; vitamins A and D (1,000,000 IU A and 500,000 IU D/454g), 12.7g; vitamin A (30,000 IU/g), 2.4g; finely ground corn, 454g. 1267.6g added/ 45.4 kg starter (as fed).

TABLE 4. ANALYSES OF VARIANCE

Source of Variation	d.f.	MS[a]	P[b]
Period	3	0	--
Calf	3	.0031	<.005
Diet	3	.0002	<.05
Error	6	.00003	

[a]Mean Square.

[b]Probability.

TABLE 5. MEAN N-RETENTION BY DIET AND BY CALF

Diet	gN/Kg Body Wt.	Calf	gN/Kg Body Wt.
Raw	.31[a]	1	.33[a]
B	.32[b]	2	.27[b]
C	.32[b]	3	.33[a]
D	.32[b]	4	.33[a]

[a,b]Means with unlike subscripts differ (P<.05).

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PROCESSED SOYBEANS AND TYPES OF HOUSING FOR YOUNG CALVES

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Two experiments were conducted to evaluate processed soybeans and compare types of housing for young calves. In the first experiment, a completely randomized repeated measures (week) design was used to assign 60 Holstein calves to experiment at 1 to 2 d of age for 8 wk. Twelve treatment combinations (3 starters x 4 types of housing) were utilized. The starters contained soybean meal (SBM), extruded whole soybeans (EXTR), or soybean meal and added fat (SBMF). Types of housing were inside floor pens, inside elevated pens, small wood hutches, and large fiberglass hutches. Each calf was fed individually and weight gains, feed consumption, and observations of health were recorded. Calves fed SBM gained more ($P<.05$) than those consuming SBMF. Gains were intermediate for calves consuming EXTR. Females gained more ($P<.05$) in wood hutches than in floor- and elevated-pens, but compared to fiberglass hutches gain was similar. Males gained similarly ($P>.05$) in the four types of housing. SBM starter intake was greater ($P<.05$) than EXTR and SBMF intake during wk 6 to 8. Calves in fiberglass hutches consumed more ($P<.05$) starter during wk 5 to 8.

In the second experiment, twenty-one samples of raw and heat treated soybeans were evaluated for crude protein, dry matter (DM), protein dispersibility index (PDI), and urease activity. These analyses were used to select four soybean treatments for further evaluation. The four types of treated soybeans were incorporated into starters for evaluation in a N-balance trial. The trial utilized four male Holstein calves, 10 to 15 wk of age, and the four starters in a 4 x 4 Latin square design. One starter contained raw soybeans having a PDI of 92 and the others contained heat treated beans having PDIs of 21, 40, and 43. The four

periods consisted of a 5 d collection and a change-over of at least 7 d. N-retention was less ($P<.05$) when the calves consumed the raw soybean diet compared to the heat treated soybean diets, which were all similar in N-retention.