EFFECTS OF PARTICLE SIZE AND PHYSICAL FORM OF SUN-CURED ALFALFA FOR GESTATING SWINE

by

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B. S., Kansas State University, 1978

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

Approved by :

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ACKNOWLEDGEMENTS

I would like to extend a sincere appreciation to Dr. Steve Pollmann for his invaluable assistance and guidance throughout this study. Thanks are also extended to Dr. Ben Brent, my major proffessor, and to Dr. Gary Allee for serving on my committee.

I would also like to thank my parents for providing me the opportunity to attend college and for thier constant words of encouragement. Finally, I would like to thank my husband, Denny, for always caring and being there when I needed him most.

L. J. N.

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Introduction

The ability of swine to utilize high fiber feeds has been established early in the 1900's and more recently reviewed by Rérat (1978). High fiber forages such as alfalfa are a good source of vitamins and minerals and have amino acid profiles similar to soybean meal. Cheeke (1977) reported that alfalfa produces more protein per acre than any other common feedstuff.

Nebraska researchers have suggested that high fiber forages may be economically feasible for gestating swine diets (Danielson, 1970, 1974). It has been shown that sun-cured alfalfa fed daily, bi-weekly, or self-fed (Moser, 1978) has no adverse effects on reproductive performance. Dehydrated alfalfa as 25% of the diet (Danielson et al, 1975) and 96.7 % of the diet self-fed (Allee, 1977) also have been studied. Teague (1955) has suggested that diets with added alfalfa furnished factors which tended to influence ovulation rate and post-natal survival of the litter favorably. These data indicate that alfalfa can be utilized successfully and may be economically competitive with concentrate diets for gestating swine.

In past studies, the amount of alfalfa in the diet has been the main research emphasis and very little research has been done on particle size or physical form. This study was conducted to determine effect of particle size and physical form of sun-cured alfalfa for gestating sows.

Review of the Literature

Feed Processing

Feed represents 65 to 80% of the total cost of production in the swine industry. Since maintaining the breeding herd is about 25% of the feed cost, any techniques used to lower the cost of the breeding herd without adversely affecting reproductive performance is of economic interest.

Grinding is one of the oldest methods of feed processing. Several advantages of grinding are: a) increased surface area making the feed ingredient more digestible, b) aids in ease of handling, c) mixing of other ingredients is expedited, and d) pelleting is more efficient with finely ground feed.

Crampton and Bell (1946) reported that 23 kg pigs attained significantly better gains as fineness of grind increased with an 85% oat diet. They also noted that the various degrees of fineness did not affect the digestibility of dry matter for older pigs. In agreement with the previous study, Lawrence (1970) compared whole barley with barley rolled, crimped or ground at three finesses. Using 20 to 30 kg barrows, Lawrence reported that all five processes produced better results than the whole barley treatment. As particle size decreased, the retention time in the gastrointestinal (GI) tract increased resulting in the highest digestibilities for crude fiber and ether extract. Also, rolled barley generally produced higher digestibilities comparable to the more finely ground barley but retention time in the GI tract was significantly less. This indicates that physical form of a feed may also influence digestibility.

Owsley et al. (1981) studied the effect of fineness of grind on digestibility using a sorghum-casein diet fed growing-finishing pigs.

The three treatments prepared consisted of dry rolled sorghum, sorghum ground with a 6.4 mm screen, and sorghum ground with a 3.2 mm screen. The modulus of fineness for each treatment was reported as 3.57, 2.85, and 2.36, respectively. Apparent ileal digestibility of dry matter, starch, gross energy, and nitrogen significantly increased with each reduction in particle size. Also, a significant improvement in total tract digestibility was observed for the 3.2 mm ground treatment as compared to the other two treatments. Although the ileal starch digestibility for the 6.4 mm ground treatment was greater ($P<.05$) than the dry rolled treatment, the total tract starch digestibilities were not significantly different. These results show that the lower GI tract plays an important role in starch digestion via microbial fermentation as starch escapes the upper GI tract.

Starch digestion in the large intestine is attributed to the intestinal microflora resulting in the production of volatile fatty acids (VFA) which the pig can efficiently absorb (Argenzio and Southworth, 1975; Farrell and Johnson, 1972). Contributions of VFA to the energy pool of swine have been reported from 5 to 28% of the digestible energy intake (Farrell and Johnson, 1972; Friend et al., 1964) depending on the amount of carbohydrate reaching the lower GI tract. Kass et al. (1980b) reported VFA absorbed from the GI tract provided 4.8, 11.4, 14.0, and 12.0 % of the energy required for maintenance in 89 kg pigs fed 0, 10, 40 or 60% alfalfa meal respectively. These data indicate that large quantities of VFA are produced in the lower GI tract and pigs can absorb them (Imoto and Namioka, 1978).

Pelleting is another important feed processing technique. It is defined as "agglomerated" feeds formed by extruding, compacting, and forcing the feed through die openings by any mechanical process.

The purpose of pelleting is to take finely divided, dusty, unpalatable, difficult to handle feed material and by applying heat, moisture, and pressure to form larger particles (Pfost, 1976).

The reported results have varied concerning the value of pelleted feeds. Most of the variation can be explained by the processing methodology. Pressure and heat cannot be precisely controlled but markedly affect the nature of the pellet. Moisture, composition, and texture of the diet influence pressure and heat during the pelleting process.

Pelleting has been shown to affect the crude fiber of a feed. When beneficial effects due to pelleting are reported, the crude fiber content of the pelleted feed was less than that of the meal (Larsen and Oldfield, 1960; Lindahl and Reynolds, 1959). Conversely, when no beneficial effect is reported for a pelleted feed, i.e., corn, the crude fiber content of the meal was equal to that of the pellet (Larsen and Oldfield, 1960).

Diet ingredients also affect the utilization of pelleted feeds. Becker (1965) showed that all diets in the absence of wheat bran were utilized more efficiently in pelleted form. Thomas and Flower (1956) using a barley/wheat diet produced similar results when comparing pelleted and non-pelleted diets. Results indicate that pelleted rations increased daily gains for growing-finishing pigs and reduced the amounts of feed required to reach market weight. The authors also reported that pigs fed pellets wasted less feed and required less time at the feeder to satisfy their appetites. Jensen and Becker (1954) and Dinusson et al. (1956) reported improved daily gains attributed to pelleting.

Seerley et al. (1962b) conducted rate of passage studies that indicated pellets had lower retention time in the GI tract compared to meal-form. Larsen and Oldfield (1960) found that crude fiber was lower in pelleted barley and reground pellets than in the original barley meal. This indicated that changes in the pelleted feed are largely physical rather than chemical. In a similar study using corn diets, pelleting produced no improvements in performance. Tribble et al. (1973) reported similar results when grain sorghum-soybean meal diets were fed to finishing swine. No significant differences were found in gains; however, pigs fed the pelleted diets required 9% less feed per unit of gain than those fed meal diets.

Fiber Analyses

Dietary fiber is nutritionally defined as the insoluble organic matter that is resistant to animal enzymes (Van Soest, 1966). Consequently, the term "fiber" should denote an entity which is closely associated with indigestibility. These residues are composed primarily of cell walls which consist of lignin, cellulose and hemicellulose. Neutral detergent fiber (NDF) represents an estimate of the cell wall components of feedstuffs. The counterpart to the cell wall fraction is the cell soluble fraction which has been reported as 98% available to the animal (Van Soest, 1967). Acid detergent fiber (ADF) represents the sum of cellulose and lignin (Colburn and Evans, 1965). Thus, the difference of ADF and NDF percentages yields an estimate of hemicellulose.

The crude fiber fraction of the proximate analysis has been used in the past to estimate dietary fiber. However, there have been discrepancies in the method which have affected the calculation of the nitrogen-free extract (NFE) of the proximate analysis. Forbes and Hamilton (1952) have shown underestimations of fiber by the crude fiber method and have recommended the use of cellulose and lignin analyses for fiber estimations.

One of the major criticisms of the crude fiber value and its effect on NFE is that neither quantity represents discrete chemical entities. In theory, the crude fiber fraction includes the sum total of indigestible nutrients. NFE is the fraction of the proximate analysis that is estimated by the difference of 100% and the sum total percentages of crude protein, ash, ether extract, and crude fiber. Thus, an overestimation of NFE is caused by the underestimation of crude fiber. The AOAC has recommended the NFE estimation be discontinued since 1940.

Another discrepancy of the crude fiber analysis is caused by specie differences in plants. Indigestible lignin and digestible hemicellulose are partially extracted with the crude fiber analysis and thereby produce lower crude fiber values. The extent of these losses is plant species dependent because the lignin of grasses is more alkali-soluble than that of alfalfa (Van Soest, 1964). Thus, the lower lignin content of grasses is consistent with a higher fiber digestibility relative to alfalfa.

Van Soest (1966) suggested the detergent fiber methods distinguish less available fractions of feedstuffs which allow classification according to mode of availability rather than specific chemical entities. The detergent fractionation as determined by Goering and Van Soest (1970) appears in table 1.

Alfalfa in Swine Diets

Alfalfa has been used in swine diets for many years and for a variety of reasons. It has been used as a diluent (Crampton et al., 1954), as a source of vitamins and minerals (Teague and Grifo, 1965), as a source of unknown factors favorable for reproduction (Teague, 1955) and for controlling intake of self-fed sows (Allee, 1977). Only recently has alfalfa been seriously considered as a major feed component of the

Table 1. Fractionation of Plant Components with Detergents.

Fraction	Organic Components
Cell contents	protein, sugars, starch, lipids pectin, gums
Neutral detergent fiber residue (NDF)	lignin, cellulose, hemicellulose, cell wall protein
Acid detergent solubles	hemicellulose, some cell wall protein
Acid detergent fiber residue (ADF)	lignin, cutin, cellulose, heat damaged protein
Crude lignin	lignin, cutin, heat damaged protein
Crude cellulose	cellulose, cutin

Goering and Van Soest (1970)

swine diet. Previously, it was assumed that swine could digest only small amounts of fiber. Contrary to this belief, many researchers have found that swine, especially sows, can digest high fiber diets for extended periods of without detrimental effects (Pollmann et al., 1981).

Bohman et al. (1953) compared diets which contained 10, 30, and 50 percent alfalfa in two trials involving growing-finishing swine. Pelleted and meal rations of 50% alfalfa were also compared. The authors reported significantly decreased rates of gain as percentage of alfalfa increased in the diet. Gains of .78, .73, and .59 kg per day were reported for 10, 30, and 50 % alfalfa, respectively. The pelleted 50 % alfalfa diet produced significantly increased gains as compared to the same diet fed as a meal. Less feed was required per unit of gain and reduction in intake was observed for the pellet-fed group compared to those consuming the same diet fed in a meal-form. Pigs fed 30 and 50 % alfalfa had a markedly enlarged stomach and intestine, suggesting that swine adjust to high levels of fiber to accommodate greater utilization. Bohman et al. (1955) and more recently USDA researchers (Pekas and Pond, 1981) have reported similar findings. Additionally, it was reported that rate of gain was inversely proportional to the crude fiber content of the diet.

Kass et al. (1980) investigated the utilization of alfalfa in different segments of the GI tract. Sixty-four 17 kg barrows were fed 0, 20, 40, and 60 % alfalfa meal to 48 or 89 kg finishing weights and sacrificed at 2, 4, 8, and 12 h after the last feeding. No significant differences were found between the 0 and 20 % alfalfa diets on daily gain and feed efficiency. Conversely, the 40 and 60 % alfalfa diets produced decreased gain and feed efficiency compared to the 0 and 20 % alfalfa diets. All segments of the empty GI tract increased in weight as the percentage of alfalfa increased in the diet. Dry matter, cellulose, hemicellulose, and nitrogen digestibilities decreased with increased percentage of alfalfa. These decreases were associated with an increased rate of passage as amount of fiber increased in the diet. It was concluded that the rate of passage induced the poor digestibility of fiber and no significant adaptation to high fiber diets were observed which is in agreement with Cunningham et al. (1962).

Danielson and Noonan (1975) investigated high roughage diets fed to gestating swine. They compared pelleted gestation diets containing 25, 33, 66, and 96.75 % alfalfa hay, 66 % prairie hay and 25 % dehydrated alfalfa. In three trials, gilts consuming diets with the highest percentage of alfalfa gave the highest farrowing rate. Sows on the highest level of alfalfa had heavier litter weaning weights. In a subsequent study using the 96.75 % alfalfa diet through three successive gestations, the beneficial effects of alfalfa were continuous with each gestation period. Conclusively, these results indicate possible attributes of feeding high levels of alfalfa to gestating swine.

Pollmann et al. (1979) fed pelleted high fiber diets (97 % suncured alfalfa or 66 % wheatgrass) to gestating sows and reported increased nutrient utilization after an 80 day adaptation period compared to digestibilities in the first trimester. Decreased digestibilities of fiber, energy and nitrogen were reported for the high fiber diets as compared to a conventional corn-soybean meal diet.

Fiber Utilization

Forbes and Hamilton (1952) fed 57 kg barrows wheat straw, woodflock, alfalfa meal and oat hulls as fiber sources. Basal diet starch was replaced with the respective fiber sources at levels to yield diets of equivalent cellulose value. The authors reported that different fiber sources produced different fiber digestiblity values. Alfalfa meal had the highest value with woodflock, wheat straw , and oat hulls following in decreasing order. Differences in digestibility were attributed to extent of lignification in the different fiber sources. Forbes and Hamilton also emphasized fiber underestimation by the crude fiber method and discussed advantages of substituting cellulose and lignin determinations for crude fiber. Cellulose plus lignin values exceeded crude fiber estimates in most cases. Degree of lignification correlated best with animal utilization. Thus, the combination of cellulose and lignin appears to be the better estimate of dietary fiber.

Cunningham et al. (1962) studied the effects of body weight , age, feed intake and adaptability on cellulose digestion by 68 kg pigs. Apparent digestibility of crude fiber and crude protein increased as feed intake was reduced to maintenance levels. Changes in body weight and level of feeding affected digestibility more than age. Digestibility of added cellulose (solka-flock) was not significantly different for pigs which had been fed solka-flock for 15 weeks as compared to those fed the treatment for one week. These results are in agreement with results reported by Kass et al. (1980a). The addition of solka-flock also increased fecal nitrogen. This increase accounted for the depressed digestibility of crude protein often associated with high levels of fiber in the diet. Concomitantly, the increased fecal nitrogen was thought to be of metabolic origin (Whiting and Bezeau, 1957a,b) or fiber bound protein (Lloyd and Crampton, 1955).

Farrell (1973) using 50-60 kg female pigs fed alkali treated straw at 25 % of the diet and reported additional nitrogen in the feces which depressed nitrogen digestibility. Farrell attributed the excess nitrogen to bacterial synthesis in the cecum and proximal colon. Using calculations of Hogan and Weston (1971), the author concluded that the digestion of cellulose in pigs could add 10.4 g of microbial nitrogen to the feces.

Kennelly and Aherne (1980) fed 67 kg barrows and gilts four diets containing differing amounts of crude fiber, energy, and protein. Oat hulls were used to replace part of the control diet (diet 1), isonitrogenously (diet 2), by simple dilution (diet 3) and isonitrogenously-isoenergetically (diet4) to produce diets with the following composition. Diet 1 contained 4.1 % crude fiber (CF), 17.1 % crude protein (CP) and 14.1 MJ digestibile energy (DE). Diets 2, 3, and 4 contained 9.8, 9.6, and 10.2 % CF, 17.0, 14.4 and 17.3 % CP and 12.2, 12.5 and 14.8 MJ DE, respectively. The authors reported depressed dry matter and energy digestibilities with added oat hulls. The method of addition significantly influenced dry matter digestibility. Apparent nitrogen digestibility was unaffected by the level of CF in the diet. Differences in amino acid digestibilities were also observed. It appeared that these differences were related to the quality and quantity of nitrogen and energy levels rather than the level of CF in the diets. One must note that amino acid content of the feces can be distorted by additional amimo acids originating from microbial activity in the lower GI tract.

Keys and Debarthe (1974) using 85 kg pigs fitted with duodenal and ileal cannulas investigated sites of dry matter and fiber utilization. Cell wall, cellulose and hemicellulose digestibilities were estimated for alfalfa, grain sorghum, Texas Kleingrass and Costal Bermuda grass. They concluded that approximately 100 % of the cellulose and 80 % of the hemicellulose digestion occurred in the large intestine of swine.

Keys et al. (1972) studied the effect of increasing dietary fiber (lignin, cellulose,and hemicellulose) level on digestibility of dry matter, crude protein and fiber by swine and rats. Increased dietary fiber decreased the digestibility of dry matter and crude protein. They also reported that hemicellulose was more readily digested than cellulose.

MATERIALS and METHODS

Experimental Procedures

Sixteen gravid crossbred sows (second parity) were used in a digestion trial to determine the influence of particle size and physical form of sun-cured alfalfa. Treatments were prepared using baled alfalfa hay ground through a Bearcat[1] grinder with a 12.5 mm screen. Half of the hay was rechopped using a 6.25 mm screen, resulting in two particle sizes. A portion of each particle size was pelleted using a California Pellet Mill Master Model[2] pelleter with a 9.5 mm die. The hay was conditioned with steam to 75 C prior to pelleting and cooled across a horizontal pellet cooler with ambient air. The pellets were scalped across a 6.25 mm screen to recover fines and packed into 23 kg bags. The alfalfa treatments were designated as 6.25 mm meal, 6.25 mm meal pelleted, 12.5 mm meal, and 12.5 mm meal pelleted. Fifty percent alfalfa was added to a sorghum grain-soybean meal supplement. The diets were fed to supply 5000 kcal metabolizable energy (ME) per day (2 kg). Alfalfa was assumed to be 60 % digestible for diet formulation. The ingredient and chemical compositions are represented in tables 2 and 3 respectively.

The sows were weighed, bred, and introduced to the treatments on day zero of the trial. Sows were reweighed prior to each collection. Treatments were hand fed once a day throughout gestation. Five day total collections were initiated at 25 and 80 days postcoitum.

Three days prior to the collection period, the sows were moved into metabolism crates. The crates were housed in a room equipped with artificial light and temperatures ranged from 25 to 28 C. Crates were

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[1]Western Land Roller Co., Hastings, NB.

[2]California Pellet Mill Co., San Fransisco, CA.

Table 2.

COMPOSITION OF DIET

Ingredient	Internat'l Feed No.	%
Alfalfa, sun-cured[a]	1-00-063	50.0
Grain sorghum	4-04-383	41.4
Soybean Meal, 44%	5-04-604	5.5
Monosodium phosphate	6-04-208	1.1
Dicalcium phosphate	6-01-080	.7
Vitamin-trace mineral premix[b,c]		1.0
Salt		.3
	Total	100.0

[a]Assumed 60% digestible.
[b]Vitamin A, 4400 IU; Vitamin D_3, 330 IU; riboflavin, 5.0 mg; calcium pantothenate, 14.3mg; choline chloride, 507 mg; niacin, 27.5 mg; Vitamin E, 22 IU; Vitamin B_{12}, 24 μg; Mn, 55 mg; Fe, 100 mg; Cu, 11 mg; Zn, 200 mg; I_2, 1.5 mg; Co, 1.0 mg. Per kg of diet.
[c]Finely ground sorghum grain was used as a carrier.

Table 3.

CHEMICAL COMPOSITION OF DIETS[a]

	Alfalfa	Supplement
Dry Matter, %	90.1	88.5
Ether Extract, %	2.9	3.6
Ash, %	8.4	7.2
Crude protein, %	20.2	17.9
Crude fiber, %	26.8	2.8
ADF, %	32.1	6.9
NDF, %	40.7	21.4
Lignin, %	8.9	2.2
Cellulose, %	23.3	4.4
Hemicellulose, %	8.7	14.5
Acid detergent insoluble N, %	.23	.39
Hot water insoluble N, %	2.27	2.27
Ca, %	1.64	.61
P, %	.29	1.45
Gross energy, kcal/kg	4524	4194

[a]Analysis on dry matter basis.

equipped nipple waterers which were turned on during the day and off at night. Bardex[3] Foley catheters (size 20, 5 cc, plug type) were inserted one day prior to the collection period which facilitated separation of urine and feces (Pollmann et al., 1977).

Urine was collected into 19 liter plastic receptacles to which 100 ml hydrochloric acid had been added. Total urine output was weighed and recorded daily with a 10 % aliquot taken as the urine was continuously mixed. The aliquots were composited for the five days and refrigerated. The composites were strained through glass wool and subsamples were analyzed for total nitrogen.

Ferric oxide (50 g) was added to the feed to mark the beginning and end of each collection period. Total fecal collections commenced at the first sign of ferric oxide in the feces. Feces were collected twice daily, placed in plastic bags, and were frozen. At the end of each collection period, the feces for each sow were thawed and mixed thoroughly. A 10 % subsample was saved and dried at 50 C in a forced air oven for 48 h, ground through a Wiley[4] mill (1 mm screen), mixed, and submitted to the laboratory for analysis.

A 2 x 2 factorial arrangement of treatments was employed with two main effects (particle size and physical form). Least square analysis of variance was used to analyze tha data in a split-plot design. Partial correlation coefficients between independent variables were calculated as outlined by Helwig and Council (1979).

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[3]C.R. Bard, INC., Murray Hill, NJ.

[4]Thomas-Wiley Laboratory Mills, Philadelphia, PA.

Criteria of Response

Criteria of response for this study were dry matter digestibility, energy digestibility, nitrogen retention, and fiber utilization. Analyses considered included proximate analysis (AOAC, 1980), detergent fiber determinations (Goering and Van Soest, 1970), and gross energy (Oxygen bomb calorimetry).

Proximate analysis (5-step) included dry matter (DM), ether extract (EE), crude fiber (CF), ash, and nitrogen (N). Detergent fiber analyses consisted of neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (Lig), and cellulose (Cell). Hemicellulose was calculated as the difference of percentage NDF and ADF. Lignin was analyzed by the potassium permanganate method. Acid detergent insoluble nitrogen (ADN) was used to estimate effects of non-enzymatic browning exhibited by feeds which have been over heated. Hot water insoluble nitrogen (HWIN) was used to estimate true protein associated with forages. Calcium and phosphorous analyses were conducted to insure proper diet formulation.

Results and Discussion

Utilization of alfalfa is shown in tables 4, 5 and 6. Since no significant particle size x physical form interactions were observed, the main effects will be discussed.

Particle Size

An estimate of particle size (Waldo et al., 1971; Pfost,1976)was conducted using a Ro-Tap[5] testing sieve shaker equipped with screens sized from 5.6 mm to 2.2 µm openings. Residual amounts remaining on each sieve are shown in appendix table 4. Particle size distribution is typically skewed but is accurately described as a log normal distribution (figure 1). This measurement is even more distorted by elongated particles such as those of ground alfalfa. Geometric mean particle size (d_{gw}) was estimated as 434 µm and 646 µm with geometric standard errors (s_{gw}) of 2.9 and 2.5 for 6.25 mm and 12.5 mm treatments, respectively.

The effects of particle size of alfalfa are reflected in figure 2. Significant increases in digestibility were observed for DM, DE, and the fiber components with decreased particle size. Digestibility for 12.5 mm and 6.25 mm treatments were DM, 70.6 vs 73.6 %, DE, 68.3 vs 73.0 %, CF, 32.2 vs 38.0 %, ADF, 36.5 vs 43.3 %, NDF, 49.3 vs 53.2 % and cellulose, 32.2 vs 47.4 %, respectively. Dry matter digestibility was correlated (r^2=.92) with DE. Crude fiber digestion was found to correlate highly with cellulose and NDF digestion, r^2=.78 and r^2= .64, respectively. Lignin and hemicellulose digestibilities were unchanged with particle size as was nitrogen utilization.

These results are in agreement with Crampton and Bell (1946) and Lawrence (1970) who reported higher digestibilities associated with

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[5]Tyler Industrial Products Co., Cleveland, Ohio.

Table 4. Effect of Particle Size and Physical Form of Alfalfa on Dry Matter, Ether Extract, and Energy Digestibiblity.

Item	Trimester	Particle Size / Physical Form	6.25mm Meal	6.25mm Pellet	12.5 mm Meal	12.5 mm Pellet
Dry Matter (%)[a,b]	1		69.6	72.4	67.1	68.8
	3		76.5	76.0	74.5	72.1
Ether Extract (%)	1		63.4	62.1	60.0	56.5
	3		63.4	54.7	63.2	56.9
Digestible Energy (%)[a,b]	1		68.7	71.2	63.3	64.5
	3		76.5	75.6	74.1	71.2
Digestible Energy (kcal/kg)[a,b]	1		2991	3102	2772	2806
	3		3331	3290	3222	3097

[a]Particle size difference ($P < .01$).
[b]Period difference ($P < .001$).

Table 5. Effect of Particle Size and Physical Form of Alfalfa on Fiber Component Digestibilities.

		Particle Size	6.25mm		12.5mm	
Item	Trimester	Physical Form	Meal	Pellet	Meal	Pellet
Crude Fiber[b,c,f]	1		20.7	32.0	19.0	23.9
	3		50.9	50.9	48.5	37.4
ADF[b,c,f]	1		27.7	36.0	28.0	33.0
	3		59.9	49.5	45.8	39.4
Lignin[d]	1		33.0	32.4	29.8	31.1
	3		51.2	39.6	50.9	44.9
Cellulose[a,c,f]	1		33.2	44.8	30.7	39.4
	3		53.2	58.5	46.5	42.6
NDF[b,c,f,g,]	1		38.4	48.5	41.5	45.2
	3		63.4	62.5	56.5	54.0
Hemicellulose[c]	1		57.0	65.0	65.3	64.8
	3		83.5	81.0	79.8	77.5

[a] Particle size difference ($P < .01$).
[b] Particle size difference ($P < .05$).
[c] Period difference ($P < .001$).
[d] Period difference ($P < .05$).
[e] Form difference ($P < .05$).
[f] Form x period ($P < .05$).
[g] Size x period ($P < .05$).

Table 6. Effect of Particle Size and Physical Form of Alfalfa on Nitrogen Utilization.

Item	Trimester	Particle Size / Physical Form	6.25mm Meal	6.25mm Pellet	12.5mm Meal	12.5mm Pellet
Intake, N g/day	1		49	53	51	54
	3		50	52	52	54
Fecal, N g/day	1		12	13	14	14
	3		11	12	12	13
Urinary, N g/day	1		22	23	22	26
	3		29	31	31	34
N-Balance, g/day[b]	1		15	17	15	14
	3		9	7	13	6
N-Retention (%)[b]	1		32.4	32.3	30.3	26.2
	3		18.4	14.9	26.4	12.8
N-Digestibility (%)	1		76.0	75.8	72.9	74.2
	3		77.4	77.3	77.7	75.8
ADN-Digestibility (%)[d]	1		63.5	65.7	66.7	63.0
	3		71.3	66.9	69.5	62.3
HWIN Digestibility (%)	1		80.8	81.2	80.1	78.8
	3		82.0	80.9	81.4	79.3

[a] Particle size difference ($P<.05$).
[b] Period difference ($P<.01$).
[c] Form difference ($P<.001$).
[d] Form difference ($P<.05$).

FIGURE 1.

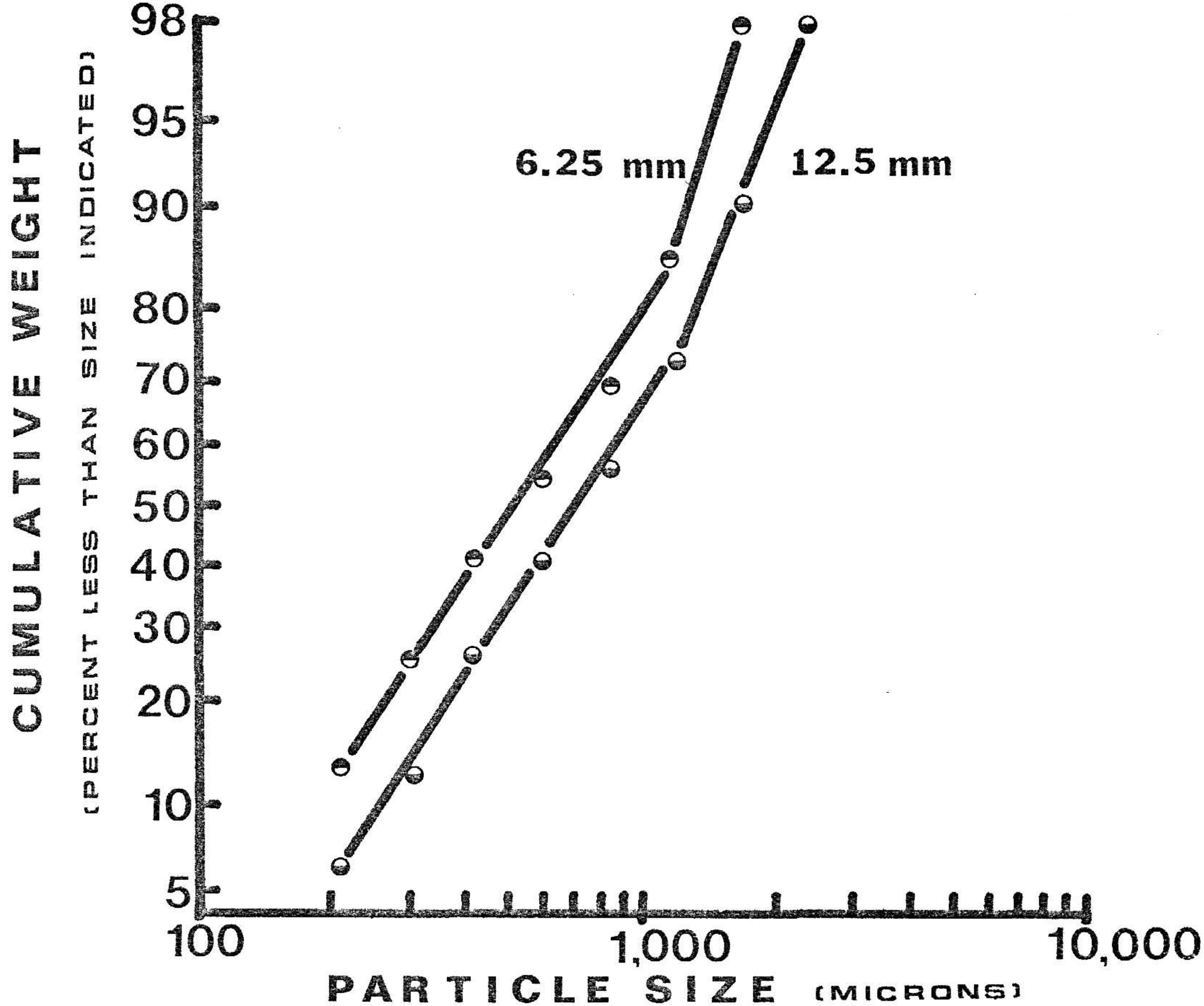
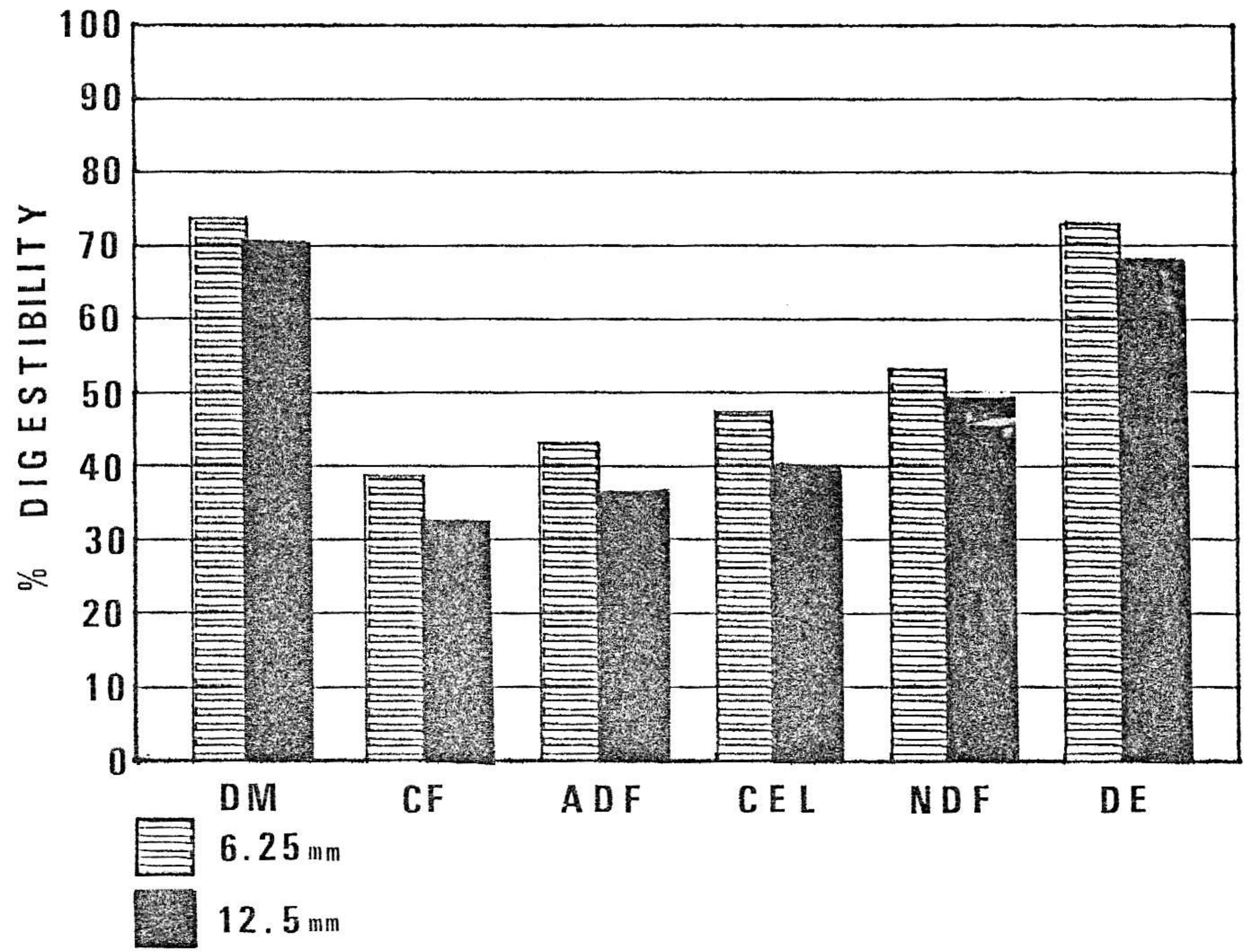

6.25 mm
12.5 mm
CUMULATIVE WEIGHT
(PERCENT LESS THAN SIZE INDICATED)
98
95
90
80
70
60
50
40
30
20
10
5
100
1,000
10,000
PARTICLE SIZE (MICRONS)

FIGURE 2.

PARTICLE SIZE OF ALFALFA



decreased particle size. Decreases in particle size expose more surface area and increase retention times in the GI tract compared to whole or unprocessed feeds. Higher digestibility is attributed to the increased retention time in the GI tract.

Physical Form

Digestibility of cellulose (49.9 vs 46.3 %) increased ($P < .01$) and ADN (67.7 vs 64.2 %) decreased ($P < .05$) with pelleting. The other digestibility coefficients were not significantly different between meal and pelleted treatments.

Many varied results have been reported concerning the pelleting of feeds. The variability is attributed to the type of feed, the processing employed and the type of diet fed. When beneficial effects due to pelleting are reported, the crude fiber content of the pelleted feed is less that that of the same feed in meal form (Larsen and Oldfield, 1960; Lindahl and Reynolds, 1959). Contrary to this, fiber digestibility of corn was not affected by pelleting as compared to the meal form (Larsen and Oldfield, 1960). In this study, there were no significant decreases in crude fiber or cellulose digestibilities that could be attributed to effects of pelleting as indicated by chemical analyses of the diets.

Seerley et al. (1962a) reported improved gains attributed to pelleting when compared to the same diet in meal form. Apparent digestible nitrogen was unaffected as opposed to increased apparent digestible energy. Seerley et al. (1962b) reported that pelleted diets had significantly shorter retention times in the GI tract. Tribble et al. (1973) reported no significant improvements with pelleting a grain sorghum diet compared to meal-form in growing-finishing swine diets. The authors observed less feed wasted with the pelleted diets and less feed was required per unit gain.

In this study, ADN was chosen as an analyte. ADN has been recognized as a sensitive determination of non-enzymatic browning associated with feeds that have been overheated (Van Soest, 1965). Non-enzymatic browning accounts for increased yields of ADF by the production of artifact lignin. The nitrogen content of the artifact lignin is greater than that of natural lignin because of increased quantities of insoluble nitrogen. Protein bound in the non-enzymatic browning reaction has been reported to be indigestible (Donoso et al., 1962). Decreased digestible nitrogen may lower digestion coefficients of the protein fraction by several percentages. Van Soest (1965) also reported that the presence of moisture and drying temperatures above 50 C increased the quantity of insoluble nitrogen. The author also observed that the damage produced by heating in the presence of retained moisture was far more severe than that observed under drying conditions.

Due to extreme temperatures and moisture employed in the pelleting process, the pelleted treatments were expected to contain a higher percentage of lignin. The results of the chemical analysis were not different for the meal and the pelleted treatments. However, the results of this study indicate that the digestibility of ADN was decreased with pelleting ($P < .07$).

Lignin and ADF digestibilities were depressed with pelleting ($P > .10$). Nitrogen balance and nitrogen retention were also decreased by pelleting whereas nitrogen digestibility was unaffected. Lignin digestibility was found to be highly correlated with apparent nitrogen digestibility ($r^2 = .80$). These results indicate that pelleting has a tendency to decrease solubility of nitrogen.

Period of Gestation

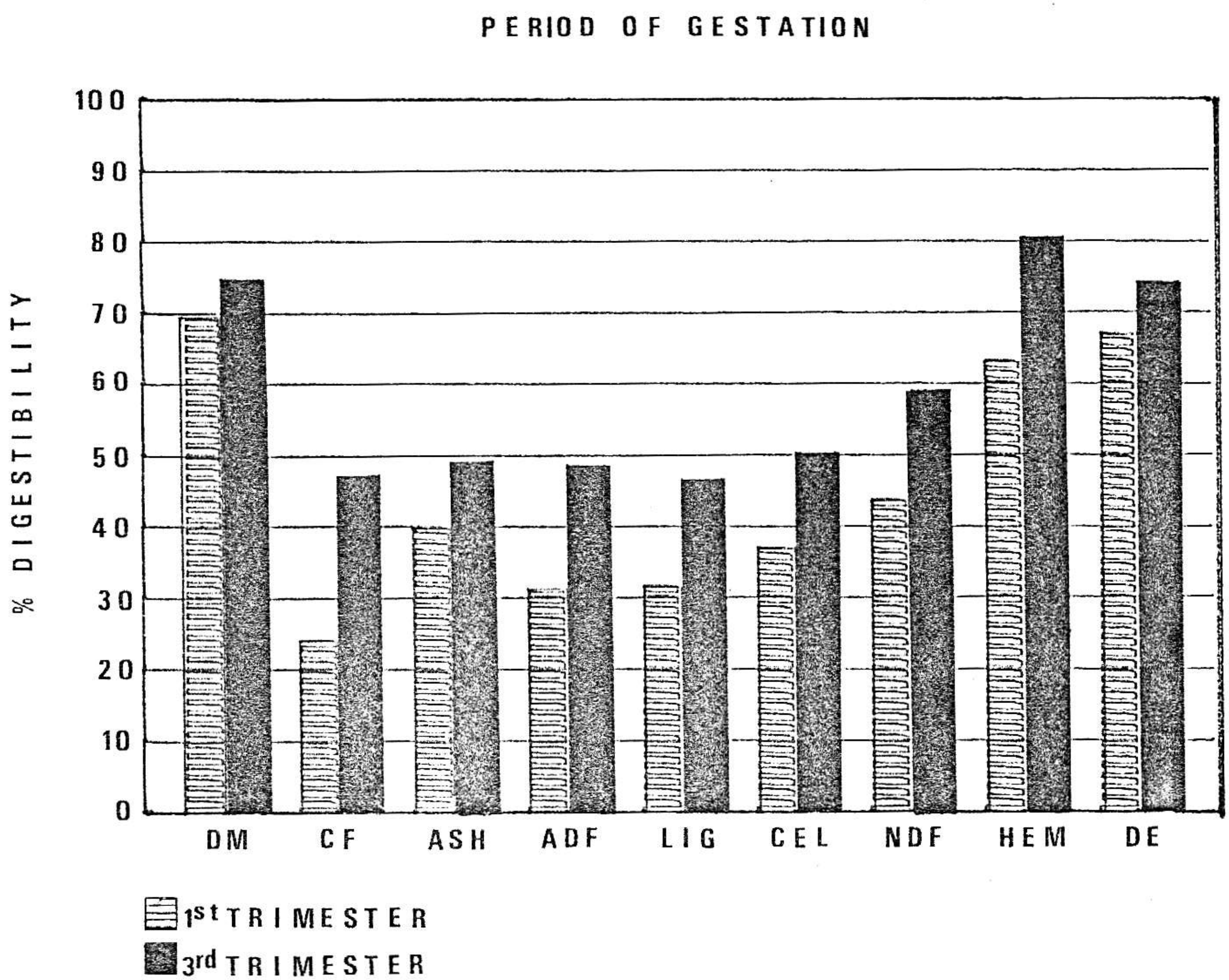
Digestibilities of all feed components studied were significantly affected between trimesters. Digestibilities of DM (65.5 vs 74.8 %), DE (66.9 vs 74.3 %), CF (23.9 vs 46.9 %), ADF (31.2 vs 48.6 %), NDF (43.4 vs 59.1 %), lignin (31.6 vs 46.6 %), cellulose (37.0 vs 50.2 %), and hemicellulose (63.0 vs 80.5 %) significantly increased from the first to the third trimester of gestation, respectively (figure 3). Nitrogen balance and nitrogen retention decreased significantly from the first to the third trimester while nitrogen digestibility increased ($P < .07$) from 74.7 to 77.1 %.

A physical form x period interaction ($P < .05$) was observed for CF, cellulose and NDF. The increase in digestibility of the meal diets were twice that of the pelleted diets from the first to the third trimesters. CF (29.8 vs 16.2 %), cellulose (17.9 vs 8.5 %) and NDF (20.0 vs 11.4 %) increased between periods for meal and pelleted diets, respectively. NDF digestibility also exhibited a particle size x period interaction ($P < .05$). The 6.25 mm diets increased 19.5 % in NDF digestibility between periods while the 12.5 mm diets increased 11.9 %.

The ability of swine to adapt to high fiber diets has long been estalished . Pollmann et al. (1979) reported increased digestion coefficients with both a 97 % sun-cured alfalfa and a 66 % tall wheatgrass diet from the first to the third trimester of gestation. The authors concluded that more nutrients were utilized as the digestive system became more accustomed to the high fiber diets.

Gargallo and Zimmerman (1981) fed three levels of solka-flock to 30 kg pigs and reported increased digestibility coefficients after a 40 day trial. Results indicated a progressive adaptation of the pigs to the high fiber diet. The authors also compared cecectomized and intact pigs

FIGURE 3.


PERIOD OF GESTATION
% DIGESTIBILITY
100
90
80
70
60
50
40
30
20
10
0
DM
CF
ASH
ADF
LIG
CEL
NDF
HEM
DE
1st TRIMESTER
3rd TRIMESTER

and concluded that the role of the cecum in fiber digestion is minimal.

Bohman et al. (1953) reported enlarged stomach and large intestine of pigs fed 30 and 50 % alfalfa diets from weaning to market. The authors theorized that the enlargement of the GI tract was one of the means by which swine adapted to high fiber diets, thereby increasing capacity for bacterial digestion to occur. This theory has been recently supported by the work of Kass et al. (1980) and USDA researchers (Pekas and Pond, 1981).

Nitrogen balance and nitrogen retention decreased from the first to the third trimester of gestation accompanied by an increase in nitrogen digestibility. Pollmann et al. (1979) feeding a 97 % sun-cured alfalfa diet reported increased nitrogen balance and retention for gestating sows from the first to the third trimester of gestation.

Elsley and MacPherson (1964) fed isocaloric diets of differing protein percentages and concluded that no consistant trends for nitrogen retention resulted during pregnancy in gilts. They also concluded that energy must be adequate for nitrogen retention to occur in late pregnancy.

Elsley (1966) reported that the nitrogen retention sharply increased in early pregnancy and leveled off in late pregnancy. This is in opposition with the findings of Moustgaurd (1962) who observed a sharp rise in nitrogen retention late in pregnancy.

Nitrogen balance data is efficiently compared when all diets are isocaloric and isonitrogenous with proteins of differing biological values as the variable. The quality and quantity of protein in a diet has been shown to affect nitrogen retention (Elsley and MacPherson, 1964).
In this study, no attempt was made to adjust for the added protein in the diet provided by the alfalfa. The sows used in this trial were bred on the first estrous cycle after lactation. These sows could have been at

zero or in negative nitrogen balance when they entered the trial. Gross compensation in nitrogen retention may have taken place when the sows were switched to the high protein diets of this trial. Nitrogen retention tapered off as the sows adapted to the alfalfa diets .

Several interesting comparisons can be made using the study of Pollmann et al. (1979). DM and DE were lower for the 50 % alfalfa diets in this study as compared to those of the corn-soybean meal diet, as would be expected with added fiber. The ADF, NDF and hemicellulose digestibilities of the 50 % alfalfa diet equaled or exceeded the digestibilty coefficients for the corn-soybean meal diet. Cellulose digestibility increased 13.2 % from the first to the third trimester on the 50 % alfalfa diet with an 80-day (third trimester) of 50.2 %. This value was lower than the cellulose digestibility reported for the corn-soybean meal diet which was unaffected by length of time on the diet. Although the 50 % alfalfa diets had distorted nitrogen balance balance early in pregnancy, the value reported in the third trimester for the alfalfa diets were equal those reported for the corn-soybean meal diet in the third trimester. Apparent nitrogen digestibility was lower for the 50 % alfalfa as would be expected due to increased nitrogen in the feces attributed to microbial protein from increased fiber digestion. The reported depression of nitrogen digestibility with high fiber diets (Cheeke,1977; Kass, et al., 1980a; Keys et al., 1970; Kornegay, 1981; Lloyd and Crampton, 1955; Pollman et al., 1979) can be attributed to three variables, less available protein added by the fiber source, increased rate of passage and increased fecal nitrogen of microbial origin. When fiber is added in the form of alfalfa , it is hard to differentiate the effect of added protein from added fiber. Conversely, when the source of fiber is void of protein , the digestibility is neglegible or depressed.

In order for fiber to cause a decrease in apparent digestibility, it must first be susceptible to microbial degradation in the hindgut resulting in increased microbial nitrogen in the feces. Adaptation of swine to the high fiber diet is another variable which influences digestibility associated with high fiber diets. Thus, when considering digestibilities of high fiber diets, adequate time must be alloted for optimal populations of microflora to become established in the lower intestinal tract for accurate estimates concerning fiber.

Summary:

Sixteen gravid crossbred sows (second parity) were employed in a digestion trial to evaluate the effect of particle size and physical form of sun-cured alfalfa. The treatments consisted of 6.25 mm meal, 6.25 mm pelleted, 12.5 mm meal, and 12.5 mm meal pelleted. Utilization of DM, DE and fiber components increased significantly with the 6.25 mm particle size compared to 12.5 mm. Nitrogen utilization was not affected by the two particle sizes. Cellulose digestibility significantly increased when pelleted and other digestion coefficients were non-significant with physical form. Period of gestation significantly affected utilization of alfalfa. After the third trimester, DM, DE and fiber components increased in digestibility compared to those in the first trimester. Apparent nitrogen digestibility increased in the third trimester but nitrogen balance and nitrogen retention decreased.

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A P P E N D I X

Table 1. Least Square Analysis of Variance of Dry Matter, Ether Extract, Ash and Energy Digestibilities.

		Mean Squares				
Source of Variation	df	DM%	EE%	Ash%	DE%	DE kcal/kg
Total	30					
Size	1	67.1278**	22.0748	103.2930	162.1875**	308323.2821**
Form	1	1.3575	180.1960	41.6538	0.0060	206.7821
Size x Form	1	4.0575	0.0174	46.0155	5.5921	12013.1282
Sow (Size x Form)-errorA	12	66.2946	879.5071	1240.4515	123.3959	263722.4167
Period	1	209.1988***	6.7496	613.2012*	404.2677***	743048.3205***
Size x Period	1	0.0012	56.7552	0.0581	13.2557	20874.0513
Form x Period	1	26.0655	47.9636	122.5509	26.3728	44688.3205
Size x Form x Period	1	0.3218	9.4259	208.2174	0.1985	32.0513
Residual- error B	11	64.9578	2014. 3778	897.0497	171.7052	293766.5833

*** $P < .001$
** $P < .01$
* $P < .05$

Table 2. Least Square Analysis of Nitrogen Utilization.

		Mean Squares				
Source of Variation	df	App. N Dig.	N-Bal.	N-Ret.	ADN Dig.	HWIN Dig.
Total	30					
Size	1	16.5370	0.0801	2.5146	12.2848	13.1364
Form	1	0.4114	28.9263	209.8052	90.6016*	8.0256
Size x Form	1	0.1045	26.5417	90.9036	28.2182	3.5286
Sow (Size x Form)-errorA	12	107.0325	231.4583	901.1308	209.2068	133.4128
Period	1	39.9686	298.1571**	1098.7133**	46.8410	3.6314
Size x Period	1	5.2858	22.0801	91.5742	16.3076	0.4524
Form x Period	1	4.6502	40.9263	75.0387	55.3986	2.6918
Size x Form x Period	1	4.5675	4.3878	16.9167	7.6673	0.1890
Residual- errorB	11	110.4048	342.7083	1215.7056	176.1044	159.0648

**P $<$.01
* P$<$.05

Table 3. Least Square Analysis of Fiber Component Digestibilites.

		Mean Squares					
Source of Variation	df	CF%	ADF%	Lignin%	Cell.%	NDF%	HEMI%
Total	30						
Size	1	305.3360*	337.9378*	0.1378	429.2523**	112.4881*	0.4013
Form	1	11.751	5.7051	133.6332	218.5708*	49.1708	3.0901
Size x Form	1	142.1685	0.2887	25.6222	66.5908	29.9212	32.2374
Sow (Size x Form)-errorA	12	560.4812	582.6782	833.4365	352.4602	270.3643	713.8086
Period	1	3903.9850***	2246.0037***	1678.4273*	1286.0456***	1817.7227***	2255.5655***
Size x Period	1	16.5370	212.4375	41.5735	100.0960	107.8533*	108.7134
Form x Period	1	344.7154*	422.6391*	154.0723	164.8371*	133.9082*	69.8545
Size x Form x Period	1	10.395	24.2317	5.9677	18.0385	9.8655	35.3567
Residual - error B	11	738.6257	720.9508	2108.9508	323.3001	157.2194	297.8915

*** P <.001
** P <.01
* P <.05

Table 4.

Particle Size Profile of Alfalfa[a]

Tyler Screen no.	Screen Opening Size (μ)	Treatments 6.25mm	12.5mm
3.5	5600	0	.1
6	3350	.3	.3
7	2800	.1	.6
8	2360	.1	.8
10	1700	1.6	7.6
14	1180	13.0	18.0
20	850	14.8	16.4
28	600	15.1	16.0
35	425	15.2	15.7
48	300	13.8	11.1
65	212	12.5	7.2
Residual		13.5	6.1
d(gw)		434μ	646μ
s (gw)		2.9	2.5

[a]Values are the percentages of a 100gm sample retained on each sieve.

Table 5. Correlation Coefficients of Metabolism Data.

Independent Variables	r^2
Dry matter digestibility	
Ether extract digestion (%)	.71**
ASH digestion (%)	.87***
Apparent N-digestion (%)	.88***
Lignin digestion (%)	.82***
NDF digestion (%)	.72**
ADN digestion (%)	.67*
HWIN digestion (%)	.67*
Digestible energy (%)	.92***
Digestible energy (kcal/kg)	.93***
Fecal N (g)	- .74**
Ether Extract	
Dry matter digestion (%)	.71**
Lignin digestion (%)	.86***
HWIN digestion (%)	.92***
Digestible energy (%)	.80**
Digestible energy (Kcal/kg)	.82***
Fecal N (g)	- .69*
Crude Fiber	
Cellulose digestion (%)	.78**
NDF digestion (%)	.65*
Ash	
Dry matter digestion (%)	.87***
Apparent N-digestion (%)	.85***
Lignin digestion (%)	.80**
Digestible energy (%)	.77**
Digestible energy (kcal/kg)	.77**
Fecal N (g)	- .76**

Table 5. Continued

Apparent N-digestibility	
Dry matter digestion (%)	.88***
Ash digestion (%)	.85***
Lignin	.80**
HWIN digestion (%)	.69*
Digestible energy (%)	.92***
Digestible energy (kcal/kg)	.92***
Fecal N (g)	- .93***
N-Balance	
Urinary N (g)	- .83***
N-Retention (%)	.99***
N-Retention (%)	
Urinary N (g)	- .84***
N-Bal (g)	.99***
ADF digestion	
N-balance (g)	.62*
N-retention (%)	.63*
NDF digestion (%)	.62*
ADN digestion (%)	.57*
Lignin digestibility	
Dry matter digestion (%)	.82***
Ether extract digestion (%)	.86***
Ash digestion (%)	.61*
Apparent N-digestion (%)	.80**
N-balance (g)	.60*
N-retention (%)	.62*
ADN digestion (%)	.67*
HWIN digestion (%)	.89***
Digestible energy (%)	.89***
Digestible energy (kcal/kg)	.91***
Urinary N (g)	- .62*
Fecal N (g)	- .81**
Cellulose Digestibilty	
Crude fiber digestibility (%)	.78**
NDF digestion (%)	.64*

Table 5. Continued

NDF digestibility	
Dry matter digestion (%)	.72**
Crude fiber (%)	.64*
Ash digestion (%)	.62*
ADF digestion (%)	.62*
Cellulose digestion (%)	.64*
ADN digestibility	
Dry matter digestion (%)	.67*
N-balance (g)	.73**
N-retention (%)	.73**
ADF digestion (%)	.58*
Lignin digestion (%)	.67*
HWIN digestibility	
Dry matter digestion (%)	.67*
Ether extract digestion (%)	.92***
Apparent N-digestibility (%)	.69*
N-retention (%)	.58*
Lignin digestion	.89***
Digestible energy (%)	.77**
Digestible energy (kcal/kg)	.80**
Urinary N (g)	- .65*
Fecal N (g)	- .73**
Digestible energy (%)	
Dry matter digestion (%)	.92***
Ether extract digestion (%)	.80**
Ash digestion (%)	.77**
Apparent N-digestibility (%)	.92***
Lignin digestion (%)	.89***
HWIN digestion (%)	.77**
Digestible energy (kcal/kg)	.99***
Fecal N (%)	- .88**

Table 5. Continued

Digestible energy (kcal/kg)	
Dry matter digestion (%)	.93***
Ether extract digestion (%)	.80**
Ash digestion (%)	.77**
Apparent N-digestion (%)	.92***
Lignin digestion (%)	.89***
HWIN digestion (%)	.80**
Digestible energy (%)	.99***
Fecal N (g)	-.87***
Urinary N (g)	
N-balance (g)	-.83***
N-retention (%)	-.84***
Lignin digestion (%)	-.62*
HWIN digestion (%)	-.65*
Fecal N (g)	
Dry matter digestion (%)	-.74**
Ether extract digestion (%)	-.69*
Ash digestion (%)	-.76**
Apparent N-digestion (%)	-.93***
Lignin digestion (%)	-.81**
HWIN digestion (%)	-.73**
Digestible energy (%)	-.88***
Digestible energy (kcal/kg)	-.87***

***P < .001
**P < .01
*P < .05

Table 6. Effect of Pregnancy on Utilization of Alfalfa.

	Digestion Coefficients					
	Trimester	DM%	EE%	Ash	DE%	DE kcal/kg
Pregnant	1	69.6	64.3	38.4	67.7	2954
	3	75.5	61.2	49.7	75.2	3271
Non-pregnant	1	69.9	54.3	37.2	67.8	2959
	3	77.0	66.3	51.9	77.0	3358

Table 7. Effect of Pregnancy on Utilization of Fiber Components of Alfalfa.

	Digestion Coefficients						
	Trimester	CF%	ADF%	Lignin%	Cell%	NDF%	Hemi%
Pregnant	1	22.7	30.1	32.2	35.7	42.0	60.2[a]
	3	50.1	52.3	46.8	52.6	60.3	80.1
Non-pregnant	1	27.6	31.9	30.3	37.9	45.3	68.9
	3	51.4	51.3	53.8	51.7	62.1	84.8

[a] $P < .05$.

Table 8. Effect of Pregnancy on Nitrogen Utilization of Alfalfa.

	Digestion Coefficients					
	Trimester	App. N Dig.%	N-Bal (g)	N-Ret%	ADN Dig.%	HWIN Dig.%
Pregnant	1	74.5	16.4	32.7	65.5	81.4
	3	77.3	11.6	22.4	69.4	81.6
Non-pregnant	1	76.0	15.0	28.6	64.7	78.6
	3	79.0	7.3	14.8	68.2	82.6

EFFECTS OF PARTICLE SIZE AND PHYSICAL FORM OF SUN-CURED ALFALFA FOR GESTATING SWINE

by

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B. S., Kansas State University, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

Sixteen crossbred sows (second parity) were used in a digestion study to determine the influence of particle size and physical form of sun-cured alfalfa. Five day collections were taken during the first and third trimesters (25 and 80 days, respectively). In a sorghum-soybean meal diet alfalfa was added at 50% and fed to supply 5000 kcal ME per day (2 kg/day). The alfalfa treatments were: 6.25mm meal, 6.25mm meal pelleted (9.5mm), 12.5mm meal, 12.5mm meal pelleted (9.5mm). Four sows were randomly assigned to each treatment by initial weight. The sows were hand-fed the treatments throughout the entire gestation period and were moved into metabolism crates three days prior to collection periods. In a split-plot design, criteria of response were: digestibilities of dry matter (DM), crude fiber (CF), acid detergent fiber (ADF), lignin (LIG), cellulose (CEL), neutral detergent fiber (NDF), hemicellulose (HEM), nitrogen (N), acid detergent nitrogen (ADN), hot water insoluble nitrogen (HWN) and energy (DE). Significant differences in digestibility were observed for 6.25mm and 12.5mm treatments, respectively: DM (73.6 vs 70.0%), CF (38.6 vs 32.2%), ADF (43.3 vs 36.5%), CEL (47.4 vs 39.8%), NDF (53.2 vs 49.3%) and DE (73.0 vs 68.3%). Only CEL and ADN were affected by physical form. CEL digestibility increased significantly with pelleting (40.9 vs 46.3%) while ADN digestibility was decreased (67.7 vs 64.2%). No significant physical form x particle size interactions were observed. Digestibility of DM, CF, ADF, LIG, CEL, HEM, NDF and DE increased significantly in the third trimester. Significant physical form x period (DM, CF, ADF, and CEL) and particle size x period (ADF and NDF) interactions were also observed. Results of this study indicate that sun-cured alfalfa ground through a 6.25mm screen (meal or pellet) improved digestibility for gestating sows.