AN ABSTRACT OF THE THESIS OF

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A study was conducted to determine the effect of dietary protein on performance of commercial New Zealand White rabbits.

In Part I of this study, three levels of crude protein (17.5, 19 and 20.5%) were fed to lactating does and their offspring during a 12 month period. Total rabbits born was higher and percentage born alive was lower for does fed the higher protein diets. The heaviest litters and greatest litter gains were recorded from does fed 19% crude protein (CP), and these does also had the most litters. Does fed 17.5% CP were lighter at 21 and 28 d of lactation which suggested that they were catabolizing body tissues for milk synthesis. Results from a digestibility and nitrogen utilization trial supported this hypothesis. Does fed 20.5% CP were able to retain 90% more nitrogen during lactation than those fed 17.5% CP. Performance of does at first parity was poorest for all traits except fertility. Fertility fluctuated throughout the first four parities and then steadily declined. One-half of the litters were continued on their respective diets from weaning (28 d) to 56 d. Postweaning feed efficiency (feed/gain) was superior but mortality was greatest for animals fed 20.5% CP. An experiment to determine the

effect of preweaning protein diet on postweaning performance revealed no significant differences but postweaning mortality was highest for animals fed 20.5% CP before weaning. Month of year had no significant effect on any of the characters studied, but a decrease in fertility was observed between September and December.

In Part II of the study, lower levels of crude protein along with amino acid supplementation were evaluated for weanling rabbits. Performance was not different for rabbits fed diets containing CP levels ranging from 16.5-22%. Methionine supplementation at .3% increased growth slightly, especially for lighter weanlings and animals fed 74% alfalfa diets. Lysine depressed growth when .3% was added to the diet.

Part III of the study was conducted to evaluate alternate protein sources for weanling rabbits. Raw soybeans, pinto beans and radish seeds were poorly utilized. Animals fed heat-treated pinto beans and 20% radish seed diets performed better than animals fed raw pinto bean and 20% radish seed diets respectively. Extruded soybeans and soy flour were of equal value to the standard soybean meal supplement.

In conclusion, 19% CP was found to be optimal for lactating does and preweaning litters. Diets containing 16.5% CP and no supplemental protein were adequate for weanling rabbits. Extruded soybeans and soy flour were the only alternate protein sources of value in this study.

EFFECT OF DIETARY CRUDE PROTEIN LEVEL AND SOURCE OF SUPPLEMENTAL PROTEIN ON PERFORMANCE OF COMMERCIAL RABBITS

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Thesis typed by Sandra Sanchez for William K. Sanchez

Dedicated to
Noreen B. Sanchez

in memory of her unselfish love for
her husband and seven children

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EFFECT OF DIETARY CRUDE PROTEIN LEVEL AND SUPPLEMENTAL SOURCE OF PROTEIN ON PERFORMANCE OF COMMERCIAL RABBITS

CHAPTER 1

INTRODUCTION

Recent consumer demand for meats that are low in cholesterol, fat and sodium makes rabbit one of the most promising meat sources of the future. Its well known prolificacy, rapid growth rate and ability to consume high roughage diets give the rabbit a competitive advantage over other livestock animals. Yet the lack of knowledge concerning nutrient requirements weighs heavy in the balance between the rabbit's great potential and factors that limit its production. Protein is a nutrient in which controversy exists about requirements for optimal growth and reproductive performance. It is also one of the most costly to provide and can have a major influence on the overall profitability of rabbit production.

Proteins have many biological roles. They are needed in structural components such as muscle, hair, connective tissue and skin (Scott et al., 1982) and are integral parts of enzymes, antibodies, hemoglobin and the molecular instruments through which genetic information is expressed (Lehninger, 1982). It is not surprising that the word protein translated from greek literally means "foremost" or "of primary importance."

It was once believed that the rabbit, being a non ruminant herbivore, could exist on low quality protein sources. Although the cecum, with its extensive microbial population, is located past the point of absorption for most nutrients, a recycling of cecal contents occurs when rabbits "practice coprophagy" or reingest their feces. This led researchers to believe that lower quality proteins could be transformed into higher quality bacterial protein. The type of feces consumed, known as "soft feces", does contain 25-30% crude protein (CP) and provides up to 2 g of protein (Davidson and Spreadbury, 1975), but is however, only a small proportion of their normal dietary intake (Spreadbury, 1978). Low quality protein sources such as ground-nut meal, cottonseed meal, gelatin and maize gluten when fed to growing rabbits were found to be utilized less effectively than soybean meal, fish meal and casein (Cheeke, 1971; Cheeke and Amberg, 1972; Davidson and Spreadbury, 1975). Non protein nitrogen sources such as urea and diammonium citrate are also utilized poorly by growing rabbits (Olcese and Pearson, 1948; Cheeke, 1972; Lebas and Colin, 1973).

It is evident that protein quality is an important aspect of rabbit nutrition. Rabbits require balanced protein diets containing the proper quantity and quality of amino acids. NRC (1977) listed the essential amino acid requirements for the growing rabbit as: .65% lysine, .6% methionine + cystine, .6% arginine, .3% histidine, 1.1% leucine, .6% isoleucine, 1.1% phenylalanine + tyrosine, .6% threonine, .2% tryptophan and .7% valine. In addition, a need for glycine has been demonstrated but the amount is unknown. Lebas (1980a) provided the following requirements for lactating rabbits: .6% methionine + cystine, .75% lysine, .8% arginine, .7% threonine, .22% tryptophan, .43% histidine, .7% isoleucine, .85% valine and 1.25% leucine.

The crude protein requirements have received much attention but controversy still remains as to the optimal levels needed during growth and lactation. Templeton (1952) was one of the first to address this problem for growing rabbits. Using diets ranging from 11-26% CP, it was found that a correlation existed between the amount of dietary protein and the rapidity with which the young developed. His recommendation was for 16-20% CP for dry does and developing young. More recently, Spreadbury (1978), using diets containing between 10 and 25% CP, reported optimal performance at 15%. Romney and Johnston (1978) found that growth was greater with 19 vs 16% CP. Omole (1982) found 18-22% CP to be the optimal level for fryers raised under tropical conditions.

Less information exists on these requirements for the lactating doe but levels as low as 17% and as high as 22% CP have been recommended (NRC, 1977; Lebas, 1980a; Partridge and Allan, 1982; Omole, 1982).

Due to the variation in the literature about the optimal crude protein requirements, the research done for this thesis examined narrow ranges of protein within the levels previously recommended. Of particular interest was the effect of crude protein on the performance of does over several lactations. Therefore, one experiment was designed to continue over a long period of time (one year). This also enabled the effect of seasonal variation to be studied. Literature is lacking in these areas as to how they relate to crude protein requirements of rabbits.

Rabbits, like other non ruminant herbivores, extract protein readily from forages such as alfalfa. They consume diets high in alfalfa and therefore may not need additional protein supplements in the diet. A series of experiments was conducted with growing rabbits to determine the effect of reducing the level of soybean meal, a common protein supplement in rabbit diets. Also investigated were the addition of the two most limiting amino acids - methionine and lysine.

Finally, alternate protein sources were examined for growing rabbits. The use of many of these feedstuffs has not been exploited because they can be toxic to animals. It is not known how rabbits are affected by many of these feeds but since plant toxins can be destroyed by heat, they may provide a viable alternative to traditional protein sources. Extruded soybeans are of interest because they are high in fat and provide large amounts of protein and energy. Substantial quantities of cull radish seeds and pinto beans are discarded annually due to the lack of information on their feeding value. If protein sources like these can be incorporated into rabbit diets without decreasing performance, considerable savings might be realized.

CHAPTER 2

EFFECT OF DIETARY CRUDE PROTEIN LEVEL ON THE REPRODUCTIVE PERFORMANCE AND GROWTH OF NEW ZEALAND WHITE RABBITS[1]

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Effect of Dietary Crude Protein Level on the Reproductive Performance and Growth of New Zealand White Rabbits

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SUMMARY

An experiment utilizing 391 preweaning and 187 postweaning litter records from 145 does was conducted for twelve months to determine the effect of dietary crude protein level on performance of commercial New Zealand White rabbits. Does and their litters were fed alfalfa-based pelleted diets containing either 17.5, 19 or 20.5% crude protein (CP). In a separate experiment, the 17.5 and 20.5% CP diets were fed during lactation to ten does to determine the digestibility and nitrogen (N) utilization. Body weights of does fed 17.5% CP were lower ($P<.01$) than for the other treatments after 21 and 28 d of lactation. No differences were observed for doe weight at kindling, percentage fertility, litter size (all days), preweaning litter mortality, 1-21 d consumption, preweaning feed efficiency and 28-56 d average daily consumpion, average daily gain and average weight. Total born tended to be higher ($P=.07$) on higher protein levels but percentage born alive was greatest ($P<.01$) on 17.5% CP. Does fed 19% CP tended to have a greater number of parities ($P=.06$). Other significant differences observed for preweaning litter traits were between the 17.5 and 19% CP groups. Does fed 19% CP had heavier litters at birth ($P<.01$), at 21 d ($P=.05$) and 28 d ($P=.06$) and had greater 1-21 d litter gains and 21-28 d consumption ($P=.05$) than those fed 17.5% CP. For postweaning performance, feed efficiency values were lowest and mortality was highest for litters fed 20.5% CP. When litters were switched to different diets after weaning, mortality tended to be higher ($P=.07$) for animals that were fed 20.5% CP prior to weaning. The month of experiment effect did not influence any of the characters studied ($P>.05$). Parity number was important for percentage fertility, percentage born alive, litter birth weight and doe weight at 21 and 28 d ($P<.05$). Does at first parity showed the poorest performance for all traits (except percentage fertility). Fertility fluctuated throughout the first four parities and then steadily declined. Does fed 20.5% CP had greater apparent DM and ADF digestibilities and N intakes ($P<.05$) and retained 90% more N during lactation ($P=.22$) than does fed 17.5%. Milk production and CP digestibility did not differ between the two diets tested. Results indicate that 17.5% CP is not optimal for the lactating commercial rabbit and 20.5% CP provides no advantage over 19% CP. A general purpose diet for both lactating does and growing fryers should contain 19% CP.

(Key words: Rabbits, Crude Protein, Reproduction, Growth, Mortality.)

INTRODUCTION

The domestic rabbit is emerging as a viable livestock species (Cheeke, 1979). One of the factors limiting rabbit production is the lack of information pertaining to optimal crude protein (CP) requirements for commercial production.

Most of the research on CP requirements has been aimed at the fast growing four to eight week-old fryer rabbit. Spreadbury (1978) using a range of diets containing 10.4-25.5% CP reported optimal performance at 15% CP. Romney and Johnston (1978) found that lower gains occurred when fryers were given 16% CP than with 19, 21 and 22% CP. By comparing diets containing 10-26% CP, Omole (1982) suggested 18-22% CP to be optimal for fryers raised under tropical conditions. Less information exists on the crude protein requirements of lactating rabbits but, as in the case of growing rabbits, contradictory reports exist in the literature. Levels as low as 17% and as high as 21.5% CP have been recommended (NRC, 1977; Partridge and Allan, 1982).

Based on a report linking high grain diets to enteritis mortality and the need for high dietary fiber to combat this disease (Cheeke and Patton, 1980) a 54% alfalfa ration containing no cereal grain was developed. While this ration contains higher than recommended levels of protein, it has given better performance than a commercial diet which met the recommended level of protein (Harris et al., 1982).

The objective of this experiment was first to determine if, under intensive production, 20.5% CP in this diet was necessary or if lower protein levels (19 and 17.5%) were adequate for both lactating and growing rabbits. Other objectives were to examine the effect of pre-weaning CP level on postweaning performance, the effect of parity number (an indication of longevity), and the effect of month of experiment on doe and litter performance traits in commercial rabbits. A final objective was to determine if there were differences in the digestibility and(or) nitrogen (N) retention by lactating does fed the 17.5 and 20.5% CP diets.

MATERIALS AND METHODS

The study was conducted over a 12 month period (January to December, 1983) at the Oregon State University Rabbit Research Center.

Diets. The dietary treatments consisted of three alfalfa based diets that differed in CP contents (17.5, 19 and 20.5%). All diets were pelleted (4.7 mm in diameter). Composition and chemical analysis of the experimental diets are presented in table 1. The diets were analyzed for crude protein using a micro-Kjeldahl method (AOAC, 1975). Fiber analysis was accomplished using a micro-method for acid detergent fiber (Waldern, 1971). Diets were analyzed for essential amino acids using a Beckman model 120B amino acid analyzer modified for single column (6 mm) analysis. All analyses (excluding amino acids) were done on a sample of each of the seven batches of feed used; mean values were reported. Amino acids were analyzed from a composite sample of all batches.

Housing. An open-sided A-frame building described by Harris et al. (1983a) was used to house the animals. This inexpensive structure provides natural ventilation and lighting. All cages were hanging, all wire quonset-style (see Harris 1983a). Breeding does were housed individually in 66 cages (76 x 76 x 46 or 76 x 61 x 46 cm) equipped with subterranean nest boxes. Weaned fryers were housed as litters in 24 cages (76 x 76 x 46 cm). An additional 16 cages of various sizes were used to house the breeding bucks and replacement stock. J-shaped screened metal feeders (25.4 cm long) and automated waterers were located at the front of each cage. Cages were hung with wire 122 cm above the ground on two sides of a concrete walkway. Manure pits were surfaced with a fine to coarse gradient of sand and gravel with perforated drain pipes located beneath. Manure was removed four times each year.

Doe and Preweaning Litter Management. Progeny of New Zealand White rabbits which were free of the bacterial organism *Pasteurella multocida* and had given satisfactory performance in earlier experiments (Harris et

TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS CONTAINING 17.5, 19 AND 20.5% CRUDE PROTEIN

Ingredient		Dietary Protein, %		
		20.5	19	17.5
Alfalfa meal	(IFN 1-00-025)	54	54	54
Soybean meal	(IFN 5-04-604)	21	15	9
Wheat mill run	(IFN 4-05-206)	20	26	32
Molasses	(IFN 4-04-696)	3	3	3
Soybean oil	(IFN 4-07-983)	1.25	1.25	1.25
Trace mineral salt[a]		.5	.5	.5
Dicalcium phosphate	(IFN 6-01-080)	.25	.25	.25
Cupric sulfate - $CuSO_4 \cdot 5H_2O$	(IFN 6-01-719)	80 ppm	80 ppm	80 ppm
Chemical analysis[b]				
Dry matter, %		91.83	92.35	92.55
Crude protein, %		20.62	19.03	17.64
Acid detergent fiber, %		23.20	23.92	23.96
DE (kcal/Kg)[c]		2539	2466	2454

[a]Mortons Farm and Ranch iOFIXT T-M SALT. Provides NaCl and the following elemental levels of mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, .35; Co, .35.

[b]All values (except dry matter) reported on dry matter basis.

[c]Calculated values.

al., 1982) were used. This breed is known for superior maternal and meat-type qualities. In January, 21 multiparous and 27 nullparous does were randomly allocated to the dietary treatments. The full capacity of the rabbitry (66 does) was achieved in late February and maintained at that number for the rest of the experiment.

Animals that died or were removed for poor performance were replaced by nullparous does of approximately 154 d of age and free of *Pasteurella multocida*. All replacements were maintained on the same diets on which they were to be evaluated, to reduce any pre-study diet effect. A strict replacement of non productive does was practiced using the following criteria:

1) Poor production as judged by severe weight loss, a failure to raise a litter to weaning on two consecutive kindlings, a failure to accept service for 14 consecutive days or a failure to conceive after three matings;

2) Respiratory problems caused by of *Pasteurella multocida*. Animals that had positive cultures of this bacteria or exhibited excessive sneezing or pneumonia were replaced;

3) Mastitis or other abcesses that failed to respond to three days of treatment with a penicillin-streptomycin antibiotic;

4) Pododermatitis (sore hocks); and

5) Other conditions, including enteric disorders, reproductive tract infection, broken back, eye infections and maloclusion (buck teeth).

All animals were first bred at approximately 154 d of age if they were in adequate physical condition and not over-fat. Each doe was serviced by a randomly selected buck with care to breed to a different buck at each mating. If a choice existed, does were bred to a buck with the most days prior to last breeding. Following mating, does were immediately re-mated to the same buck to ensure adequate servicing. Fourteen days after mating, does were palpated to detect pregnancy. Animals that failed to conceive were returned to a different buck the following day and each day thereafter until mating was observed. On the 28th d of gestation does were provided a four sided wooden nest box lined at the bottom with 3.2 mm and 6.4 mm wire mesh. Laboratory grade wood shavings were added. At parturition, the number of live and dead kits and the weight of the doe were recorded. Does were fed ad libitum from kindling, and were re-bred 14 days post-partum. When the litter was 21 d old, the nest box was removed and the litter weight, doe weight and remaining feed were measured. Young were weaned at 28 d, weighed and removed to a separate cage; the doe and remaining feed were also weighed at this time.

At any time the doe was without a nursing litter, including gestation, restricted feeding was practiced. Dry does were fed according to the amount that was consumed in the previous 24 hour period. They were fed less when feed was remaining and more if all the feed was consumed. These amounts ranged from 180-240 g daily and varied according to temperature in the rabbitry.

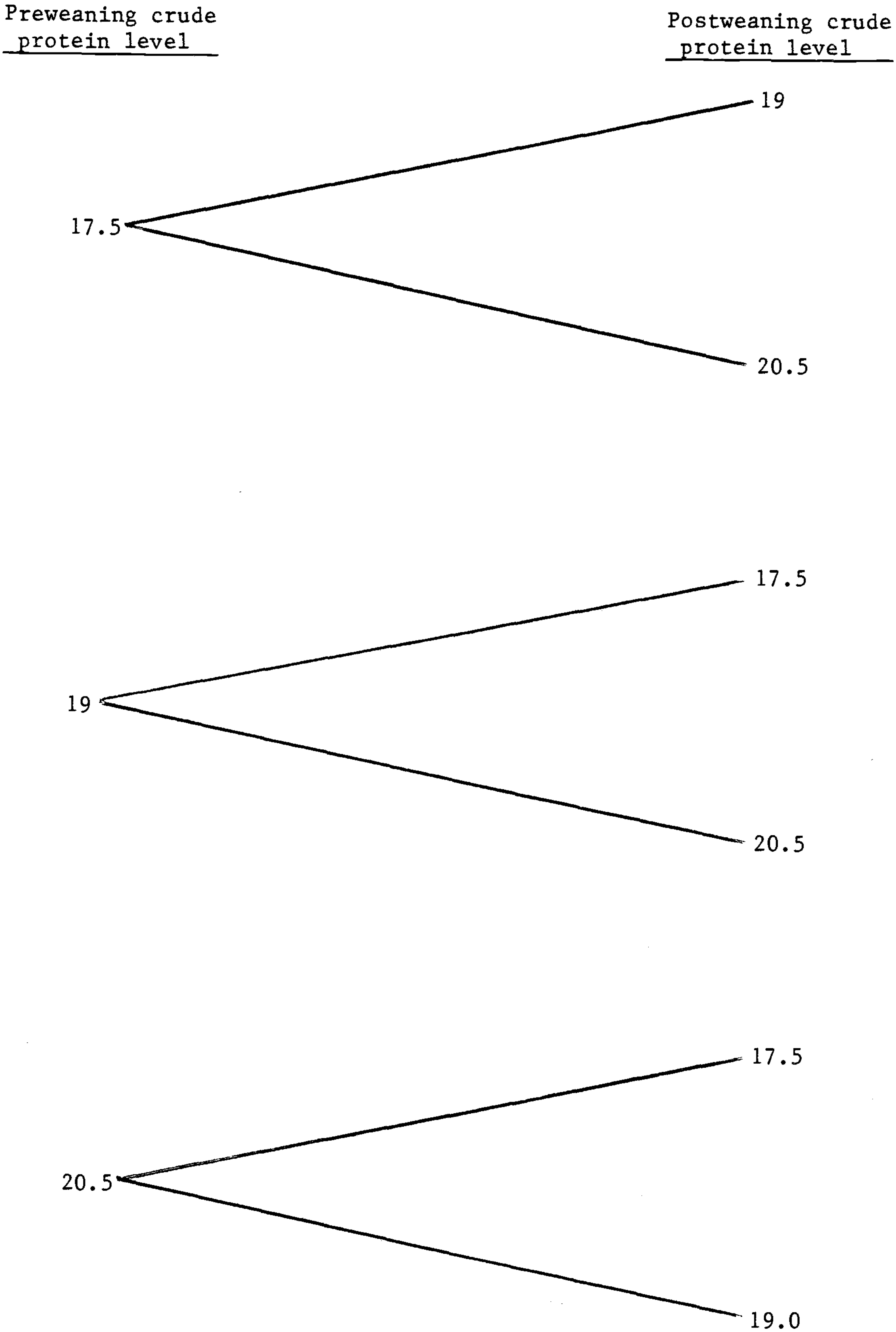
Performance traits recorded included number of live and dead born; total and live weight of the litter at birth; percent of litter born alive; doe weight at birth, 21 d and 28 d; percent conception (number services/litter); number of parities/doe (lactation records); number alive, litter gain from 1-21 d and 21-28 d; litter weight at 21 d and 28 d; mortality from 1-21 d and 21-28 d; doe and litter feed consumption and feed efficiency (doe and litter intake/litter gain) from 1-21 d and 21-28 d. These traits are of economic importance to the producer.

Postweaning Litter Management. Postweaning data were collected in two parts. In part one, every second litter of each doe (not including the first) was continued on treatment for further evaluation. Upon weaning at 28 d, rabbits were ear-tagged for identification, and the entire litter was moved to a new cage and given feed and water *ad libitum*. Beginning weight, ending weight, feed consumption and mortality were recorded. Postweaning evaluation in part one lasted 10 months (April 1983 to January 1984). Part two was conducted to determine the effect of preweaning protein level on postweaning performance. An additional 60 litters (10 per treatment) were given different diets after weaning than they had received preweaning. The schematic diagram in figure 1 illustrates the treatments used. In all litters, data were collected between four and eight weeks of age.

Performance traits included litter size at 28 and 56 d, average weight at 28 and 56 d, average daily consumption, average daily gain, feed efficiency and 28-56 d mortality percentage. Average daily consumption (ADC) was the ratio of total intake for all animals in a cage to the sum of days animals survived in that cage. Average daily gain (ADG), calculated only for surviving animals, was the difference in mean weight of the litter at 56 and 28 d divided by the number of days on trial (28). Feed efficiency (feed/gain) was the ratio of ADC to ADG.

Digestibility and N utilization. Five does were allocated to each of the 17.5 and 20.5% CP diets. The does had previously completed at least one lactation and had given adequate performance. During pregnancy, the does were housed in cages and fed as described for the 12

FIGURE 1. SCHEMATIC DIAGRAM REPRESENTING TREATMENTS USED BEFORE AND AFTER WEANING IN PART TWO OF THE POSTWEANING EXPERIMENT



month experiment. At parturition the litter was weighed, the number born alive and dead recorded and the live young returned to the nest box. Does were weighed and transferred to metabolism cages (described by Harris 1983b) after kindling and thereafter for a three-week lactation period were removed only once per day to nurse their litter. This method is consistent with the normal nursing behavior of rabbits (Venge, 1963; Zarrow et al., 1965). Does were allowed access to feed and water *ad libitum*.

Urine and feces were collected daily and samples were pooled each week for chemical analysis using the methods of AOAC (1975). After each collection, 10 ml of 5N HCl was added to each of the urine collecting flasks to prevent volatilization of ammonia.

Milk production was measured daily by weighing the doe to the nearest 10 g before and after nursing. Data collected were dry matter (DM), acid detergent fiber (ADF) and CP digestibility, milk production and N retention.

Statistical Procedures. Data were analyzed using analysis of variance. Litters were treated as the experimental unit. In the 12 month long experiment, diet, month of experiment, parity number and interactions were used as potential sources of variation in the data set of 391 litter records. Only litters born alive (N=339) were used in doe and litter birth traits (excluding number born and percent born alive). For other preweaning traits only litters in which at least one of the young survived to weaning age were included in the analysis (N=309). For postweaning performance traits, every other litter from each doe (excluding the first) in which at least two young survived to weaning age were considered for postweaning evaluation (N=187). In part one (which lasted 10 months), month of experiment was included with diet as main effects. In part two, data were collected only over a five month period, so month effect was not included. Parity and parity x diet interaction effects were assumed to be negligible and were not included. In cases of a significant overall F-test, means were compared by the Tukey-Kramer method for unequal sample sizes (Sokal and Rohlf, 1981).

For the digestibility and N utilization trial, data were analyzed using one-way analysis of variance with diet as the main effect.

RESULTS AND DISCUSSION

Results are grouped into doe, preweaning litter and postweaning litter performance traits. Litter performance was separated into 1-21 d, 21-28 d and 28-56 d records. The first 21 d is a reflection of milk production since the litter is completely dependent upon the dams milk until late in the third week of lactation when the litter leaves the nest box and begins consuming solid feed (Lang, 1981b). Performance during 21-28 d reflects a period of adaptation to solid feed and decreased dependence on the doe for milk, while the 28-56 d postweaning period is one of fast growth when feed consumption increases linearly.

Doe Performance. Doe traits are presented in table 2. Fertility did not differ among treatments but was higher than reported in other studies using similar rebreeding schedules (Harris et al., 1982; Lukefahr et al., 1983a). The reasons for greater conception rates are two-fold. Non fertile does (replaced after three consecutive failures to conceive) and does replaced after service, but before parturition, were not used to calculate fertility percentage. With these records

TABLE 2. DIET MEANS AND STANDARD ERRORS FOR REPRODUCTIVE TRAITS OF DOES FED DIETS CONTAINING 17.5, 19 AND 20.5% CRUDE PROTEIN

CP Diet	N	Fertility %	N	No. parities/doe	N	Doe wt at birth, kg	N	Doe wt 21 d, kg	N	Doe wt 28 d, kg	N	Doe and Litter Feed Efficiency 1-21 d
17.5	127	89.2±1.91	127	2.7±.14	119	4.55±.05	107	4.76±.05[a]	107	4.76±.05[c]	101	4.54±.11
19	128	92.1±1.71	128	3.1±.16	110	4.56±.05	93	4.96±.05[b]	96	4.92±.05[d]	92	4.36±.14
20.5	129	91.0±1.78	129	2.7±.15	114	4.69±.05	100	5.05±.06[b]	99	5.02±.06[d]	98	4.72±.31

[a,b]Column means bearing unlike superscripts differ ($P<.05$).

[c,d]Column means bearing unlike superscripts differ ($P<.01$).

included, fertility was 72, 70 and 66% for 17.5, 19 and 20.5% CP diets respectively. The breeding management may have also contributed to the increased fertility. Remating does immediately after their first service ensures that adequate quantities of sperm are available for fertilization. This breeding practice has been reported to increase both fertility and receptivity in breeding does (Szendro et al., 1984).

Doe weights at kindling were not different; however, does fed 17.5% CP were lighter ($P<.01$) at the peak of lactation (21 d) and at weaning (28 d). Cowie (1969) found that the crude protein content of rabbit milk increases after the third week of lactation. A possible explanation for lower body weights in does fed the low protein diet was a catabolism of muscle tissues to provide for milk synthesis.

Does fed 19% CP tended to have the greatest number of parities ($P=.06$). Lukefahr et al. (1983a) similarly reported greater longevity for does fed higher protein levels, although diets used in that study were of differing alfalfa levels.

Consumption (1-21 d) was 9.13, 9.37 and 9.03 kg for does fed 17.5, 19.0 and 20.5% CP respectively. Feed efficiency (doe feed/litter gain) values for all diets were similar. Causes of replacement of breeding does and total number replaced were similar among diets (table 3).

Preweaning Litter Performance. Preweaning litter traits are presented in tables 4, 5 and 6. Total born tended to be higher ($P=.07$) on higher levels of protein. Reddy and Moss (1982) and Omole (1982) reported similar results. Adams (1983) reported that lower than recommended levels of protein could be fed during gestation with no decrease in performance. Mahan and Mangan (1975) found that first litter sows could be fed low protein gestation diets when lactation

TABLE 3. NUMBER AND PERCENT OF BREEDING DOES REPLACED ON THE 17.5, 19 AND 20.5% CRUDE PROTEIN DIETS

	Dietary Protein, %					
	17.5		19		20.5	
Replacement Cause	No.	%	No.	%	No.	%
Poor production[a]	5	20	5	17.9	10	34.5
Respiratory problems[b]	2	8	7	25	5	17.2
Mastitis	3	12	2	7.1	2	6.9
Pododermatitis	3	12	2	7.1	1	3.5
Two or more causes	2	8	1	3.6	3	10.3
Death	6	24	9	32.2	6	20.7
Other[c]	4	16	2	7.1	2	6.9
Total	25	100	28	100	29	100.00

[a]Included severe weight loss, failure to raise a litter to weaning on two consecutive kindlings, failure to accept service for 14 consecutive days and failure to conceive after three matings.

[b]Included infection of Pasteurella multocida, excessive sneezing or pneumonia.

[c]Included enteric disorders, reproductive tract infections, broken back, eye infection and maloclussion.

TABLE 4. DIET MEANS AND STANDARD ERRORS FOR LITTER BIRTH TRAITS OF DOES FED 17.5, 19 AND 20.5% CRUDE PROTEIN

CP Diet	N	Total born	N	Born alive, %	N	Live litter wt, g
17.5	128	8.6±.26	128	86.4±2.35[a]	118	478±13.85[a]
19	131	9.2±.24	131	75.6±3.22[b]	109	542±14.80[b]
20.5	129	9.4±.26	129	78.9±3.01[a,b]	112	517±16.81[a,b]

[a,b]Column means bearing unlike superscripts differ ($P<.01$).

TABLE 5. DIET MEANS AND STANDARD ERRORS FOR 1-21 DAY PREWEANING LITTER TRAITS OF DOES FED 17.5, 19 AND 20.5% CRUDE PROTEIN

CP Diet	N	Litter wt 21 d, kg	N	Litter size 21 d	N	Mortality 1-21 d, %	N	Litter gain[a] 1-21 d, kg
17.5	106	2.55±.06	110	7.14±.24	111	9.85±1.43	107	2.06±.05
19	93	2.78±.07	93	7.85±.26	95	6.91±1.10	93	2.24±.06
20.5	99	2.69±.07	102	7.74±.26	102	10.03±1.36	99	2.16±.06

[a]Negative gain values due to excessive mortality were not included.

TABLE 6. DIET MEANS AND STANDARD ERRORS FOR 21-28 DAY PREWEANING TRAITS OF LITTERS FED 17.5, 19 AND 20.5% CRUDE PROTEIN

CP Diet	N	Litter wt 28 d, kg	N	Litter size 28 d	N	Mortality 21-28 d, %	N	Litter gain 21-28 d, kg
17.5	109	3.99±.11	111	7.07±.24	111	1.88±.84	100	1.43±.06
19	97	4.38±.12	93	7.72±.25	98	1.04±.77	83	1.63±.05
20.5	98	4.12±.12	102	7.63±.26	100	1.63±.65	83	1.49±.06

dietary protein is sufficient. In the present study, an increased number of total born was of no advantage because of a decrease in the percentage born alive ($P<.01$). A crude protein level of 17.5% during gestation does not appear to be deficient and may be of benefit by decreasing the number of still born.

Does fed 19% CP had heavier live litters ($P<.01$) than those fed 17.5%. There were greater 21 d ($P=.05$) and 28 d ($P=.06$) litter weights on this diet. Litter weight at 21 d is an excellent indicator of doe milk production and litter weaning weight (Partridge and Allan 1982). Reddy (1982) reported higher weaning weights for litters fed 18 vs 16 and 17% CP. Litter gains, also a good indicator of milk yield (Cowie, 1969), were highest for does fed 19% CP ($P=.05$). Litter size and mortality did not differ among treatments.

The highest doe and litter feed intake recorded (21-28 d) was 5.12 kg ($P=.05$) for the 19% CP groups. Consumption of 17.5 and 20.5% CP diets was 4.81 and 4.73 kg respectively. Consumption has been reported to reflect protein quality (Spreadbury, 1978). The 19% CP diet came the closest to meeting the amino acid requirements (table 7) which could explain its greater consumption. Pontes et al. (1980) also reported greater feed intakes by does and litters when a balanced 18.9% CP diet was fed. Doe and litter feed efficiency did not differ among diets.

Postweaning Litter Performance. Postweaning litter traits are presented in table 8. No significant differences were observed among diets for litter size, average weight, ADC and ADG. Total litter weights for 19 and 20.5% CP were greater ($P<.05$) than for 17.5% CP but reflected the slightly larger litter size on these treatments. Feed efficiency values were superior for rabbits fed 20.5% CP ($P<.05$). This

TABLE 7. AMINO ACID ANALYSIS OF DIETS CONTAINING 17.5, 19 AND 20.5% CRUDE PROTEIN AND AMINO ACID REQUIREMENTS FOR GROWTH AND LACTATION

Amino Acid	Requirements for Growth[a]	Requirements for Lactation[b]	Dietary Protein 17.5%	Dietary Protein 19%	Dietary Protein 20.5%
Methionine + Cystine	.60	.60	.13[f]	.15[f]	.15[f]
Lysine	.65	.75	.75	.89	.94
Arginine	.60	.80	.93	1.09	1.18
Threonine	.60[c]	.70	.64	.69	.78
Tryptophan	.20[c]	.22	---[e]	---[e]	---[e]
Histidine	.30[c]	.43	.40	.41	.57
Isolencine	.60[c]	.70	.59	.69	.74
Valine	.70	.85	.83	.87	.91
Leucine	1.10	1.25	1.10	1.31	1.36
Phenylalanine + Tyrosine	1.10[c]	---[e]	1.12	1.35	1.58
Glycine	---[d]	---[e]	0.74	0.77	0.89

[a]NRC (1977)

[b]Lebas (1980a)

[c]May not be minimum but known to be adequate

[d]Quantitative requirement not determined, but dietary need demonstrated

[e]Not available

[f]Acid hydrolysis may have resulted in lower than actual value

TABLE 8. DIET MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS OF POSTWEANING LITTERS FED DIETS CONTAINING 17.5, 19 AND 20.5% CRUDE PROTEIN

CP Diet	No. of Litters	Litter size at 28 d	Average 28 d wt, kg	Litter size at 56 d	Average 56 d wt, kg	Average daily[a] gain, g	Feed[b] Efficiency	Mortality 28-56 d, %
17.5	47	7.60±.35	.590±.02	7.46±.36	1.67±.04	38.5±.84	3.13±.04[c]	2.12±.77[c]
19	40	8.50±.39	.570±.02	8.41±.40	1.67±.03	39.0±.93	3.08±.07[c]	.61±1.42[d]
20.5	40	8.40±.32	.557±.02	7.97±.35	1.65±.03	38.8±.90	2.88±.06[d]	5.62±1.49[e]

[a] Average daily gain was the ratio of average individual gain to the number of days on trial (28 d).

[b] Feed efficiency was the ratio of average daily consumption to average daily gain.

[c,d] Column means bearing unlike superscripts differ ($P<.05$)

is in agreement with Lang (1981a) who reviewed reports in which protein levels of 17-20% gave more efficient gains than lower levels (16%). Mortality was lowest for 19% CP and highest for 20.5% CP ($P<.05$). Lebas (1980b) has suggested that high dietary protein levels may increase enteritis incidence. He states that bacteria within the cecum of the rabbit use excess protein as an energy source and produce ammonia as a waste product. The absorbed ammonia may cause ammonia toxicity and be a contributing factor to enteritis mortality. In the present study enteritis was the leading cause of death in postweaning rabbits. Overall, mortality was lower than has been previously reported for fryers (Harris et al., 1982; Lukefahr, 1983b). The open-sided housing may have reduced the stress by cutting down on the ammonia that can be present in enclosed buildings. Also, copper sulfate has been reported to reduce enteritis (Patton et al., 1982), and the addition of 80 ppm may have been a factor in controlling enteritis in this study.

Postweaning litter traits for animals fed different diets after weaning than prior to weaning are presented in table 9. No differences were observed among diets for any of the traits studied. Mortality tended to be highest ($P=.07$) for animals that were fed 20.5% CP prior to weaning which suggests a possible carryover effect.

Month Effect. The influence of month on fertility, which appears to rise in August (does bred in July) and decrease throughout the rest of the year, is presented in figure 2. Fertility early in the year may be confounded by the use of highly fertile non parous does during that period. All month and month x treatment interaction effects were not important ($P>.05$). Seasonal variation in conception rates of rabbits has been reported (Sittman et al., 1964; Enos et al., 1979). Season of

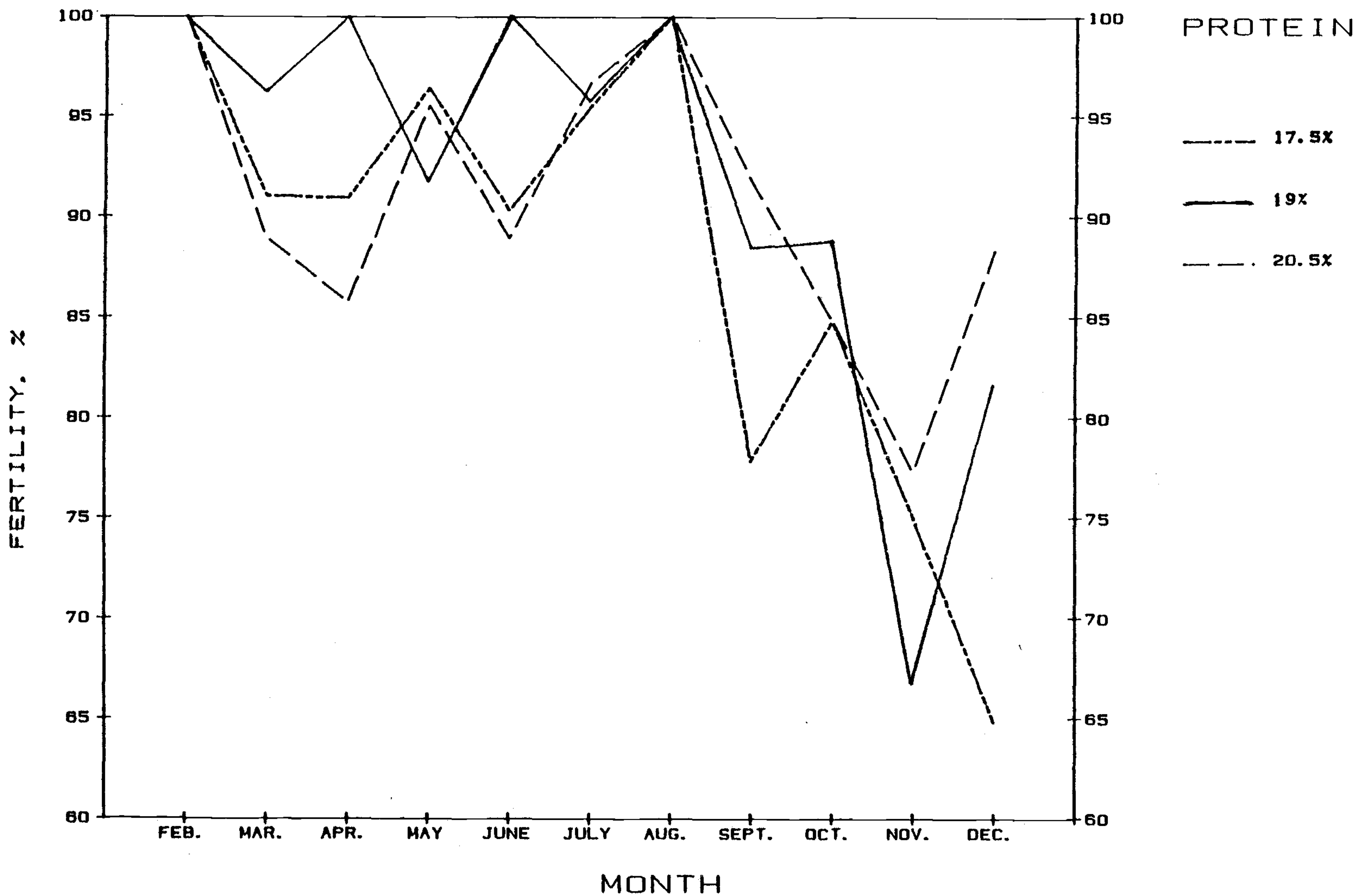
TABLE 9. DIET MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS OF POSTWEANING LITTERS FED DIFFERENT LEVELS OF CRUDE PROTEIN BEFORE AND AFTER WEANING

CP Diet Prewean	CP Diet Postwean	Litter size at 28 d	Average 28 d wt, kg	Litter size at 56 d	Average 56 d wt, kg	Average[a] daily gain, g	Feed[b] Efficiency	Mortality 28-56 d, %
17.5	19	6.00±.71	.662±.05	6.00±.71	1.77±.09	39.7±2.28	3.15±.12	0±0
17.5	20.5	6.73±.89	.554±.03	6.55±.89	1.67±.09	40.0±2.24	3.01±.23	2.27±2.27
19	17.5	6.50±.75	.584±.84	6.30±.78	1.74±.07	42.2±1.57	2.99±.10	3.43±2.33
19	20.5	7.70±.42	.611±.05	7.20±.49	1.81±.05	42.9±1.29	2.67±.14	5.87±4.51
20.5	17.5	5.70±.78	.636±.04	5.30±.79	1.76±.07	40.1±1.67	3.32±.15	7.77±4.40
20.5	19	7.50±.83	.573±.03	7.30±.80	1.68±.06	39.4±1.89	2.99±.20	6.06±3.59

[a]Average daily gain was the ratio of average individual gain to the number of days on trial.

[b]Feed efficiency was the ratio of average daily consumption to average daily gain.

FIGURE 2. INFLUENCE OF MONTH OF EXPERIMENT ON FERTILITY PERCENTAGE OF DOES FED 17.5, 19 AND 20.5% CRUDE PROTEIN



birth has also been reported to influence postweaning mortality incidence (Lukefahr et al., 1983b). The mild extremes in temperature (high 86°F, low 23°F) may have been the reason for the lack of any month effect (figure 3).

Parity Effect. Parity effect was important for percentage fertility, percentage born alive, live litter birth weight and doe weight at 21 d and 28 d ($P<.05$). Interaction was observed among all three treatments for percentage fertility and between the two higher protein levels for all other traits (figures 4-7). Fertility fluctuated throughout the first four parities but declined steadily thereafter (figure 4). Examination of the interactions revealed no apparent trend.

The percentage born alive was lowest at first parity then increased steadily until the fourth (20.5% CP) or fifth lactation (figure 5). Live birth weight (figure 6) shows a similar trend except that a decline is observed after the second (17.5% CP) or the third (19 and 21.5% CP) parity. German workers (Kalinowski and Rudolph, 1975) studied milking performance over several lactations and found that performance at first lactation was also poorest, but in their study does were lighter at first parity suggesting that mature body weights had not been reached. Lighter body weights of does at first parity were not observed in the present study. Live birth weights were similar among treatments at first parity but lighter litters (ca. 75g) were observed for does fed the low protein diet during successive lactations. The reason for the rise in birth weight at sixth parity for does fed 19% CP is not known.

Doe weights at 21 d (peak lactation) show a downward trend for all treatments (figure 7). This is particularly evident on the low protein diet where losses of nearly 500g were observed from the first through

FIGURE 3. WEEKLY TEMPERATURES DURING THE EXPERIMENTAL PERIOD (JANUARY TO DECEMBER, 1983)

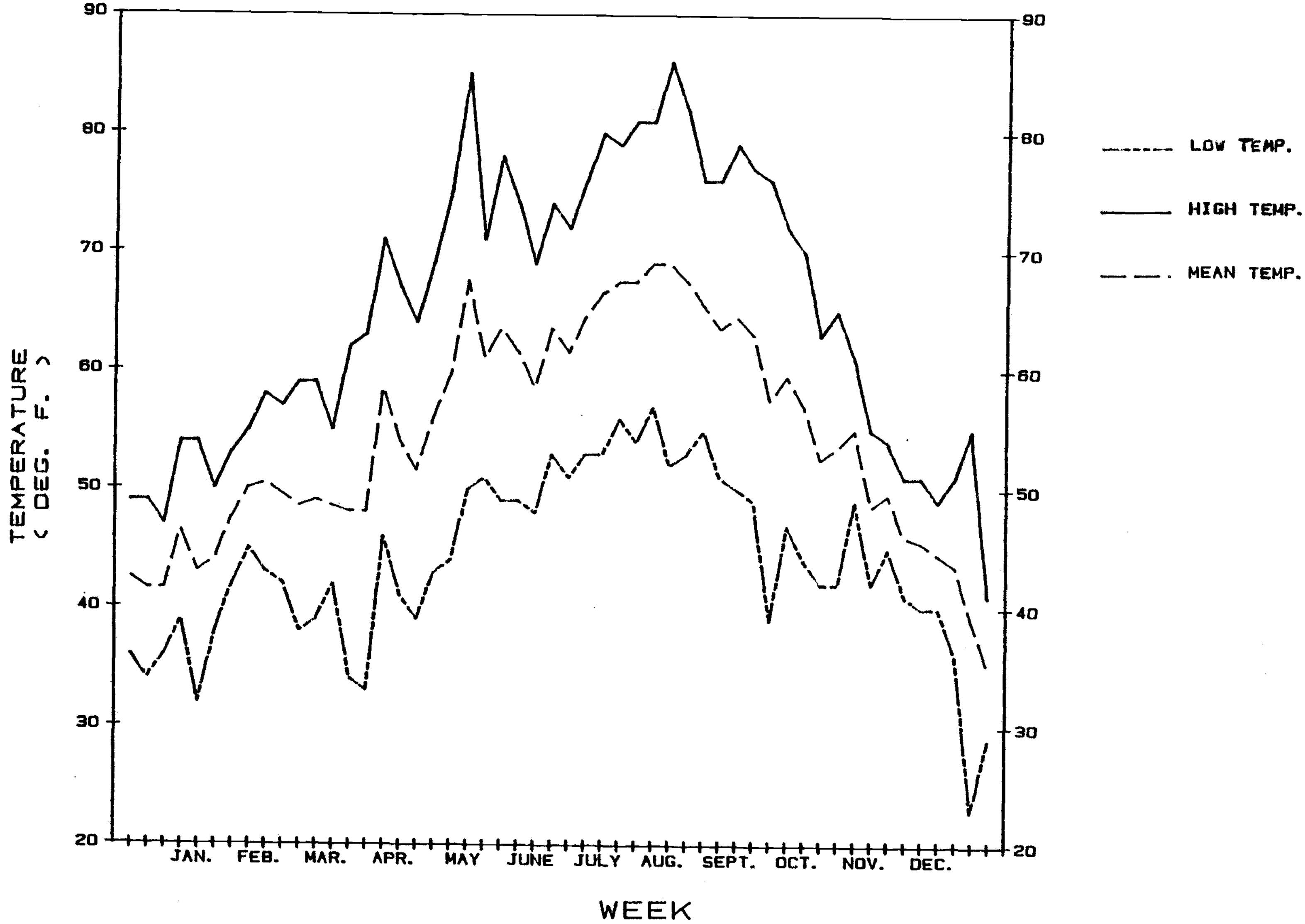


FIGURE 4. INFLUENCE OF PARITY NUMBER ON FERTILITY PERCENTAGE OF DOES FED 17.5, 19 AND 20.5% CRUDE PROTEIN

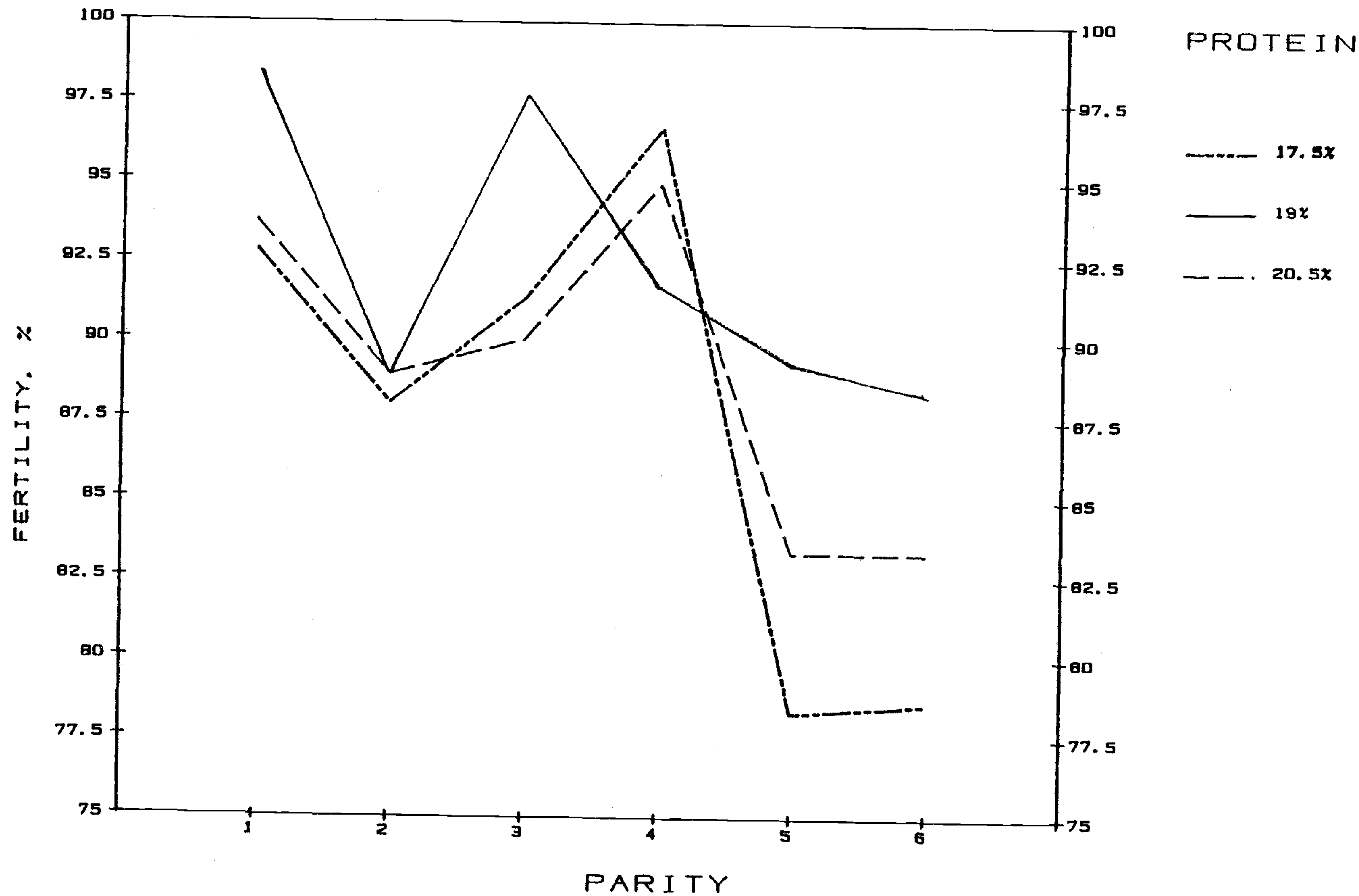


FIGURE 5. INFLUENCE OF PARITY NUMBER ON PERCENTAGE BORN ALIVE WITHIN LITTERS OF DOES FED 17.5, 19 AND 20.5% CRUDE PROTEIN

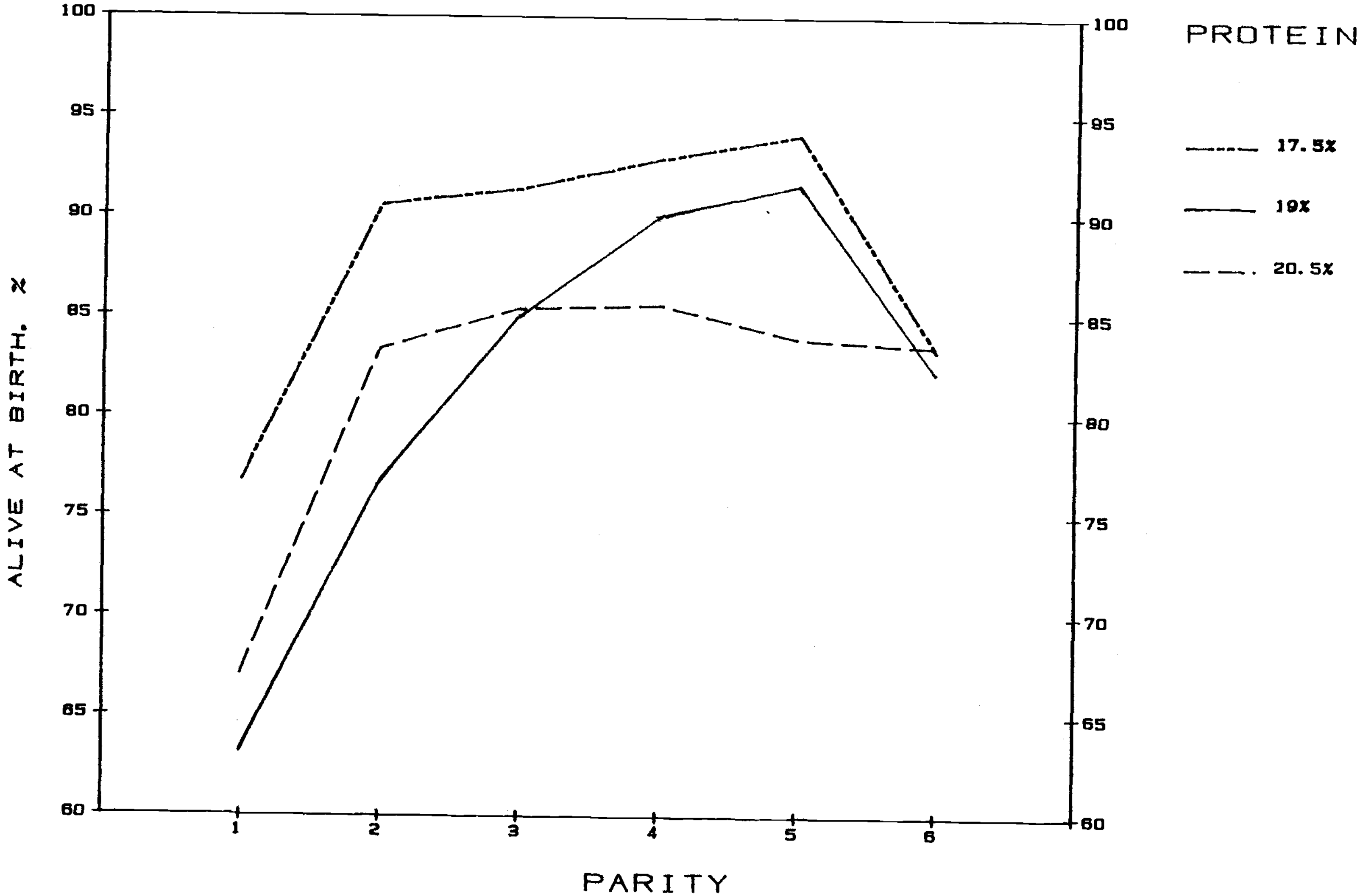
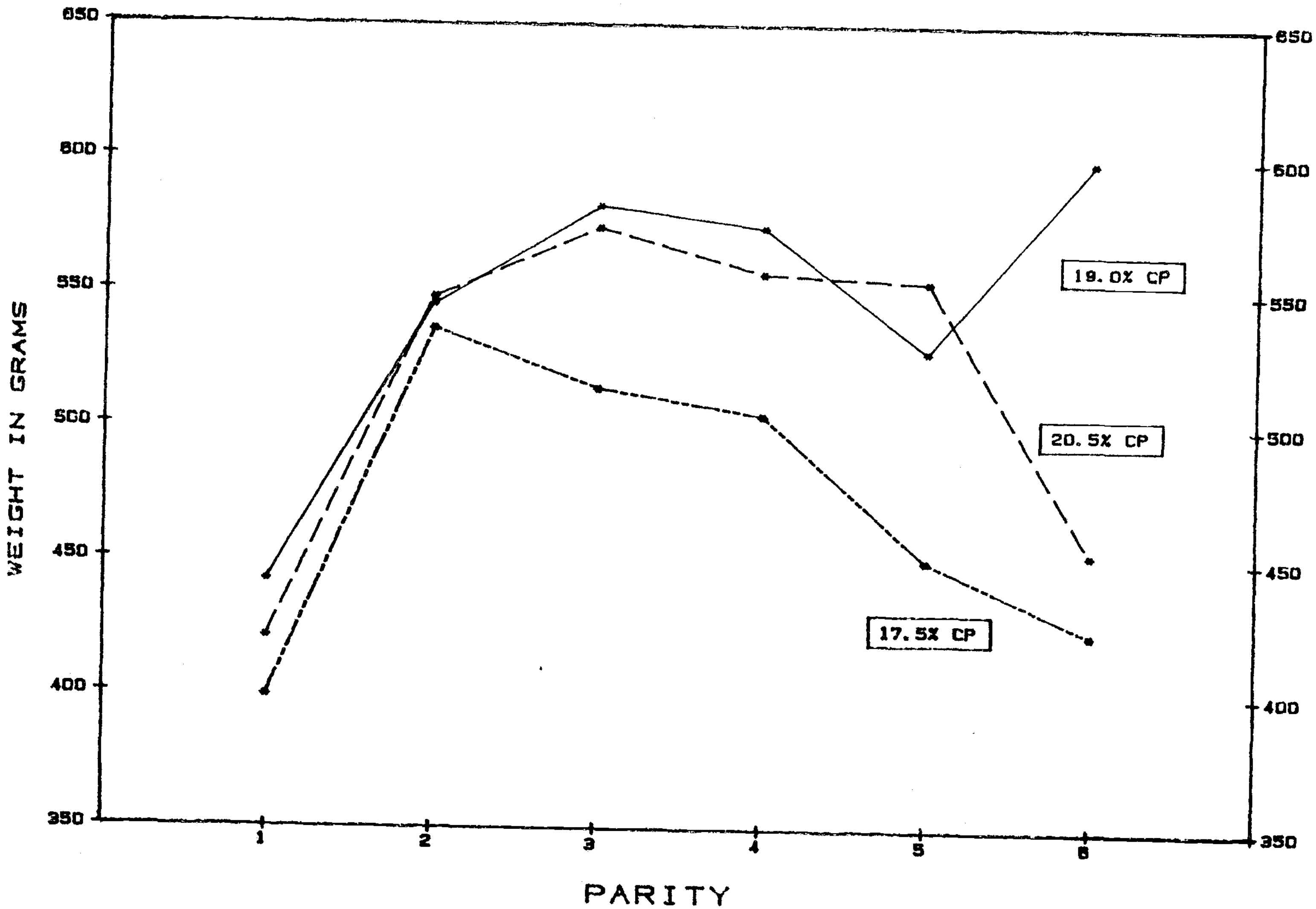


FIGURE 6. INFLUENCE OF PARITY NUMBER ON LIVE LITTER WEIGHTS OF DOES FED 17.5, 19 AND 20.5% CRUDE PROTEIN



the fifth lactation. It is uncertain why such a large weight decrease (400g) occurred between the second and third lactation of does fed 20.5% CP. Does fed 19% CP had the least amount of fluctuation in weight. Increased weights observed after the fifth lactation may have been a reflection of genetic superiority in animals that had reached their sixth lactation. Eight parities were the maximum observed (19 and 21.5% CP) but this lactation and the seventh were deleted from the figures because of the low numbers.

Digestibility and N Utilization. For all traits that differed, 19% CP was generally the superior diet. The only major differences observed between does fed 17.5 and 20.5% CP was in doe weight at 21 d and 28 d. Therefore, the digestibility and N utilization experiment was conducted to determine if doe weights differed because of differences in digestibility or N retention. Digestibility data is presented in table 10. Apparent DM and ADF digestibility values were greater ($P<.05$) for does fed 20.5% CP, but CP digestibility did not differ. Consumption of each of the diets was not different; animals fed the higher protein diet consumed more N ($P<.05$).

Four-week totals of milk production were not different between diets (4.53 and 4.44 kg for 17.5 and 20.5% CP respectively), but two does fed 20.5% CP had small litter sizes (five and three) which may have reduced milk output from these does. Cowie (1969) concluded that six young would be needed to empty all the mammary glands. Partridge and Allan (1982) reported significantly lower milk production in does nursing four vs eight kits. Peak milk yield on both diets was on d 19 of lactation as has been reported previously (Partridge and Allan, 1982). Milk protein composition is stable until the end of the third

FIGURE 7. INFLUENCE OF PARITY NUMBER ON 21 DAY LACTATION WEIGHT OF DOES FED 17.5, 19 AND 20.5% CRUDE PROTEIN

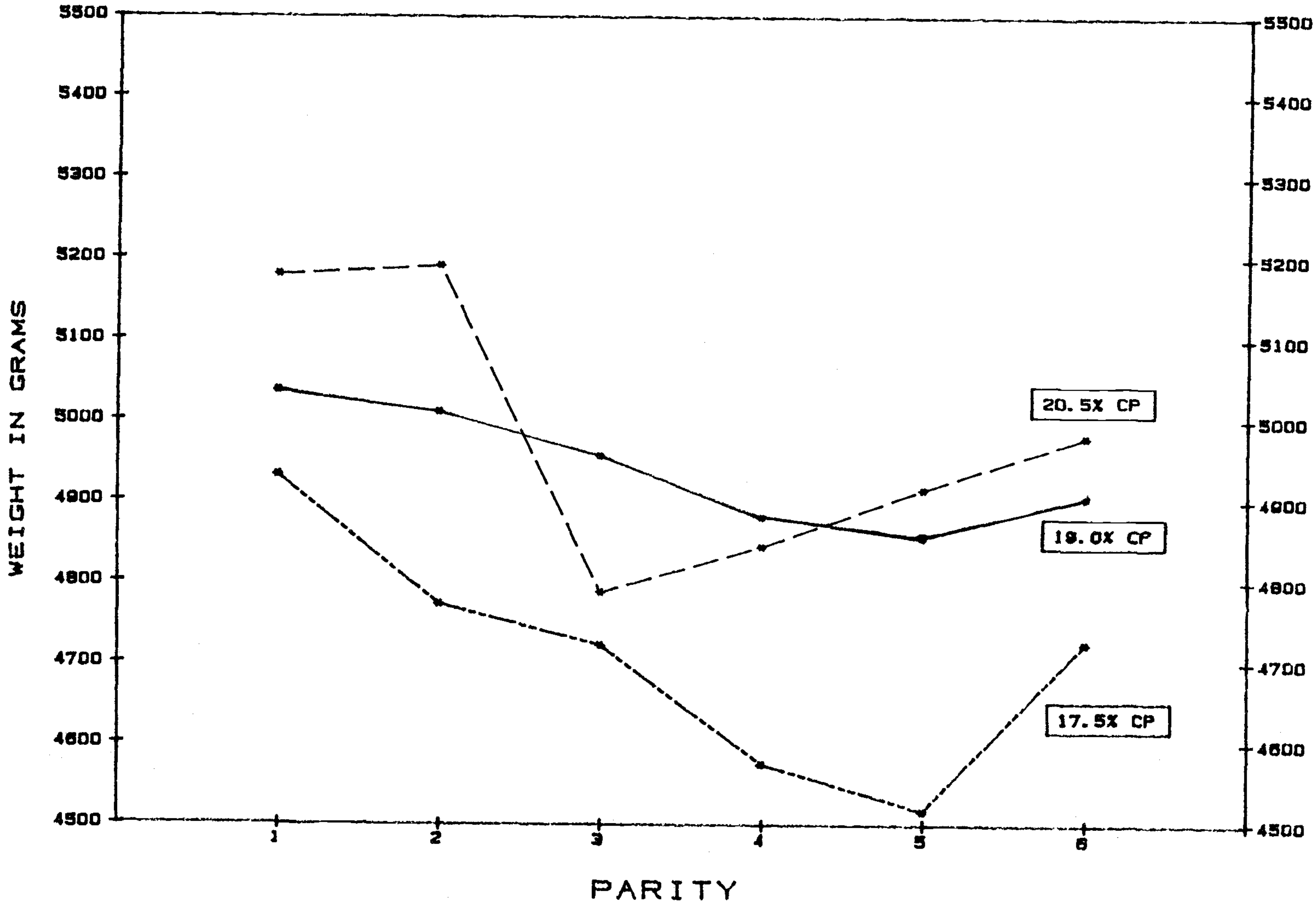


TABLE 10. APPARENT DIGESTIBILITY OF 17.5 AND 20.5% CRUDE PROTEIN DIETS BY LACTATING RABBITS

CP Diet	N	DM Digestibility	ADF Digestibility	CP Digestibility	Weekly N Intake
17.5%	5	60.86±1.23[a]	18.10±1.60[a]	69.24±1.19	71.03±3.87[a]
20.5%	5	66.02±1.65[b]	29.06±3.53[b]	71.15±1.43	83.31±3.64[b]

[a,b]Column means bearing unlike superscripts differ ($P<.05$).

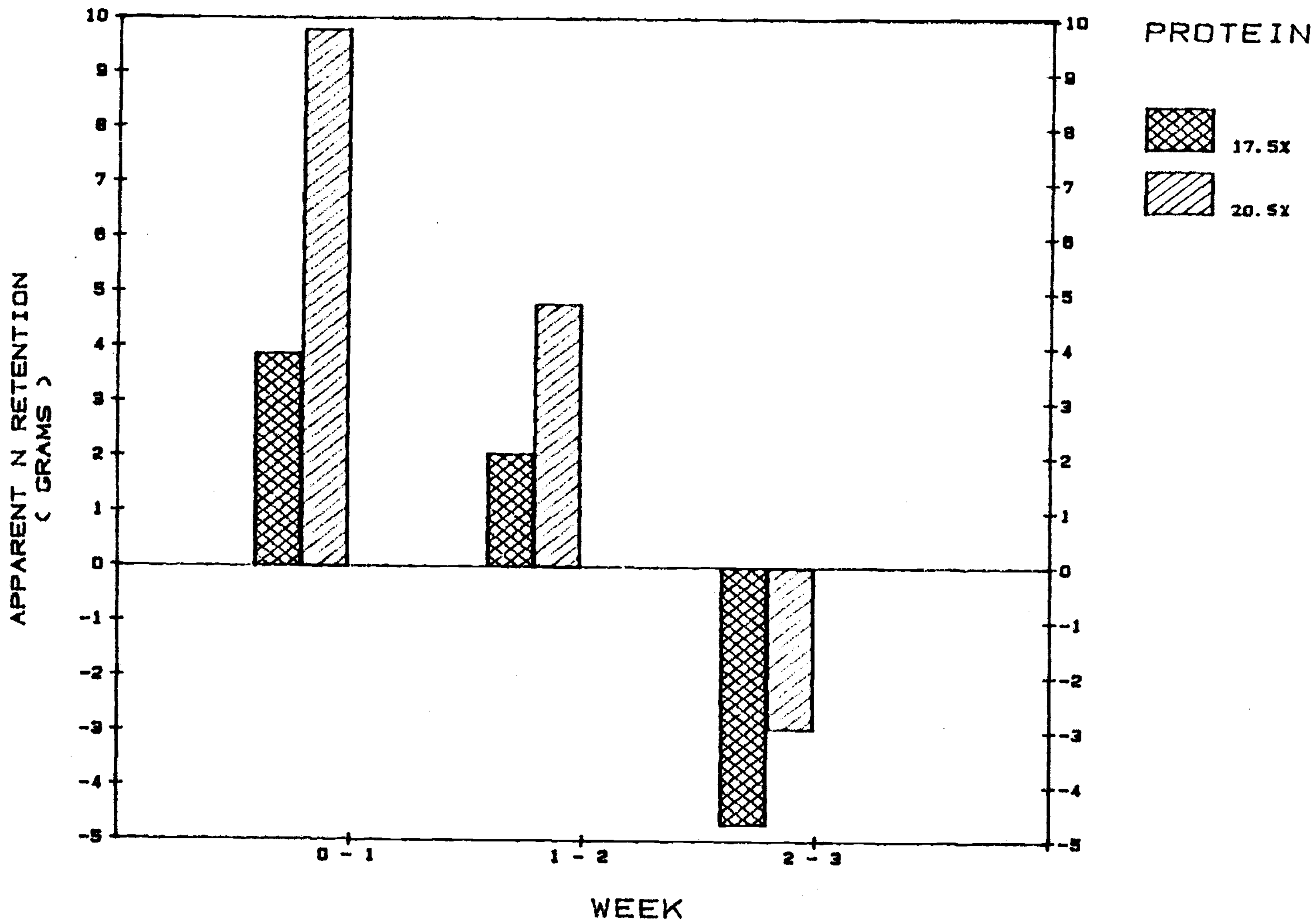
week of lactation (Coates et al., 1964; Cowie, 1969; Lebas, 1971) and is independent of dietary protein (Partridge and Allan, 1982).

Lang (1981b) used compositional values derived from these reports and others to arrive at a value of 13-14% CP in the milk. Using 13% as the estimated protein content of milk in this study, we found that does fed 17.5% CP retained 90% less N (P=.22) during lactation (figure 8). N retention was calculated by the difference between N consumed and N lost in the urine, feces and milk. Three-week totals for N retention were 1.3 and 11.7 g for 17.5 and 20.5% CP respectively. Negative N retention was observed only in the third week when milk yields are at their highest and milk protein percentage increases. Partridge and Allan (1982) reported similar results.

The fact that does fed 17.5% CP were lighter at peak lactation and showed the greatest decrease in weight through subsequent lactations, along with their apparent trend for lower N retention suggests that this diet may not meet the heavy demands placed on them by the 14 d rebreeding schedule and the concurrent gestation and lactation.

With intensive rebreeding of does, 19% CP during lactation allows for a greater number of parities, heavier litters and greater litter gains while maintaining the does weight over several parities. A CP level of 17.5% does not provide the same level of performance but may be adequate during gestation. The additional protein in the 20.5% CP diet is of no added benefit. Although no increases in gain were observed with higher protein levels, the low mortality observed with 19% CP would warrant its use for postweaning fryers. Based on the results of this study, high alfalfa feeds intended to supply the needs of both lactating and growing rabbits should contain 19% CP.

FIGURE 8. NITROGEN RETENTION OF LACTATING DOES FED 17.5 AND 20.5% CRUDE PROTEIN



CHAPTER 3

INFLUENCE OF DIETARY LEVEL OF SOYBEAN MEAL, METHIONINE AND LYSINE ON THE PERFORMANCE OF WEANLING RABBITS FED HIGH-ALFALFA DIETS[1,2]

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Influence of Dietary Level of Soybean Meal,
Methionine and Lysine on the Performance
of Weanling Rabbits Fed High-Alfalfa Diets

W.K. Sanchez, P.R. Cheeke and N.M. Patton

SUMMARY

The effect of level of dietary soybean meal and methionine and lysine in high alfalfa diets fed to weanling rabbits was evaluated in three growth trials. Four hundred and twelve, 4-5 week old New Zealand White rabbits were fed for either 28 or 35 days diets ranging from 16.5 to 22% crude protein (CP) containing between 0 and 21% soybean meal (SBM). In experiment one, 54% alfalfa diets containing four levels of SBM (21, 15, 9, 3; and CP 22.1, 19.6, 18.2, 17%) with or without the addition of 0.3% methionine hydroxy analogue (MHA) were fed to two weight-classes of rabbits (average initial weight 573 and 776 g). No differences were observed among diets but gains of the animals fed MHA approached significance (P=.14). Rabbits in the heavier weight-class consumed more (P<.01) and gained more (P<.05). In experiment two, rabbits were fed 54 or 74% alfalfa diets containing either 0 or 21% soybean meal with or without the addition of 0.3% MHA. The poorest growth and the greatest response to MHA was observed on the 74% alfalfa diet with 0% SBM, but none of these differences were significant. In experiment three, 54% alfalfa diets containing 21% SBM (control), 0% SBM, 0% SBM + .3% lysine-HCl (LYS) or 0% SBM + .3% LYS + .3% MHA were fed to growing rabbits. The control diet contained 22.7% CP and the 0% SBM diet had 17% CP. No differences were observed between the control and 0% SBM fed rabbits but a depression in growth (P<.05) was observed for animals fed diets supplemented with LYS alone. When MHA was added

to the LYS supplemented diet, growth was improved but was still below that of the controls. Feed conversion was more efficient on the control diet ($P<.05$). These resulted indicated that high alfalfa diets containing no soybean meal (16.5% CP) and no supplementation with methionine or lysine were adequate for normal growth of the weanling rabbit.

INTRODUCTION

Relative to other livestock species, very little information is available on the nutrient requirements of domestic rabbits. At the Oregon State University Rabbit Research Center, considerable work has been done to formulate a ration for growing rabbits that provides fast, efficient gains but does not lead to extensive mortality. Through the increased understanding of the multiple causes of enteritis mortality (Patton et al., 1978; Cheeke and Patton, 1980) and the extensive work with high alfalfa diets (Pote et al., 1980; Harris et al., 1981), a 54% alfalfa ration was developed. This diet contains no cereal grain and has sufficient levels of fiber to reduce enteritis incidence. However, this diet may contain higher than necessary levels of soybean meal and protein. Most of the reports in the literature recommend lower levels of dietary protein than the 20-22% crude protein (CP) present in this diet.

Spreadbury (1978) found that feed intake and growth of weanling rabbits increased with dietary CP concentration until a level of 15.6% (18.5% dry matter basis) was reached. Lebas (1980a) similarly recommended 15% CP for the growing 4-12 week old rabbit. Others (Romney and

Johnston, 1978; Omole, 1982) have found that higher gains could be achieved with levels of 18-22% CP.

Along with crude protein, variation exists in the literature as to the requirements of the amino acids most commonly in short supply - methionine and lysine (Lang 1981a). Methionine and cystine levels as high as .63 and as low as .45% have been found to meet the requirements. Similarly for lysine, levels as high as .94 and as low as .70% have been listed as the requirement (Lang, 1981a).

The objectives of the following experiments were to (1) evaluate lower levels of soybean meal (SBM) and thus protein in the 54% alfalfa OSU rabbit diet (2) determine if performance could be improved with the addition of the .3% methionine hydroxy analogue (MHA) and(or) .3% lysine and (3) evaluate a higher alfalfa diet (74%) both with and without SBM and(or) MHA.

MATERIALS AND METHODS

This study consisted of three experiments. In all experiments, 4-5 week-old weanling New Zealand White rabbits were housed in indoor facilities equipped with electric fans for ventilation, controlled lighting (16 h light, 8 h dark) and above ground manure pits. Rabbits were raised in hanging all-wire quonset-style cages (76 x 76 x 46 cm), ear-tagged for identification, fed pelleted diets (4.7 mm) in screened metal feeders, and allowed access to feed and water *ad libitum*. Littermates were randomly distributed to the different dietary treatments. Prior to collection of data, animals were provided an adaptation period (3-4 days) to become accustomed to the diets.

Beginning and ending weight, feed consumption and mortality were recorded. In each of the separate experiments, different batches of ingredients were used in the preparation of diets, thus explaining any differences in chemical analysis of identical rations used in separate experiments. The diets were analyzed for crude protein using a micro-Kjeldahl method (AOAC, 1975). Fiber analysis was accomplished using a micro-method for acid detergent fiber (Waldern, 1971). For all experiments, a control diet (54% alfalfa ration) that has given good performance for growing rabbits in previous experiments (Harris et al., 1982; Lukefahr et al., 1983b) was used. In the following experiments, as the dietary level of SBM was lowered, the level of wheat mill run was raised accordingly.

Experiment One. This experiment included 160 weanling rabbits which were randomly allotted to four diets with or without the addition of 0.3% MHA. A total of eight dietary treatments were given which contained 54% alfalfa and varying levels of SBM. Treatments were as follows:

1. 21% SBM (control)
2. 21% SBM + .3% MHA
3. 15% SBM
4. 15% SBM + .3% MHA
5. 9% SBM
6. 9% SBM + .3% MHA
7. 3% SBM
8. 3% SBM + .3% MHA

The composition and chemical analyses of the experimental rations are presented in table 11. Treatments were replicated into four cages containing five rabbits each. Half of the replicate cages contained a light weight-class of rabbits (average initial weight 573 g) and half contained a heavy weight-class (average initial weight 776 g). A randomized block design was used for the experimental design. Based on preliminary results, part of this experiment (analyzed separately) was repeated. An additional 60 rabbits (average initial weight 824 g) were randomly allotted to three of the above diets; rations 1, 7 and 8. This experiment lasted 28 days.

Experiment Two. In this experiment two alfalfa diets (54 and 74%) were fed to 120 weanling rabbits (average initial weight 778 g) for 35 days. For each alfalfa diet, three rations were formulated resulting in a total of six treatments. Rations were as follows:

1. 54% alfalfa, 21% SBM (control)
9. 54% alfalfa, 0% SBM
10. 54% alfalfa, 0% SBM, .3% MHA
11. 74% alfalfa, 21% SBM
12. 74% alfalfa, 0% SBM
13. 74% alfalfa, 0% SBM, .3% MHA

The composition and chemical analyses of the experimental rations are presented in table 12. Treatments were replicated with four cages containing five rabbits each and a completely randomized design was used.

TABLE 11. COMPOSITION AND CHEMICAL ANALYSIS OF 54% ALFALFA DIETS CONTAINING DIFFERENT LEVELS OF SOYBEAN MEAL WITH AND WITHOUT THE SUPPLEMENTATION OF METHIONINE HYDROXY ANALOGUE

		Ration Number[a]			
Ingredient		1 (control)	3	5	7
Alfalfa meal	(IFN 1-00-025)	54	54	54	54
Soybean meal	(IFN 5-04-604)	21	15	9	3
Wheat mill run	(IFN 4-05-206)	20	26	32	38
Molasses	(IFN 4-04-696)	3	3	3	3
Soybean oil	(IFN 4-07-983)	1.25	1.25	1.25	1.25
Trace mineral salt[b]		.5	.5	.5	.5
Dicalcium phosphate	(IFN 6-01-080)	.25	.25	.25	.25
Chemical analysis[c]					
Dry matter, %		91.00	91.44	92.43	91.42
Crude protein, %		22.09	19.61	18.17	16.95
Acid detergent fiber, %		20.05	19.97	19.62	19.65
Methionine + cystine, %[d]		.66	.61	.57	.52

[a]Rations 2, 4, 6, and 8 were identical to rations 1, 3, 5, and 7 respectively except for the addition of 0.3% methionine hydroxy analogue.

[b]Mortons Farm and Ranch iOFIXT T-M SALT. Provides NaCl and the following elemental levels in mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, .35; Co, .35.

[c]All values (except dry matter) reported on a dry matter basis.

[d]Calculated values.

TABLE 12. COMPOSITION AND CHEMICAL ANALYSIS OF 54% AND 74% ALFALFA DIETS CONTAINING DIFFERENT LEVELS OF SOYBEAN MEAL WITH AND WITHOUT THE SUPPLEMENTATION OF METHIONINE HYDROXY ANALOGUE

		Ration Number[a]			
Ingredient		1 (control)	9	11	12
Alfalfa meal	(IFN 1-00-025)	54	54	74	74
Soybean meal	(IFN 5-04-604)	21		21	
Wheat mill run	(IFN 4-05-206)	20	41		21
Molasses	(IFN 4-04-696)	3	3	3	3
Soybean oil	(IFN 4-07-983)	1.25	1.25	1.25	1.25
Trace mineral salt[b]		.5	.5	.5	.5
Dicalcium phosphate	(IFN 6-01-080)	.25	.25	.25	.25
Chemical analysis[c]					
Dry matter, %		90.28	90.35	91.84	92.25
Crude protein, %		20.79	16.56	20.69	17.42
Acid detergent fiber, %		21.43	21.76	23.82	26.92
Methionine + cystine, %[d]		.66	.49	.63	.48

[a]Rations 10 and 13 were identical to rations 9 and 12 respectively except for the addition of 0.3% methionine hydroxy analogue.

[b]Mortons Farm and Ranch iOFIXT T-M SALT. Provides NaCl and the following elemental levels in mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, .35; Co, .35.

[c]All values (except dry matter) reported on a dry matter basis.

[d]Calculated values.

Experiment Three. Randomly allotted to four dietary treatments in experiment four were 72 weanling rabbits (average initial weight 641 g). Table 13 shows the composition and chemical analysis of the 54% alfalfa diets. Treatments were replicated into six cages containing three rabbits each and a completely randomized design was used. Animals were fed the following 54% alfalfa diets for 35 days:

1. 21% SBM (control)
9. 0% SBM
14. 0% SBM + .3% L-lysine HCl (LYS)
15. 0% SBM + .3% LYS + .3% MHA

The available lysine in the supplement was .225% (assuming 75% activity).

Statistical Procedures. Data were analyzed using analysis of variance. Cage was treated as the experimental unit. Performance traits included average daily feed consumption, average daily gain, feed efficiency and mortality percentage. Average daily consumption (ADC) was the ratio of total intake for all animals in a cage to the sum of days animals were alive in that cage. Average daily gain (ADG), calculated only for surviving animals, was the difference in mean weight of the rabbits at the end and beginning of the trial, divided by the number of days on trial. Feed efficiency (feed/gain) was the ratio of ADC to ADG. In the case of a significant overall F-test, means were compared by Student-Newman-Keuls multiple range test.

TABLE 13. COMPOSITION AND CHEMICAL ANALYSIS OF 54% ALFALFA DIETS CONTAINING DIFFERENT LEVELS OF SOYBEAN MEAL WITH AND WITHOUT METHIONINE HYDROXY ANALOGUE AND LYSINE-HCl

		Ration Number[a]	
Ingredient		1 (control)	9
Alfalfa meal	(IFN 1-00-025)	54	54
Soybean meal	(IFN 5-04-604)	21	
Wheat mill run	(IFN 4-05-206)	20	41
Molasses	(IFN 4-04-696)	3	3
Soybean oil	(IFN 4-07-983)	1.25	1.25
Trace mineral salt[b]		.5	.5
Dicalcium phosphate	(IFN 6-01-080)	.25	.25
Chemical analysis[c]			
Dry matter, %		86.18	86.32
Crude protein, %		22.69	17.11
Acid detergent fiber, %		18.39	17.99
Methionine + cystine, %		.66	.49
Lysine, %			.70

[a]Rations 14 and 15 were identical to ration 9 except for the addition of 0.3% lysine and 0.3% lysine-HCl + 0.3% methioinine hydroxy analogue, respecitvely.

[b]Mortons Farm and Ranch iOFIXT T-M SALT. Provides NaCl and the following elemental levels of mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, .35; Co, .35.

[c]All values (except dry matter) reported on dry matter basis.

[d]Calculated values.

RESULTS AND DISCUSSION

Experiment One. Performance traits for experiment one are summarized in table 14. No significant differences in performance were observed among any of the diets. Overall, animals fed diets supplemented with MHA tended to gain more ($P=.14$). The response to methionine was greater for animals fed lower protein diets (figure 9).

Rabbits in the heavier weight-class consumed more ($P<.01$) and had greater gains ($P<.05$). Although rabbits were all of the same age, animals in the lighter weight-class were of the same body size as younger rabbits. Their lower gains may have been due to a higher protein requirement. Pigs are known to require more protein prior to weaning than just after weaning (Agricultural Research Council, 1967). In support of this, an examination of the subclass means revealed that lighter animals gained 4.2 g more per day on the control vs other unsupplemented diets, but heavy rabbits only gained .48 g more per day. After further examination of the weight-class means (table 15), it became apparent that most of the animals showing a response to methionine were in the light weight-class; lighter animals fed diets with 0.3% MHA gained on the average 3.2 g more per day than those fed non supplemented diets while the heavier rabbits showed no response to MHA supplementation.

Initial assumptions were that rabbits would not perform well on the lowest protein diet, but since the results were contrary to this assumption, the control (ration 1) and the low protein rations (7 and 8) were fed again in a separate experiment to confirm or contrast these results. When this trial was repeated, there were again no differences observed

TABLE 14. DIET AND WEIGHT-CLASS MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS OF RABBITS FED 54% ALFALFA DIETS CONTAINING VARYING LEVELS OF SOYBEAN MEAL (SBM) WITH AND WITHOUT METHIONINE HYDROXY ANALOGUE (MHA)

Diet	Class[a]	Average daily gain, g[c]	Feed Efficiency[d]	Mortality, %
21% SBM	light	36.80±2.00	2.86±.09	10±9.97
	heavy	38.35±3.05	3.01±.24	0±0
15% SBM	light	32.70±2.70	2.79±.26	20±20
	heavy	36.45±1.85	3.09±.17	10±9.97
9% SBM	light	34.45±0.65	2.89±.25	0±0
	heavy	39.10±0.60	3.03±.14	0±0
3% SBM	light	30.65±0.65	3.19±.05	30±9.97
	heavy	38.05±1.05	2.77±.06	0±0
21% SBM +.3% MHA	light	36.80±2.40	2.87±.07	0±0
	heavy	39.35±1.15	2.92±.06	10±9.97
15% SBM +.3% MHA	light	37.15±5.95	2.99±.26	0±0
	heavy	39.90±5.40	3.09±.10	0±0
9% SBM +.3% MHA	light	38.05±3.75	2.99±.11	10±9.97
	heavy	38.85±1.65	3.06±.18	20±0
3% SBM +.3% MHA	light	35.40±0.60	3.00±.06	0±0
	heavy	37.30±1.30	3.06±.03	0±0
Repeated experiment[b]				
21% SBM		37.95±0.48	3.27±.22	15±5
3% SBM		37.38±1.15	3.31±1.66	10±5.75
3% SBM + .3% MHA		37.98±1.89	3.46±.10	15±9.55

[a]Light weight-class (average initial weight 573 g) had lower consumption (P<.01) and gains (P<.05) than heavy weight-class (average initial weight 776 g).

[b]Analyzed separately.

[c]Average daily gain was the ratio of average individual gain to the number of days on trial (28 d).

[d]Feed efficiency was the ratio of average daily consumption to average daily gain.

FIGURE 9. EFFECT OF DIETARY METHIONINE HYDROXY ANALOGUE SUPPLEMENTATION ON AVERAGE DAILY GAIN OF GROWING RABBITS FED THE VARIOUS CRUDE PROTEIN DIETS

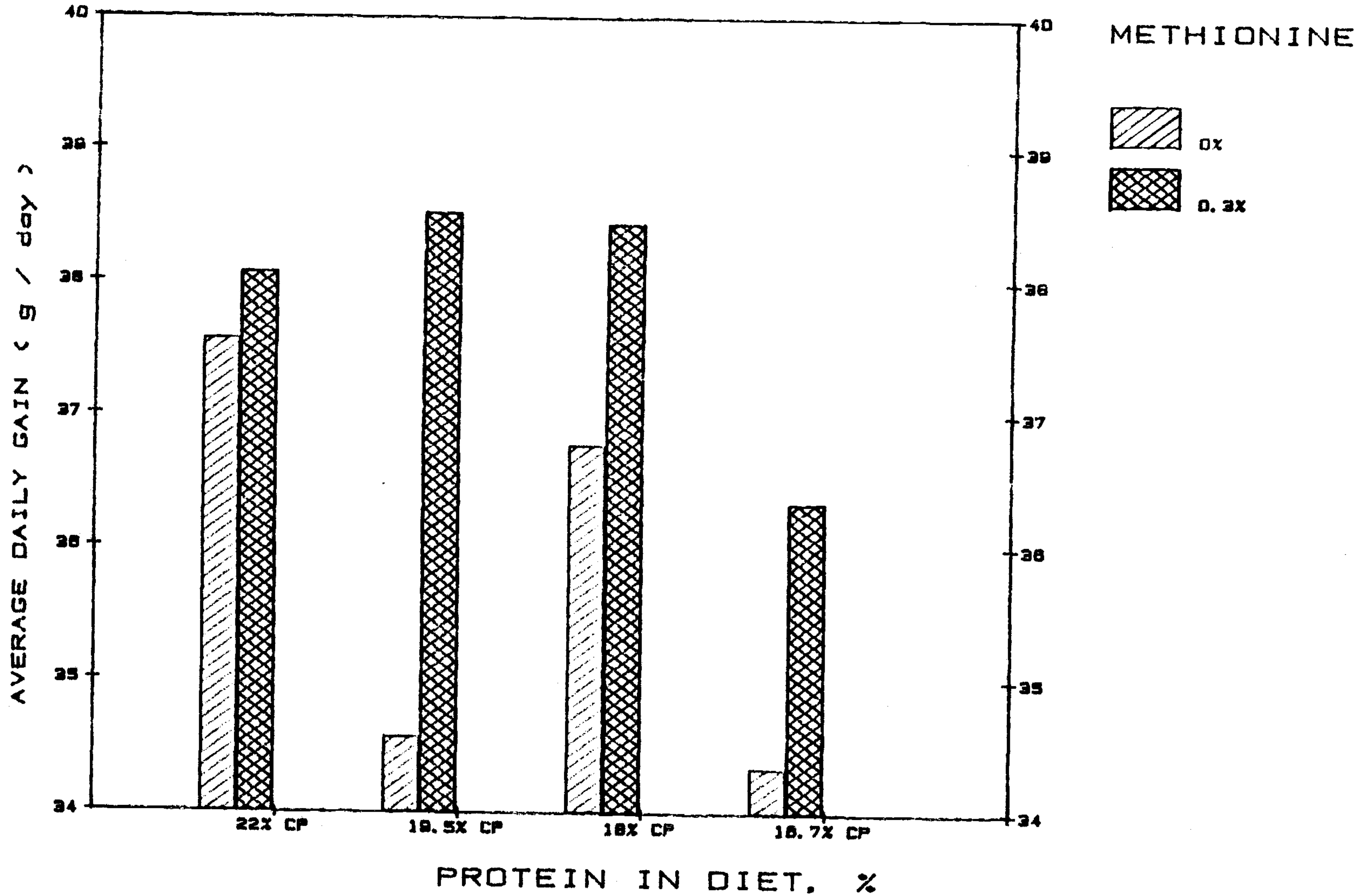

TABLE 15. CLASS MEANS FOR PERFORMANCE TRAITS OF RABBITS FED 54% ALFALFA DIETS WITH AND WITHOUT .3% METHIONINE HYDROXY ANALOGUE

Class	Methionine hydroxy analogue	Average daily gain, g [a]	Feed Efficiency [d]	Mortality %
Light	-	33.65[b]	3.18	15
Light	+	36.85[b]	2.96	2.5
Heavy	-	38.00[c]	2.98	2.5
Heavy	+	38.85[c]	3.03	7.5

[a] Average daily gain was the ratio of average individual gain to the number of days on trial (28 d)

[b,c] Column means bearing unlike superscripts were different ($P<.05$).

[d] Feed efficiency was the ratio of average daily consumption to average daily gain.

among diets (table 14) indicating that the growing rabbit can perform well on high alfalfa diets supplemented with only 3% soybean meal. There was no trend noted for a response to MHA supplementation. It should be noted that animals used in this part of this experiment were in the heavy weight-class (average initial weight 824 g).

Experiment Two. Performance of rabbits in experiment two is presented in table 16. The poorest growth rate observed was on the low protein 74% alfalfa diet (ration 12) and this diet supplemented with MHA (ration 13) provided the greatest growth response. However, none of these differences were significant ($P > .05$). A response to MHA supplementation for animals fed the low protein 74% alfalfa diet was expected since forages such as alfalfa are characteristically known for their low sulfur amino acid (methionine + cystine) contents (NRC, 1982). It is not certain whether or not the MHA levels were excessive and if lower levels would have given more of a response. Colin and Arkhurst (1975) reported slight growth depression when soybean meal based diets with 0.3% methionine were fed, but diets used in that study were much lower in protein (10 and 13%). Average daily consumption was not different among diets (120 to 134 g) but was numerically highest for the 74% alfalfa diet without SBM + .3% MHA. Lukefahr et al. (1983b) also reported greater consumption rates for weanlings fed 74% alfalfa than for those fed 54% alfalfa rations. The greater consumption of these diets in this study was probably due to the lower energy content (2350 and 2650 Kcal/Kg for 74 and 54% alfalfa diets respectively). Spreadbury and Davidson (1978) showed that the 5-8 week old New Zealand White rabbits growing at about 40 g/day adjusted their food intake to maintain

TABLE 16. DIET MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS OF RABBITS FED 54% AND 74% ALFALFA DIETS CONTAINING VARYING LEVELS OF SOYBEAN MEAL (SBM) WITH AND WITHOUT METHIONINE HYDROXY ANALOGUE (MHA)

Diet	Average[a] daily gain, g	Feed[b] Efficiency	Mortality, %
54% Alfalfa			
21% SBM	34.40±1.28	3.51±.09	15.0±9.55
0% SBM	33.88±0.66	3.81±.11	10±10
0% SBM +.3% MHA	33.53±1.46	3.79±.29	10±5.75
74% Alfalfa			
21% SBM	32.60±1.06	3.76±.06	10±10
0% SBM	31.93±1.34	3.86±.21	10±5.75
0% SBM +.3% MHA	34.08±1.52	3.91±.21	10±5.75

[a] Average daily gain was the ratio of average individual gain to the number of days on trial (35 d).

[b] Feed efficiency was the ratio of average daily consumption to average daily gain.

a constant daily energy intake of about 260 Kcal. Feed efficiency and mortality percentage were also not different among treatments.

Experiment Three. Performance of rabbits in experiment three is presented in table 17. No difference was observed between the control (ration 1) and the unsupplemented low protein diet (ration 9). However, a depression in growth ($P<.05$) was observed for the diet supplemented with lysine alone. When MHA was also added, growth was increased but was still below that of the controls. Munaver and Harper (1959) pointed out that the extent of utilization of one amino acid was limited when the diet was deficient in another. In this experiment, the utilization of lysine was improved when methionine was added. Lysine has been reported to have a depressive effect on growth when only slightly in excess of requirements (Adamson and Fischer, 1973; Colin and Arkhurst, 1975), but in other reports, high lysine had no adverse effect on growth (Cheeke and Amberg, 1972; Colin 1975). It is well documented that relatively small additions of the second most limiting amino acid causes a severe amino acid imbalance and growth depression which can be overcome by the addition of the first limiting amino acid (Harper et al., 1970). Based on the results of this experiment, methionine rather than lysine was the amino acid closest to be limiting in these diets. Consumption of the diets was not different, which indicates that palatability was not the reason for the depressed growth in animals fed lysine supplemented diets. The control diet was used more efficiently ($P<.05$) than all others. Overall, mortality was low (2.8%) and did not differ significantly among any of the groups.

Conclusions. Based on performance of weanling rabbits, soybean meal supplementation of diets based on alfalfa and wheat mill run is not

TABLE 17. DIET MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS OF RABBITS FED 54% ALFALFA DIETS CONTAINING VARYING LEVELS OF SOYBEAN MEAL (SBM) WITH AND WITHOUT METHIONINE HYDROXY ANALOGUE (MHA) AND LYSINE-HCl (LYS)

Diet	Average[a] daily gain, g	Feed[d] Efficiency	Mortality, %
21% SBM	39.72±0.82[c]	3.45±.12[c]	5.6±5.5
0% SBM	39.12±0.60[c]	3.84±.06[d]	0±0
0% SBM +.3% LYS	35.90±1.06[d]	3.97±.07[d]	5.6±5.5
0% SBM +.3% LYS +.3% MHA	38.52±0.86[c,d]	3.73±.03[d]	0±0

[a]Average daily gain was the ratio of average individual gain to the number of days on trial (35 d).

[b]Feed efficiency was the ratio of average daily consumption to average daily gain.

[c,d]Column means bearing unlike superscripts were different ($P<.05$).

necessary, and 16.5% CP is adequate for normal growth. The addition of methionine and lysine to improve protein quality did not significantly improve performance but methionine appears to be the most limiting amino acid in these diets, especially for lighter animals. Since dietary amino acid contents were calculated and not directly analyzed in this experiment, any amino acid excess or deficiency in these diets was only speculative. It remains to be determined if 16.5% CP is the lowest level that can be fed without decreasing growth performance. Methionine and lysine supplementation at lower dietary protein levels needs to be further researched.

CHAPTER 4

EVALUATION OF RAW AND EXTRUDED SOYBEANS AND EXTRUDED SOY FLOUR AS PROTEIN SOURCES FOR WEANLING NEW ZEALAND WHITE RABBITS[1,2]

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Evaluation of Raw and Extruded Soybeans and Extruded Soy Flour as Protein Sources for Weanling New Zealand White Rabbits

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SUMMARY

Performance of rabbits fed diets containing raw soybeans, extruded soybeans and extruded soy flour was evaluated to determine the feeding value of these protein sources. Five-week-old weanling rabbits were fed a control diet containing solvent-extracted soybeans (SBM) or experimental diets containing either raw soybeans (RS), extruded soybeans (ES), extruded low-trypsin-inhibitor soy flour (LT) or extruded low-fat low-trypsin-inhibitor soy flour (LF) for thirty-five days.

Trypsin-inhibitor values (TIU/mg) were: LF, 6.8; LT, 11.8; ES, 25.4; and RS, 70.0. Average daily feed intake and average daily gain were: SBM, 142.9, 37.6; RS, 123.1, 27.6; ES, 134.5, 40.1; LT, 139.8, 39.3; and LF, 136.3, 36.6. Feed efficiency (feed/gain) values were: 3.85, 4.98, 3.38, 3.56 and 3.76 for SBM, RS, ES, LT and LF respectively. The RS-fed rabbits grew the slowest and had the least efficient gains ($P<.05$). Percent mortality was low (1.9% overall) and did not differ significantly among treatments. Histological examination of pancreatic tissue from SBM and RS-fed rabbits revealed no differences. Results indicate that extruded soybeans and soy flour overcame growth depression caused by raw soybeans.

INTRODUCTION

Information about the nutritional value of alternate protein sources for growing rabbits is limited. Most commercial rabbit diets contain solvent-extracted soybean meal which is very high in protein (ca. 45%) and is used extensively in poultry and swine rations. Because rabbits generally consume diets high in alfalfa, also a good source of protein (ca. 17%), the soybean meal may be unnecessary to meet the protein needs of the rabbit which range from 15-18% crude protein (CP) (NRC, 1977; Lebas, 1980; Omole, 1982).

Whole raw soybeans (Glycine max) contain less protein (ca. 38%) and may be more economical than solvent extracted soybean meal but deleterious effects of feeding raw soybeans to animals have been observed. Raw soybeans inhibit normal growth when fed to pigs (Yen et al., 1974), dogs (Patten et al., 1971), guinea-pigs (Patten et al., 1973), and chicks and rats (Lepkovsky et al., 1971). The poor growth has been attributed to toxic protease inhibitors present in the raw legumes which is destroyed by the solvent extraction process (Liener, 1976; Stein, 1976). Trypsin inhibitors cause an enlarged pancreas in smaller animals, including chicks and rats (Lepkovsky et al., 1971) but not in larger animals such as calves (Kakade et al., 1976), pigs (Yen et al., 1977), dogs (Patten et al., 1971) and adult guinea-pigs (Patten et al., 1973). Kakade et al. (1973) concluded that approximately 40% of the pancreatic hypertrophy could be accounted for by trypsin inhibitors and the remaining 60% of the growth-inhibiting and pancreatic hypertrophic effects were the result of resistance of native protein to attack by digestive enzymes. Enlarged pancreas tissue shows hypertrophy (Konijn and Guggenheim, 1967), hyperplasia and a depletion of zymogen granules (Applegarth et al., 1964).

Extruded soybeans, similar in CP content to raw soybeans, were of equal value to soybean meal when fed to pigs (Cheeke and England, 1976) and, when compared to raw soybeans, extruded soybeans overcame both growth depression and pancreatic hypertrophy in broilers (Paradis et al. 1983). In earlier work at this station (Sanchez et al., 1983), extrusion did not overcome growth-inhibiting effects of raw soybeans fed to rabbits. Rancidity of the diets in that study was the suggested reason for the lack of response. No other information has been found on the feeding value of raw and extruded soybeans for rabbits.

The objectives of this study were to re-evaluate the feeding value of raw and extruded soybeans as protein sources for weanling rabbits and to determine if rabbits exhibit pancreatic changes when fed raw soybeans.

MATERIALS AND METHODS

Five-week-old New Zealand White weanling rabbits were fed a control diet containing solvent-extracted soybean meal (SBM) or experimental diets containing either raw soybeans (RS), extruded soybeans (ES), extruded low-trypsin inhibitor soy flour (LT) or extruded low-fat low-trypsin-inhibitor soy flour (LF). Extruded soybeans and soybean flour were extruded for 26 seconds (300°F) using the Insta-Pro Model 2000 extruder.[5] All soybean products were coarsely ground before incorporation into diets. Ethoxyquin was added to the diets (0.0125%)

[5]Insta-Pro Division, Triple F Feeds, Inc., Des Moines, Iowa

to prevent lipid peroxidation (rancidity). All diets were steam pelleted through a 4.7 mm pellet dye. Trypsin inhibitor activity was measured using the method described by Kakade et al. (1974). Composition and chemical analyses of the experimental rations are shown in table 18. The diets were analyzed for crude protein using a micro-Kjeldahl method (AOAC, 1975). Fiber analysis was accomplished using a micro-method for acid detergent fiber (Waldern, 1971).

Randomly allotted to the five dietary treatments were 105 weanling rabbits. Treatments were replicated into seven cages containing three rabbits each, for a total of 21 rabbits per treatment. Cages were hanging, all wire quonset-style (76 x 76 x 46 cm) as described by Harris (1983a). Animals were housed in indoor commercial rabbit building equipped with electric ventilating fans, controlled lighting (16 h light and 8 h dark), and above ground manure pits.

The study was begun after a four d adaptation period. Animals were provided feed and water *ad libitum* during the 35 d trial. Beginning weight, ending weight, and mortality were recorded. Data were analyzed using analysis of variance. Cage was treated as the experimental unit. Performance traits included average daily feed consumption, average daily gain, feed efficiency and mortality percentage. Average daily consumption (ADC) was the ratio of total intake for all animals in a cage to the sum of days animals were alive in that cage. Average daily gain (ADG), calculated only for surviving animals, was the difference in mean weight of the rabbits at the end and beginning of the trial, divided by the number of days on trial. Feed efficiency (feed/gain) was the ratio of ADC to ADG. In the case of a significant overall F-test, means were compared by Student-Newman-Keuls multiple

TABLE 18. COMPOSITION AND CHEMICAL ANALYSIS OF EXPERIMENTAL DIETS CONTAINING VARIOUS SOYBEAN PRODUCTS

Ingredient		Supplemental Protein Source[a]				
		SBM	RS	ES	LT	LF
Alfalfa meal	(IFN 1-00-025)	54	54	54	54	54
Soybean product[b]		15	20	23	18	13
Wheat mill run	(IFN 4-05-206)	26	21	18	23	28
Molasses	(IFN 4-04-696)	3	3	3	3	3
Soybean oil	(IFN 4-07-983)	1.25	1.25	1.25	1.25	1.25
Trace mineralized salt[c]		.5	.5	.5	.5	.5
Dicalcium phosphate	(IFN 6-01-080)	.25	.25	.25	.25	.25
Chemical analysis[d]						
Dry matter, %		89.05	89.50	90.10	90.26	89.67
Crude protein, %		18.24	18.13	18.10	18.45	18.46
Acid detergent fiber, %		22.98	23.00	20.18	23.58	20.47

[a]SBM = soybean meal -44% CP (IFN 5-04-604); RS = raw soybeans (IFN 5-04-610); ES = extruded soybeans; LT = low trypsin-inhibitor soy flour; LF = low-fat low trypsin-inhibitor soy flour.

[b]Varied according to treatment; added on isonitrogenous basis.

[c]Mortons Farm and Ranch 10FIXT T-M SALT. Provides NaCl and the following elemental levels in mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, .35; Co, .35.

[d]All values (except dry matter) reported on a dry matter basis.

range test. SBM vs RS and RS vs ES, LT and LF were compared by orthogonal contrasts using the pooled variance estimate (Snedecor and Cochran, 1980).

At the end of the experiment, three rabbits of similar weight (average 1743 g) from SBM and RS groups were sacrificed, and their pancreatic tissue was removed, at a depth of 6 cm inside the duodenal loop, for histological examination. Tissue samples were prepared in 10% buffered formalin, sectioned at 6 microns and then stained with hematoxylin and eosin.

RESULTS AND DISCUSSION

Performance. Rabbit performance and selected contrasts on the five treatments are presented in Table 19. Average daily gain (ADG) was poorest for rabbits fed raw soybeans ($P<.05$); however, when soybeans were extruded, growth depression was alleviated. This agrees with previous work in which raw and extruded soybeans were fed to broilers (Paradis et al., 1978), and weanling pigs (Cheeke and England, 1976). In an earlier report, Sanchez et al., (1983) found that rabbits fed extruded soybeans consumed and gained less than those fed the control diets. Diets used in that study were rancid, as determined by high peroxidation values of extracted lipids, which causes a decrease in palatability. Rancidity was prevented in this trial by the addition of ethoxyquin. Consumption rates of all diets in this study were similar.

Feed efficiency (feed/gain) values followed a trend similar to average daily gain and feed consumption. The RS-fed rabbits had the poorest feed efficiency ($P<.05$), but no differences were observed among

TABLE 19. DIET MEANS, STANDARD ERRORS AND SELECTED ORTHOGONAL CONTRASTS FOR PERFORMANCE TRAITS OF RABBITS FED VARIOUS SOYBEAN PRODUCTS

Treatment[a]	Average daily consumption, g[b]	Average daily gain, g[c]	Feed efficiency[d]
SBM	142.9±7.1	37.6±2.9	3.85±.15
RS	123.1±6.6	27.6±2.6*	4.98±.46*
ES	134.5±3.7	40.1±1.6	3.38±.15
LT	139.8±5.7	39.3±1.7	3.56±.08
LF	136.3±3.6	36.6±2.0	3.76±.14
Pooled Contrasts:			
SBM vs RS	19.8 ± 8.2*	10.0 ± 3.1**	-1.12 ± .30*
RS vs ES, LT, LF	-41.4 ± 20.9	-33.2 ± 7.7***	4.20 ± .76***

[a]SBM = -44% CP soybean meal (IFN 5-04-604); RS = raw soybeans (IFN 5-04-610); ES = extruded soybeans; LT = low trypsin-inhibitor soy flour; LF = low-fat low trypsin-inhibitor soy flour.

[b]Average daily consumption was the ratio of total intake for all animals in a cage to the sum of days animals survived in that cage.

[c]Average daily gain was the ratio of average individual gain to the number of days on trial (35 d).

[d]Feed efficiency was the ratio of average daily consumption to average daily gain.

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

the other groups. Percent mortality (1.9% overall) did not differ significantly among treatments.

Orthogonal contrasts showed that feed consumption ($P<.05$), ADG and feed efficiency ($P<.01$) were greater for SBM as compared to RS. When RS was compared to ES, LT and LF, the extruded products gave greater and more efficient gains ($P<.001$) and were consumed at a higher rate ($P=.06$).

Trypsin-inhibitor values (TIU/mg) were lowest for LF, 6.8; followed by LT, 11.8; ES, 25.4; and RS, 70.0. Growth response indicated that rabbits were insensitive to residual trypsin-inhibitor values of 25.4 or less but growth was depressed when these values approached 70.0.

The SBM and LF diets consisted of hard, compact pellets that did not break apart in the feeder. Crumbling of RS, ES and LT diets was probably caused by higher fat contents, which causes the pellet to pass through the pellet mill too quickly for proper binding. A "high-fat" pellet dye could possibly overcome this problem. Two pens of rabbits consuming RS had pronounced feed wastage and were not included in calculations of feed consumption and feed efficiency.

<u>Effect on Pancreas</u>. Pancreatic weights were not obtained because in rabbits this organ is diffuse and amorphous and not easily distinguishable from the enteric mesentery. Histological examination of pancreata from ES and SBM groups revealed no gross differences in cell size or number. Zymogen granules were not discernible by this staining method. Based on these results, it appears that rabbits are similar to dogs and pigs in their response to raw soybeans.

<u>Conclusions</u>. The detrimental effect of feeding raw soybeans to rabbits was demonstrated in this study. These effects were completely

overcome by decreasing the trypsin-inhibitor activity of soybeans through extrusion. The extrusion process allows for greater utilization of both the protein and energy available in the soybean. Recent findings (W.K. Sanchez, unpublished data) show that rabbits do not require the additional protein provided by high-protein supplements like SBM, but may need additional energy in the diet to improve growth, when traditional high alfalfa diets are used. The ES and LT are higher in energy than SBM and may constitute a more complete feed supplement providing both protein and energy.

Extrusion eliminates the anti-nutritional factors in soybeans while maintaining the protein quality and caloric content of the diet. If the cost of rabbit production continues to rise, the feeding of extruded soy products could provide an economic advantage to the producer.

CHAPTER 5

EVALUATION OF RAW AND HEAT-TREATED PINTO BEANS AS PROTEIN SOURCES FOR WEANLING NEW ZEALAND WHITE RABBITS[1]

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Evaluation of Raw and Heat-Treated Pinto Beans as Protein Sources for Weanling New Zealand White Rabbits

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SUMMARY

Raw (RP) and autoclaved (AP) pinto beans were evaluated as protein sources in diets for weanling New Zealand White rabbits. These feedstuffs were non-pelleted in Trial 1 and pelleted in Trial 2. A pelleted control diet containing soybean meal (SBM) was used in both trials. Average daily gain (ADG) and feed consumption (ADC) in g for Trial 1 were: SBM: 35.7, 139.3; RP: 14.4, 87.2; AP: 21.9, 93.8, respectively. In Trial 2, ADG and ADC in grams were: SBM: 38.6, 122.9; RP: 10.1, 68.7; AP: 20.2, 72.8. Average daily gain was greater ($P<.05$) for the SBM than for the other groups in both trials. Feed efficiency (feed/gain) was poorer ($P<.05$) for the RP than for the other groups. Results indicate severe growth depression with raw pinto beans, which was partially overcome by autoclaving. Percent mortality was: SBM, 0, 20; RP, 0, 20; AP, 0, 0, for Trials 1 and 2 respectively.

INTRODUCTION

Pinto beans (Phaseolus vulgaris) contain approximately 25% crude protein (CP) and may have potential as a supplemental protein source for growing rabbits. However, there have been deleterious effects observed when raw pinto beans were fed to animals. When fed to pigs (Meyer et al., 1982), Japanese quail (Jayne-Williams & Burgess, 1974), chicks (Wagh et al., 1963) and rats (Jaffe and Vegas Lette, 1968; Honover et al., 1962) normal growth was inhibited. The low nutritional value has been attributed to the presence of toxic substances called hemagglutinins or lectins (Liener, 1976; Stein, 1976). Heat treatment of the raw legume seeds improves their feeding value (Jaffe, 1950; Honover et al., 1962; Stein, 1976). There are no reports on the feeding value of pinto beans for growing rabbits.

This study was conducted to determine the effect of feeding raw pinto beans on consumption, growth, feed efficiency and mortality of young rabbits and to determine the effect of heat treatment of the beans on these performance traits.

MATERIALS AND METHODS

The pinto beans were purchased at a local grocery store. The beans were ground in a hammer mill before their incorporation into the diets. Heat treatment of the beans involved autoclaving for 30 minutes at 250°F and 15 psi (lb/in^2). The experiment was divided into two trials. Diets were non-pelleted in Trial 1 and pelleted (4.7 mm) in Trial 2. The control diet in both trials consisted of a pelleted 54% alfalfa ration containing solvent extracted soybean meal (Harris et al., 1981). Composition of the diets is shown in Table 20; nutrient analysis is presented in Table 21. The diets were analyzed for crude protein using a micro-Kjeldahl method (AOAC, 1975). Fiber analysis was accomplished using a micro-method for acid detergent fiber (Waldern, 1971).

In each trial, thirty 4-5 week-old weanling New Zealand White rabbits were randomly divided into three equal groups. Animals were housed five per cage. Cages were all wire hanging quonset-style cage

TABLE 20. COMPOSITION OF EXPERIMENTAL DIETS CONTAINING EITHER SOYBEAN MEAL OR PINTO BEANS AS THE SUPPLEMENTAL PROTEIN SOURCE

		Control	Pinto Bean
Alfalfa meal	(IFN 1-00-025)	54.0	20.0
Soybean meal	(IFN 5-04-604)	21.0	4.5
Wheat mill run	(IFN 4-05-206)	20.0	
Ground pinto beans[a]			40.0
Rolled barley[b]	(IFN 4-00-530)		30.0
Molasses	(IFN 4-04-696)	3.0	5.0
Soybean oil	(IFN 4-07-983)	1.25	
Trace mineral salt[c]		0.50	0.50
Dicalcium phosphate	(IFN 6-01-080)	0.25	

[a]Added in either raw or autoclaved form, according to treatment.

[b]In Trial 2, ground barley-oats was substituted for rolled barley.

[c]Mortons Farm and Ranch iOFIXT T-M SALT. Provides NaCl and the following elemental levels of mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, .35; Co, .35.

TABLE 21. CHEMICAL ANALYSIS OF CONTROL, RAW PINTO BEAN AND AUTOCLAVED PINTO BEAN DIETS[a]

Trial[b]	Diet	Dry matter, %	Crude protein, %	Acid detergent fiber, %
1	Control	93.19	18.01	24.97
	Raw pinto bean	91.90	18.77	15.20
	Autoclaved pinto bean	91.75	18.61	17.32
2	Control	93.19	18.01	24.97
	Raw pinto bean	88.79	18.95	14.15
	Autoclaved pinto bean	89.16	18.10	16.36

[a]All values (except dry matter) expressed on dry matter basis

[b]Diets were non-pelleted in Trial 1 and pelleted in Trial 2

(76 x 76 x 42 cm) with two replicate cages per treatment. Animals were housed in indoor facilities equipped with electric fans for ventilation, controlled lighting (16 h light 8 h dark), and above ground manure pits. The study was begun after a four day adaptation period and animals were allowed access to feed and water *ad libitum*. Weekly weights and feed consumption and mortality were recorded. Performance traits included average daily feed consumption, average daily gain, feed efficiency and mortality percentage. Average daily consumption (ADC) was the ratio of total intake for all animals in a cage to the sum of days animals were alive in that cage. Average daily gain (ADG), calculated only for surviving animals, was the difference in mean weight of the rabbits at the end and beginning of the trial, divided by the number of days on trial. Feed efficiency (feed/gain) was the ratio of ADC to ADG. Data were collected over a 28 d period and analyzed by pens using one-way analysis of variance. Means were compared by least significant difference after an overall significant F-test.

RESULTS AND DISCUSSION

Rabbit performance on the various treatments is presented table 22. Pelleting the diets did not improve feeding value. This is not consistent with other work comparing pelleted vs non-pelleted feedstuffs for rabbits showing that pelleting improved performance (Chapin, 1965; Harris et al., 1983b). In both trials average daily gain and feed intake were greater ($P<.05$) for the control.

Growth and feed efficiency were greater for rabbits fed autoclaved beans than for those fed raw beans. In Trial 1, rabbits fed autoclaved

TABLE 22. DIET MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS OF RABBITS FED DIET SUPPLEMENTED WITH SOYBEAN MEAL (SBM), RAW PINTO BEANS OR AUTOCLAVED PINTO BEANS

Trial	Treatment	Average[a] daily consumption, g	Average[b] daily gain	Feed[c] Efficiency	Mortality, %
1	Control (SBM)	139.3 ± 5.1^{d}	35.7 ± 0.4^{d}	3.9 ± 0.1^{d}	0
	Raw pinto bean	87.2 ± 2.0^{e}	14.4 ± 2.1^{e}	6.1 ± 1.1^{e}	0
	Autoclaved pinto bean	93.8 ± 1.6^{e}	21.9 ± 5.3^{e}	4.3 ± 1.0^{d}	0
2	Control (SBM)	122.9 ± 11.8^{d}	38.6 ± 0.7^{d}	3.2 ± 0.3^{d}	20
	Raw pinto bean	68.7 ± 2.0^{e}	10.1 ± 0.4^{e}	6.8 ± 0.1^{e}	20
	Autoclaved pinto bean	72.8 ± 11.7^{e}	20.2 ± 5.6^{f}	3.6 ± 1.6^{d}	0

[a]Average daily consumption was the ratio of total intake for all animals in a cage to the sum of days animals survived in that cage.

[b]Average daily gain was the ratio of average individual gain to the number of days on trial (28 d).

[c]Feed efficiency was the ratio of average daily consumption to average daily gain.

[d,e,f]Columns bearing unlike superscripts were different ($P < .05$).

beans gained 7 g more per day and had superior feed efficiency ($P<.05$). In Trial 2, greater and more efficient gains ($P<.05$) were observed for animals fed the heat-treated beans. In both trials, feed efficiency was similar for this group and the control. There was no difference in mortality for animals fed raw bean, autoclaved bean or control diets.

Although diarrhea was very prevalent in rabbits fed raw pinto beans, only two animals died on that treatment. Raw pinto beans contain hemagglutinins (Liener, 1962) which can bind carbohydrates (Sharon, 1976), decreased protein digestibility and decrease absorption of amino acids and glucose (Kakade and Evans, 1964; Liener, 1976). This appears to be the cause of the excessive diarrhea. Normally rabbits that have diarrhea associated with other causes, such as enteritis complex, exhibit a high degree of mortality (Grobner, 1982).

Conclusions. In both feeding trials, weanling rabbits fed a 54% alfalfa ration with solvent-extracted soybean meal had greater average daily gains and feed intake than those fed either pelleted or non-pelleted 20% alfalfa diets containing raw and autoclaved pinto bean diets. Results were similar for pelleted and non-pelleted diets. Rabbits fed raw pinto beans had the lowest growth rate and the poorest feed efficiency. Results indicated that rabbits were severely affected by raw pinto beans at the levels used in this study. Autoclaving the beans improved performance, but growth rate with the treated beans was still greatly reduced, indicating that autoclaving does not eliminate all the deleterious factors in pinto beans for rabbits.

CHAPTER 6

EVALUATION OF RAW AND HEAT-TREATED RADISH SEEDS AS PROTEIN SOURCES FOR WEANLING NEW ZEALAND WHITE RABBITS[1,2]

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Evaluation of Raw and Heat-Treated Radish Seeds as Protein Sources for Weanling New Zealand White Rabbits

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SUMMARY

A study was conducted to determine the effect of feeding raw and autoclaved radish seeds as protein sources for weanling New Zealand White rabbits. Rabbits were fed a control diet containing solvent-extracted soybean meal or experimental diets containing either 20 or 40% raw or autoclaved radish seeds. Consumption, feed efficiency and mortality were not significantly different ($P>.05$) among treatments but animals fed 40% autoclaved radish seed tended to have greater mortality ($P=.08$). Gains were greatest for the control ($P<.05$) and animals fed 20% radish seed gained more ($P<.05$) than those fed 40% radish seed diets. Autoclaving radish seeds did not improve performance. Results indicate that at 20 and 40% of the diet, radish seeds were not suitable protein sources for growing rabbits.

INTRODUCTION

Considerable quantities of cull radish seeds (*Raphanus sativa*) are discarded because radish seed growers have no market for the screenings and broken seeds. These products are high in protein (ca. 28%) and may have potential as protein sources for growing rabbits. Radish plants belong to the Cruciferae family which are known to contain toxic compounds called glucosinolates. One of the potential problems of using radish seed as a feedstuff is the presence of glucosinolates, which are unpalatable and can cause thyroid enlargement (Tookey et al., 1980). Little information is available on the feeding of glucosinolate-containing feeds to rabbits.

Rapeseed, another cruciferous plant, meal was found to be acceptable to levels of 12-14% in rabbit diets (Lebas and Colin, 1977; Throckmorton et al., 1979). Throckmorton et al., (1981) found that steam cooked meadow foam meal (another glucosinolate-containing feed) could be fed to rabbits at levels of 20 or 40% of the diet with no decrease in performance. There are no reports on the feeding value of radish seeds for rabbits.

The objective of this study was to examine performance of rabbits fed diets containing 20 and 40% raw and autoclaved radish seed.

MATERIALS AND METHODS

New Zealand White weanling rabbits (4-5 weeks old) were fed a control diet containing solvent extracted soybean meal as the protein source (Harris et al., 1981) or experimental diets containing raw and heat-treated radish seed at 20 and 40% of the diet. After being ground in a hammer mill, radish seeds were incorporated into steam pelleted diets (4.7 mm); heat treatment of the seeds involved autoclaving for 30 minutes at 250°F at 15 psi (lb/in^2). Composition and chemical analysis of the experimental diets is shown in table 23. The diets were analyzed for crude protein using a micro-Kjeldahl method (AOAC, 1975). Fiber analysis was accomplished using a micro-method for acid detergent fiber (Waldern, 1971).

Randomly allotted to the five dietary treatments were 50 weanling rabbits. Treatments were replicated into two cages containing five

TABLE 23. COMPOSITION AND CHEMICAL ANALYSIS OF THE CONTROL AND 20% AND 40% RADISH SEED DIETS

Ingredient		Dietary Treatment		
		Control	20% Radish Seed	40% Radish Seed
Alfalfa meal	(IFN 1-00-025)	54	53	52
Soybean meal	(IFN 5-04-604)	21	12	2
Radish seed[a]			20	40
Wheat mill run	(IFN 4-05-206)	20	10	
Molasses	(IFN 4-04-696)	3	3	3
Soybean oil	(IFN 4-07-983)	1.25	1.25	1.25
Trace mineral salt[a]		.5	.5	.5
Dicalcium phosphate	(IFN 6-01-080)	.25	.25	.25
Chemical analysis[c]				
Dry matter, %		93.86	94.56	95.33
Crude protein, %		20.10	22.16	24.10
Acid detergent fiber, %		23.59	19.51	21.44

[a]Dry matter 95.4%, crude protein 28.9%, acid detergent fiber 10.1%.

[b]Mortons Farm and Ranch iOFIXT T-M SALT. Provides NaCl and the following elemental levels of mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, .35; Co, .35.

[c]All values (except dry matter) reported on dry matter basis.

rabbits each. Cages were hanging all wire quonset style (76 x 76 x 46 cm) as described by Harris (1983a). Animals were housed in an indoor commercial rabbit production building equipped with electric ventilating fans, controlled lighting (16 h light, 8 h dark) and below ground manure pits.

The study was begun after a four day adaptation period. Animals were provided feed and water ad libitum during the 28 d trial. Beginning weight, ending weight, feed consumption and mortality were recorded. Performance traits included average daily feed consumption, average daily gain, feed efficiency and mortality percentage. Average daily consumption (ADC) was the ratio of total intake for all animals in a cage to the sum of days animals were alive in that cage. Average daily gain (ADG), calculated only for surviving animals, was the difference in mean weight of the rabbits at the end and beginning of the trial, divided by the number of days on trial. Feed efficiency (feed/gain) was the ratio of ADC to ADG. Data were analyzed by cage using one-way analysis of variance. After an overall significant F-test, means compared by Student-Newman-Keuls multiple-range test .

RESULTS AND DISCUSSION

Performance traits of rabbits fed the control and radish seed diets are shown in table 24. Rabbits fed the control diet had greater gains ($P<.05$) than any of the rabbits fed radish seed diets. Rabbits fed 20% radish seed diets gained more ($P<.05$) than rabbits fed 40% radish seed diets. Consumption, which ranged from 78 to 120 g/d, was not significantly different but was numerically lowest for the 40% raw radish seed

TABLE 24. DIET MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS OF RABBITS FED THE CONTROL AND 20% AND 40% RADISH SEED DIETS

Treatment	Average[a] daily gain, g	Feed[e] Efficiency	Mortality, %
Control	38.2±1.30[b]	3.15±.11	0
20% raw radish seed	24.4±1.45[c]	4.75±.06	10±9.97
20% autoclaved radish seed	26.8±0[c]	3.31±.02	0
40% raw radish seed	8.2±1.25[d]	10.05±4.05	0
40% autoclaved radish seed	9.4±6.10[d]	20.92±14.36	20±20

[a]Average daily gain was the ratio of average individual gain to the number of days on trial (28 d)

[b,c,d]Column means bearing unlike superscripts were different ($P<.05$).

[e]Feed efficiency was the ratio of average daily consumption to average daily gain.

diet. Feed efficiency values (feed/gain) were also not significantly different, but were poorest for rabbits fed 40% radish seed diets. The reason for the lack of statistical difference in these values may have been due to the low numbers of replicates used. Mortality tended to be greatest (P=.08) for rabbits fed 40% autoclaved radish seed diets.

Autoclaving the radish seed diets had no effect on performance. This is in contrast to work done by Throckmorton et al. (1981) in which steam cooking reduced total glucosinolate content of meadowfoam meal by 60%.

Performance of animals fed autoclaved radish seed diets was so poor that this treatment was stopped after 18 days into the trial. Radish seeds contain indolyl and p-hydroxy benzyl glucosinolates which can be hydrolyzed to release the toxic thiocyanate (SCN^-) ion (Tookey et al., 1980). Rabbits fed diets containing carrots, rape or kale had decreased growth, elevated blood levels of SCN^- and histological changes in the thyroid gland (Avanzi and Janella, 1976). Other toxic compounds that can be released upon hydrolysis are nitriles which caused growth depression and liver and kidney necrosis in rats (Van Etten et al., 1969). In addition, radish seeds contain erucic acid, a long chained fatty acid (Huileshen and Summers, 1981), which has caused fatty infiltration of cardiac tissues in chicks (Beare-Rogers, 1970). The presence of these toxic constituents were not investigated in this study, but the presence of one or more of these does seem likely considering the growth depression observed.

Results indicated that radish seed was not a suitable protein source for rabbits when fed raw or autoclaved at levels of 20 and 40% of the diet.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

From the results of these experiments, several conclusions and recommendations for further research can be made.

1) It is now known that the level of protein in the 54% alfalfa diet currently recommended by the OSU Rabbit Research Center is higher than needed for both growing and lactating rabbits. For lactating rabbits, performance was superior with a 19% crude protein diet containing only 15% soybean meal. The 17.5% crude protein diet should be further evaluated with the addition of amino acids such as methionine to improve protein quality.

2) It was found that the performance of does at first parity was generally the poorest. This should be studied more carefully to ascertain reasons why and to develop management techniques to improve performance at this stage of the reproductive cycle.

3) Supplemental protein was found to be unnecessary for growing rabbits fed high alfalfa diets. Feeding less protein reduces the feed costs and increases profitability. Further reductions in feed costs may be realized through subsequent modification in the levels of alfalfa meal and wheat mill run in these diets. There is also potential for less expensive fiber sources. Different levels of methionine supplementation should be studied to determine the optimal level.

4) Based on the favorable results with feeding extruded soybeans to growing rabbits, this protein source should be evaluated for lactating does also. The oil in extruded soybeans can provide additional energy in the diet which may be limiting for does during peak lactation.

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