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Title: A MORPHOLOGICAL, PHYSIOLOGICAL, AND GENETIC INVESTIGATION OF THE AFRICAN PYGMY GOAT

Abstract approved: Ralph Bogart
Dr. Ralph Bogart

Six groups of goats were used in the study. These were the normal group (Saanen, French Alpine, and Nubian breeds), 1/4 pygmy group (first backcross to normal), 1/2 pygmy group (F_1), 3/4 pygmy group (first backcross to pygmy), 7/8 pygmy group (second backcross to pygmy), and pygmy group. The mean weight of the 1/2 pygmy group approximated more closely that of the normal group than that of the pygmy group. The mean weight of the 1/4 pygmy group approximated that of the normal group more closely than the mean weight of the 1/2 pygmy group. The mean weight of the 3/4 pygmy group approximated the mean weight of the 1/2 pygmy group more closely than that of the pygmy group. The same relationships among groups that were observed for the weights were also observed for the 12 and 24 week measurements, and the 15 month weights and measurements.

As the relationship to the pure pygmy group increased, the goats became proportionally deeper, wider, longer and greater in circumference than would have been expected on the basis of the measurements of the normal goats. In the same manner, as the relationship to the pygmy increased, the weights and measurements of the internal organs increased above that expected on the basis of weights and measurements of the normal goats.

Three blood chemicals, amino acid nitrogen, urea nitrogen, and alkaline phosphatase, were examined at 4, 6, 8, 10, 12, 16, 20, and 24 weeks of age. Amino acid nitrogen did not change significantly with increasing age or weight. However, the level generally decreased in the six groups during the preweaning period, and increased during the postweaning period. Urea nitrogen levels increased significantly in both sexes as age and weight increased. The levels of urea nitrogen increased during both the preweaning and postweaning periods. Alkaline phosphatase activity decreased significantly with increasing age, but showed no significant association with changes in weight. Three levels of alkaline phosphatase activity were observed; high, medium, and low. All three levels were found in the normal, 1/4 pygmy, and 1/2 pygmy groups. The medium and low levels were found in the 3/4 pygmy, and 7/8 pygmy groups. Only the low level was found in the pygmy group. The low point in alkaline phosphatase activity was found during the period

following weaning.

A genetic model was proposed for the inheritance of the pygmy characteristic. The proposed model consists of two genes, a major gene and a modifier gene. The effect of the major gene is to produce large changes in the size of the animals, while the effect of the modifier gene is to regulate the effectiveness of the major gene. Both appear to show incomplete dominance when in the heterozygous condition. The genotype of the normal goats was proposed as being NNaa, that of the pygmy as being nnAA, and that of the 1/2 pygmy as being NnAa where N and n are alleles of the major gene, and A and a are alleles of the modifier gene. Using the weight of the normal goat as a standard, the theoretical values of each possible genotype in each group was calculated. Theoretical means were calculated for each of the groups and found not to be significantly different from the means actually obtained.

A Morphological, Physiological and Genetic Investigation of the African Pygmy Goat

by

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A MORPHOLOGICAL, PHYSIOLOGICAL AND GENETIC INVESTIGATION OF THE AFRICAN PYGMY GOAT

INTRODUCTION

Although miniature goats are referred to as African Pygmy goats, they are not restricted to Africa. They have been reported, for example, in Siberia, India, Arabia, southern Israel, Lapland, and Equatorial Africa. Fossil materials of miniature goats have also been found in Switzerland and Egypt.

The African miniature goat was known to Linneaus as Capra reversa, while Fitzinger (1859) described it further and called it Hircus reversus. It is known today as Capra hircus, although it is argued that it should properly be called Capra domesticus. Several strains of African miniature goats are known and have been described. Epstein (1946) found the weight of the African Hejaz dwarf goat males to be about 22 kg and the females 19 kg, with the height of neither sex reaching over 60 cm. Mason (1951) described the West African dwarf goat as averaging 40-50 cm in height at the withers and 18-20 kg in weight, although variation within the strain was encountered. Chang and Landauer (1950) found that skeletons of miniature goats from different parts of Africa (Cameroon, Kosi, and West Africa) showed very similar body conformations. Further descriptions of African miniature goats can be found in publications

by Hilzheimer (1916), Klatt (1917), and Staffe (1938).

The origin of the miniature goat used in the United States today is not certain. Metcalfe and Hoversland (1970) suggest that they are a mixture of Lapland and African strains. Herre (1943) postulated that the Lapland and African miniature goats are mutants of the now extinct Bezoa goat. The height and weight of both strains are approximately the same as the pygmy goat used for research in the United States. Both strains have had little selection pressure from man, permitting natural selection to dominate (Metcalfe and Hoversland, 1970).

Pygmy goats have been exhibited at zoos around the world but have had little economic importance. They have been relatively rare in the United States, and quite expensive to purchase. Only recently have enough animals been made available to permit large scale investigations.

The Oregon colony of pygmy goats has been established from stock provided by the Catskill Game Farm, Catskill, New York; Battelle-Northwest, Richland, Washington (relocated now at the University of California at Davis); and Jungle Land, Thousand Oaks, California. The majority of the Oregon colony is located at the University of Oregon Medical School, Portland, Oregon.

A limited quantity of literature of an experimental nature is presently available on the pygmy goat. A list of publications is contained in the bibliography. Several institutions, however, have

initiated new studies which include reproductive physiology and basic biology (University of Oregon Medical School), nutrition (University of Florida and Michigan State University), immunology (Cleveland Clinic), nutrition-environment relationships (University of Alberta), animal model for pediatric research (University of British Columbia), pathology (Oregon Regional Primate Research Center), lactation (Antioch College and University of Missouri), radiation (University of California at Davis), genetics and nutrition (Oregon State University). The small size of the pygmy goat, relatively low cost of upkeep, ease in handling, and hardiness are a few of the reasons for their increased use as experimental animals.

Studies on the biology of the pygmy goat were initiated at Oregon State University in 1963. Two areas were selected for investigation: genetics and nutrition. The goals of the research were twofold. First, to provide knowledge of the basic biology of the pygmy goat as a reference for further studies. Second, to relate the results obtained from pygmy goat research to work on breeds of larger goats such as Saanens, Nubians, and French Alpines (collectively referred to in this paper as "normal" goats) as well as to determine the degree of interaction between pygmy and normal goats. For this reason, at Oregon State University, identical studies have been carried out concurrently on pygmy, normal, and crossbred goats. Three aspects of the Oregon State University goat research project as

described in this paper are: a physical description of the goats used in the study, an analysis of three chemical constituents of the blood, and a proposed genetic interpretation of the pygmy characteristic.

METHODS AND MATERIALS

Animals

Seven female and three male pygmy goats were obtained from the University of Oregon Medical School, Portland, Oregon to form the foundation of the pygmy goat colony at Oregon State University. This was enlarged by six castrated males and ten intact females from the Battelle-Northwest goat colony. Normal goats representing Saanen, Nubian, and French Alpine breeds were obtained from diverse sources. All goats obtained as foundation stock were received in good health and were typical of their respective breeds. Six groups (pure pygmy, 7/8 pygmy, 3/4 pygmy, 1/2 pygmy, 1/4 pygmy, and pure normal) were developed through a breeding program initiated in 1963. By 1967, there were sufficient breeding females in each group to initiate comparative studies.

The data for the present study were collected over a three-year period starting with the 1968 kid crop and extending through the 1970 kid crop. The basic cross-breeding program and the number of kids born during each of the three years of this study are shown in Table 1.

The breeding season for 1967 lasted from October 1967 through April 1968; for 1968, from August 1968 through February 1969; and

for 1969, from July through August 1969. During gestation the does were allowed to roam on open range, but at parturition, they were confined with their kids to a barn with adjoining exercise yard. Kids were weaned at 12 weeks and kept penned indoors until termination of the blood studies at 24 weeks of age. At this time, male goats were castrated. While confined, all animals were fed alfalfa hay and grain. Husbandry practices with respect to pasture utilization, barn usage, feeding regime, and care of animals were maintained as uniformly as possible during the three years of the study.

Table 1. Breeding program and number of kids born during the three years of study.

Parent's Breeding		Kids Breeding		No. kids born in each year of study			Total
Male	Female			'68	'69	'70	
Pygmy	Pygmy	Pygmy	(P_1)	0	7	6	13
Pygmy	Normal	1/2 Pygmy	(F_1)	4	12	3	19
Pygmy	1/2 Pygmy	3/4 Pygmy	(Back cross 1 to P_1)	6	9	10	25
Pygmy	3/4 Pygmy	7/8 Pygmy	(Back cross 2 to P_1)	17	16	17	50
Normal	1/2 Pygmy	1/4 Pygmy	(Back cross 1 to P_2)	9	7	7	23
Normal	Normal	Normal	(P2)	16	2	12	30

Measurements

Weights were obtained on all kids born during the study at birth and at 4, 6, 8, 10, 12, 16, 20, and 24 weeks of age.

External body measurements were taken at 12 and 24 weeks of age and include the following (Figure 1): (1) height at withers, (2) depth of chest, (3) width of chest, (4) length from shoulders to pin bones, (5) width of iliac crest, (6) heart girth (measured immediately behind shoulders), (7) paunch girth (greatest circumference), (8) length of right metacarpus, (9) length of right metatarsus (both metacarpus and metatarsus were measured while animal was lying on its left side), (10) length of head, (11) width of head.

Slaughter data were collected from castrated males at 15 months of age and include the following: (1) live weight at slaughter, (2) length of right metacarpus, (3) heart wet-weight, (4) liver wet-weight, (5) total kidney wet-weight, (6) total adrenal wet-weight, (7) pituitary wet-weight, (8) thyroid wet-weight, (9) total stomach volume (obtained by first flushing out the stomach contents and tying off the opening to the esophagus with a string, then filling the stomach with water through the pylorus of the abomasum until all wrinkles were removed. Repeated measurements were within ±200 ml.), (10) length of small intestine, (11) length of large intestine, (12) length of caecum (intestine and caecum lengths were obtained by

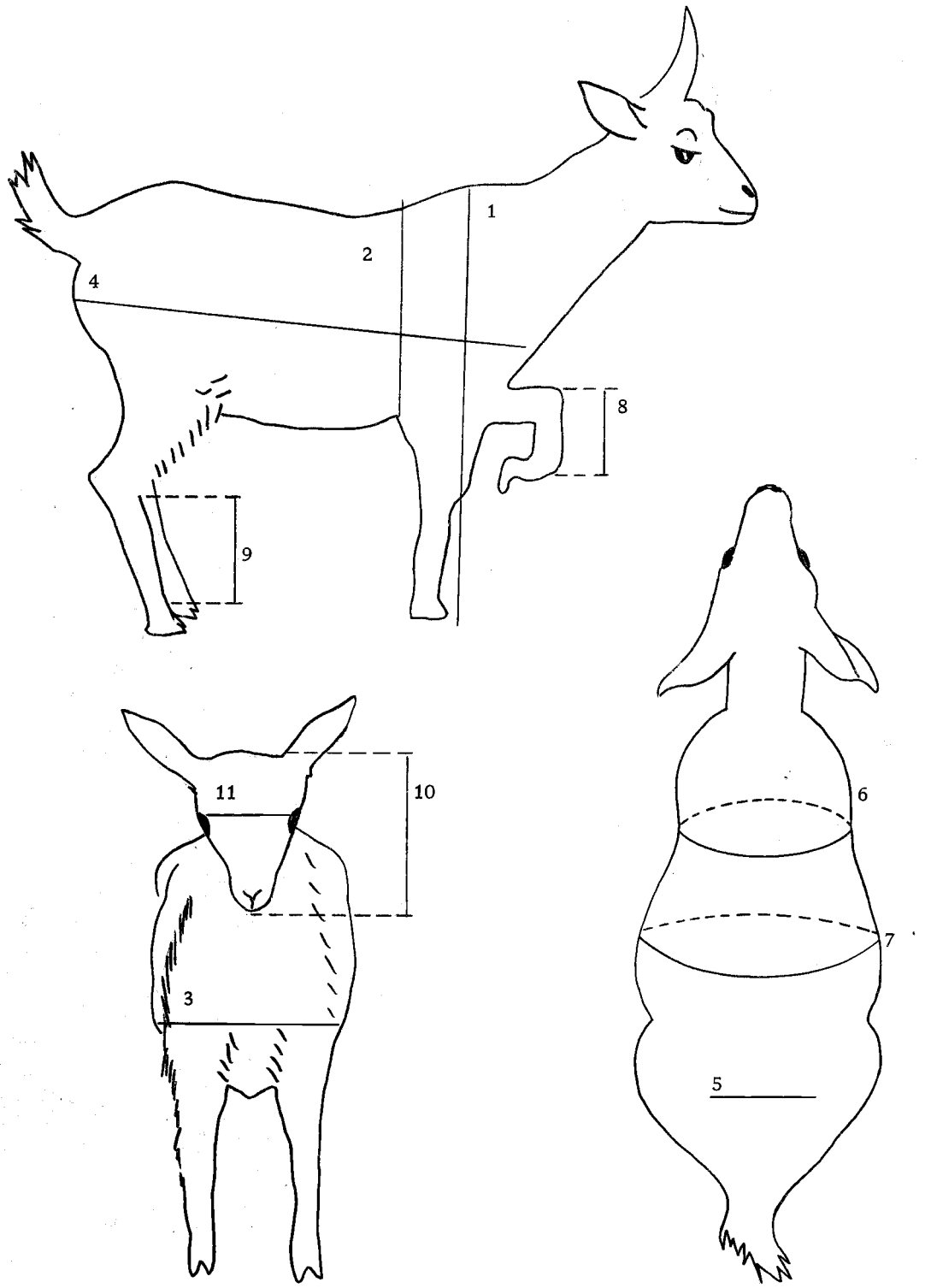

Figure 1. An illustration of body measurements taken at 12 and 24 weeks of age. 1) Height at withers, 2) Depth of chest, 3) Width of chest, 4) Length from shoulders to pin bones, 5) Width of iliac crest, 6) Heart girth, 7) Paunch girth, 8) Length of right metacarpus, 9) Length of right metatarsus, 10) Length of head, 11) Width of head.

unraveling and stretching organs on a wet concrete floor).

Blood Tests

Kids were organized into groups for bleeding by date of birth (±2 days). Blood samples were collected from each group at 4, 6, 8, 10, 12, 16, 20, and 24 weeks. Kids were isolated without food or water approximately 12 hours before blood was collected. Blood was taken from the jugular vein in untreated 12 ml. centrifuge tubes, using 14 gauge bleeding needles. Each tube was placed in crushed ice in the field and refrigerated in the laboratory. One hour from the time the final goat was bled, all samples were centrifuged and the serum removed. One half ml. of serum was used for determination of alkaline phosphatase activity and 1.5 ml. was utilized to obtain a Folin-Wu filtrate following the procedure enclosed in packages of stable Hycel Tungstic Acid (Hycel, Inc., Post Office Box 36329, Houston, Texas, 77036).

Alkaline phosphatase activity was obtained following the method described in the Sigma Technical Bulletin #104 (Sigma Chemical Company, 3500 DeKalb Street, St. Louis, Missouri, 63118). Activity was determined colorimetrically by incubating the serum with a buffered substrate of p-nitrophenyl phosphate.

Amino acid nitrogen content was determined following the method of Danielson (Hawk et al., pp. 565, 567). Color was developed by

the reaction between amino acids and β-naphthoquinone-4-sulfonic acid in an alkaline solution.

Serum urea nitrogen content was determined following the instruction packaged with a Hycel Urea Nitrogen Reagent. Color was developed by the reaction of urea with the dimethyl diketone and As_2O_5 in the acid medium of the reagent. Colorimetric determinations were made for the above three tests with a standard Bausch and Lomb Spectronic 20 Colorimeter.

The overall program for breeding and data collecting can be seen in Table 2.

Statistical Analysis

No corrections for year of birth or number of siblings were made. A multiple regression analysis showed that corrections would not meaningfully or significantly alter the results (Appendix 1).

An analysis of variance was used to test for differences between the means of the six groups of goats for all weekly blood tests and weights, 12 and 24 week body measurements, and 15 month slaughter data. Those characteristics with significant differences between the means were further tested with the student's t-test. The following pairs of groups were tested for significant differences: normal and 1/4 pygmy, normal and 1/2 pygmy, 1/2 pygmy and

pygmy, 3/4 pygmy and pygmy, 7/8 pygmy and pygmy.

All possible simple phenotypic correlations were determined for all data obtained when the goats were 12 and 24 weeks of age and for pooled data on blood tests and weights for the entire 24 week period, and the slaughter data at 15 months of age.

Table 2. General program for breeding and data collection.

Breeding Program
PYGMY X PYGMY → 7/8 PYGMY
PYGMY X 7/8 PYGMY → 3/4 PYGMY
PYGMY X 3/4 PYGMY → 1/2 PYGMY
PYGMY X 1/2 PYGMY → 1/4 PYGMY
NORMAL X 1/4 PYGMY → NORMAL
Pygmy, 7/8 Pygmy, 3/4 Pygmy, 1/2 Pygmy, 1/4 Pygmy, Normal

Weighing and Blood Chemical Analysis Schedule

	Weeks							
	Birth	4	6	8	10	12	16	20	24
Weight	x	x	x	x	x	x	x	x	x
Alkaline Phosphatase		x	x	x	x	x	x	x	x
Urea Nitrogen		x	x	x	x	x	x	x	x
Amino Acid nitrogen		x	x	x	x	x	x	x	x

12 and 24 Week Body Measurements

Body length	Withers height	Chest depth	Chest width	Iliac crest	Head length	Head width	Heart-Paunch girth	Length metatarsus	Length metacarpus
x	x	x	x	x	x	x	x	x	x

15 Month Slaughter Weights and Measurements

Weight of:	Pituitary	Thyroid	Adrenal	Heart	Liver	Kidney	Body
Length of:	Large Intestine	Small Intestine		Caecum	Metacarpus		
Volume of:	Stomach						

RESULTS

Growth curves for the males of each group are shown in Figure 2 and for the females of each group in Figure 3. Appendix 2 contains the data on which these figures are based. At each week of age the mean weight was generally lower as the relationship to the pure pygmy increased. The pygmy group exhibited the smallest mean weights, however the normal goats did not necessarily have the heaviest mean weights. The mean weight of the 1/4 pygmy males was higher at 24 weeks than that of the normal males, and the mean weight of the 1/4 pygmy females was generally higher than that of the normal females.

The mean weight of the males was higher throughout the 24-week period than that of the females in each group except the pure pygmy. The mean weight for the pygmy males was higher only at birth, 4 weeks, 6 weeks, and 24 weeks.

The growth rates (kg/wk) between birth and 12 weeks and between 12 weeks and 24 weeks are given for each group in Table 3. The growth rate between birth and 12 weeks is greater than the rate between 12 and 24 weeks for both sexes in each group. The males of all groups but the pygmy have higher growth rates than the females at both the birth-to-12-week interval and the 12-to-24-week interval.

An analysis of variance was used to test for differences among the means of the weights of the six groups at birth, and at 12 and 24

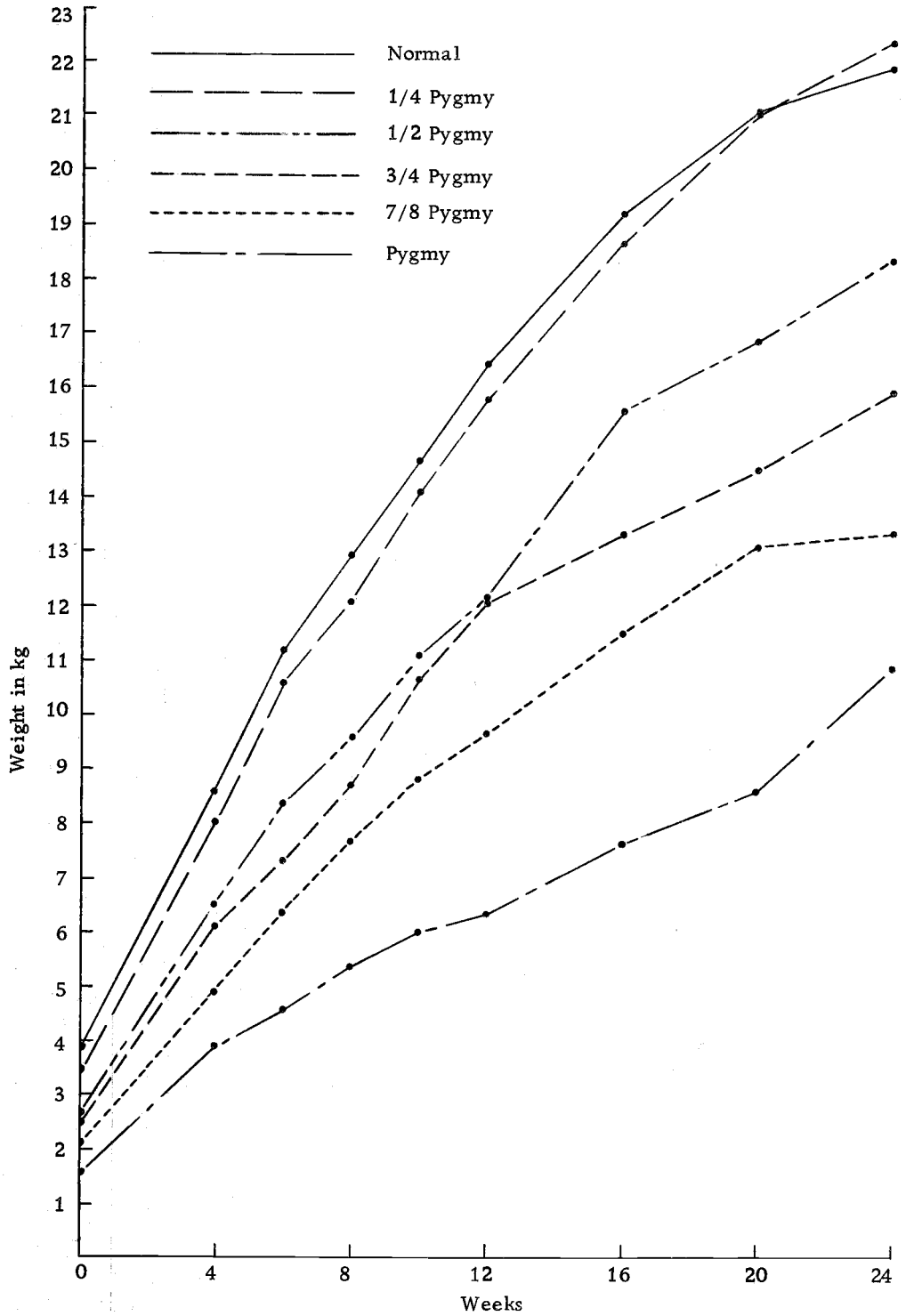

Figure 2. Growth curves for males of the normal, 1/4 pygmy, 1/2 pygmy, 3/4 pygmy, 7/8 pygmy and pygmy groups. Note the general decrease in the weight of the groups as the relationship to the pygmy group increases.

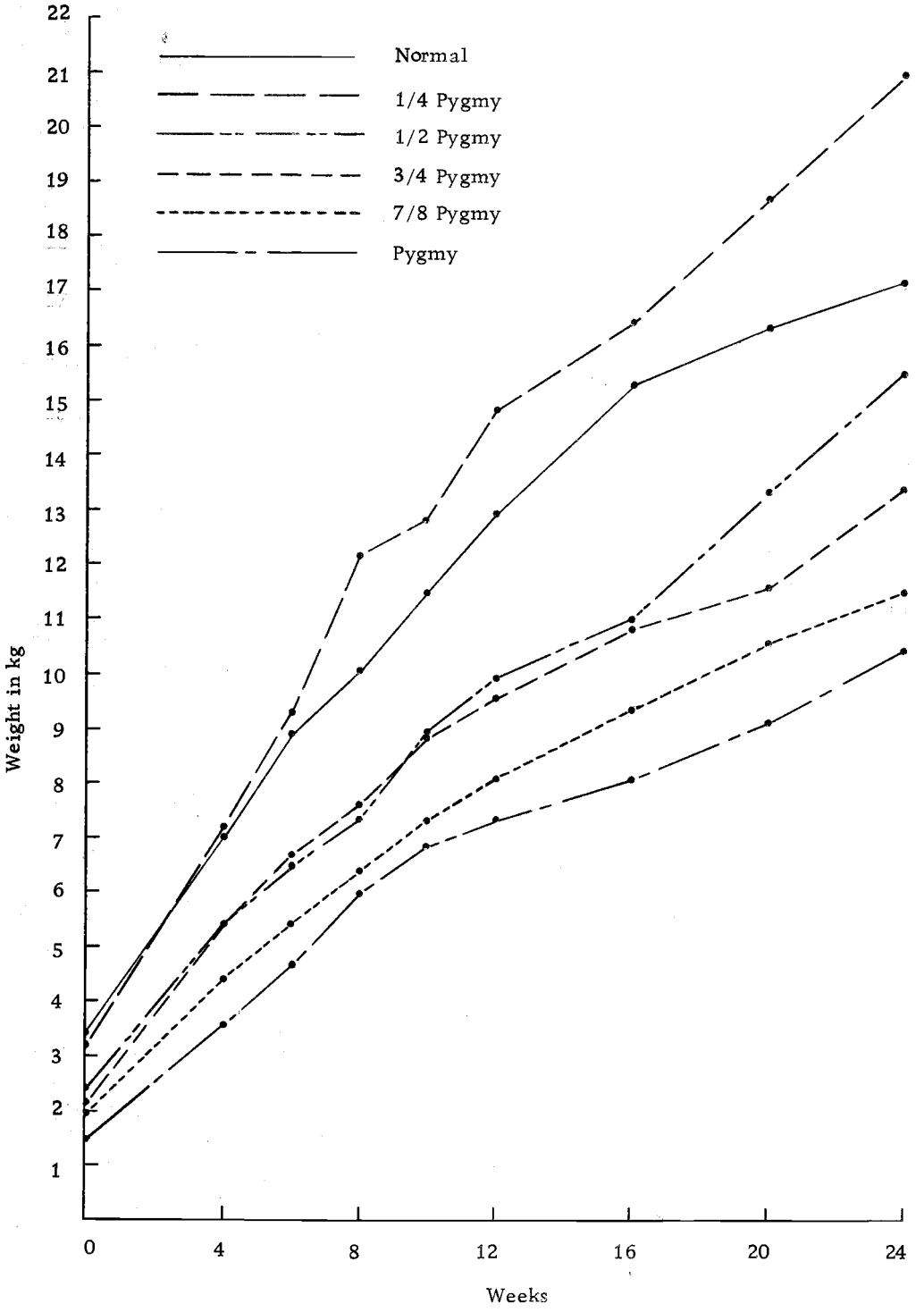

Figure 3. Growth curves for females of the normal, 1/4 pygmy, 1/2 pygmy, 3/4 pygmy, 7/8 pygmy and pygmy groups. Note the general decrease in the weight of the groups as the relationship to the pygmy group increases.

weeks. The F values obtained are given in Table 6. Those characteristics with significant differences among means were further tested with the student's t-test. The difference between the means of the normal and 1/4 pygmy, between the normal and 1/2 pygmy, between the 1/2 pygmy and pygmy, between the 3/4 pygmy and pygmy, and between the 7/8 pygmy and pygmy groups were examined and the differences are given in Table 7.

Table 3. Growth rates in kg/week between birth and 12 weeks, and between 12 and 24 weeks for males and females of all six groups.

Sex	Growth period	Groups					
		Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy
♂	Birth to 12 weeks	1.0510	1.0295	0.7913	0.8052	0.6213	0.3926
♂	12 to 24 weeks	0.4443	0.5437	0.5065	0.3178	0.3023	0.3743
♀	Birth to 12 weeks	0.7910	0.9676	0.6268	0.6123	0.5123	0.4768
♀	12 to 24 weeks	0.3660	0.5124	0.4664	0.3201	0.2823	0.2590

Body weight did not show a significant difference between means at birth but did show a significant difference at 12 and 24 weeks (Table 6). The means were tested at 12 and 24 weeks with the Student's t-test (Table 7). Significant differences were found between the means of the normal and 1/4 pygmy females at 24 weeks, between

normal and 1/2 pygmy males and females at 12 and 24 weeks, between both the 3/4 pygmy and pygmy males and females at 12 and 24 weeks, and between both the 7/8 pygmy and pygmy males and females at 12 weeks.

The means for alkaline phosphatase activity, amino acid nitrogen level, and urea nitrogen level are plotted against age in Figures 4, 5, and 6. The information on which these figures are based is presented in Appendix 3.

Alkaline phosphatase activity for both males and females was highest at four weeks and declined with age. A low point in activity was generally observed at week 16, the period following weaning. Within each group neither the males nor the females had a consistently higher level of alkaline phosphatase activity than the other.

A wide range of alkaline phosphatase activity was found. The normal goats appear to have three levels of activity; high (activity level of an individual not exceeding 15% transmittance during the 24 weeks), medium (activity level of an individual not exceeding 40% transmittance during the 24 weeks), and low (activity level of an individual exceeding 40% transmittance sometime during the 24 week period). The 3/4 pygmy group show the medium and low levels, while the pygmy group shows only the low level. The means and ranges of each of these levels are presented in Table 8. The 1/4 pygmy and 1/2 pygmy groups have a distribution similar to the normal group while the 7/8 pygmy group has a distribution similar to the 3/4 pygmy

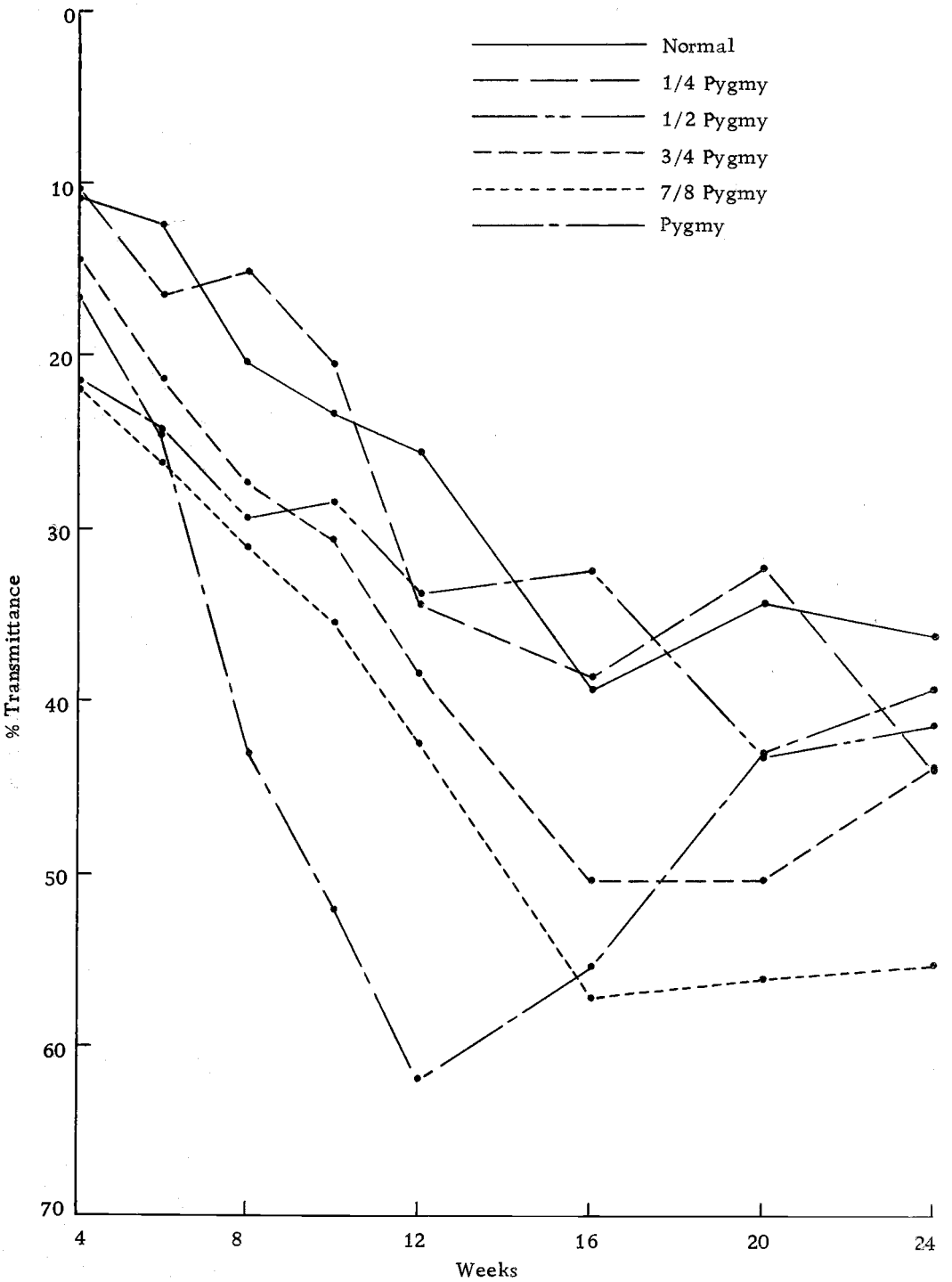

Figure 4a. Alkaline phosphatase levels of males for each of the six groups of goats. An increasing percent of transmittance indicates a decreasing level of activity. Note the general decrease in activity with age up to about 16 weeks, then the general increase in activity.

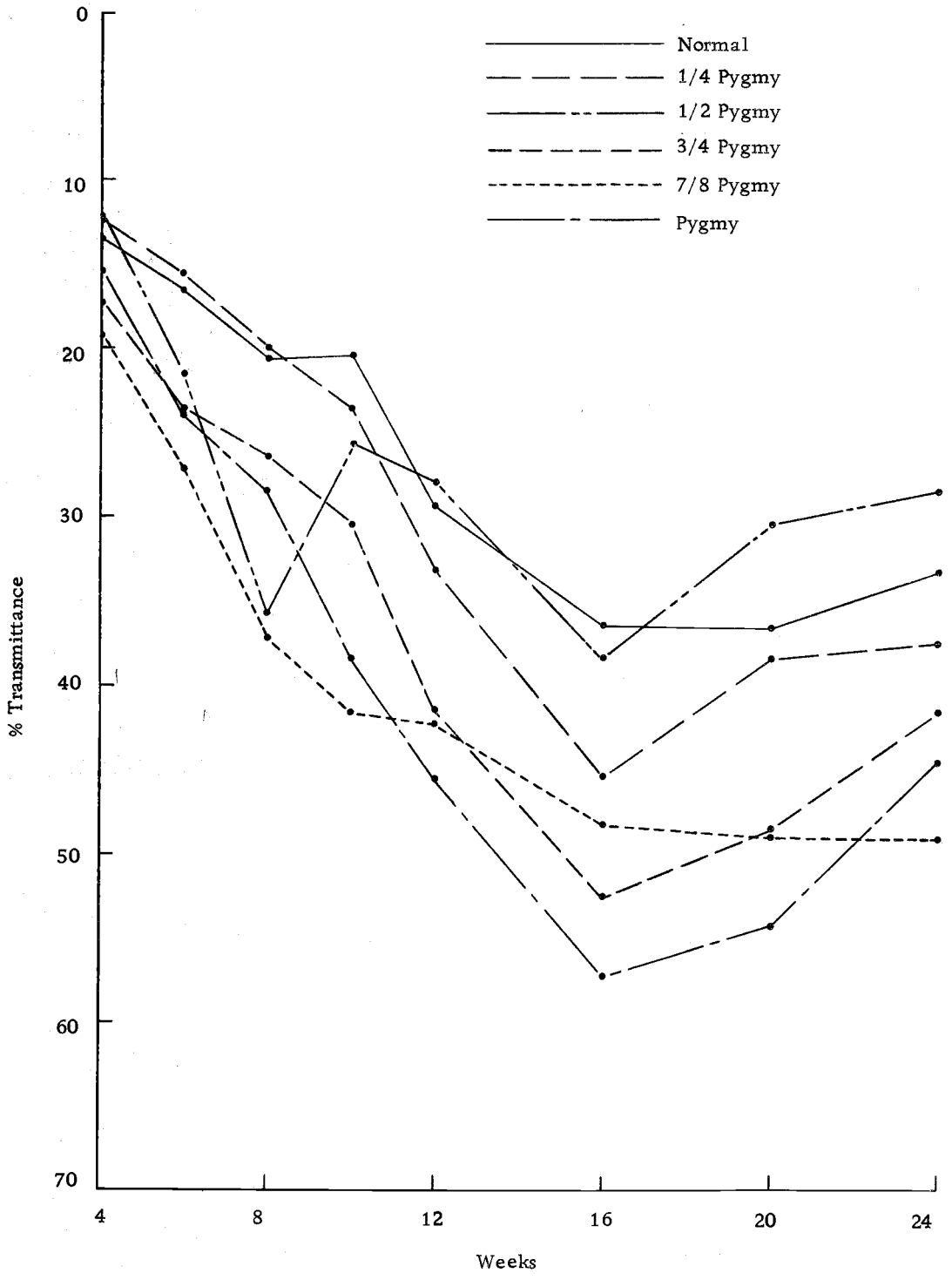

Figure 4b. Alkaline phosphatase levels of females for each of the six groups of goats. Note the general decrease in activity with age up to about 16 weeks then the general increase in activity.

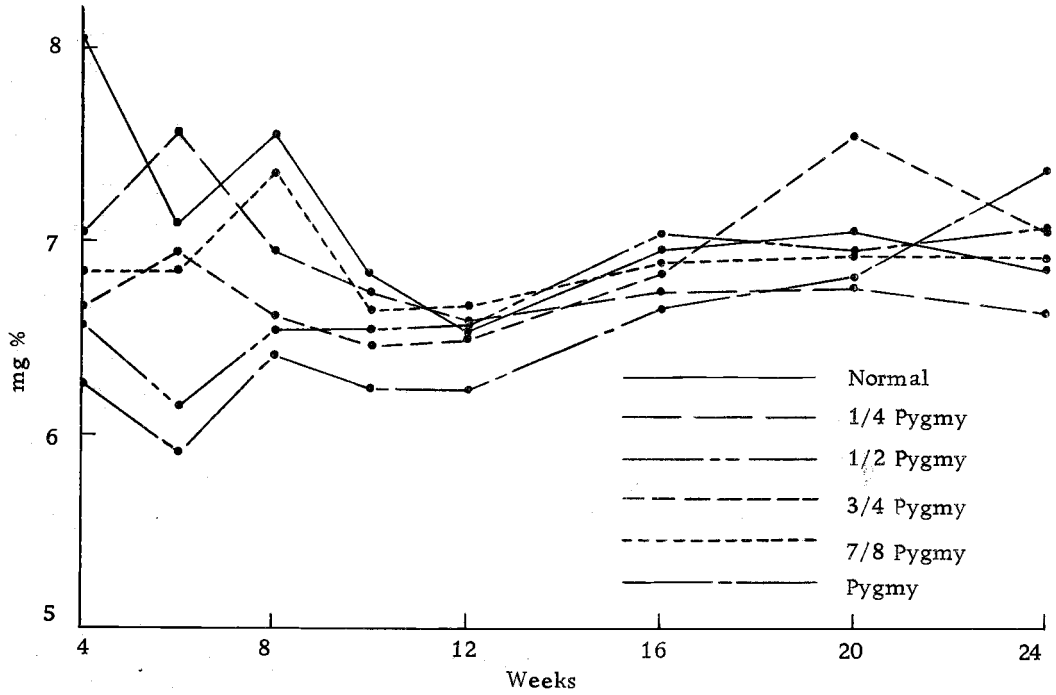

Figure 5a. Amino acid nitrogen levels for the males of the six groups of goats. Except for the early weeks, there is a great similarity between means.

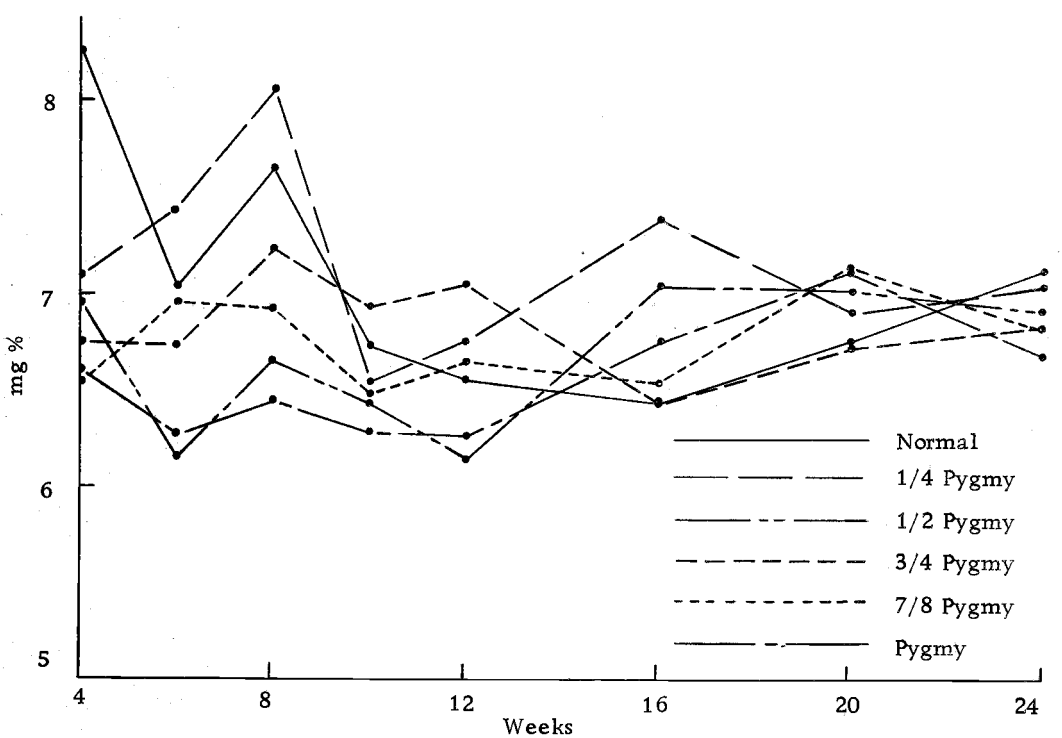

Figure 5b. Amino acid nitrogen levels for the females of the six groups of goats. As for the males, note the similarity between means except during the early weeks.

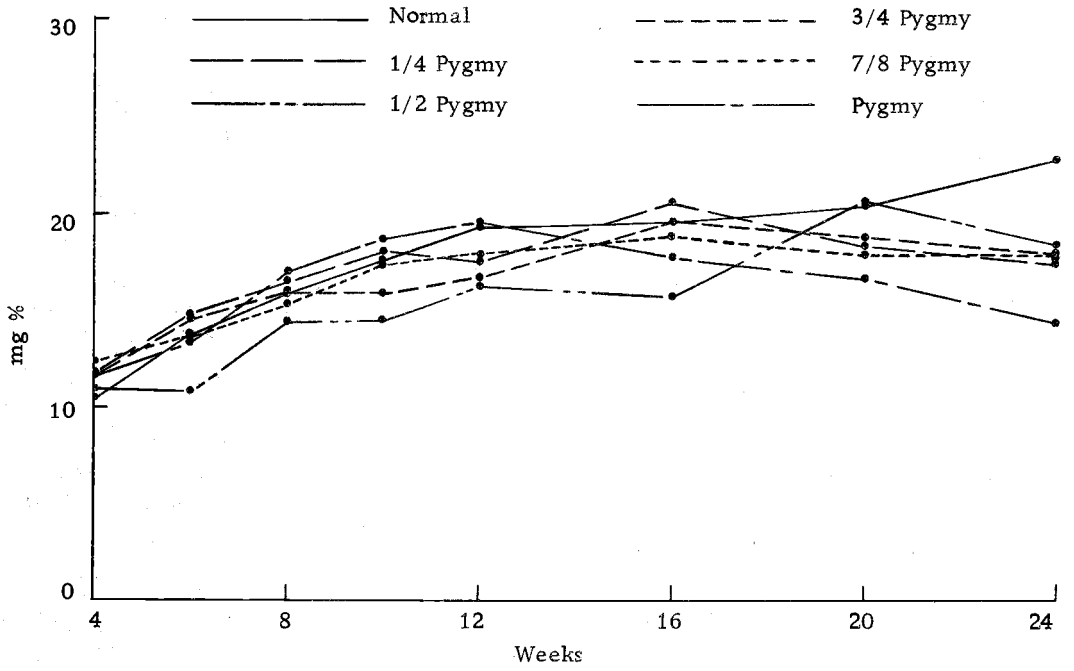

Figure 6a. Urea nitrogen levels for the males of the six groups of goats. Note the general increase with age.

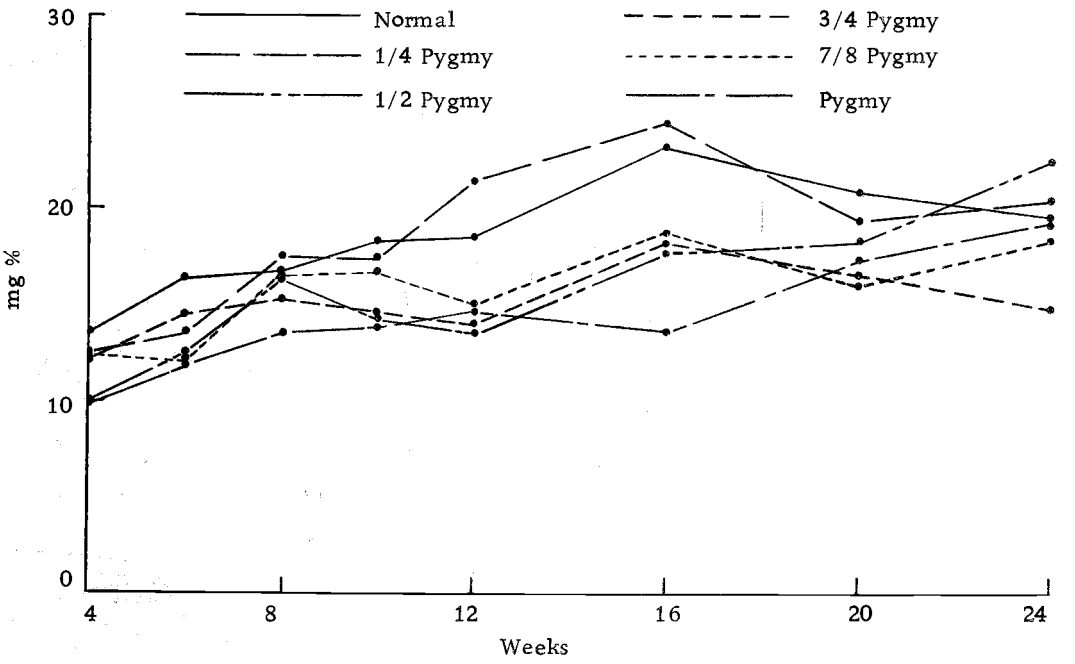

Figure 6b. Urea nitrogen levels for females of the six groups. As for the males note the general increase with age.

group.

An analysis of variance was used to test for differences among the means of alkaline phosphatase activity for the six groups at 12 and 24 weeks. A significant difference was further tested with the Student's t-test in the same manner as for the weights.

Alkaline phosphatase activity showed significant differences among means only at 24 weeks for the females (Table 6). The only significant difference was found between the means of the 1/2 pygmy and pygmy groups (Table 7).

The amino acid nitrogen level varied considerably during the first 12 weeks (Figure 5 and Appendix 3), but from 12 to 24 weeks tended toward a gradual increase. The levels of amino acid nitrogen within each group were generally higher in females than in males. However, at 12 weeks the normal and 1/2 pygmy males had a higher level than their corresponding females, and at 24 weeks the normal and 1/4 pygmy males had a higher level than their corresponding females. The 24-week levels of amino acid nitrogen were higher than the 12-week levels for all groups except the 3/4 pygmy where the female level was higher at 12 weeks.

An analysis of variance was used to test for differences among means of amino acid nitrogen for the six groups at 12 and 24 weeks. Amino acid nitrogen did not show a significant difference between means for either sex at either 12 or 24 weeks (Table 6).

Urea nitrogen levels showed a general increase with age in all groups (Figure 6 and Appendix 3). Males in each groups had higher values at 12 and 24 weeks than did their corresponding females with the exception of the 1/4 pygmy group at week 12, and the normal and 3/4 pygmy groups at week 24. The urea nitrogen level for each group was higher at 24 weeks than at 12 weeks with the exception of the 7/8 pygmy and pygmy males and 1/4 pygmy females.

An analysis of variance was used to test for differences among the means of urea nitrogen for the six groups at 12 and 24 weeks. A significant difference was further tested with the Student's t-test. Urea nitrogen showed a significant difference among means for the females at 12 weeks (Table 6). A significant difference existed between the means of the normal and 1/2 pygmy (Table 15) groups (Table 7).

Values of urea nitrogen obtained at 4 and 6 weeks were averaged as were values obtained at 10 and 12 weeks, and at 20 and 24 weeks. The same was done for amino acid nitrogen. These averages were compared with the changes in weight during the same time intervals (4-6 weeks, 10-12 weeks, and 20-24 weeks). The results are presented in Table 9. The amount of change in weight decreased from the 4-6-week period to the 20-24-week period for both males and females with the exception of the pygmy males and 3/4 pygmy females. Although within each of the six groups the amino acid nitrogen levels did not change consistently with changes in weight, the urea nitrogen levels generally increased with weight and age within each

group except the pygmy.

The mean, standard deviation, and range for each body measurement taken at 12 and 24 weeks and the number of goats in each group are given in Table 10. The means for each body measurement generally decreased in size from the larger animals of the normal and the 1/4 pygmy groups to the smaller animals of the 7/8 pygmy and pygmy groups. The 1/4 pygmy females were larger in general than the normal females at both 12 and 24 weeks. In all groups but the pygmy, the males tended to have larger measurements than the females. However, the normal, 1/4 pygmy, and 3/4 pygmy males had a smaller chest width than their respective females. The normal males show larger measurements than the 1/4 pygmy males, while the opposite is true for the females.

The amount of growth between 12 and 24 weeks is given for all body measurements in Table 11. For the males in each group most of the measurements showed an increase in amount of growth from smaller increases in the normal and 1/4 pygmy groups to larger increases in the 7/8 pygmy and pygmy groups. The females in each group generally showed a stepwise decrease in amount of growth from larger increases in the normal and 1/4 pygmy groups to smaller increases in the 7/8 pygmy and pygmy groups.

An analysis of variance was used to test for differences among the means of all of the body measurements taken at 12 and 24 weeks.

All body measurements for both sexes at both 12 and 24 weeks, except the width of chest for the females at 12 weeks, showed a significant difference between means (Table 6).

The measurements with a significant difference in means were further tested with the Student's t-test (Table 7).

For the most part, the means of both the length from shoulders to pinbones and the heart girth were significantly different between the normal and 1/2 pygmy groups for both males and females at 12 and 24 weeks; between the 1/2 pygmy and pygmy groups for both males and females at 12 and 24 weeks; and between the 3/4 pygmy and pygmy groups for both males and females at both 12 and 24 weeks. The difference in means between both the normal and 1/4 pygmy groups and between the 7/8 pygmy and pygmy groups were, for the most part, not significantly different for either sex at 12 or 24 weeks.

Significant differences between means of both the width of chest and width of iliac crest were found primarily between the 1/2 pygmy and pygmy groups for both sexes at 12 and 24 weeks. Generally, the difference in means between the other pairs of groups was not significantly different.

The mean of the length of metacarpus was significantly different between the normal and 1/2 pygmy groups for both males and females at 12 and 24 weeks, and between the 1/2 pygmy and normal groups for

both sexes at 12 and 24 weeks. The means of both males and females in the normal and 1/4 pygmy groups were significantly different at 24 weeks, but not at 12 weeks. The means of the metacarpus of the 3/4 pygmy and pygmy males were significantly different at 12 and 24 weeks, but the means of the females were not significantly different at either 12 or 24 weeks. Between the 7/8 pygmy and pygmy groups, only the males had a significant difference in means for the length of metacarpus.

The length of the metatarsus had a significant difference between all pairs of groups except between the 1/4 pygmy and normal groups. This was found for males and females at both 12 and 24 weeks.

The means of both the length of head and width of head were significantly different between the 1/2 pygmy and pygmy groups for both males and females at 12 and 24 weeks. The difference in means of both the length and width of head between the normal and 1/4 pygmy groups were not significantly different for either sex at 12 or 24 weeks. The means of both head measurements were significantly different between the 7/8 pygmy and pygmy males at 12 weeks, but not at 24 weeks. The head measurements of females of these two groups were not significantly different at either 12 or 24 weeks. The means of both head measurements were significantly different between the normal and 1/2 pygmy groups for both sexes at 12 weeks, but only the width of head measurement for the males at 24 weeks was significantly different. The means of the length of head for the females of these two groups were not significantly different for either 12 or 24 weeks. The means of the width of head was significantly

different between the 3/4 pygmy and pygmy groups for both males and females at 12 weeks but not at 24.

The ratio of selected body measurements to body weight for both 12 and 24 weeks is given in Table 12. The size of the ratio for each measurement generally increased from smaller ratios for the normal and 1/4 pygmy groups to larger ratios for the 7/8 pygmy and pygmy groups. The measurements with the greatest variation in size of ratio were the paunch girth and the heart girth.

The ratio of selected body measurements to height at withers is given in Table 13. The same general trends are observed here as for the measurement-to-body weight ratios, except that the ratios for weight, metacarpus, and metatarsus tended to decrease in size from larger ratios for the normal and 1/4 pygmy groups to smaller ratios for the 7/8 pygmy and pygmy groups for both sexes. The measurements with the greatest variation in the size of the ratio were, again, the paunch girth and the heart girth.

The mean, standard deviation, and range for each weight and measurement taken at 15 months and the number of goats slaughtered are given in Table 14. The weights and measurements generally decreased in size with the means of the normal and 1/4 pygmy groups larger than the means of the 7/8 pygmy and pygmy groups. The weights and measurements of the 1/4 pygmy group were generally larger than those of the normal group.

The thyroid glands of the pygmy goats had a wide range in weight (Table 4). Animals 6133 and 6135 had very large thyroids in comparison to the other pygmy goats. As all of the goats had access to the same care and diet, a dietary deficiency as the only factor seems unlikely. No explanation is offered at present for the difference in weight of these glands.

Table 4. Weight of thyroid glands in pygmy goats. Note the unusual size from animals 6133 and 6135.

Animal	Weight of thyroid in grams	Animal	Weight of thyroid in grams
6131	1.96	6135	5.74
6133	7.15	316	1.32
6134	1.70	360	1.31

An analysis of variance was used to test for differences among the means of the slaughter weights and measurements (Table 6).

All of the slaughter weights and measurements had a significant difference between means. As with the 12 and 24 week measurements, the 15 month slaughter measurements were further tested with the Student's t-test (Table 7).

Three characteristics, live weight, length of metacarpus, and length of small intestine had significant differences among all pairs of groups tested except between the 1/4 pygmy and normal groups.

Three other characteristics, the wet-weight of the liver, length of large intestine, and length of caecum had significant differences between the means of the 1/2 pygmy and pygmy groups, between the 3/4 pygmy and pygmy groups, and between the 7/8 pygmy and pygmy groups.

Four wet-weights, the heart, the kidney, adrenal, and pituitary only showed significant differences between the means of the 1/2 pygmy and pygmy groups, and between the 3/4 pygmy and pygmy groups. The means of the stomach volume were significantly different between only the normal and 1/4 pygmy groups and between the 3/4 pygmy and pygmy groups.

The ratio of each measurement and weight to live weight at slaughter is given in Table 15. In general, the size of the ratio increased from smaller ratios in the normal and 1/4 pygmy groups to larger ratios in the 7/8 pygmy and pygmy groups. The ratio of each body measurement and weight to length of metacarpus is shown in Table 16. The size of the ratio for the wet-weights of the heart, liver, kidney, and adrenal, and for the live weight generally decreased from a larger ratio in the normal and 1/4 pygmy groups to a smaller ratio in the 7/8 pygmy and pygmy groups. On the other hand, the size of the ratio for the wet-weights of the pituiary and thyroid, and the lengths of the small intestine, large intestine and caecum generally increased.

The number of slaughtered animals for which figures are reported in this paper is small, but the data serve to indicate general trends.

Caution must be used when interpreting the results from measuring the lengths of large and small intestine, length of caecum, and volume of stomach. Alvarez (1928) pointed out the difficulty in measuring intestine length at autopsy and suggested such measurements a fallacy. Espe and Cannon (1940) found that the measurement of the combined length of small and large intestine at autopsy was three times as great as the same measurements taken for the same animals while alive. The techniques utilized in this study for measuring the lengths of the small and large intestine, length of caecum and volume of stomach were as identical as possible for all groups, and although the results may not represent the active in vivo measurements they can be utilized in a relative manner for comparing groups.

All possible correlation coefficients were determined among blood chemicals, live weight, and body measurements at 12 and 24 weeks for both males and females (Tables 17 and 18). Significant correlation coefficients were found between weight and alkaline phosphatase activity and all body measurements for the males at 12 weeks, and with urea nitrogen and all body measurements at 24 weeks (Table 17). Weight had a significant positive correlation with alkaline phosphatase activity, urea nitrogen level, and all body weights for the

females at 12 weeks, and with alkaline phosphatase activity and all body weights at 24 weeks (Table 18).

Significant positive correlation coefficients were found between alkaline phosphatase activity and weight and all body measurements for the males at 12 weeks, but had no significant correlations at 24 weeks (Table 17). Alkaline phosphatase activity had a significant positve correlation with weight and most body measurements for the females at 12 weeks and a significant positive correlation with weight, urea nitrogen level, and most body measurements at 24 weeks (Table 18).

Amino acid nitrogen level was not significantly correlated with any other blood chemical, weight, or any of the body measurements for either sex at 12 or 24 weeks (Tables 17 and 18).

A significant negative correlation was found between urea nitrogen level and width of iliac crest for males at 12 weeks, but urea nitrogen had a positive significant correlation with weight and most of the body measurements at 24 weeks (Table 17). Urea nitrogen levels had a significant positive correlation with weight, alkaline phosphatase activity and most body measurements for the females at 12 weeks, and had a significant positive correlation with alkaline phosphatase activity and most body measurements at 24 weeks (Table 18).

All possible correlations between the body measurements taken

at 12 and 24 weeks had a significant positive correlation for both males and females (Tables 17 and 18).

Significant positive correlation coefficients were found between live weight, amino acid nitrogen, urea nitrogen, and alkaline phosphatase for the data pooled from weeks four through 24 for both sexes (Table 5). Urea nitrogen was positively correlated with age and weight, in both sexes while amino acid nitrogen was not significantly correlated with either age or weight in males or females. Alkaline phosphatase activity had a significant negative correlation with age in both sexes, but did not have a significant correlation with weight.

Table 5. Correlation coefficients for correlations between age, weight, alkaline phosphatase, amino acid nitrogen, and urea nitrogen. For data pooled from 4 to 24 weeks. Only those values significant at 0.5 are given.

	Males				Females			
	Weight	Alkaline Phosphatase	Amino Acid Nitrogen	Urea Nitrogen	Weight	Alkaline Phosphatase	Amino Acid Nitrogen	Urea Nitrogen
Age	.645	-.468	--	.366	.660	-.453	--	.370
Weight		--	--	.303		--	--	.387
Alkaline phosphatase			--	-.302			--	-.120
Amino acid nitrogen				--				.127

Correlation coefficients for slaughter weights and measurements are shown in Table 19. All possible correlations between weights and measurements had significant positive correlation coefficients except the wet-weight of the thyroid gland which was not significantly related to any of the other traits.

Table 6. Analysis of variance table for live weight, blood chemicals, 12 and 24 week measurements and 15 month weights and measurements.

Characteristic	Sex	Age	Degrees of Freedom	F	Significant at .05
Weight	♂	Birth	5, 83	1.1465	
	♀	Birth	5, 65	1.7899	
	♂	12 wks	5, 74	26.6944	+
	♂	24	5, 71	15.6463	+
	♀	12	5, 56	17.1537	+
	♀	24	5, 58	16.7702	+
Alkaline phosphatase	♂	12	5, 74	4.4217	+
	♂	24	5, 71	2.2950	
	♀	12	5, 56	1.8476	
	♀	24	5, 58	2.6531	+
Amino acid nitrogen	♂	12	5, 74	0.3238	
	♂	24	5, 71	1.3892	
	♀	12	5, 56	1.5391	
	♀	24	5, 58	0.4158	
Urea nitrogen	♂	12	5, 74	0.7200	
	♂	24	5, 71	2.3208	
	♀	12	5, 56	5.5080	+
	♀	24	5, 58	2.0595	
Height at withers	♂	12	5, 74	34.7591	+
	♂	24	5, 71	25.0189	+
	♀	12	5, 56	35.5718	+
	♀	24	5, 58	30.1369	+
Depth of chest	♂	12	5, 74	30.9957	+
	♂	24	5, 71	19.0160	+
	♀	12	5, 56	21.9232	+
	♀	24	5, 58	23.5331	+
Width of chest	♂	12	5, 74	6.1714	+
	♂	24	5, 71	4.8796	+
	♀	12	5, 56	2.2357	
	♀	24	5, 58	5.6180	+

Table 6. (Continued)

Characteristic	Sex	Age	Degrees of Freedom	F	Significant at .05
Length from shoulders to pin bones	♂	12	5, 74	28.5999	+
	♂	24	5, 71	24.6886	+
	♀	12	5, 56	25.6101	+
	♀	24	5, 58	25.9786	+
Width of Iliac crest	♂	12	5, 74	9.0840	+
	♂	24	5, 71	9.4377	+
	♀	12	5, 56	5.8145	+
	♀	24	5, 58	6.8904	+
Heart girth	♂	12	5, 74	18.5830	+
	♂	24	5, 71	15.0216	+
	♀	12	5, 56	9.2136	+
	♀	24	5, 58	12.0712	+
Paunch girth	♂	12	5, 74	21.6947	+
	♂	24	5, 71	18.7808	+
	♀	12	5, 56	11.8694	+
	♀	24	5, 58	16.2810	
Length of metacarpus	♂	12	5, 74	52.1826	+
	♂	24	5, 71	43.3517	+
	♀	12	5, 56	34.5753	+
	♀	24	5, 58	52.1666	+
Length of metatarsus	♂	12	5, 74	43.3896	+
	♂	24	5, 71	45.4673	+
	♀	12	5, 56	51.6577	+
	♀	24	5, 58	65.9448	+
Length of head	♂	12	5, 74	19.7459	+
	♂	24	5, 71	15.2560	+
	♀	12	5, 56	14.4194	+
	♀	24	5, 58	13.9992	+
Width of head	♂	12	5, 74	14.6227	+
	♂	24	5, 71	13.6586	+
	♀	12	5, 56	14.8062	+
	♀	24	5, 58	17.6166	+

Table 6. (Continued)

Characteristic	Sex	Age	Degrees of Freedom	F	Significant at .05
Live weight	w	15	5, 30	19.5211	+
Length of metacarpus	w	15	5, 30	63.8581	+
Heart wet-weight	w	15	5, 30	14.4009	+
Liver wet-weight	w	15	5, 30	14.3878	+
Kidney wet-weight	w	15	5, 30	9.7367	+
Adrenal wet-weight	w	15	5, 30	12.5902	+
Pituitary wet-weight	w	15	5, 30	5.6441	+
Thyroid wet-weight	w	15	5, 30	1.5197	
Stomach volume	w	15	5, 30	13.6953	+
Length of sm. intestine	w	15	5, 30	22.4333	+
Length of large intestine	w	15	5, 30	20.5154	+
Length of caecum	w	15	5, 30	8.0715	+

Table 7. t-values for comparisons of weight, blood chemicals, 12 and 24 week measurements and 15 month weights and measurements. Only those values significant at .05 are given.

Character-istic	Sex	Age	Normal & 1/4 Pygmy	Normal & 1/2 Pygmy	1/2 Pygmy & Pygmy	3/4 Pygmy & Pygmy	7/8 Pygmy & Pygmy
Weight	♂	12 wks	--	3.140	3.751	5.202	3.082
	♂	24	--	--	3.645	3.327	--
	♀	12	--	3.383	3.475	2.513	--
	♀	24	2.475	--	5.123	2.294	--
Alkaline phosphatase	♀	24	--	--	2.691	--	--
Urea nitrogen	♀	12	--	3.081	--	--	--
Height at withers	♂	12	2.084	4.381	3.599	2.932	2.115
	♂	24	--	3.818	4.024	3.187	2.128
	♀	12	--	5.574	8.181	2.273	--
	♀	24	--	5.525	5.638	2.163	--
Depth of chest	♂	12	--	3.371	4.275	4.936	3.564
	♂	24	--	2.677	4.404	3.856	2.407
	♀	12	--	3.760	6.006	2.452	--
	♀	24	2.412	2.767	4.745	--	--
Width of chest	♂	12	--	--	2.533	2.964	2.286
	♂	24	--	--	2.160	--	--
	♀	12	--	--	--	--	--
Length from shoulders to pin bones	♂	12	--	2.495	3.825	4.360	2.613
	♂	24	--	2.996	4.071	2.973	--
	♀	12	2.285	2.230	7.074	3.078	--
	♀	24	--	2.967	5.161	--	--
Width of Iliac crest	♂	12	--	--	2.451	2.438	--
	♂	24	--	--	3.741	--	--
	♀	12	--	--	3.011	2.409	--
	♀	24	--	--	3.996	--	--

Table 7. (Continued)

Characteristic	Sex	Age	Normal & 1/4 Pygmy	Normal & 1/2 Pygmy	1/2 Pygmy & Pygmy	3/4 Pygmy & Pygmy	7/8 Pygmy & Pygmy
Heart girth	♂	12	--	2.292	3.780	5.359	3.336
	♂	24	--	--	3.219	2.451	--
	♀	12	--	3.235	4.497	2.426	--
	♀	24	--	2.586	3.491	--	--
Paunch girth	♂	12	--	2.486	5.363	4.307	5.323
	♂	24	--	2.375	4.274	3.390	2.360
	♀	12	--	3.528	3.874	--	2.234
	♀	24	--	4.122	4.856	2.196	--
Length of metacarpus	♂	12	--	6.359	5.010	5.685	3.442
	♂	24	3.550	5.235	4.442	2.436	--
	♀	12	--	4.045	4.876	--	--
	♀	24	2.195	7.575	5.010	--	--
Length of metatarsus	♂	12	--	5.142	7.292	4.407	3.436
	♂	24	--	4.723	5.977	2.747	2.398
	♀	12	--	6.058	9.222	3.009	2.095
	♀	24	--	6.353	8.743	4.353	2.729
Length of head	♂	12	--	2.392	3.546	3.596	2.487
	♂	24	--	--	4.064	2.830	--
	♀	12	--	3.740	4.140	--	--
	♀	24	--	--	3.728	--	--
Width of head	♂	12	--	2.739	4.061	3.885	2.667
	♂	24	--	--	3.789	--	--
	♀	12	--	2.658	4.090	3.447	--
	♀	24	--	2.585	6.033	--	--

Table 7. (Continued)

Character-istic	Sex	Age	Normal ♂ 1/4 Pygmy	Normal ♂ 1/2 Pygmy	1/2 Pygmy ♂ Pygmy	3/4 Pygmy ♂ Pygmy	7/8 Pygmy ♂ Pygmy
Live weight	w	15 mos.	--	3.433	4.343	9.418	4.124
Length of metacarpus	w	15	--	6.395	11.168	5.520	4.954
Heart wet-weight	w	15	--	--	2.758	3.053	--
Liver wet-weight	w	15	--	--	4.628	3.039	2.597
Kidney wet-weight	w	15	--	--	2.663	3.331	--
Adrenal wet-weight	w	15	--	--	2.303	3.261	--
Pituitary wet-weight	w	15	--	--	2.547	3.401	--
Stomach volume	w	15	--	3.878	--	3.143	--
Length of sm. intestine	w	15	--	4.886	4.736	4.336	2.679
Length of lg. intestine	w	15	--	--	3.513	4.138	3.301
Length of caecum	w	15	--	--	5.976	6.265	2.281

Table 8. Variation in alkaline phosphatase activity in normal, 3/4 pygmy, and pygmy goats. The following levels are present for the normal goats: a high level (activity does not exceed 15% transmittance during the 24 weeks), a medium level (activity does not exceed 40% transmittance during the 24 weeks), and a low level (activity does exceed 40% transmittance sometime during the 24 weeks. The medium and low levels are present in the 3/4 pygmy group, and just the low level is present in the pygmy goats.

Group Sex	Activity Level	% transmittance	Number Observed	Weeks 4	6	8	10	12	16	20	24
Normal ♂	High	Mean	2	4.3	4.5	4.5	5.0	7.0	12.5	8.5	8.8
		Range		3.5/5.0	4.0/5.0	4.0/5.0	4.0/6.0	6.0/8.0	10.0/15.0	6.0/11.0	6.0/11.5
	Medium	Mean	4	7.8	8.0	10.5	9.9	12.4	17.12	25.2	23.1
		Range		6.0/9.0	6.0/12.0	4.5/19.0	4.9/16.0	7.0/21.0	8.0/25.0	11.0/38.0	15.0/39.0
	Low	Mean	7	13.9	15.2	29.9	39.4	38.5	61.3	48.9	51.4
		Range		6.0/28.0	4.0/28.0	12.0/42.0	17.0/60.0	18.5/61.7	35.8/83.0	32.0/72.0	37.0/7.10
Normal ♀	High	Mean	2	5.5	9.0	10.0	6.5	11.0	6.5	6.5	7.0
		Range		5.0/6.0	8.0/10.0	7.0/13.0	7.0/6.0	10.0/12.0	6.0/7.0	6.0/7.0	7.0/7.0
	Medium	Mean	0	---------- Not Observed ----------							
		Range									
	Low	Mean	9	13.9	16.6	18.8	21.6	33.0	43.7	43.9	39.7
		Range		7.0/25.0	8.5/27.0	3.5/28.0	5.0/49.7	17.2/49.5	22.5/8.00	25.0/74.0	15.0/62.2
3/4 Pygmy ♂	Medium	Mean	2	11.0	13.5	19.5	25.0	24.0	30.0	34.0	26.0
		Range		6.0/16.0	5.0/22.0	17.0/22.0	14.0/36.0	12.0/36.0	25.0/35.0	31.0/37.0	25.0/27.0
	Low	Mean	10	13.9	22.9	28.8	29.5	35.8	54.5	53.7	47.7
		Range		6.0/24.0	10.0/34.0	11.0/42.0	15.0/50.1	13.0/47.0	35.0/66.0	34.0/76.0	31.0/76.0
3/4 Pygmy ♀	Medium	Mean	1	16.0	19.0	24.0	31.0	35.0	16.0	40.0	32.0
		Range		16.0/	19.0/	24.0/	31.0/	35.0/	16.0/	40.0/	32.0/
	Low	Mean	11	17.5	23.9	26.5	30.4	42.2	56.2	52.4	41.4
		Range		13.0/24.0	9.0/38.0	10.0/51.0	11.0/49.5	23.0/69.0	27.0/81.5	24.0/74.0	21.0/68.1
Pygmy ♂	Low	Mean	7	15.1	24.1	43.1	52.3	62.1	55.9	43.1	39.4
		Range		2.0/21.0	14.0/30.0	23.0/54.0	25.0/74.0	36.0/76.0	29.0/75.0	27.0/64.0	23.5/62.0
Pygmy ♀	Low	Mean	6	17.3	23.7	28.7	38.7	45.5	57.3	55.2	41.5
		Range		11.0/23.0	12.0/30.0	20.0/37.0	27.0/50.0	31.0/53.0	51.0/64.0	39.0/77.0	27.0/53.0

Table 9. The average amino acid nitrogen level, urea nitrogen level, and change in weight during the 4-6-week, 10-12-week and 20-24-week intervals for both sexes in all groups.

Group	Males 4-6-Week Interval						Females 4-6-Week Interval					
	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy
Change in Weight (kg/wk)	1.303	1.258	0.946	0.758	0.645	0.306	0.958	1.003	0.572	0.641	0.473	0.578
Average Amino Acid Nitrogen Level (mg %)	7.59	7.30	6.36	6.81	6.86	6.10	7.63	7.28	6.56	6.75	6.77	6.44
Average Urea Nitrogen Level (mg %)	12.01	13.38	10.64	13.08	12.76	12.41	14.87	13.02	11.09	13.27	12.24	10.94
	Males 10-12-Week Interval						Females 10-12-Week Interval					
Change in Weight (kg/wk)	0.891	0.755	0.550	0.688	0.451	0.133	0.697	1.002	0.485	0.401	0.436	0.234
Average Amino Acid Nitrogen Level (mg %)	6.69	6.65	6.56	6.49	6.66	6.23	6.65	6.67	6.31	6.99	6.58	6.29
Average Urea Nitrogen Level (mg %)	18.37	17.59	15.17	16.19	17.52	18.98	18.30	19.29	13.92	14.23	15.99	14.18
	Males 20-24-Week Interval						Females 20-24-Week Interval					
Change in Weight (kg/wk)	0.161	0.337	0.377	0.368	0.060	0.550	0.241	0.550	0.555	0.440	0.231	0.325
Average Amino Acid Nitrogen Level (mg %)	6.98	6.70	6.13	7.28	6.93	7.09	6.95	6.98	6.96	6.79	6.99	6.90
Average Urea Nitrogen Level (mg %)	21.52	17.83	19.28	18.40	17.75	15.42	20.35	19.71	20.21	15.69	17.11	18.22

Table 10. The means, standard deviations, ranges, and number of observations for each body measurement taken at 12 and 24 weeks for both sexes in all groups of goats. All measurements are in centimeters.

Measurement	Group	Mean	Standard Deviation	Range	Number
♂ at 12 weeks					
Height					
at withers (cm)	Normal	53.27	2.95	48.0/60.4	15
	1/4 Pygmy	50.66	3.28	45.6/55.4	11
	1/2 Pygmy	45.00	5.18	35.7/52.8	9
	3/4 Pygmy	42.26	3.88	38.3/48.8	12
	7/8 Pygmy	40.30	3.81	32.0/46.1	26
	Pygmy	36.70	4.05	33.3/44.3	7
Depth					
of chest (cm)	Normal	23.37	1.46	20.0/25.0	15
	1/4 Pygmy	22.83	0.91	21.3/24.2	11
	1/2 Pygmy	20.33	2.46	16.4/23.8	9
	3/4 Pygmy	19.46	1.28	18.3/22.2	12
	3/4 Pygmy	18.49	1.87	15.0/21.3	26
	Pygmy	16.01	1.57	14.3/18.8	7
Width					
of chest (cm)	Normal	13.82	1.70	10.3/16.2	15
	1/4 Pygmy	13.46	1.34	11.4/15.6	11
	1/2 Pygmy	12.59	1.58	10.5/15.8	9
	3/4 Pygmy	12.60	1.12	11.0/14.7	12
	7/8 Pygmy	12.09	1.45	9.3/14.3	26
	Pygmy	10.54	1.62	9.0/13.8	7
Length					
from shoulders					
to pin bones (cm)	Normal	52.48	2.71	47.2/56.6	15
	1/4 Pygmy	53.47	3.17	46.0/57.8	11
	1/2 Pygmy	46.93	6.33	37.2/55.3	9
	3/4 Pygmy	45.06	3.02	41.3/50.0	12
	7/8 Pygmy	41.55	4.47	32.2/48.7	26
	Pygmy	36.30	4.79	30.0/43.5	7
Width of					
Iliac crest (cm)	Normal	10.07	0.95	7.9/11.3	15
	1/4 Pygmy	10.14	0.96	8.6/11.9	11
	1/2 Pygmy	9.41	1.51	7.1/11.8	9
	3/4 Pygmy	9.04	0.80	8.2/10.3	12
	7/8 Pygmy	8.44	1.08	6.4/10.3	26
	Pygmy	7.56	1.49	6.0/10.1	7

Table 10. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
♂ at 12 weeks					
Heart girth (cm)	Normal	60.94	4.42	50.96/66.45	15
	1/4 Pygmy	60.13	2.55	54.86/63.09	11
	1/2 Pygmy	55.30	6.54	46.63/67.06	9
	3/4 Pygmy	55.09	2.95	51.82/61.57	12
	7/8 Pygmy	51.38	4.90	41.76/59.44	26
	Pygmy	44.81	4.55	39.64/53.34	7
Paunch girth (cm)	Normal	72.25	6.40	59.13/80.16	15
	1/4 Pygmy	70.80	3.61	65.53/78.33	11
	1/2 Pygmy	65.63	6.26	58.83/78.33	9
	3/4 Pygmy	61.44	5.70	53.34/71.63	12
	7/8 Pygmy	61.13	4.46	48.77/67.66	26
	Pygmy	51.77	4.03	47.55/59.44	7
Length of metacarpus (cm)	Normal	10.38	0.88	9.14/12.19	15
	1/4 Pygmy	9.67	0.97	7.62/10.97	11
	1/2 Pygmy	7.96	0.92	7.01/9.75	9
	3/4 Pygmy	7.70	0.70	7.01/9.14	12
	7/8 Pygmy	6.97	0.73	5.49/8.84	26
	Pygmy	6.23	0.43	5.79/7.01	7
Length of metatarsus (cm)	Normal	11.60	1.05	9.45/13.41	15
	1/4 Pygmy	11.25	0.94	9.75/12.50	11
	1/2 Pygmy	9.75	0.71	8.84/10.97	9
	3/4 Pygmy	8.89	0.95	7.62/10.06	12
	7/8 Pygmy	8.30	0.89	6.40/10.06	26
	Pygmy	7.27	0.64	6.71/8.53	7
Length of head (cm)	Normal	18.67	0.94	17.1/20.5	15
	1/4 Pygmy	18.63	0.75	17.4/19.9	11
	1/2 Pygmy	17.17	1.74	14.6/19.7	9
	3/4 Pygmy	16.58	1.08	15.3/18.3	12
	7/8 Pygmy	15.87	1.38	13.5/17.6	26
	Pygmy	14.43	1.35	13.2/17.1	7
Width of head (cm)	Normal	10.33	0.41	9.5/10.8	15
	1/4 Pygmy	10.27	0.58	9.3/11.5	11
	1/2 Pygmy	9.62	0.70	8.4/10.5	9
	3/4 Pygmy	9.49	0.72	8.7/10.6	12
	7/8 Pygmy	9.04	0.78	6.2/9.8	26
	Pygmy	8.33	0.57	7.5/9.3	7

Table 10. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
♂ at 24 weeks					
Height					
at withers (cm)	Normal	57.29	4.78	48.8/64.0	14
	1/4 Pygmy	54.21	3.77	48.3/60.8	11
	1/2 Pygmy	49.60	4.67	41.8/55.5	9
	3/4 Pygmy	47.11	4.35	37.1/53.8	12
	7/8 Pygmy	44.47	4.00	37.7/50.8	24
	Pygmy	40.70	4.15	36.8/48.4	7
Depth					
of chest (cm)	Normal	26.00	2.34	21.7/29.5	14
	1/4 Pygmy	25.31	1.66	23.0/28.6	11
	1/2 Pygmy	23.46	2.15	20.0/26.0	9
	3/4 Pygmy	22.63	2.13	18.3/25.6	12
	7/8 Pygmy	20.96	2.00	17.3/24.3	24
	Pygmy	18.93	1.95	16.3/22.0	7
Width					
of chest (cm)	Normal	14.66	1.31	12.1/17.0	14
	1/4 Pygmy	14.70	1.34	12.1/17.4	11
	1/2 Pygmy	14.57	1.65	12.3/17.3	9
	3/4 Pygmy	13.48	1.48	11.9/16.3	12
	7/8 Pygmy	13.03	1.33	10.0/15.6	24
	Pygmy	12.96	1.33	11.4/14.9	7
Length					
from shoulders					
to pin bones (cm)	Normal	58.41	3.85	53.0/64.3	14
	1/4 Pygmy	58.02	3.93	53.0/63.7	11
	1/2 Pygmy	52.59	4.94	43.5/58.8	9
	3/4 Pygmy	49.29	4.23	38.7/54.8	12
	7/8 Pygmy	46.17	4.66	37.6/54.8	24
	Pygmy	43.67	3.82	38.3/50.0	7
Width of					
Iliac crest (cm)	Normal	11.33	0.98	9.7/12.8	14
	1/4 Pygmy	11.34	1.33	9.3/13.3	11
	1/2 Pygmy	11.09	1.16	9.5/13.3	9
	3/4 Pygmy	10.06	1.08	8.0/11.8	12
	7/8 Pygmy	9.59	1.03	7.9/11.8	24
	Pygmy	9.01	1.05	8.0/11.2	7

Table 10. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
♂ at 24 weeks					
Heart girth (cm)	Normal	66.67	5.42	57.61/74.68	14
	1/4 Pygmy	64.73	4.14	58.52/72.24	11
	1/2 Pygmy	62.42	4.87	54.86/70.10	9
	3/4 Pygmy	59.51	3.14	53.34/67.66	12
	7/8 Pygmy	56.16	4.20	49.09/62.48	24
	Pygmy	54.17	5.25	47.24/63.70	7
Paunch girth (cm)	Normal	81.75	5.60	71.63/92.36	14
	1/4 Pygmy	82.41	4.74	77.72/90.83	11
	1/2 Pygmy	75.69	6.20	67.06/86.26	9
	3/4 Pygmy	72.34	5.78	64.01/83.82	12
	7/8 Pygmy	69.17	5.74	58.83/78.64	24
	Pygmy	64.40	4.35	57.61/71.93	7
Length of metacarpus (cm)	Normal	11.84	1.04	10.36/14.02	14
	1/4 Pygmy	10.48	0.89	8.84/11.28	11
	1/2 Pygmy	9.49	1.06	8.53/11.28	9
	3/4 Pygmy	8.25	0.67	6.71/9.45	12
	7/8 Pygmy	7.82	1.02	6.10/9.45	24
	Pygmy	7.27	0.94	6.40/9.14	7
Length of metatarsus (cm)	Normal	12.95	1.25	11.58/16.15	14
	1/4 Pygmy	12.30	1.27	10.67/14.02	11
	1/2 Pygmy	10.80	0.93	10.06/12.80	9
	3/4 Pygmy	9.17	1.05	7.32/11.28	12
	7/8 Pygmy	8.84	0.88	7.32/10.36	24
	Pygmy	7.79	1.05	6.71/9.75	7
Length of head (cm)	Normal	20.32	1.39	18.1/22.8	14
	1/4 Pygmy	20.17	1.01	18.9/21.7	11
	1/2 Pygmy	19.43	1.54	16.4/21.5	9
	3/4 Pygmy	18.28	1.26	15.8/19.7	12
	7/8 Pygmy	17.54	1.33	15.0/19.3	24
	Pygmy	16.60	1.25	15.4/18.8	7
Width of head (cm)	Normal	11.09	0.53	10.4/12.1	14
	1/4 Pygmy	10.89	0.66	9.9/11.8	11
	1/2 Pygmy	10.67	0.49	10.0/11.5	9
	3/4 Pygmy	10.67	0.61	8.8/11.1	12
	7/8 Pygmy	9.89	0.55	8.8/10.6	24
	Pygmy	9.51	0.68	8.5/10.5	7

Table 10. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
♀ at 12 weeks					
Height					
at withers (cm)	Normal	49.56	2.94	44.3/53.1	12
	1/4 Pygmy	49.39	3.65	44.6/55.0	9
	1/2 Pygmy	43.61	1.83	41.3/46.0	8
	3/4 Pygmy	39.24	4.34	31.3/43.8	12
	7/8 Pygmy	37.57	2.86	31.9/43.0	15
	Pygmy	36.02	1.63	34.0/38.1	6
Depth					
of chest (cm)	Normal	21.53	1.59	18.5/27.9	12
	1/4 Pygmy	22.08	1.60	19.0/24.0	9
	1/2 Pygmy	19.40	0.93	17.8/20.6	8
	3/4 Pygmy	18.24	1.81	16.2/20.2	12
	7/8 Pygmy	17.35	1.43	14.5/19.3	15
	Pygmy	16.78	0.70	15.6/17.5	6
Width					
of chest (cm)	Normal	12.66	2.11	9.6/16.6	12
	1/4 Pygmy	13.49	1.03	11.3/14.5	9
	1/2 Pygmy	11.65	1.51	8.9/13.4	8
	3/4 Pygmy	12.44	2.04	9.4/15.7	12
	7/8 Pygmy	11.51	1.27	9.2/13.3	15
	Pygmy	11.67	1.09	9.5/12.5	6
Length					
from shoulders					
to pin bones (cm)	Normal	48.38	3.15	43.4/53.2	12
	1/4 Pygmy	51.06	2.20	45.4/52.5	9
	1/2 Pygmy	45.78	2.08	40.6/49.0	8
	3/4 Pygmy	42.04	4.42	37.7/49.2	12
	7/8 Pygmy	39.45	3.46	33.4/44.7	15
	Pygmy	37.08	2.41	34.5/41.7	6
Width of					
Iliac crest (cm)	Normal	9.44	0.89	7.7/10.8	12
	1/4 Pygmy	9.76	1.05	8.3/10.8	9
	1/2 Pygmy	8.96	0.62	7.9/9.6	8
	3/4 Pygmy	8.94	1.12	7.8/11.0	12
	7/8 Pygmy	8.06	1.00	6.0/9.8	15
	Pygmy	7.95	0.62	7.4/9.0	6
Heart girth					
(cm)	Normal	56.82	3.23	51.82/61.57	12
	1/4 Pygmy	59.28	5.45	48.46/64.62	9
	1/2 Pygmy	52.24	3.02	47.85/55.47	8
	3/4 Pygmy	52.17	7.83	38.10/64.62	12
	7/8 Pygmy	48.81	3.64	41.76/54.86	15
	Pygmy	46.41	1.80	44.20/49.38	6

Table 10. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
♀ at 12 weeks					
Paunch girth (cm)	Normal	67.01	5.19	58.83/75.90	12
	1/4 Pygmy	69.09	4.95	60.35/75.59	9
	1/2 Pygmy	60.31	3.30	54.86/63.70	8
	3/4 Pygmy	58.98	8.09	48.16/74.68	12
	7/8 Pygmy	57.26	2.83	50.70/65.84	15
	Pygmy	54.86	1.93	53.34/57.91	6
Length of metacarpus (cm)	Normal	9.86	1.29	7.32/10.97	12
	1/4 Pygmy	9.89	0.84	8.23/11.89	9
	1/2 Pygmy	8.00	0.76	6.71/9.14	8
	3/4 Pygmy	7.06	0.80	6.40/7.01	12
	7/8 Pygmy	6.53	0.67	5.18/7.92	15
	Pygmy	6.61	0.25	6.40/7.01	6
Length of metatarsus (cm)	Normal	10.97	0.84	9.45/12.50	12
	1/4 Pygmy	10.80	0.34	10.06/11.58	9
	1/2 Pygmy	9.18	0.48	8.23/10.06	8
	3/4 Pygmy	8.23	1.02	6.71/10.06	12
	7/8 Pygmy	7.69	0.61	6.71/8.84	15
	Pygmy	7.27	0.30	6.71/7.62	6
Length of head (cm)	Normal	17.56	1.03	15.5/19.2	12
	1/4 Pygmy	18.21	0.84	16.3/19.0	9
	1/2 Pygmy	16.25	0.52	15.3/17.0	8
	3/4 P7gmy	15.95	1.56	14.5/18.7	12
	7/8 Pygmy	15.13	1.15	13.3/18.3	15
	Pygmy	14.85	0.70	14.0/15.7	6
Width of head (cm)	Normal	9.69	0.54	8.6/10.4	12
	1/4 Pygmy	10.13	0.48	9.3/10.7	9
	1/2 Pygmy	9.16	0.35	8.7/9.7	8
	3/4 Pygmy	9.16	0.58	8.5/9.8	12
	7/8 Pygmy	8.73	0.48	7.7/9.5	15
	Pygmy	8.43	0.31	8.1/8.8	6
♀ at 24 weeks					
Height at withers (cm)	Normal	53.89	3.13	47.8/57.8	12
	1/4 Pygmy	54.42	4.86	47.6/64.3	10
	1/2 Pygmy	47.08	2.51	42.6/49.8	9
	3/4 Pygmy	43.47	4.42	37.3/50.2	11
	7/8 Pygmy	41.63	3.49	34.7/47.3	16
	Pygmy	39.93	2.33	37.3/43.3	6

Table 10. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
♀ at 24 weeks					
Depth of chest (cm)	Normal	23.79	1.17	21.6/25.8	12
	1/4 Pygmy	25.61	2.13	22.1/29.0	10
	1/2 Pygmy	22.09	1.54	20.1/24.3	9
	3/4 Pygmy	20.09	1.99	18.1/23.4	11
	7/8 Pygmy	19.62	1.88	16.3/22.5	16
	Pygmy	18.95	1.02	17.8/20.7	6
Width of chest (cm)	Normal	14.84	1.63	11.7/17.4	12
	1/4 Pygmy	15.37	1.24	13.5/17.8	10
	1/2 Pygmy	13.80	1.03	11.8/14.8	9
	3/4 Pygmy	13.92	1.83	11.5/17.5	11
	7/8 Pygmy	12.70	1.15	10.8/15.2	16
	Pygmy	13.85	1.33	11.5/15.3	6
Length from shoulders to pin bones (cm)	Normal	53.95	2.41	49.5/59.3	12
	1/4 Pygmy	56.39	3.44	49.2/62.5	10
	1/2 Pygmy	50.11	3.27	45.3/54.0	9
	3/4 Pygmy	45.50	4.33	40.5/52.8	11
	7/8 Pygmy	43.39	4.41	33.8/50.5	16
	Pygmy	43.17	1.93	40.3/45.0	6
Width of Iliac crest (cm)	Normal	10.87	1.01	9.5/12.8	12
	1/4 Pygmy	11.16	1.06	9.3/12.8	10
	1/2 Pygmy	10.79	0.96	9.5/11.7	9
	3/4 Pygmy	9.76	1.20	8.2/11.5	11
	7/8 Pygmy	9.47	0.93	8.1/11.2	16
	Pygmy	9.22	0.56	8.7/10.0	6
Heart girth (cm)	Normal	63.78	3.52	60.35/73.15	12
	1/4 Pygmy	67.33	4.80	58.52/73.15	10
	1/2 Pygmy	60.05	3.08	55.78/64.01	9
	3/4 Pygmy	57.88	6.60	49.68/67.97	11
	7/8 Pygmy	55.01	5.23	48.16/64.01	16
	Pygmy	53.69	3.69	47.24/58.52	6

Table 10. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
♀ at 24 weeks					
Paunch girth (cm)	Normal	77.60	4.15	71.02/83.82	12
	1/4 Pygmy	80.74	4.45	72.24/86.56	10
	1/2 Pygmy	71.73	2.31	67.06/76.20	9
	3/4 Pygmy	70.35	8.46	60.96/81.38	11
	7/8 Pygmy	65.77	4.93	38.10/78.03	16
	Pygmy	63.96	3.44	57.91/68.58	6
Length of metacarpus (cm)	Normal	11.08	0.47	10.36/12.19	12
	1/4 Pygmy	10.52	0.68	9.75/11.89	10
	1/2 Pygmy	8.95	0.74	7.01/9.45	9
	3/4 Pygmy	7.95	1.00	6.71/9.45	11
	7/8 Pygmy	7.47	0.78	5.49/8.53	16
	Pygmy	7.21	0.60	6.40/8.23	6
Length of metatarsus (cm)	Normal	11.79	0.77	10.67/12.80	12
	1/4 Pygmy	11.83	0.91	10.67/13.41	10
	1/2 Pygmy	10.07	0.46	9.24/10.67	9
	3/4 Pygmy	9.03	0.71	7.92/10.06	11
	7/8 Pygmy	8.40	0.57	7.62/9.45	16
	Pygmy	7.67	0.56	7.01/8.53	6
Length of head (cm)	Normal	18.92	0.99	17.1/20.5	12
	1/4 Pygmy	19.80	1.39	17.4/22.8	10
	1/2 Pygmy	18.59	0.66	17.7/19.8	9
	3/4 Pygmy	17.13	1.34	15.5/19.0	11
	7/8 Pygmy	16.68	1.10	14.5/19.0	16
	Pygmy	17.85	1.00	16.0/18.6	6
Width of head (cm)	Normal	10.50	0.50	9.7/11.4	12
	1/4 Pygmy	10.85	0.61	9.8/12.1	10
	1/2 Pygmy	10.08	0.23	9.8/10.5	9
	3/4 Pygmy	9.58	0.62	8.9/10.5	11
	7/8 Pygmy	9.44	0.47	8.5/10.5	16
	Pygmy	9.12	0.34	8.8/9.5	6

Table 11. The amount of growth between 12 and 24 weeks for each body measurement for both sexes in all groups. All measurements are given in centimeters.

	♂						♀					
	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy
Height at withers (cm)	4.02	3.55	4.60	4.85	4.17	4.00	4.33	5.03	3.47	4.23	4.06	3.91
Depth of chest (cm)	2.63	2.48	3.13	3.17	2.47	2.92	2.26	3.53	2.69	1.85	2.27	2.17
Width of chest (cm)	0.84	1.24	1.98	0.88	0.94	2.42	2.18	1.88	2.15	1.48	1.19	2.18
Length from shoulders to pin bones (cm)	5.93	4.55	5.66	4.23	4.62	7.37	5.57	5.33	4.33	3.46	3.94	6.09
Width of Iliac crest (cm)	1.26	1.20	1.68	1.02	1.15	1.45	1.43	1.40	1.83	0.82	1.41	1.27
Heart girth (cm)	5.73	4.60	7.12	4.42	4.78	9.36	6.96	8.05	7.81	5.71	6.20	7.28
Paunch girth (cm)	9.50	11.61	10.06	10.90	8.04	12.63	10.59	11.65	11.42	11.37	8.51	9.10
Length of metacarpus (cm)	1.46	0.81	1.53	0.55	0.85	1.04	1.22	0.63	0.95	0.89	0.94	0.60
Length of head (cm)	1.65	1.54	2.26	1.70	1.67	2.17	1.36	1.59	2.34	1.18	1.55	2.00
Width of head (cm)	.76	0.62	1.05	1.18	0.85	1.18	.81	.72	0.92	0.42	0.71	0.69

Table 12. Ratio of body measurement to body weight for selected measurements taken at 12 and 24 weeks for both sexes in all groups.

	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy
	♂ at 12 weeks						♀ at 12 weeks					
Height at withers	3.24	3.20	3.69	3.49	4.16	5.84	3.86	3.35	4.42	4.11	4.63	4.96
Depth of chest	1.42	1.44	1.67	1.61	1.91	2.55	1.68	1.50	1.97	1.91	2.14	2.31
Width of chest	0.84	0.85	1.03	1.04	1.25	1.68	0.99	0.91	1.18	1.30	1.42	1.61
Length from shoulders to pin bones	3.19	3.38	3.84	3.72	4.28	5.78	3.77	3.46	4.64	4.40	4.68	5.10
Width of Iliac crest	0.61	0.64	0.77	0.75	0.87	1.20	0.74	0166	0.91	0.94	0.99	1.09
Heart girth	3.71	3.80	4.53	4.55	5.30	7.14	4.42	4.01	5.29	5.46	6.01	6.39
Paunch girth	4.39	4.48	5.37	5.07	6.30	8.24	5.22	4.68	6.11	6.18	7.05	7.55
	♂ at 24 weeks						♀ at 24 weeks					
Height at withers	2.63	2.43	2.71	2.96	3.34	3.78	3.13	2.60	3.04	3.25	3.62	3.85
Depth of chest	1.19	1.13	1.28	1.42	1.57	1.76	1.38	1.22	1.43	1.50	1.71	1.83
Width of chest	0.67	0.66	0.80	0.85	0.98	1.20	0.86	0.74	0.89	1.04	1.10	1.34
Length from shoulders to pin bones	2.68	2.60	2.88	3.09	3.47	4.06	3.13	2.70	3.24	3.40	3.83	4.16
Width of Iliac crest	0.52	0.51	0.61	0.63	0.72	0.84	0.63	0.53	0.70	0.73	0.82	0.89
Heart girth	3.06	2.90	3.41	3.74	4.22	5.03	3.70	3.22	3.88	4.32	4.78	5.18
Paunch girth	3.75	3.69	4.14	4.54	5.19	5.98	4.50	3.86	4.64	5.25	5.72	6.17

Table 13. Ratio of the means of body measurements to the mean height at withers for selected measurements taken at 12 and 24 weeks for both sexes in all groups.

	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy
	♂ at 12 weeks						♀ at 12 weeks					
Body weight	0.309	0.312	0.271	0.287	0.241	0.171	0.259	0.299	0.226	0.244	0.216	0.202
Depth of chest	0.439	0.451	0.452	0.460	0.459	0.436	0.434	0.447	0.445	0.465	0.462	0.440
Width of chest	0.259	0.266	0.280	0.298	0.300	0.287	0.255	0.273	0.267	0.317	0.306	0.324
Length from shoulders to pin bones	0.985	1.07	1.04	1.07	1.03	0.99	0.976	1.03	1.05	1.07	1.05	1.03
Width of Iliac crest	0.189	0.200	0.209	0.214	0.209	0.210	0.191	0.198	0.206	0.228	0.215	0.221
Heart girth	1.140	1.19	1.23	1.30	1.28	1.22	1.15	1.20	1.20	1.33	1.30	1.29
Paunch girth	1.360	1.40	1.46	1.45	1.52	1.41	1.35	1.40	1.38	1.50	1.52	1.52
	♂ at 24 weeks						♀ at 24 weeks					
Body weight	0.380	0.412	0.369	0.338	0.300	0.265	0.320	0.384	0.329	0.308	0.276	0.260
Depth of chest	0.454	0.467	0.473	0.480	0.471	0.465	0.441	0.471	0.469	0.462	0.471	0.475
Width of chest	0.256	0.271	0.294	0.286	0.393	0.318	0.275	0.282	0.293	0.320	0.305	0.347
Length from shoulders to pin bones	1.02	1.07	1.06	1.05	1.04	1.07	1.00	1.04	1.06	1.05	1.04	1.08
Width of Iliac crest	0.198	0.209	0.224	0.214	0.216	0.220	0.202	0.205	0.229	0.225	0.228	0.230
Heart girth	1.16	1.19	1.26	1.26	1.26	1.33	1.18	1.24	1.28	1.33	1.32	1.35
Paunch girth	1.43	1.52	1.53	1.54	1.56	1.58	1.44	1.48	1.53	1.62	1.58	1.60

Table 14. The means, standard deviations, ranges and number of observations for all weights and measurements taken at 15 months for castrated males in all groups.

Measurement	Group	Mean	Standard Deviation	Range	Number
Live weight (kg)	Normal	37.551	3.694	30.618/43.319	7
	1/4 Pygmy	40.222	8.563	28.120/55.660	7
	1/2 Pygmy	28.397	5.080	22.907/36.290	5
	3/4 Pygmy	27.897	0.600	27.443/28.577	3
	7/8 Pygmy	23.916	3.227	20.639/29.257	8
	Pygmy	17.539	2.557	15.649/21.773	6
Length of metacarpus (cm)	Normal	13.8	0.55	13.0/14.6	7
	1/4 Pygmy	13.1	0.76	12.5/14.4	7
	1/2 Pygmy	11.6	0.60	11.0/12.6	5
	3/4 Pygmy	10.9	0.85	10.0/11.7	3
	7/8 Pygmy	9.8	0.86	8.4/10.7	8
	Pygmy	8.0	0.44	7.3/8.7	6
Wet-weight of heart (gm)	Normal	156.77	31.90	123.5/209.9	7
	1/4 Pygmy	189.24	36.72	137.9/252.9	7
	1/2 Pygmy	123.94	30.58	97.1/171.3	5
	3/4 Pygmy	124.33	21.04	109.4/148.4	3
	7/8 Pygmy	99.06	13.17	80.5/117.1	8
	Pygmy	81.72	16.84	63.4/110.1	6
Wet-weight of liver (gm)	Normal	584.31	89.45	462.9/717.5	7
	1/4 Pygmy	610.11	71.70	504.7/728.0	7
	1/2 Pygmy	547.84	112.94	340.2/700.4	5
	3/4 Pygmy	499.67	107.07	376.9/573.7	3
	7/8 Pygmy	382.89	74.68	274.4/493.5	8
	Pygmy	309.17	25.56	267.9/334.8	6
Wet-weight of kidney (gm)	Normal	106.09	14.54	92.1/136.7	7
	1/4 Pygmy	102.00	14.58	81.5/123.3	7
	1/2 Pygmy	88.20	23.12	57.8/113.6	5
	3/4 Pygmy	88.17	13.30	72.9/97.2	3
	7/8 Pygmy	70.95	12.92	55.5/87.6	8
	Pygmy	57.53	12.41	48.2/80.3	6

Table 14. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
Wet-weight of adrenal (gm)	Normal	2.32	0.16	2.00/2.50	7
	1/4 Pygmy	2.20	0.42	1.44/2.52	7
	1/2 Pygmy	1.84	0.54	1.25/2.65	5
	3/4 Pygmy	1.62	0.13	1.55/1.77	3
	7/8 Pygmy	1.37	0.24	1.06/1.80	8
	Pygmy	1.25	0.22	0.91/1.58	6
Wet-weight of pituitary (mg)	Normal	365.14	60.69	302/461	7
	1/4 Pygmy	379.86	85.64	234/453	7
	1/2 Pygmy	378.40	133.24	152/471	5
	3/4 Pygmy	388.00	80.30	332/480	3
	7/8 Pygmy	249.13	55.79	168/310	8
	Pygmy	221.33	38.91	151/258	6
Wet-weight of thyroid (gm)	Normal	2.28	0.53	1.49/3.25	7
	1/4 Pygmy	2.38	0.48	1.65/2.94	7
	1/2 Pygmy	2.21	0.58	1.53/3.12	5
	3/4 Pygmy	2.58	0.35	2.32/2.98	3
	7/8 Pygmy	8.53	0.40	1.05/2.26	8
	Pygmy	3.15	2.52	1.31/7.15	6
Volume of stomach (ml)	Normal	8195.0	620.22	6975/8900	7
	1/4 Pygmy	7833.0	756.00	6780/9300	7
	1/2 Pygmy	6222.0	1009.66	5500/7400	5
	3/4 Pygmy	6680.0	341.17	6400/7060	3
	7/8 Pygmy	5976.38	682.31	5050/6925	8
	Pygmy	4991.67	1224.10	3100/6200	6
Length of small intestine (m)	Normal	23.360	2.074	18.898/25.146	7
	1/4 Pygmy	22.116	2.367	18.898/26.670	7
	1/2 Pygmy	18.825	1.112	17.273/20.199	5
	3/4 Pygmy	18.085	0.567	17.556/18.648	3
	7/8 Pygmy	17.138	1.097	15.636/18.562	8
	Pygmy	15.372	1.306	14.204/17.465	6

Table 14. (Continued)

Measurement	Group	Mean	Standard Deviation	Range	Number
Length of large intestine (m)	Normal	6.517	0.435	5.974/7.391	7
	1/4 Pygmy	6.945	0.587	6.309/7.833	7
	1/2 Pygmy	5.595	0.999	3.917/6.501	5
	3/4 Pygmy	5.354	0.490	4.999/5.913	3
	7/8 Pygmy	4.900	0.631	4.084/5.944	8
	Pygmy	3.003	0.604	2.667/4.420	6
Length of caecum (cm)	Normal	24.25	5.66	19.81/33.53	7
	1/4 Pygmy	32.12	5.41	24.99/38.10	7
	1/2 Pygmy	28.23	3.02	24.08/30.48	5
	3/4 Pygmy	29.77	2.66	26.82/32.00	3
	7/8 Pygmy	22.59	3.15	18.59/27.43	8
	Pygmy	19.96	0.71	18.90/20.42	6

Table 15. Ratio of the means of organ weights and measurements to the mean live weight at slaughter for all weights and measurements taken at 15 months from castrated males in all groups. For uniformity, the decimal point has been moved so that at least one digit is included to the left of the decimal point.

	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy	Pygmy
Length of metacarpus	3.68	3.26	4.09	3.91	4.10	4.56
Heart wet-weight	4.17	4.70	4.36	4.46	4.14	4.66
Liver wet-weight	1.56	1.51	1.92	1.79	1.60	1.76
Kidney wet-weight	2.83	2.54	3.11	3.16	2.97	3.28
Adrenal wet-weight	6.18	5.47	6.48	5.81	5.73	7.13
Pituitary wet-weight	9.72	9.44	13.33	13.91	10.42	12.62
Thyroid wet-weight	6.07	5.92	7.78	9.25	6.40	18.00
Stomach volume	2.18	1.95	2.19	2.40	2.50	2.85
Length of large intestine	1.74	1.73	1.97	1.92	2.05	1.71
Length of small intestine	6.22	5.50	6.63	6.48	7.17	8.76
Length of caecum	6.46	7.99	9.94	10.67	9.44	11.38

Table 16. Ratio of the means of organ weights and measurements to the mean length of metacarpus for all weights and measurements taken at 15 months from castrated males in all groups. For uniformity, the decimal point has been moved so that at least one digit is to the left of the decimal point.

	Normal	1/4 Pygmy	1/2 Pygmy	3/4 Pygmy	7/8 Pygmy
Live weight at slaughter	2.72	3.07	2.45	2.56	2.44
Heart - wet weight	1.13	1.44	1.06	1.14	1.01
Liver - wet weight	4.23	4.66	4.72	4.58	3.91
Kidney-wet weight	7.69	7.79	7.60	8.09	7.24
Adrenal-wet weight	1.68	1.68	1.59	1.49	1.41
Pituitary-wet weight	2.65	2.90	3.26	3.56	2.54
Thyroid-wet weight	1.65	1.82	1.91	2.37	1.56
Stomach volume	5.94	5.98	5.36	6.13	6.11
Length of large intestine	4.72	5.30	4.82	4.91	5.00
Length of small intestine	1.69	1.69	1.62	1.66	1.75
Length of caecum	1.76	2.45	2.43	2.73	2.31

Table 17a. Correlation coefficients for correlations between the blood chemical level, live weight, and body measurements at week 12. Results are for data pooled from males in all six groups. Only those significant values higher than the 5% level are shown.

	Alkaline phosphatase	Amino acid nitrogen	Urea nitrogen	Height at withers	Depth of chest	Width of chest	Length from shoulders to pin bones	Width of Iliac crest	Heart girth	Paunch girth	Length of metacarpus	Length of metatarsus	Length of head	Width of head
Body weight	.537	--	--	.908	.943	.752	.938	.862	.931	.825	.880	.876	.905	.812
Alkaline phosphatase		--	--	.517	.543	.428	.514	.625	.543	.537	.453	.462	.574	.569
Amino acid nitrogen			--	--	--	--	--	--	--	--	--	--	--	--
Urea nitrogen				--	--	--	--	-.257	--	--	--	--	--	--
Height at withers					.956	.629	.935	.833	.866	.804	.882	.923	.923	.811
Depth of chest						.708	.958	.886	.930	.850	.870	.898	.942	.836
Width of chest							.686	.713	.837	.784	.702	.646	.718	.637
Length from shoulders to pin bones								.876	.909	.823	.846	.897	.842	.828
Width of Iliac crest									.901	.810	.697	.744	.889	.825
Heart girth										.884	.836	.830	.910	.819
Paunch girth											.812	.833	.823	.741
Length of metacarpus												.916	.834	.729
Length of metatarsus													.866	.725
Length of head														.845

Table 17b. Correlation coefficients for correlations between the blood chemical levels, live weight, and body measurements at 24 weeks. Results are for data pooled from males in all six groups. Only those significant values higher than the 5% level are shown.

	Alkaline phosphatase	Amino acid nitrogen	Urea nitrogen	Height at withers	Depth of chest	Width of chest	Length from shoulders to pin bones	Width of Iliac crest	Heart girth	Paunch girth	Length of metacarpus	Length of metatarsus	Length of head	Width of head
Body weight	--	--	.285	.900	.930	.714	.938	.903	.949	.881	.844	.779	.931	.886
Alkaline phosphatase		--	--	--	--	--	--	--	--	--	--	--	--	--
Amino acid nitrogen			--	--	--	--	--	--	--	--	--	--	--	--
Urea nitrogen				.392	.421	--	.387	.339	.358	--	.276	--	.380	.368
Height at withers					.918	.580	.945	.839	.875	.826	.871	.823	.896	.865
Depth of chest						.675	.954	.861	.945	.812	.830	.756	.938	.866
Width of chest							.657	.634	.736	.695	.664	.596	.673	.627
Length from shoulders to pin bones								.875	.921	.832	.885	.836	.930	.905
Width of Iliac crest									.881	.767	.757	.679	.913	.895
Heart girth										.854	.851	.761	.927	.880
Paunch girth											.846	.837	.806	.793
Length of metacarpus												.942	.808	.825
Length of metatarsus													.735	.776
Length of head														.903

Table 18a. Correlation coefficients for correlations between the blood chemical level, live weight, and body measurements at 12 weeks. Results are for data pooled from females in all six groups. Only those significant values higher than the 5% level are shown.

	Alkaline phosphatase	Amino acid nitrogen	Urea nitrogen	Height of withers	Depth of chest	Width of chest	Length from shoulders to pin bones	Width of Iliac crest	Heart girth	Paunch girth	Length of metacarpus	Length of metatarsus	Length of head	Width of head
Body weight	.381	--	.321	.867	.936	.696	.893	.826	.879	.880	.790	.819	.925	.874
Alkaline phosphatase		--	--	.487	.435	--	.432	.403	.478	.401	.289	.338	.426	.417
Amino acid nitrogen			--	--	--	--	--	--	--	--	--	--	--	--
Urea nitrogen				.358	.306	--	--	--	--	.300	.487	.420	--	.256
Height at withers					.941	.428	.895	.724	.810	.779	.850	.907	.865	.825
Depth of chest						.573	.919	.785	.856	.852	.813	.867	.923	.872
Width of chest							.541	.655	.710	.746	.451	.461	.662	.604
Length from shoulders to pin bones								.764	.833	.813	.788	.856	.902	.866
Width of Iliac crest									.794	.758	.601	.657	.877	.819
Heart girth										.858	.663	.742	.871	.814
Paunch girth											.742	.796	.850	.791
Length of metacarpus												.936	.766	.734
Length of metatarsus													.833	.766
Length of head														.888

Table 18b. Correlation coefficients for correlations between the blood chemical level, live weight, and body measurements at 24 weeks. Results are for data pooled from females in all six groups. Only those significant values higher than the 5% level are shown.

	Alkaline phosphatase	Amino acid nitrogen	Urea nitrogen	Height at withers	Depth of chest	Width of chest	Length from shoulders to pin bones	Width of Iliac crest	Heart girth	Paunch girth	Length of metacarpus	Length of metatarsus	Length of head	Width of head
Body weight	.319	--	--	.893	.933	.740	.911	.869	.917	.867	.816	.772	.911	.912
Alkaline phosphatase		--	.310	.402	.402	--	.444	.372	.354	--	.364	--	.344	.363
Amino acid nitrogen			--	--	--	--	--	--	--	--	--	--	--	--
Urea nitrogen				.276	.353	--	.344	.303	.286	--	.249	--	.333	--
Height at withers					.932	.591	.931	.765	.852	.798	.916	.845	.872	.907
Depth of chest						.658	.949	.831	.928	.839	.870	.797	.902	.918
Width of chest							.625	.710	.733	.796	.615	.616	.644	.644
Length from shoulders to pin bones								.786	.875	.799	.897	.806	.879	.878
Width of Iliac crest									.852	.768	.682	.635	.876	.838
Heart girth										.873	.818	.716	.862	.881
Paunch girth											.791	.813	.789	.817
Length of metacarpus												.890	.789	.821
Length of metataursus													.734	.779
Length of head														.901

Table 19. Correlation coefficients for correlations between all weights and measurements taken at 15 months. Only those significant values higher than the 5% level are shown.

	Length of metacarpus	Heart wet-weight	Liver wet-weight	Kidney wet-weight	Adrenal wet-weight	Pituitary wet-weight	Thyroid wet-weight	Stomach volume	Length of sm. intestine	Length of lg. intestine	Length of caecum
Live weight	.900	.918	.839	.833	.811	.652	--	.781	.751	.902	.660
Length of metacarpus		.806	.815	.793	.777	.603	--	.799	.808	.870	.532
Heart wet-weight			.847	.843	.784	.658	--	.688	.675	.852	.701
Liver wet-weight				.920	.759	.767	--	.704	.755	.876	.673
Kidney wet-weight					.731	.779	--	.716	.747	.845	.587
Adrenal wet-weight						.516	--	.732	.746	.749	.483
Pituitary wet-weight							--	.450	.602	.650	.611
Thyroid wet-weight								--	--	--	--
Stomach volume									.800	.759	.487
Length of sm. intestine										.802	.426
Length of lg. intestine											.666

DISCUSSION

Dwarfism has been described in most domestic and laboratory animals and the genetic mode of inheritance has been studied in many of these cases. Sollas (1914) found that a ratio of three normal size to one dwarf existed in the offspring produced from the mating of two guinea pigs heterozygous for a dwarf characteristic. The dwarfs were sterile and he was unable to develop a pure dwarf line. He concluded that the mode of inheritance was by a simple recessive allele. King (1950) reported that a ratio of three normal size to one pygmy resulted from crossing mice heterozygous for a dwarf characteristic. The dwarfs were sterile and the mode of inheritance was also believed to be due to a recessive allele. In rabbits both dominant and recessive alleles have been found determining dwarfism. Castle (1940) reported on dwarf rabbits which were not sterile and was able to cross them together. When dwarf rabbits heterozygous for the dwarf characteristic were mated, a ratio of one normal size to three dwarfs was obtained. He concluded that the dwarf characteristic in this case was determined by a dominant allele. Green (1940) described in detail dwarf Polish rabbits, and concluded that the dwarfism in that case was due to an incompletely recessive characteristic.

Dwarfism in cattle has been studied extensively due to its

economic importance. Both recessive and dominant alleles have been shown to be the mode of inheritance (Elings, 1953; Gregory et al., 1951, 1952, 1953; Johansson and Rendel, 1968; Johnson et al., 1950; Pahnish et al., 1952). Dwarfism in poultry has also been studied. Punnett (1923) described a cross of a Golden-pencilled Hamburg cock to Silver Sebright bantam hens. The progeny were intermediate in weight, but closer in size to the larger breed. A wide range of size was found in the F_2 generation with several of the progeny being larger than the Hamburg cock, and others being smaller than the Sebright hens. It was suggested that transgressive inheritance might be involved.

Frequently associated with dwarfism are congenital defects, sterility, and high pre-adult mortality. The pygmy goats, on the other hand, have no associated congenital defects, are fertile, and do not appear to have a significant amount of early life mortality.

Epstein (1946) believed that the dwarfing of the African Hejaz dwarf goat was due to hereditary hypoplasia of the pituitary gland, while Staffe (1938) conjectured that the African dwarf goat represented a special case of disproportionate dwarfism of chondrodystrophy kind. Chang and Landauer (1950) in their study of the dwarf goat found, however, that the bones did not show any of the features typical of chondrodystrophy, and concluded that it was not the cause of the dwarfing. In their examination of the thyroid gland they found

no evidence of disfunction and examination of the pituitary gland showed none of the features characteristic of other pituitary dwarfism. A preliminary endocrine study of the African pygmy goat (Bogart, unpublished data) indicated that blood taken from the cavernous sinus of castrated 3/4 pygmy and 7/8 pygmy males contained less growth and more gonadotropic hormones than blood from castrated normal males. Further examination of the endocrine glands needs to be done.

The results of the present study show that the pygmy goat is significantly smaller in size than the normal goat. When weights of the normal and pygmy goats used in the study are compared with weights obtained from other studies (Table 20) a close similarity is observed. The greater 12-week weights of the pygmy goats reported by Rogers et al. (1969) than those of goats in the present study can be explained in part by the practice at the University of Oregon Medical School of bottle feeding the pygmy kids. The weights for Saanen goats reported by Spector (1956) show a higher 24-week weight than do the normal goats from the present study. The reason may be in part due to the mixed breeding of our normal goats, and part due to differences in husbandry techniques.

An examination of the mean weights of the crossbred groups (Figure 2 and Figure 3) show that the mean weight of the 1/2 pygmy group tends to approximate the mean of the normal group more

closely than the mean of the pygmy group. The mean weight of the 1/4 pygmy group approximates the mean of the normal group more closely than the mean of the 1/2 pygmy group. In addition, the mean weight of the 3/4 pygmy group approximates the mean of the 1/2 pygmy group more closely than the mean of the pygmy group. The same tendencies are also seen in the means of measurements both at 12 and 24 weeks of age (Table 10). Slaughter weights and measurements at 15 months of age also show these tendencies (Table 14).

Table 20. Mean weights in kg of normal and pygmy goats obtained from the literature compared to the results from the present study.

	Pygmy (Rogers 1969)		Pygmy (This study)	
	Males	Females	Males	Females
Birth	1.9 kg	1.7 kg	1.6 kg	1.4 kg
12 weeks	9.0 kg	7.4 kg	6.3 kg	7.3 kg

	Saanen Goats (Spector 1956)		Normal Goats (This study)	
	Males	Females	Males	Females
Birth	3.6	3.1	3.8	3.6
12 weeks	15.0	14.5	16.5	12.9
24 weeks	24.5	24.5	21.8	17.2

As the relationship to the pure pygmy increased, the ratios of body measurements to weight (Table 12) and the ratios of body measurements to height at withers (Table 13) also increased. Thus, as the relationship to the pygmy increased, the goats became

proportionally deeper, wider, longer, and greater in circumference than would have been predicted on the basis of the measurements of the normal goats. The ratio of slaughter weights and measurements to body weight (Table 15), and the ratio of slaughter weights and measurements to length of metacarpus (Table 16) both show that as the relationship to the pure pygmy increased the size of the organs became proportionally larger than would have been predicted on the basis of the measurements and weights of the normal goats.

From Table 1 it can be seen that goats from all groups except the pygmy were examined in each of the three years of this study. Blood analyses were performed on the day the animals were bled. Thus, the results presented in this study represent trends observed over a three year period.

None of the blood chemicals tested showed a pattern between the six groups that remained constant throughout the 24 week period for either males or females (Figures 4, 5 and 6). When the means of the blood chemicals were tested by an analysis of variance for significant differences between means, only alkaline phosphatase activity for the females at 24 weeks, and urea nitrogen for the females at 12 weeks showed a significant difference (Table 6). From an examination of Table 9 it can be seen that amino acid nitrogen and urea nitrogen did not have a constant pattern from group to group within any of the three growth periods examined. However,

a trend does exist if the preweaning and postweaning levels of amino acid nitrogen and urea nitrogen within each group of goats are examined separately (Table 9). During the preweaning period the levels of amino acid nitrogen were higher at the 4-6-week period than during the 10-12-week period. The level of amino acid nitrogen decreased during the preweaning period. During the postweaning period, however, the level of amino acid nitrogen was lower during the 10-12-week period than during the 20-24-week period. The amino acid nitrogen level increased during the postweaning period. This was true for both sexes in all groups with the exception of the pygmy group. Urea nitrogen levels on the other hand, constantly increased throughout the 24 week period in both sexes in all groups except the pygmy males. Plasma levels of amino acid nitrogen and urea nitrogen have been reported for normal adult non-lactating females as 6.45 mg % and 17.43 mg % respectively (Houchin et al., 1939). Amino acid nitrogen levels in serum are expected to be slightly higher than in plasma because amino acids are released during clotting (Hawk et al., 1954). Serum levels of urea nitrogen have been reported for 12 and 26 week old pygmy males as 17.1 mg % and 19.9 mg % respectively, and for pygmy females 12 and 26 weeks as 15.9 mg % and 25.0 mg % respectively (Metcalfe et al., 1970). The values obtained in the present study are comparable (Appendix 3). The lower value of urea nitrogen obtained for the pygmy

males at 24 weeks in the present study (Appendix 3) may be due in part to the rapid rate of gain of these goats during the 20-24-week period (Table 9).

Bogart et al. (1963), working with beef cattle, have suggested that rapidly gaining animals have a greater capacity for withdrawing amino acids from the blood stream resulting in lower levels of amino acid nitrogen in the blood, than in the slower gaining animals. The latter deaminize excess amino acids and excrete the nitrogenous fraction as urea resulting in higher levels of urea nitrogen in the blood and urine. These ideas were to be tested in the normal, pygmy, and crossbred goats. It is assumed that the goats raised in this study were on an adequate, although not high, plane of nutrition. The animals were group fed all of the alfalfa hay they would consume during a 24-hour period and were given supplemental grain daily. All of the animals had equal access to hay and grain. It is, therefore, most probable that the levels of amino acid nitrogen and urea nitrogen obtained are representative values, and can be used in a comparative way. The larger and more rapidly gaining goats in the study did not have a consistently lower level of amino acid nitrogen than did the smaller, slower gaining animals (Table 9 and Figure 5). Furthermore, amino acid nitrogen was not significantly correlated with weight at either 12 or 24 weeks either for the males or the females. Urea nitrogen levels were also not consistently higher in the slower

gaining animals (pygmy) than in the faster gaining animals (normals) (Table 9 and Figure 6). It appears as though interactions between age, maturity, amount of growth, and absolute weight are interrelated in determining the urea nitrogen levels.

The original design of the investigation called for a concurrent study of the nutrition of the six groups of goats used in the present investigation. The nutrition work had to be abandoned due to lack of funds. It is unfortunate, then, that a complete interpretation of the amino acid nitrogen and urea nitrogen levels cannot be made at this time.

The results obtained for urea nitrogen and amino acid nitrogen were not compared to a metabolically effective body weight (W^b) due to the young age of the animals (W^b is equal to $W^{1.0}$) and to the lack of information on the metabolism of the goats (Brody, 1945).

Variation in alkaline phosphatase activity indicated the presence of a polymorphic condition (Table 8). Variation in alkaline phosphatase activity has been described in several species of animals including sheep (Rendel et al., 1964), cattle (Kunkel et al., 1953), swine (Combs et al., 1959) and chickens (Wilcox, 1963).

Rendel et al. (1964) found three levels of alkaline phosphatase activity in sheep. These levels corresponded closely to blood type groupings. Kunkel et al. (1953) found that Brahman cattle and breeds of European cattle had different levels of alkaline phosphatase

activity. Furthermore, although the activity of the alkaline phosphatase dropped rapidly with age in the European cattle, the activity of alkaline phosphatase remained high in the Brahman cattle, even with age. Wilcox (1963) has been able to breed lines of chickens with high and low levels of alkaline phosphatase activity. In the present study there does not appear to be a significant correlation of alkaline phosphatase activity with weight (Table 5). Furthermore, it was not possible to determine a particular phenotype within each group of goats on the basis of alkaline phosphatase activity.

It is interesting to note that the lowest activity level of alkaline phosphatase generally occurred in each group between weeks 12 and 16; that is, the period immediately following weaning. It has been suggested (Correll and Wise, 1938; Hibbs et al., 1945; Combs et al., 1955) that alkaline phosphatase activity reflects various nutritional states. It is possible therefore, that the low point following weaning is indicative of a nutritional stress brought about by a change of diet.

Using the data obtained from the present study, it is possible to propose a genetic model for the pygmy characteristic. Such a model must meet three criteria. First, it must apply not only to the normal and pygmy groups, but also to the crossbred groups. Second, it must explain the distributions encountered in the crossbred groups. Third, the proposed model must be consistent with the available data.

The proposed model consists of two genes, a major gene and a modifier gene. The effect of the major gene is to produce large changes in size of the animals. The effect of the modifier gene is to modify the effectiveness of the major gene. Both the major and modifier genes appear to show incomplete dominance when in the heterozygous condition.

In the following discussion, N will represent one allele of the major gene and n the other allele. A will represent one allele of the modifier gene and a the other allele. The genotype of the normal goats will be given as NNaa and that of the pygmy goats as nnAA.

A genotype of NnAa would be produced in the offspring (1/2 pygmy group) of a normal and pygmy cross. Four genotypes NnAa, Nnaa, NNAa, and NNaa could be produced within different offspring (1/4 pygmy group) by backcrossing the F_1 to the normal group. Four genotypes, NnAa, NnAA, nnAa, and nnAA could also be produced in different offspring (3/4 pygmy group) by backcrossing the F_1 to the pygmy group. The same four genotypes found in the 3/4 pygmy group could also be found in the 7/8 pygmy group but in different proportions (as seen later).

If the 12 and 24 week weights in Appendix 2 are examined it can be seen that for both sexes the mean weight of the pygmy group is approximately 60% that of the normal group, and that the mean weight of the 1/2 pygmy group is approximately 80% that of the normal group.

Using the genotypes of the normal, 1/2 pygmy, and pygmy groups as reference points, the effects of the major and modifier genes can be calculated.

It is proposed for the major gene that NN will determine maximum effectiveness of the major gene's potential effect, that Nn will determine 70% of the maximum value and that nn will determine 40% of the maximum value. For the modifier gene it is proposed that AA increases the value of the major gene it is modifying by 40%, that Aa increases the value of the major gene it is modifying by 20%, and that aa does not increase (or increases very slightly) the value of the major gene it is modifying.

Using the proposed values for NN, Nn, nn, AA, Aa, and aa the expected weights for both males and females at 12 and 24 weeks have been calculated. These are shown along with the actual values in Table 23. The results of testing the actual and theoretical values by the Chi-square test are shown in Table 21. The distributions were not significantly different for either sex at 12 or 24 weeks.

Table 21. Chi-square values testing the significance between the actual and predicted distributions of body weight for males and females at 12 and 24 weeks. Chi-square is significant at A = .05 if the value exceeds 7.82 with 3 degrees of freedom.

Week	Sex	Chi-square
12	♂	.661
24	♂	.396
12	♀	.7276
24	♀	1.6588

The same calculations were performed for body height at withers for both sexes at 12 and 24 weeks. In this case NN again determined the maximum potential effectiveness of the major gene, but Nn determined 75% of the maximum potential of the major gene, and nn determined 50% of the maximum potential of the major gene. Values for AA, Aa, and aa remained at 40%, 20%, and 0% respectively.

The predicted results are shown along with the actual results in Table 24. These results were also tested with the Chi-square test (Table 22), and the distribution of the actual results, again, were not significantly different from the predicted. The effect of the major gene was increased when calculating the height at the withers because the pygmy and 1/2 pygmy groups were taller in proportion to the normal goat than that found for weight.

The distribution of actual weights of 1/4 pygmy, 3/4 pygmy, and 7/8 pygmy males and females at 12 weeks are found in Figure 7, and for 24 weeks in Figure 8. Although the numbers in each group are small, the general distribution predicted in Table 23 can be seen.

The 1/4 pygmy males and females show fewer low weight animals (i.e. Nnaa) than predicted. This tends to increase the mean weight above that which is expected. Early mortality of some of the smaller 1/4 pygmy kids may be part of the answer. The females of the 1/4 pygmy group show the predicted NNAa (animals larger than

the normals) better than do the males. Although the 3/4 pygmy group does not show definite peaks at the predicted points, the distribution is comparable to that predicted. The 7/8 pygmy group has fewer of the smaller animals (i.e. nnAA) and fewer of the larger animals (i.e. NnAA) than predicted. Early mortality of some of the smaller 7/8 kids may be part of the reason. The distribution of the 7/8 group is, however, comparable to that predicted. The model appears to meet the criteria established.

Table 22. Chi-square values testing the significance between the actual and predicted distributions of height at withers for males and females at 12 and 24 weeks. Chi-square is significant at A = .05 if value exceeds 7.82 with 3 degrees of freedom.

Week	Sex	Chi-square
12	♂	.1651
24	♂	.1268
12	♀	.1575
24	♀	.3595

In the truest sense, this is an example of transgressive inheritance. Similarities are noted between the present study and the results obtained in the Hamburg-Sebright experiments mentioned earlier (Punnett, 1923), in that the F_1 approximates the size of the larger parent more than the smaller parent, and that animals larger and smaller than the parent types were obtained. It is predicted that in the F_2 generation, kids will be produced exceeding in size the normal goats (NNAA, NNAa), and smaller in size than the pygmy

(nnaa, Nnaa). Breeding together of F_1's has been initiated, but results have not yet been obtained.

Two possible practical applications arise from the results of this study. It might be possible to increase the size of the commercial breeds of goats by a selected breeding program. Pygmy males could be crossed with females of the desired breed. The F_1 generation should in turn be crossed among themselves and the largest kids of the F_2 generation selected. By breeding these selected animals together it should be possible to produce a pure breeding strain of goats (NNAA) that are larger in size than the original breed (NNaa). This could result in more marketable products (for example goat's milk) per animal than are now obtained. Brody (1945) has shown that all other conditions being equal, the conversion of feed into milk production will increase with an increase in the size of the body. The increase in milk production was shown to be related with, approximately, the .7 power of body weight ($W^{.7}$). That is, a 10% increase in body weight should be accompanied with a 7% increase in milk production. It remains to be seen if the dairy quality of the goat would be reduced by the introduction of pygmy genes.

A second possible practical application could be the development of better tasting goat meat. Johnston et al. (1963) showed that members of a trained taste panel found lambs producing the more desirable meat had significantly higher alkaline phosphatase activities

than did the animals producing the less desirable meat. It is possible that through selection, lines of goats could be produced with high levels of alkaline phosphatase activity. With the world food supply becoming less adequate, there is an increased demand for new and better foods and food production methods. The goat represents a relatively undeveloped source of food production.

Table 23. The predicted distribution and values for body weight for each genotype within the 1/2 pygmy, 1/4 pygmy, 3/4 pygmy, 7/8 pygmy and pygmy groups, along with the expected and actual mean weights for each group at 12 and 24 weeks.

Week	Group	Sex	Genotypes	Values of genotypes in kg	Proportion of genotypes within groups	Expected mean weight in kg	Actual mean weight in kg
12	1/2 pygmy	♂	NnAa	13.814	1	13.814	12.212
12	1/4 pygmy	♂	NNAa	19.734	1/4		
	1/4 pygmy	♂	NNaa	16.445	1/4	15.286	15.814
	1/4 pygmy	♂	NnAa	13.814	1/4		
	1/4 pygmy	♂	Nnaa	11.152	1/4		
12	3/4 pygmy	♂	NnAa	13.814	1/4		
	3/4 pygmy	♂	NnAA	16.116	1/4	11.753	12.115
	3/4 pygmy	♂	nnAa	7.884	1/4		
	3/4 pygmy	♂	nnAA	9.199	1/4		
12	7/8 pygmy	♂	NnAa	13.814	1/16		
	7/8 pygmy	♂	NnAA	16.116	3/16	10.537	9.697
	7/8 pygmy	♂	nnAa	7.884	3/16		
	7/8 pygmy	♂	nnAA	9.199	9/16		
12	pygmy	♂	nnAA	9.199	1	9.199	7.267
24	1/2 pygmy	♂	NnAa	18.293	1	18.293	18.290
24	1/4 pygmy	♂	NNAa	26.132	1/4		
	1/4 pygmy	♂	NNaa	21.777	1/4		
	1/4 pygmy	♂	NnAa	18.293	1/4	20.361	22.338
	1/4 pygmy	♂	Nnaa	15.244	1/4		
24	3/4 pygmy	♂	NnAa	18.338	1/4		
	3/4 pygmy	♂	NnAA	21.342	1/4	15.585	15.929
	3/4 pygmy	♂	nnAa	10.465	1/4		
	3/4 pygmy	♂	nnAA	12.195	1/4		
24	7/8 pygmy	♂	NnAa	18.338	1/16		
	7/8 pygmy	♂	NnAA	21.342	3/16	13.969	13.324
	7/8 pygmy	♂	nnAa	10.465	3/16		
	7/8 pygmy	♂	nnAA	12.195	9/16		
24	pygmy	♂	nnAA	12.195	1	12.195	10.770

Table 23. (Continued)

Week	Group	Sex	Genotypes	Values of genotypes in kg	Proportion of genotypes within groups	Expected mean weight in kg	Actual mean weight in kg
12	1/2 pygmy	♀	NnAa	10.793	1	10.793	9.871
12	1/4 pygmy	♀	NNAa	15.419	1/4		
	1/4 pygmy	♀	NNaa	12.849	1/4	12.013	14.767
	1/4 pygmy	♀	NnAa	10.793	1/4		
	1/4 pygmy	♀	Nnaa	8.994	1/4		
12	3/4 pygmy	♀	NnAa	10.793	1/4		
	3/4 pygmy	♀	NnAA	12.592	1/4	9.187	9.548
	3/4 pygmy	♀	nnAa	6.168	1/4		
	3/4 pygmy	♀	nnAA	7.196	1/4		
12	7/8 pygmy	♀	NnAa	10.793	1/16		
	7/8 pygmy	♀	NnAA	12.592	3/16	8.239	8.120
	7/8 pygmy	♀	nnAa	6.168	3/16		
	7/8 pygmy	♀	nnAA	7.196	9/16		
12	pygmy	♀	nnAA	7.196	1	8.239	8.120
24	1/2 pygmy	♀	NnAa	14.483	1	14.483	15.478
24	1/4 pygmy	♀	NNAa	20.689	1/4		
	1/4 pygmy	♀	NNaa	17.241	1/4	16.120	20.916
	1/4 pygmy	♀	NnAa	14.483	1/4		
	1/4 pygmy	♀	Nnaa	12.069	1/4		
24	3/4 pygmy	♀	NnAa	14.483	1/4		
	3/4 pygmy	♀	NnAA	16.897	1/4	12.327	13.389
	3/4 pygmy	♀	nnAa	8.275	1/4		
	3/4 pygmy	♀	nnAA	9.654	1/4		
24	7/8 pygmy	♀	NnAa	14.483	1/16		
	7/8 pygmy	♀	NnAA	16.897	3/16	11.055	11.507
	7/8 pygmy	♀	nnAa	8.275	3/16		
	7/8 pygmy	♀	nnAA	9.654	9/16		
24	pygmy	♀	nnAA	9.654	1	9.654	10.373

Table 24. The predicted distribution and value for height at withers for each genotype within the 1/2 pygmy, 1/4 pygmy, 7/8 pygmy, and pygmy groups, along with the expected and actual mean heights for each group at 12 and 24 weeks.

Week	Group	Sex	Genotype	Values of genotypes in mm	Proportion of genotypes within group	Expected mean height in mm	Actual mean height in mm
12	1/2 pygmy	♂	NnAa	47.94	1	47.94	45.00
12	1/4 pygmy	♂	NNAa	63.82	1/4		
	1/4 pygmy	♂	NNaa	53.27	1/4	51.24	50.66
	1/4 pygmy	♂	NnAa	47.94	1/4		
	1/4 pygmy	♂	Nnaa	39.95	1/4		
12	3/4 pygmy	♂	NnAa	47.94	1/4		
	3/4 pygmy	♂	NnAA	55.93	1/4	43.28	42.26
	3/4 pygmy	♂	NnAa	31.97	1/4		
	3/4 pygmy	♂	nnAA	37.30	1/4		
12	7/8 pygmy	♂	NnAa	47.94	1/16		
	7/8 pygmy	♂	NnAA	55.93	3/16	40.46	40.30
	7/8 pygmy	♂	nnAa	31.97	3/16		
	7/8 pygmy	♂	nnAA	37.30	9/16		
12	pygmy	♂	nnAA	37.30	1	37.30	36.70
24	1/2 pygmy	♂	NnAa	51.56	1	51.56	49.60
24	1/4 pygmy	♂	NNAa	68.75	1/4		
	1/4 pygmy	♂	NNaa	57.29	1/4	55.14	54.21
	1/4 pygmy	♂	NnAa	51.56	1/4		
	1/4 pygmy	♂	Nnaa	42.97	1/4		
24	3/4 pygmy	♂	NnAa	51.56	1/4		
	3/4 pygmy	♂	NnAA	60.15	1/4	46.55	47.11
	3/4 pygmy	♂	nnAa	34.38	1/4		
	3/4 pygmy	♂	nnAA	40.11	1/4		
24	7/8 pygmy	♂	NnAa	51.56	1/16		
	7/8 pygmy	♂	NnAA	60.15	3/16	43.51	44.47
	7/8 pygmy	♂	nnAa	34.38	3/16		
	7/8 pygmy	♂	nnAA	40.11	9/16		
24	pygmy	♂	nnAA	40.11	1	40.11	40.70

Table 24. (Continued)

Week	Group	Sex	Genotype	Values of genotypes in mm	Proportion of genotypes within group	Expected mean height in mm	Actual mean height in mm
12	1/2 pygmy	♀	NnAa	44.60	1	44.60	43.62
12	1/4 pygmy	♀	NNAa	59.47	1/4		
	1/4 pygmy	♀	NNaa	49.56	1/4	47.70	49.39
	1/4 pygmy	♀	NnAa	44.60	1/4		
	1/4 pygmy	♀	Nnaa	37.17	1/4		
12	3/4 pygmy	♀	NnAa	44.60	1/4		
	3/4 pygmy	♀	NnAA	52.03	1/4	40.26	39.24
	3/4 pygmy	♀	nnAa	29.74	1/4		
	3/4 pygmy	♀	nnAA	34.70	1/4		
12	7/8 pygmy	♀	NnAa	44.60	1/16		
	7/8 pygmy	♀	NnAA	52.03	3/16	37.64	37.57
	7/8 pygmy	♀	nnAa	29.74	3/16		
	7/8 pygmy	♀	nnAA	34.70	9/16		
12	pygmy	♀	nnAA	34.70	1	34.70	36.02
24	1/2 pygmy	♀	NnAa	48.23	1	48.23	47.08
24	1/4 pygmy	♀	NNAa	64.31	1/4		
	1/4 pygmy	♀	NNaa	53.59	1/4	51.58	54.42
	1/4 pygmy	♀	NnAa	48.23	1/4		
	1/4 pygmy	♀	Nnaa	40.19	1/4		
24	3/4 pygmy	♀	NnAa	48.23	1/4	43.54	43.47
	3/4 pygmy	♀	NnAA	56.27	1/4		
	3/4 pygmy	♀	nnAa	32.16	1/4		
	3/4 pygmy	♀	nnAA	37.52	1/4		
24	7/8 pygmy	♀	NnAa	48.23	1/16		
	7/8 pygmy	♀	NnAA	56.27	3/16	40.71	41.63
	7/8 pygmy	♀	nnAa	32.16	3/16		
	7/8 pygmy	♀	nnAA	37.52	9/16		
24	pygmy	♀	nnAA	37.52	1	37.52	39.93

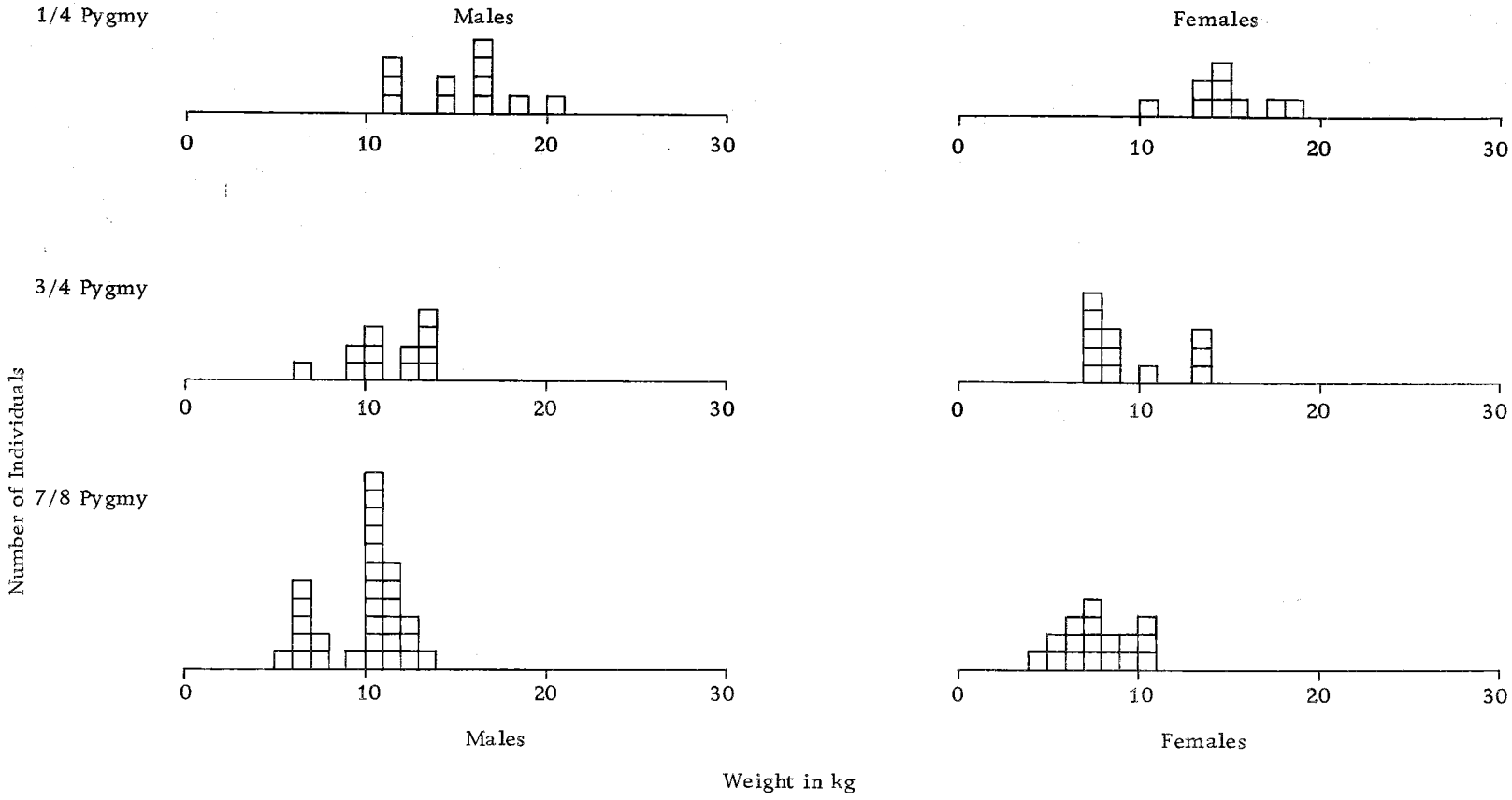

Figure 7. The actual distribution of weights (kg) in 1/4 pygmy, 3/4 pygmy and 7/8 pygmy groups for males and females at 12 weeks. Distributions approximate those predicted on the basis of the two gene models.

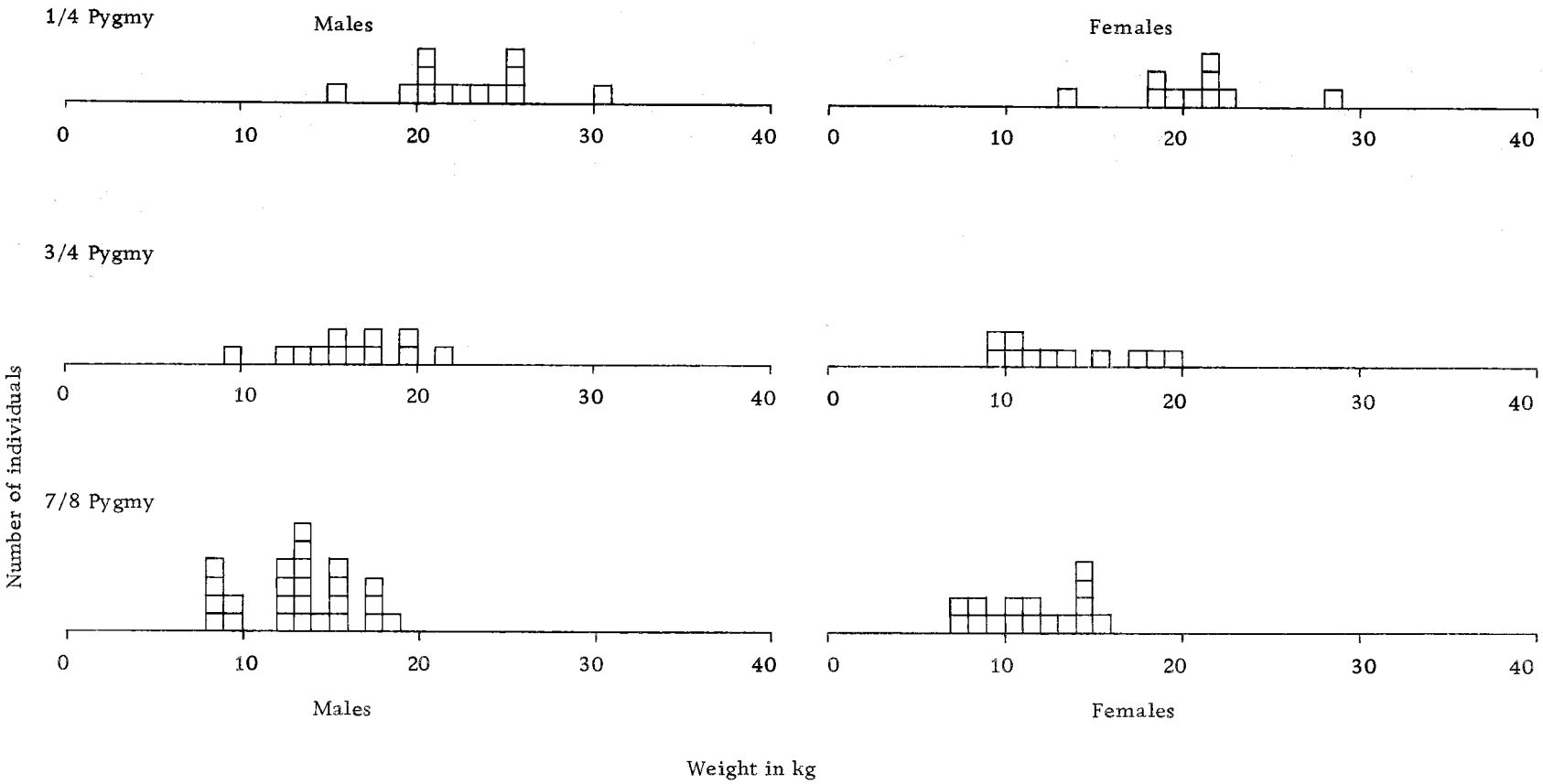

Figure 8. The actual distribution of weights (kg) in 1/4 pygmy, 3/4 pygmy and 7/8 pygmy groups for males and females at 24 weeks. Distributions approximate those predicted on the basis of the two gene models.

SUMMARY AND CONCLUSIONS

Six groups of goats (normal, 1/4 pygmy, 1/2 pygmy, 3/4 pygmy, 7/8 pygmy, and pygmy) were used in the study. The mean weight of the 1/2 pygmy group approximated more closely that of the normal group than that of the pygmy group. The mean weight of the 1/4 pygmy group approximated that of the normal group more closely than the mean weight of the 1/2 pygmy group. The mean weight of the 3/4 pygmy group approximated the mean weight of the 1/2 pygmy group more closely than that of the pygmy group. The same relationships among groups that were observed for the weights were also observed for the 12 and 24 week measurements, and the 15 month weights and measurements.

A wide range in weight, 12 and 24 week body measurements, and weights and measurements taken at 15 months was found in the crossbred groups. Some animals in the 1/4 pygmy group were larger than some of the normal goats, and some animals in the 3/4 pygmy and 7/8 pygmy groups were smaller than some of the pure pygmy animals.

As the relationship to the pure pygmy group increased, the goats became proportionally deeper, wider, longer, and greater in circumference than would have been expected on the basis of the normal goats. In the same manner, as the relationship to the pygmy

increased, the weights and measurements of the internal organs increased above that expected on the basis of weights and measurements of the normal goats.

Three blood chemicals, amino acid nitrogen, urea nitrogen, and alkaline phosphatase, were examined at 4, 6, 8, 10, 12, 16, 20 and 24 weeks of age. Amino acid nitrogen did not change significantly with increasing age or weight. However, the level generally decreased in the six groups during the preweaning period, and increased during the postweaning period. Urea nitrogen levels increased significantly in both sexes as age and weight increased. The levels of urea nitrogen increased during both the preweaning and postweaning periods. Alkaline phosphatase activity decreased significantly with increasing age, but showed no significant association with changes in weight. Three levels of alkaline phosphatase activity were observed; high, medium, and low. All three levels were found in the normal, 1/4 pygmy, and 1/2 pygmy groups. The medium and low levels were found in the 3/4 pygmy, and 7/8 pygmy groups. Only the low level was found in the pygmy group. The low point in alkaline phosphatase activity was found during the period following weaning.

A genetic model was proposed for the inheritance of the pygmy characteristic. The proposed model consists of two genes, a major gene and a modifier gene. The effect of the major gene is to produce

large changes in the size of the animals, while the effect of the modifier gene is to regulate the effectiveness of the major gene. Both appear to show incomplete dominance when in the heterozygous condition. The genotype of the normal goats was proposed as being NNaa, and that of the pygmy as being nnAA, where N and n are alleles of the major gene, and A and a are alleles of the modifier gene. Using the weight of the normal goat as a standard, the theoretical values of each possible genotype in each group was calculated. Theoretical means were calculated for each of the groups and found not significantly different from the means actually obtained. The model served to explain the wide range in size found within each of the crossbred groups.

Two possible applications arise from the study. The first is the possibility of increasing the size of present commercial goats by a breeding and selection program using pygmy and normal goats. The second is the possibility of developing lines of goats with high levels of alkaline phosphatase activity, in the hopes of producing more desirable goat meat.

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APPENDICES

APPENDIX 1

The multiple correlation coefficients (R^2) for the correlation of weight with the number of siblings and the year of birth. The correlation coefficients indicate the contribution of the variables in reducing the variance of weight. The low R^2 values indicate that the number of siblings accounted for less than 2.5% of the variance in weight in any of the periods tested. Weights at birth, 12 weeks, and 24 weeks were examined.

Age	R^2 for number of siblings	R^2 for year of birth
Birth	.024	.028
12 weeks	.008	.010
24 weeks	.020	.024

APPENDIX 2

The means, standard deviations, ranges and number of observations for the weights from birth through 24 weeks of age of male and female goats.

The means, standard deviations, ranges and number of observations for the weights from birth through 24 weeks of age of male and female goats, by group.

Sex	Age	Mean (kg)	Standard Deviation (±)	Range (kg)	Number
Normal Group					
♂	Birth	3.833	0.354	3.266/4.355	16
	4 weeks	8.634	1.478	6.985/11.068	9
	6 weeks	11.240	1.309	9.027/13.880	14
	8 weeks	13.041	1.633	10.070/15.422	14
	10 weeks	14.663	2.079	10.614/17.282	15
	12 weeks	16.445	2.281	11.975/19.187	15
	16 weeks	19.168	3.538	12.202/27.216	14
	20 weeks	21.133	4.139	13.018/28.732	14
	24 weeks	21.777	5.158	14.515/30.456	14
♀	Birth	3.357	0.499	2.359/4.445	14
	4 weeks	6.994	1.060	5.307/9.208	11
	6 weeks	8.909	1.603	5.715/11.884	12
	8 weeks	10.084	1.719	7.031/13.336	13
	10 weeks	11.455	2.434	7.439/15.695	13
	12 weeks	12.849	2.449	8.029/16.330	12
	16 weeks	15.266	3.065	10.297/19.596	11
	20 weeks	16.276	2.697	12.882/20.593	11
	24 weeks	17.241	3.058	12.156/22.453	12
1/4 Pygmy Group					
♂	Birth	3.459	0.637	2.177/4.400	12
	4 weeks	8.041	1.802	4.763/10.660	9
	6 weeks	10.557	1.876	6.305/12.565	12
	8 weeks	12.066	2.274	7.348/14.606	11
	10 weeks	14.304	2.227	9.435/17.010	12
	12 weeks	15.814	2.742	11.068/20.457	11
	16 weeks	18.692	3.485	14.243/23.814	12
	20 weeks	20.991	3.910	15.332/27.216	12
	24 weeks	22.338	4.325	15.377/30.397	11
♀	Birth	3.155	0.478	2.449/3.856	11
	4 weeks	7.276	0.868	4.627/8.437	10
	6 weeks	9.282	1.623	6.623/11.975	11
	8 weeks	12.213	5.308	8.256/13.835	11
	10 weeks	12.763	1.874	9.526/15.921	11
	12 weeks	14.767	2.413	10.025/18.053	9
	16 weeks	16.441	2.649	11.794/22.181	11
	20 weeks	18.716	3.529	13.608/27.670	10
	24 weeks	20.916	3.775	28.577/13.699	10

Appendix 2 (Continued)

Sex	Age	Mean (kg)	Standard Deviation (±)	Range (kg)	Number
1/2 Pygmy Group					
♂	Birth	2.717	0.582	1.950/3.674	9
	4 weeks	6.515	1.440	4.672/8.845	8
	6 weeks	8.407	1.932	5.851/11.612	9
	8 weeks	9.581	2.440	6.078/13.245	9
	10 weeks	11.113	3.101	6.441/15.967	9
	12 weeks	12.212	3.637	6.895/17.328	9
	16 weeks	15.609	4.441	8.845/21.455	9
	20 weeks	16.783	4.829	9.072/23.360	9
	24 weeks	18.290	5.008	10.569/25.492	9
♀	Birth	2.350	0.457	1.724/3.402	10
	4 weeks	5.398	0.918	4.445/7.122	8
	6 weeks	6.542	0.957	5.035/7.893	9
	8 weeks	7.312	1.405	4.944/9.163	10
	10 weeks	8.902	1.291	4.397/10.886	8
	12 weeks	9.871	1.483	7.983/11.884	8
	16 weeks	11.043	2.200	8.754/13.699	9
	20 weeks	13.250	2.149	10.387/16.239	9
	24 weeks	15.468	2.079	12.610/18.008	9
3/4 Pygmy Group					
♂	Birth	2.453	0.428	1.860/3.266	13
	4 weeks	5.806	1.507	3.629/8.301	11
	6 weeks	7.321	1.673	6.537/9.571	12
	8 weeks	8.679	1.836	5.625/11.340	12
	10 weeks	10.740	1.350	8.256/12.383	9
	12 weeks	12.115	1.651	6.532/13.744	12
	16 weeks	13.275	2.734	7.439/16.738	12
	20 weeks	14.457	3.303	8.709/18.779	12
	24 weeks	15.929	3.347	9.480/21.319	12
♀	Birth	2.200	0.282	1.770/2.631	12
	4 weeks	5.386	0.745	3.946/6.305	11
	6 weeks	6.668	1.358	4.899/8.981	12
	8 weeks	7.632	1.487	5.761/9.979	12
	10 weeks	8.747	2.162	6.486/12.338	12
	12 weeks	9.548	2.540	7.258/13.835	12
	16 weeks	10.803	2.824	7.847/15.468	12
	20 weeks	11.629	3.581	7.530/17.146	11
	24 weeks	13.389	3.663	9.480/19.641	11

Appendix 2 (Continued)

Sex	Age	Mean (kg)	Standard Deviation (±)	Range (kg)	Number
7/8 Pygmy Group					
♂	Birth	2.241	0.332	1.633/2.767	32
	4 weeks	4.957	0.860	3.221/6.532	26
	6 weeks	6.247	1.440	3.493/8.210	26
	8 weeks	7.695	1.731	4.309/10.070	27
	10 weeks	8.795	1.889	4.763/11.385	29
	12 weeks	9.697	2.269	5.171/13.245	26
	16 weeks	11.542	2.813	5.443/16.420	27
	20 weeks	13.085	3.154	7.484/18.915	25
	24 weeks	13.324	3.109	8.482/18.371	24
♀	Birth	1.973	0.331	1.406/2.631	18
	4 weeks	4.428	0.758	3.266/5.670	18
	6 weeks	5.374	1.132	3.583/7.167	17
	8 weeks	6.383	1.430	4.082/8.709	17
	10 weeks	7.248	1.740	4.491/10.342	17
	12 weeks	8.120	1.853	4.990/10.977	15
	16 weeks	9.286	2.208	6.124/12.156	14
	20 weeks	10.584	2.578	6.577/14.152	15
	24 weeks	11.507	2.735	7.348/15.649	16
Pygmy Group					
♂	Birth	1.568	0.327	1.225/2.041	7
	4 weeks	3.975	0.965	2.767/5.262	7
	6 weeks	4.588	0.969	3.720/6.124	7
	8 weeks	5.417	1.708	3.901/8.754	7
	10 weeks	6.014	2.325	3.992/10.660	7
	12 weeks	6.279	2.687	3.856/11.703	7
	16 weeks	7.757	2.958	4.990/13.926	7
	20 weeks	8.570	3.209	5.443/14.969	7
	24 weeks	10.770	3.209	8.074/17.055	7
♀	Birth	1.543	0.091	1.452/1.679	6
	4 weeks	3.584	0.538	2.858/4.899	4
	6 weeks	4.740	0.598	3.765/5.625	6
	8 weeks	6.026	1.027	4.491/7.666	6
	10 weeks	6.797	1.334	5.080/9.072	6
	12 weeks	7.265	1.314	5.489/9.526	6
	16 weeks	8.066	1.405	6.214/10.115	6
	20 weeks	9.072	1.569	7.076/10.478	6
	24 weeks	10.373	1.748	8.165/12.610	6

APPENDIX 3

The means, standard deviations, ranges and number of observations for alkaline phosphatase, amino acid nitrogen, and urea nitrogen for both males and females in each group of goats.

The means, standard deviations, ranges and number of observations for alkaline phosphatase, amino acid nitrogen and urea nitrogen for both males and females in each group of goats.

Group Sex	Age	Alkaline Phosphatase Mean (% transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance) Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
Normal							
♂	4 weeks	10.9 7.51	3.5/28.0 9	8.07 1.31	6.0/9.43 9	10.38 3.54	5.25/15.50 9
	6	12.2 7.74	4.0/28.0 14	7.10 0.80	5.25/8.46 14	13.64 5.39	4.88/27.88 14
	8	20.1 13.39	4.5/42.0 14	7.55 1.20	5.80/9.65 14	15.67 4.65	9.50/25.68 14
	10	23.4 18.66	4.0/60.0 15	6.84 0.93	5.81/9.87 15	17.55 4.16	10.25/23.75 15
	12	25.7 18.05	6.0/61.7 15	6.53 0.77	5.43/8.25 15	19.19 5.59	11.13/34.25 15
	16	39.7 26.31	8.0/83.0 14	6.97 0.63	6.00/8.56 14	19.46 4.66	12.25/27.25 14
	20	34.4 19.91	6.0/72.0 14	7.06 0.76	6.00/8.56 14	20.10 5.54	12.50/31.75 14
	24	36.3 19.61	6.0/71.0 14	6.89 0.55	5.71/7.68 14	22.93 8.36	12.00/38.50 14

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase Mean (% transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance) Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
Normal ♀	4 weeks	13.7 6.85	5.0/25.0 11	8.24 1.26	5.68/9.62 11	13.45 2.46	8.38/16.75 11
	6	16.8 12.6	8.0/51.0 12	7.03 1.22	5.49/9.21 12	16.28 4.38	7.75/25.25 12
	8	20.9 14.85	3.5/51.0 13	7.67 1.40	5.93/9.84 13	16.78 5.99	5.00/31.25 13
	10	20.6 15.69	5.0/49.7 13	6.75 1.02	6.00/9.79 13	18.03 4.49	8.75/25.75 13
	12	29.1 12.97	10.0/75.5 12	6.55 0.91	5.54/8.00 12	18.56 3.76	10.00/25.25 12
	16	36.3 22.20	6.0/80.0 11	6.44 0.78	4.92/7.31 11	23.14 7.80	15.00/36.25 11
	20	36.6 21.37	6.0/74.0 11	6.78 0.99	5.05/9.06 11	20.96 6.74	13.75/34.50 11
	24	33.1 18.64	7.0/62.2 12	7.11 0.87	5.68/8.46 12	19.74 6.80	10.00/30.75 12

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase Mean (% transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance) Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
1/4 Pygmy							
♂	4 weeks	10.4	5.0/20.5	7.04	5.40/8.78	11.81	6.50/16.00
		6.12	9	1.16	9	2.85	9
	6	16.9	6.0/48.0	7.56	5.72/10.22	14.94	10.75/22.38
		13.17	12	1.51	12	3.77	12
	8	15.0	7.0/32.2	6.96	5.55/9.87	16.39	9.50/24.50
		9.12	11	1.24	11	4.71	11
	10	20.42	6.0/62.0	6.73	6.00/7.50	17.92	10.88/23.75
		17.16	12	0.49	12	4.83	12
	12	34.3	65/88.0	6.57	6.07/7.74	17.26	11.63/23.00
		30.29	11	0.48	11	3.88	11
	16	38.9	7.0/85.2	6.77	5.57/8.14	20.59	11.25/32.50
		23.19	12	0.76	12	5.66	12
	20	32.1	8.0/76.9	6.78	6.00/8.29	18.18	9.25/32.25
		24.36	12	0.77	12	6.44	12
	24	44.5	6.0/71.0	6.61	6.06/7.33	17.47	9.63/31.50
		18.30	11	0.39	11	5.98	11

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase Mean (% transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance) Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
1/4 Pygmy ♀	4 weeks	12.7 6.48	6.0/24.5 10	7.10 1.01	6.08/9.54 10	12.56 2.15	7.75/15.13 10
	6	15.8 6.72	8.0/25.2 11	7.44 1.71	5.75/10.77 11	13.48 3.78	6.25/18.50 11
	8	20.0 9.39	10.0/38.2 11	8.09 1.80	6.21/11.02 11	17.87 3.00	13.25/24.00 11
	10	23.6 15.92	9.0/57.0 11	6.56 0.53	5.87/8.00 11	17.30 3.76	12.75/25.25 11
	12	33.2 26.69	10.0/84.5 9	6.78 0.64	6.00/7.57 9	21.28 5.63	11.63/29.00 9
	16	45.4 24.81	9.0/78.0 11	7.40 0.91	5.92/8.73 11	24.11 10.66	11.38/45.50 11
	20	38.5 17.97	12.0/67.9 10	6.90 0.63	5.85/8.05 10	19.21 5.49	10.50/24.75 10
	24	37.6 19.60	11.5/61.4 10	7.05 0.50	6.30/7.70 10	20.21 6.90	12.88/30.38 10

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase Mean (%transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance) Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
1/2 Pygmy ♂	4 weeks	21.4 18.22	5.0/59.0 8	6.57 0.53	5.93/7.60 8	10.63 1.76	9.13/14.50 8
	6	24.4 20.78	6.0/60.2 9	6.14 0.34	5.43/6.55 9	10.65 2.31	7.75/14.25 9
	8	29.6 23.75	6.0/69.8 9	6.56 0.37	6.00/7.22 9	14.22 3.28	10.25/18.63 9
	10	28.9 22.05	4.7/64.1 9	6.57 0.45	6.15/7.42 9	14.27 4.80	7.50/20.00 9
	12	34.0 21.47	7.0/75.8 9	6.55 0.72	5.63/7.83 9	16.06 4.35	11.13/25.25 9
	16	32.7 20.34	8.0/70.0 9	7.02 0.60	6.38/7.89 9	15.64 2.75	12.13/19.75 9
	20	43.3 26.68	8.1/75.0 9	6.98 0.74	5.85/8.11 9	20.19 8.67	7.50/32.00 9
	24	41.6 27.38	8.0/83.0 9	7.06 0.72	6.40/8.74 9	18.36 6.08	10.38/26.75 9

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase Mean (% transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
1/2 Pygmy ♀	4 weeks	12.6 7.18	6.0/23.5 8	6.94 1.34	5.86/9.06 8	10.03 2.50	5.50/14.75 8
	6	21.6 12.89	7.0/47.0 9	6.17 0.91	5.40/8.40 9	12.14 3.72	7.75/20.75 9
	8	35.8 16.22	14.0/64.0 10	6.69 1.04	5.64/8.69 10	16.23 8.06	7.25/34.50 10
	10	25.9 18.15	8.0/63.0 8	6.45 0.43	5.86/6.92 8	14.39 3.36	9.50/18.25 8
	12	28.0 15.19	10.0/56.0 8	6.16 0.36	5.68/6.67 8	13.44 3.56	8.75/17.75 8
	16	38.4 22.93	10.0/84.0 9	7.05 1.87	5.19/11.74 9	17.97 4.67	11.88/25.50 9
	20	30.6 18.50	8.0/68.5 9	7.00 0.41	6.16/7.62 9	18.06 6.10	11.88/30.75 9
	24	28.9 14.51	8.0/48.0 9	6.91 0.63	6.13/7.71 9	22.35 5.74	13.25/32.50 9

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase		Amino Acid Nitrogen		Urea Nitrogen	
		Mean (% transmittance) Standard deviation (±)	Range (% transmittance) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number
3/4 Pygmy							
♂	4 weeks	14.2	6.0/24.0	6.66	5.65/8.17	11.49	7.75/15.00
		5.45	11	0.89	11	2.31	11
	6	21.3	5.0/34.0	6.95	6.08/8.48	14.67	10.00/19.50
		8.74	12	0.72	12	3.33	12
	8	27.3	11.0/42.0	6.60	5.69/7.73	15.79	10.25/22.0
		10.02	12	0.53	12	3.14	12
	10	30.9	15.0/50.1	6.47	6.13/6.92	15.90	8.50/23.38
		12.01	9	0.25	9	4.22	9
	12	38.5	12.0/47.0	6.51	5.51/7.33	16.47	10.50/21.50
		8.25	12	0.63	12	3.23	12
	16	50.4	25.0/66.0	6.82	5.85/8.07	19.46	7.13/30.50
		13.31	12	0.70	12	7.19	12
	20	50.4	31.0/76.0	7.54	5.92/11.06	18.86	12.50/28.00
		14.13	12	1.51	12	4.12	12
	24	44.0	25.0/76.0	7.02	6.14/7.74	17.93	9.50/28.25
		16.21	12	0.42	12	5.05	12

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase		Amino Acid Nitrogen		Urea Nitrogen	
		Mean (% transmittance) Standard deviation (±)	Range (% transmittance) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number
3/4 Pygmy							
♀	4 weeks	17.3	13.0/24.0	6.76	5.59/8.56	12.01	10.00/14.75
		3.52	11	0.93	11	1.79	11
	6	23.5	9.0/41.0	6.73	5.20/8.65	14.52	9.63/18.75
		9.27	12	1.05	12	3.20	12
	8	26.23	10.0/51.0	7.24	6.15/8.95	15.01	11.50/17.75
		13.18	12	0.79	12	2.15	12
	10	30.4	11.0/49.5	6.93	6.24/9.56	14.67	9.50/18.25
		10.55	12	0.87	12	2.75	12
	12	41.6	23.0/69.0	7.05	6.00/8.50	13.78	10.00/21.00
		15.46	12	0.82	12	3.68	12
	16	52.8	16.0/81.0	6.47	4.92/8.25	18.02	9.25/27.13
		21.03	12	0.99	12	4.80	12
	20	48.7	24.0/68.0	6.75	5.60/8.18	16.46	11.63/23.00
		12.89	11	0.81	11	3.91	11
	24	41.9	21.0/68.1	6.83	5.87/7.85	14.91	10.00/18.25
		13.29	11	0.55	11	2.71	11

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase		Amino Acid Nitrogen		Urea Nitrogen	
		Mean (% transmittance) Standard deviation (±)	Range (% transmittance) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number
7/8 Pygmy ♂	4 weeks	21.9 13.13	5.0/59.0 26	6.84 1.09	5.59/9.21 26	12.06 4.11	5.25/19.25 26
	6	26.2 18.18	5.0/70.0 26	6.87 0.76	5.63/9.11 26	13.46 4.83	7.13/23.50 26
	8	31.0 17.84	6.0/71.0 27	7.36 1.56	5.74/10.77 27	15.28 4.36	8.50/25.00 27
	10	35.7 17.01	6.0/70.2 29	6.65 0.75	5.52/8.56 29	17.26 5.29	9.75/34.50 29
	12	42.8 14.19	6.0/63.0 26	6.66 0.94	5.63/10.06 26	17.78 6.07	8.75/33.75 26
	16	57.4 17.3	27.0/84.5 27	6.88 0.71	5.50/8.36 27	18.99 5.52	10.00/32.25 27
	20	56.1 15.12	27.0/86.0 25	6.95 0.83	5.43/8.29 25	17.96 6.15	9.25/37.50 25
	24	55.7 16.83	21.0/85.0 24	6.92 0.72	6.06/8.50 24	17.53 5.36	10.00/28.50 24

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase Mean (% transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance) Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
7/8 Pygmy							
♀	4 weeks	19.3	8.0/44.0	6.54	5.64/8.54	12.26	8.50/26.75
		9.15	18	0.93	18	4.17	18
	6	27.2	8.0/60.0	6.99	5.62/9.28	12.21	6.50/20.50
		14.49	17	1.00	17	3.91	17
	8	37.1	16.0/61.7	6.91	5.57/11.80	16.30	9.25/22.63
		13.49	17	1.35	17	3.55	17
	10	41.8	15.0/63.0	6.47	5.47/8.25	16.89	12.25/23.75
		13.90	17	0.71	17	3.72	17
	12	42.0	22.0/76.0	6.68	5.31/8.99	15.09	8.00/22.00
		15.40	15	1.03	15	4.25	15
	16	48.1	11.0/81.0	6.53	5.45/8.12	18.55	8.50/28.50
		19.09	14	0.78	14	6.71	14
	20	48.9	24.0/76.2	7.14	5.63/9.72	16.07	7.63/31.75
		15.58	15	1.16	15	5.80	15
	24	49.1	16.0/76.0	6.83	5.77/8.74	18.15	8.50/27.50
		14.31	16	0.79	16	5.50	16

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase Mean (% transmittance) Standard deviation (±)	Alkaline Phosphatase Range (% transmittance) Number	Amino Acid Nitrogen Mean (mg %) Standard deviation (±)	Amino Acid Nitrogen Range (mg %) Number	Urea Nitrogen Mean (mg %) Standard deviation (±)	Urea Nitrogen Range (mg %) Number
Pygmy ♂	4 weeks	15.8 4.58	10.0/20.0 8	6.29 0.85	5.44/7.95 8	11.56 4.83	4.00/14.75 8
	6	24.1 5.21	14.0/30.0 7	5.90 0.31	5.49/6.26 7	13.25 3.80	7.75/19.25 7
	8	43.1 9.63	23.0/54.0 7	6.42 0.31	5.93/6.75 7	16.77 4.11	10.13/22.00 7
	10	52.3 16.94	25.0/74.0 7	6.23 0.36	5.86/6.93 7	18.61 6.23	11.65/28.25 7
	12	62.1 13.11	36.0/76.0 7	6.23 0.95	5.66/8.33 7	19.34 5.96	10.00/28.50 7
	16	55.7 16.47	29.0/75.0 7	6.65 0.56	5.68/7.42 7	17.71 6.03	11.00/29.50 7
	20	43.1 11.71	27.0/64.0 7	6.80 0.47	6.38/7.73 7	16.47 2.34	11.63/18.63 7
	24	39.4 16.83	23.5/63.0 7	7.38 0.78	6.60/8.65 7	14.36 4.81	8.75/20.00 7

Appendix 3 (Continued)

Group Sex	Age	Alkaline Phosphatase		Amino Acid Nitrogen		Urea Nitrogen	
		Mean (%transmittance) Standard deviation (±)	Range (%transmittance) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number	Mean (mg %) Standard deviation (±)	Range (mg %) Number
Pygmy ♀	4 weeks	15.8 4.03	11.0/23.0 4	6.59 4.056	6.10/7.23 4	10.00 3.18	7.75/18.50 4
	6	23.7 8.96	12.0/37.0 6	6.28 0.45	5.86/6.95 6	11.88 1.91	10.00/14.75 6
	8	28.7 5.72	26.0/37.0 6	6.48 0.39	6.00/7.00 6	13.63 2.92	9.50/17.25 6
	10	38.7 9.95	27.0/50.0 6	6.30 0.79	5.55/7.69 6	13.86 3.36	10.38/18.75 6
	12	45.5 9.81	31.0/58.0 6	6.28 0.38	5.61/6.67 6	14.5 3.08	9.50/17.50 6
	16	57.3 5.65	51.0/64.0 6	6.77 0.73	6.00/7.68 6	13.42 4.86	8.25/21.25 6
	20	54.2 13.51	39.0/77.0 6	7.10 0.95	6.27/8.82 6	17.14 4.38	11.63/22.88 6
	24	44.8 8.38	29.0/53.0 6	6.70 0.94	5.56/7.95 6	19.29 3.52	12.25/22.00 6