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A STUDY OF BLOOD TYPE FREQUENCIES AND ASSOCIATION OF BLOOD TYPES WITH OTHER TRAITS IN AN ANGUS HERD

A Thesis

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Master of Science

Degree

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ABSTRACT

Over a ten-year period (1970), blood types, weaning and post-weaning weights and gains and body measurements have been recorded from animals in the Angus herd at the University of Tennessee Plateau Experiment Station. Analyses of blood group frequencies revealed that either random genetic drift or changes and/or additions in blood typing procedures could be an important consideration in assessing trends in the herd. The herd became infected with brucellosis in 1976, and eradication was accomplished in 1980. Impressively low probabilities (.12 to .16) of chance occurrence of greater chi-square values were obtained in the B, C, and S blood group systems and in the blood serum transferrin system when chi-square was calculated using the observed frequency of reactors to the brucellosis test in the entire herd as a basis for calculating expected numbers of reactors in each blood group within a system. Even though these probabilities are greater than the traditional .05 significance level, they constitute reasonably strong evidence for some association of frequency of brucellosis reactors with blood type. Analyses of variance were performed on adjusted weaning and postweaning weights, average daily gains and body measurements to determine if any associations existed with blood types within a system. The effects of sire within year were removed from all analyses and, where applicable, data were adjusted to remove variation due to differences in age of dam, sex of calf, and age of calf. Significant ($P < .05$ or $P < .01$) differences were found among least-squares means of average daily gains of cattle of different types within the S system and within the blood

serum transferrin system, among least-squares means of adjusted weaning weights in the Z system and transferrins and among least-squares means of adjusted postweaning weights in the S system. Significant ($P < .05$ or $P < .01$) differences were found among least-squares means of various body measurements of cattle of different types within the F-V, J and S blood group systems. Observations were divided within blood group systems into two large classes of heterozygous and homozygous blood types and analyses of variance were performed with the same quantitative variables mentioned above as dependent variables. Significant ($P < .05$ or $P < .01$) differences between homozygotes and heterozygotes were found in the S and Z systems with respect to average daily gains and adjusted weaning and postweaning weights, and, within the M and S systems, differences were found with respect to various body measurements. In a comparison of observed and expected heterozygosis within the F-V and R'-S' systems, no significant differences were found in any year with respect to the F-V system. Significant differences were found in years 1975 to 1979 within the R'-S' system, but due to unreliability of the blood typing procedures in this system, no definite conclusion can be drawn.

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CHAPTER I

INTRODUCTION

Researchers have been interested in blood types in several species and have attempted to discover associations between cellular phenogroups of blood group systems and traits such as quantitative production traits and disease resistance. In the Angus herd at the University of Tennessee Plateau Experiment Station, blood types, weaning and postweaning weights and gains, and body measurements, have been recorded annually. Due to an outbreak of brucellosis in this herd, cattle were tested at regular intervals and records were kept of all animals reacting to the test. The objectives of this investigation were to combine these data for the years 1970 through 1979 and analyze them to:

1. Determine the frequencies of the various blood phenogroups within blood group systems in each calf crop and use fluctuations of these from calf crop to calf crop as an indication of the extent of random genetic drift.

2. Determine if any associations exist between blood types and reaction to the brucellosis test.

3. Determine if any associations exist between blood types and recorded quantitative variables.

4. Determine if any associations exist between heterozygous and homozygous blood types and recorded quantative variables.

5. Compare observed and calculated heterozygosis in the F-V and R'-S' blood group systems.

CHAPTER II

REVIEW OF LITERATURE

General Information

The blood type of an animal refers to the combination of known blood antigens found on the erythrocytes, determined by tests made with available reagents (Stormont et al., 1951). Blood types in cattle, as usually typed, are divided into eleven blood group systems. A blood group system is comprised of a series of antigens controlled by the alleles at a particular chromosome locus. The eleven systems used in blood typing at present are symbolically designated as A, B, C, F-V, J, K, L, M, S, Z, R'-S' and T. Each of those systems contains blood groups or phenogroups. A blood group or phenogroup is comprised of one or more blood antigens. In some systems, such as the B system, 9 or more antigens combine together to form one blood group. Blood factors belonging to the same genetic blood group system are inherited by means of allelic genes, each a simple Mendelian dominant in contrast to its absence, which is recessive, in all but the F-V and R'-S' systems in which dominance is not complete. Each bovine blood antigen makes its appearance on the red blood cells only when present on one or both of the individual's parents' erythrocytes (Stormont, 1967).

Blood typing is the process of testing red blood cells of an individual with antibody fluids referred to as reagents. The blood factors on the red cells act as antigens, and, when they come in contact with their specific antibody, the antibody is bound to that red blood

cell. The appearance of this reaction will be agglutination or clumping of the red blood cells. Another reaction that can take place is hemolysis, but hemolysis will not take place unless an enzyme-like substance known as complement is added to the red blood cell-antibody mixture. Complement is obtained from fresh serum. Cattle red cells will not readily agglutinate, hence lytic procedures must be used, and fresh rabbit serum is the complement used (Stormont, 1967; Irwin, 1974; Stormont, 1962).

Cattle blood types are the most complex of any species known. The most complex system is the B system with more than 300 alleles at one locus. Following in decreasing order of complexity are C, A, S, F-V, M, R'-S', J, L, T, and Z. It has been estimated that somewhere in the neighborhood of two trillion blood types are possible. This is probably greater than the number of cattle that have thus far inhabited the earth, thus, cattle blood type is indeed a unique trait. The study of immunogenetics is not a static field. New alleles, blood groups and even systems still have the potential of being discovered. Thus, blood type data are ever changing as more information becomes available, but the individual animal's blood type itself is fixed and unchanging (Stormont, 1967; Weseli, 1972).

Blood type data have been used to solve disputed cases of parentage, in twin studies and in identifying free-martins (Irwin, 1974; Rasmusen, 1959). Studies have been conducted in the hope of discovering associations of blood types with production characteristics and with disease resistance. More discussion concerning these aspects will follow. Population genetics studies have been conducted using

blood type data to determine breed origins, relationships between breeds and in studies concerning herds that have been isolated for long periods of time (Rausch et al., 1967; Larsen et al., 1974; Miller, 1966; Stormont, 1967). These are the most common uses of blood type data thus far. The cellular phenogroups do constitute genetic markers that may be used to detect events or presence of additional heritable traits that otherwise might go unnoticed (Irwin, 1974).

Relationships Between Diseases and Blood Groups

A study was conducted by Briles et al. (1977) with two lines of chickens. One line had been selected over several generations for resistence to Marek's disease and the other line was selected for susceptibility to Marek's disease. The individual chickens were blood typed, and agglutination tests for antigens of the B alloalleles were performed. All 313 individuals comprising the resistant line were homozygous for the allele B^{21}, and, among the 420 susceptible individuals, two other alleles existed, B^{13} with a frequency of .03 and B^{19} with a frequency of .97. Backcrosses were made using F_1 females which were the result of crosses made between resistant individuals and susceptible individuals. These F_1 females were mated to susceptible males. These matings produced the same results; that is, those individuals which were resistant to Marek's disease contained the B^{21} allele, and the susceptible birds possessed the B^{13} and B^{19} alleles. In all the matings combined, the incidence of the disease among chicks of genotype $B^{19}B^{19}$ was approximately eight times that among those of genotype $B^{19}B^{21}$. The authors of this paper reasoned that these observations

suggest that the relationship between a particular allele of the B system and the degree of resistance to Marek's disease is due to differences in immune response. Citations of other research concerning the relationship between Marek's disease and the B^{21} and B^{19} alleles in which the same basic results were found have been included in the Briles et al. (1977) paper.

In Finnish cattle, an interesting case occurred in which twelve calves were produced from inbred matings of a bull named Saku. These twelve calves all possessed a lethal gene for hairlessness and prolonged gestation. Most of these calves were stillborn, but a few lived for as long as 36 hours. Maijala et al. (1964) decided to investigate the possibility of a relationship between this recessive lethal gene and the blood group genes. The A, B, C, F-V, J, L, M, S and Z systems were studied. No evidence was found to link the gene for hairlessness with any blood group allele analyzed within these systems.

A study was made in the Soviet Union to determine whether a particular blood group allele occurred at a higher frequency in leukemic animals. Shadmanov et al. (1976) found that the L and Z alleles occurred more frequently in leukemic animals than in healthy animals. In addition, they found that the I allele of the B system occurred more often in the healthy animals. Within this herd of Black Spotted cattle, the $BC_3O_3Y_2O'$ and $Y_2E'I'$ alleles of the B system occurred only in leukemic animals two to four years of age.

Steinberg et al. (1980) reported findings of an association between blood group O and peptic ulcer incidence in humans. Individuals with blood group O have a 30 to 40 percent greater incidence of peptic

ulcers than those with the remaining blood groups. This observation has been reported by other researchers in other countries studying different racial and ethnic groups. This association has been observed particularly with duodenal ulcer, combined gastric and duodenal ulcers and ulcers of the body of the stomach. A small, statistically significant relationship between blood group O and ulcer complications, particularly bleeding, have been observed. No physiological basis for the blood group O association has been found.

Relationships Between Production Traits and Blood Groups

Many researchers have studied the possible effect of blood groups upon milk production characteristics. One of the earlier studies was conducted by Mitseterlick et al. (1959). They found a rather strong depression in the milk yield of German-Friesian cattle carrying the M gene. Heifers with the M allele produced 332 kg less milk, on the average, than did their non-M paternal half sibs. Neimann-Sorensen and Robertson (1961) conducted an extensive study of three Danish dairy breeds, namely, the Red Danish Dairy (RDM), Black and White Dairy (SDM) and Jersey. They studied a total of 2378 animals within 185 progeny groups. Analyses were conducted using the A, J, L, M, F-V, Z, three alleles of the S, seven alleles of the C, and nine alleles of the B systems. The production characteristics included in the analyses were weight on arrival at the experiment station, age at first calving, service period, 304-day milk yield, fat percentage and milking time. No significant effects of blood group alleles could be found within any breed on weight on arrival, age at first calving, service period

or milking time. Significant differences were found among blood types in milk yield and fat percentage. RDM heifers with the B allele BO_1Y_1D' had significantly ($P < .05$) higher fat percentage ($.064 \pm .015$) than did their contemporaries. The heifers were then divided into two groups by breed. Those with the highest fat percentage were grouped separately from those with the lowest fat percentage, and those with the highest milk yield were grouped separately from those with the lowest milk yield. In the B system, twice as many animals with the BO_1Y_1D' allele were in the high fat percentage group of the RDM breed. In Jerseys, the GD' alleles occurred more frequently in the high fat percentage group while $O_1TE'_3K'$ occurred more frequently in the low fat percentage group. When the B system was compared to all other systems in a multiple allele chi-square test, significant deviations from expectation were found in the RDM breed for fat percentage and milk yield, and in Jerseys for fat percentage. It was noted in these results, as is generally observed, that an increase in fat percentage is accompanied by a decrease in milk yield. Bulls carrying the BO_1Y_1D' allele were compared to bulls not carrying this allele within groups of paternal half brothers. The progeny of sires carrying BO_1Y_1D' tested lower by 39 kg for milk yield and higher by .017 for fat percentage.

Rendel (1961) conducted a study of Swedish cattle to determine if there was an association between blood groups and fat percentage, fat yield and heart girth measurements of paternal half sibs. He found that daughters of bulls with the BO_1Y_1D' allele had a higher average fat percentage of .19 units than did their paternal half sibs lacking this allele. He found also that the J allele had an increasing

effect on fat percentage and the L allele had a decreasing effect on fat percentage. The SRB (Swedish Red and White) cows with the BO_1Y_1D' allele had an average fat percentage of 4.23 percent which was significantly higher ($P < .001$) by .11 units than that of their contemporaries without this allele. The SLB (Swedish Friesian) cows with the BO_1Y_1D' allele had an average fat percentage of 4.07 percent which proved to be significantly higher ($P < .05$) than that of their contemporaries without this allele by .11 units. Although Neimann-Sorensen and Robertson (1961) did not find a significant effect of the J allele on fat percentage, the observed effect was positive in all three breeds.

In the United States, Brum et al. (1968) studied Holstein cattle to determine if associations exist between blood types and lactation traits. Data were adjusted to remove herd, sire, year and season effects. Milk yield, fat yield and the percentage of fat in the milk were the production traits studied. No noticeable effects were observed in the A, J, L, and Z systems. In the F-V system, a trend toward superiority of the F^V allele was evident with the homozygote F^{VV} being superior, the homozygote F^{FF} intermediate and the heterozygote F^{FV} the least desirable. Differences were significant ($P < .01$) in both milk yield and fat yield. The B system showed a significant ($P < .05$) difference with a higher fat percentage associated with the K' and G alleles. The least-squares constants were +.0384 and +.0265, respectively. The S system exhibited significant differences with respect to fat yield, with the $S^{H'}$ being superior, $S^{SH'}$ intermediate and S^S least desirable.

Several studies have been conducted concerning possible relationships between transferrin types and production characteristics.

Transferrins are iron binding globulins in the blood serum of cattle. They are not blood antigens, but appear to be inherited in the same way. They are detected by electrophoresis of the serum and can be expressed singly or in pairs in different animals (Kiddy et al., 1975). Brum et al. (1968) included transferrin types in their study with Holstein cattle. They found a trend toward superiority of the Tf^{A} allele, with the Tf^{D} allele intermediate and the Tf^{E} allele least desirable for fat yield and milk yield. The five types analyzed were Tf^{AA}, Tf^{AD}, Tf^{AE}, Tf^{DD} and Tf^{DE}. The least-squares constants for milk yield were 348 kg, 158 kg, -56 kg, -42 kg and -409 kg, respectively, and the least-squares constants for fat yield were 13.8 kg, 5.5 kg, -5.1 kg, 1.7 kg and -16.0 kg, respectively. These results show an additive effect.

On the other hand, Kiddy et al. (1975) found different results concerning transferrin types, using DHIA sire summaries of 2774 Holstein, 491 Guernsey and 492 Jersey bulls. Transferrin types were analyzed with respect to predicted differences for milk, fat, first lactation milk and fat, and daughter average fat percentage. Least-squares analysis was done using a model that contained transferrin type, year of summary, regression on average age at first calving and kind of service as independent variables. The three breeds were analyzed separately, and Tf^{A} and Tf^{D} types were studied in all analyses, whereas, Tf^{E} types were excluded in the initial analysis because of low frequencies. When the sire effects were removed, differences among genotypes were significant ($P < .05$) with respect to predicted difference for milk in first lactation heifers (PDM-1st) in both Holsteins and Guernseys, and predicted difference for fat in first lactation heifers (PDF-1st) in

Holsteins and PDF-1st in Jerseys. In Holsteins, the Tf^{DD} individuals had higher PDM than Tf^{AA} animals with Tf^{AD} individuals being intermediate, thus showing an additive effect. Holsteins exhibited a trend toward Tf^{D} superiority, whereas, Guernseys and Jerseys exhibited a trend toward the superiority of Tf^{A}. Previous research has indicated an association between Tf^{E} and low milk production. The analyses of these data tends to support these findings but, due to low frequencies, little confidence can be placed in the least-squares constants. White and Banfield (1967) reported similar findings in Australian cattle.

Hargrove et al. (1980) have recently studied blood groups in relation to reproductive performance in Holsteins. Data represented 32,000 services in 15,000 service periods of 6,000 cows and 700 service sires. The S system appears to have the most influence with statistical significance found in five out of ten traits. These traits were conception rate in all services for female phenotypes, male phenotypes, male by female phenotypes combined, conception rate in first services for female phenotypes and probability of conception for female phenotypes. Within the S system, the U'_1 females had the highest conception rates, followed by those with UH', and those having no S antigens were least desirable. Cows with UH' or U' had higher probabilities of conception. In the F-V system, matings between F/V heterozygotes had higher conception rates than matings between F/F homozygotes or matings between F/F and F/V. Concerning transferrin types, males with Tf^{AD} had the highest conception rates over all services (54 percent), followed by Tf^{DD} (52 percent), Tf^{AA} (50 percent) and Tf^{DE} (48 percent).

Little research has been reported concerning beef production and blood and transferrin types. One study was conducted by Makarechian and Howell (1967) in Canada with 763 feedlot steers to determine if a relationship existed between the four co-dominant allelic genes responsible for transferrin type and production and carcass characteristics. These steers were of British breeds and represented five separate groups on a feeding trial. The steers were weighed weekly from the time they arrived at the feedlot, and, at slaughter, carcass weights were recorded, longissimus dorsi muscle areas and fat thicknesses were measured. Serum was collected, and transferrin types were determined. Data were analyzed by least-squares analysis with adjustments to remove effects of ration and DES implantation. Five of the most frequent transferrin types were used in the analysis. They were Tf^{AA}, $Tf^{AD}1$, $Tf^{AD}2$, $Tf^{D}1^{D}2$ and $Tf^{D}2^{D}2$. The least-squares estimates of gain in the feedlot and carcass characteristics displayed small differences among the transferrin types compared. Analysis of variance showed no significant differences among transferrin types with respect to either gain in the feedlot or carcass characteristics.

Salerno (1964) conducted an investigation to determine possible relationship between live weights of cattle at birth, 6, 12, 18, and 24 months of age and the presence of a particular blood group. His analysis was done by t-test within sire groups to eliminate differences between sires. The results are as follows: at birth, in the F-V system, females with F^{V} allele weighed 6.73 kg more ($P < .05$) than did those with F^{F} allele; in the S system, females with the $S^{S}1$ allele weighed 4.38 less ($P < .001$) than did those having no S antigens, at 6 months, in the F-V system,

females with F^V allele weighed 89.77 kg more ($P < .001$) than did those with the F^F allele; in the L system, females with the L^L allele weighed 15.58 kg more ($P < .01$) than did those without the L allele; at 18 and 24 months, in the M system, males with the M^M allele weighed 154.86 kg and 212.88, respectively, less ($P < .05$) than did males without the M allele.

Neimann-Sorensen and Robertson (1961) discussed the practical applications of blood group analysis in cattle, taking into consideration the equation $r_{GP} = \sqrt{\frac{V_G}{V_P}}$ where r_{GP} symbolizes the coefficient of correlation between the additive genetic value (G) of the animal and her performance (P), and V_G symbolizes additively genetic variance and V_P symbolizes phenotypic variance. This shows that additive genetic variation is only a fraction of the total variance found in the performance of individuals. Other factors that play a part in this variation are nutrition, environmental effects, etc. The equation $r_{BG} = \sqrt{\frac{V_B}{V_G}}$ where r_{BG} is the coefficient of correlation between the additively genetic value of an animal and the genetic value predicted on the basis of the animals blood groups. V_B symbolizes the variance due to differences in blood group and V_G symbolizes additively genetic variance. This equation points out that the variance due to differences in blood groups would be only a fraction of the total variance in genotype. Only characteristics which are highly heritable, i.e., having a high V_G value, would be practical to include in an analysis relating production to blood groups.

The Effects of Heterozygosity of Blood Groups on Production Characteristics

W.E. Briles has reported a considerable body of research concerning the effects of heterozygosity in the B blood group system on various production characteristics in chickens. Briles et al. (1953) studied three inbred lines of Leghorn chicks. In two out of three lines, male chicks heterozygous for B blood group alleles were found to be significantly heavier at 9 weeks of age than those that were homozygous for B alleles. The results with female chicks were similar and followed the same pattern, but the differences were not significant. These results were substantiated again by Briles (1954). Briles (1957a) studied 218 ten-week-old cockerals and 172 ten-week-old pullets. The heterozygous cockerals weighed 2.8 percent more than did their homozygous sisters. Briles (1954) studied also hatchability and egg production. Hatchability was studied by grouping matings according to the percent heterozygosity expected among the zygotes based on blood type of the parents. The hatchability of fertile eggs produced by matings producing 0, 50, 75, and 100 percent heterozygosity were 42, 62, 71 and 78 percent, respectively. These results indicate that the probability of heterozygous embryos hatching is 1.7 times greater than that of homozygous embryos hatching. This work was substantiated by Briles and Krueger (1955). The average monthly egg production in these lines where 12 or more birds of each genotype were available showed superiority of the heterozygous female. The average egg production of heterozygotes within each line was 9 percent to 30 percent more than that of homozygotes.

Briles and Krueger (1955) found chick livability to nine weeks of age to be 8 to 15 percent greater in heterozygous individuals. Briles (1956) found that heterozygous females consistently outranked homozygous individuals in hen-day production. All of these results indicate that heterozygosity of the B blood group system in chicks has a broad effect on many production characteristics over the whole life span of the individual.

Neimann-Sorensen and Robertson (1961) in research with RDM, SDM and Jersey cattle also conducted heterozygosity tests within the F-V, Z and B systems. No obvious trends were observed in cattle heterozygous for any of these systems. Conneally (1962) found a significant excess of Z/z individuals over expectation within the Z system and evidence for heterozygote superiority was found at this locus. Embryonic mortality was significantly greater in Z/Z zygotes. Z/z heterozygotes significantly excelled z/z cows with respect to milk yield, fat yield and percent butterfat.

Studies Concerning the Degree of Heterozygosity and Homozygosity of Blood Groups

Due to regulations preventing importation of cattle into the Isle of Jersey, the nucleus of Jersey cattle on the island has been isolated for about 200 years. Jersey cattle from all over the world originated from these cattle. Larsen et al. (1974) investigated this nucleus herd and compared gene frequencies in this herd with the gene frequencies in Jersey cattle the world over and, in particular, Danish Jersey cattle. The Danish Jersey cattle, except for limited semen importation, developed from 5300 animals imported from the Isle of Jersey at the

turn of the century. When comparisons of the two herds were made, significant differences were found in all but two systems, the transferrin and the T' system. In the B system, three alleles, fairly frequent in the Danish Jerseys, were not found in the animals sampled from Jersey Island. The degree of homozygosity for the B and C system was higher in Island Jerseys (25 percent and 16 percent, respectively) than in the Danish cattle (10 percent and 12 percent, respectively). Heterogeneity over time was observed in only the F-V system in the Island animals. Hardy-Weinberg tests for equilibrium revealed a surplus of homozygotes in six of eight systems of the Island cattle.

Rausch et al. (1967) compared gene frequencies of three beef breeds; namely, Angus, Hereford and Beef Shorthorn. The A, B, C, F-V, J, L, M, S, Z, and Tf systems were analyzed. Large frequency differences among breeds were observed, indicating each of the breeds to be distinctly different from the others. In two breed comparisons, results indicated that the Angus and Shorthorn are more nearly alike than are the Hereford and either of the other breeds. The co-dominant systems were tested for genetic equilibrium using the Hardy-Weinberg model and chi-square probability estimates. All three breed samples are in genetic equilibrium at these loci; however, probability of equilibrium is lower in the Angus sample. An excess of heterozygotes was observed in the F-V system and an excess of homozygotes in the Tf system.

Briles et al. (1975) reported results of a heterozygosity test on members of 73 closed populations, 71 clearly possessing two or more B alleles each. Inbreeding had a rather marked effect on the number of

alleles. All 16 lines having inbreeding coefficients above .65 uniformly possessed two alleles while three to eight alleles were observed in 28 of the remaining 57 lines with inbreeding coefficients of .65 or below. Previously published papers concerning heterozygosity and production traits had indicated a genetic polymorphism, and the data from this study indicate that it must be of the balanced type in contrast to transient polymorphism, in which an advantageous gene is in the process of spreading through a population. A balance between the three possible genotypes in lines possessing only two alleles would be expected to depend on the relative superiority of the single heterozygous type over each of the two homozygous types. In lines in which three or more alleles exist, the superiority would be expected to determine the frequencies of each allele. Considerng the relatively small size of populations, random drift would be expected to eliminate an occasional low-frequency allele in closed populations. This could be important in the case of decreasing overall heterozygosity if this is found to be associated with production superiority.

Summary of Findings

Researchers have attempted to discover associations between cellular phenogroups of cattle blood group systems and traits such as quantitative production traits and disease resistance. Investigations into relationships among blood groups and resistance to Marek's disease in chickens, leukemia in cattle and a recessive lethal gene for hairlessness in cattle have been conducted. Relationships were found with respect

to Marek's disease and leukemia. Studies concerning blood groups and production characteristics in both beef and dairy cattle have been reported. Relationships both favorable and unfavorable have been found with respect to milk yield, fat yield, fat percentage and conception rates in dairy cattle, and with respect to weights at birth, 6, 12, 18 and 24 months in beef cattle. Heterozygosity of blood groups have been reported to have a favorable effect on production characteristics in chickens and in cattle. Higher than expected heterozygosis has been observed in blood groups of both cattle and chickens.

CHAPTER III

EXPERIMENTAL PROCEDURE

Source of Data

The data for this study were collected from purebred Angus cattle born from January 1970 through April 1979 at the University of Tennessee Plateau Experiment Station, Crossville, Tennessee. Since 1968 the cow herd has been maintained in four separate groups, a 60-cow, 4-sire group in which all replacements were selected at random from within sire progeny groups, a 60-cow, 4-sire group in which all replacements were selected within sire progeny groups on the basis of the highest average daily gain (ADG) to one year of age, a 60-cow, 4-sire group (referred to as the "inbred broup") in which replacements were selected in the same manner as in the latter group but no effort has been made to control inbreeding. In these three groups, selected bulls were used as long yearlings for one season only. A fourth group from which data were obtained has contained a fluctuating number of cattle. In this group, replacement heifers were selected for highest ADG to a year of age; but bulls from the other groups were used and some bulls were retained for more than one year. Heifers were bred as yearlings and all cows and heifers were randomly assigned to a bull within groups, while limiting inbreeding of each mating to a maximum of .125 except in the "inbred group." Calves were born from January through early April and are nursed by their dams without supplemental feeding. No castration was practiced. At weaning (average age, 230 days), body measurements,

weights and blood samples were taken from each calf. Blood samples were mailed to the Texas A & M Immunogenetics Laboratory, Texas A & M University, College Station, Texas for antigenic and transferrin typing. Calves were separated from their dams, and bull calves were separated from heifer calves at that time. Bulls received 2.72 kg concentrate and heifers 1.36 kg concentrate per day. All calves were fed corn silage ad libitum. Individual postweaning body measurements and weight were collected at approximately one year of age (average age, 383 days).

Cows were culled from the herd if open two successive seasons or for obvious unsoundness. In order to keep the generation interval as small as possible, older cows were culled at approximately seven years of age and replaced by selected yearling heifers.

Description of Data

The variables (abbreviations in parentheses) used in the analyses are listed below:

1. Birth Weight (BW)
2. Weaning Weight (WW)
3. Average Daily Gain from birth to weaning, adjusted for age of dam and sex of calf (AADG)
4. Heart Girth at weaning (WHG) - circumferance immediately posterior to the shoulder
5. Body Length at weaning (WLENGTH) - measured on the dorsal midline from midpoint of scapula to a line connecting the posterior prominences of the pin bones
6. Hip Width at weaning (WHIWTH) - distance between the distal extremities of the tuber coxae

7. Hip Height at Weaning (WHIHT) - distance from ground to the top of the hips

8. Postweaning Weight (PWT)

9. Postweaning Average Daily Gain from weaning to time of postweaning data collection (PADG)

10. Lifetime Average Daily Gain from birth to approximately one year of age (LADG)

11. Weaning Weight adjusted to 205 days (AWW) -

    $AWW = \{\{WW-BW)/WAGE\} \times 205\} + BW$

    WAGE = Weaning age in days

12. 205-day weaning weight adjusted for age of dam and sex of calf (ACFWW)

13. 365-day weight adjusted for age of calf (APWT)

    $APWT = \{\{(PWT-WW)/NPWD\} \times 160\} + AWW$

    NPWD = Number of days between weaning and postweaning data collection

14. Body Volume at weaning (VOL)

15. Shape Ratio (SRATIO)

    $SRATIO = VOL/WHIHT$

Body length, hip width and heart girth were taken with a flexible steel tape calibrated in inches, but measurements were converted to metric units before analysis. Hip height was taken with an aluminum height stick calibrated in inches and converted to metric units. The blood group systems present in the Plateau Experiment Station Angus herd are A, B, C, F-V, J, L, M, R'-S', S and Z, and blood serum transferrins. Throughout this thesis, the blood phenogroups will be referred to by blood system codes. Each code is designated by a letter representing the blood group system of which it is a member and a unique code number

provided by the Texas A & M Immunogenetics Laboratory. In all systems, the letter representing the blood group system followed by a zero indicates that the animal does not possess an antigen within that system. If blanks were present in the data, blood typing procedures at the time the blood was typed were unable to determine which blood group antigen(s) were present. The following is a list of codes and the blood groups to which they pertain.

Blood Group System Phenogroups in Angus Cattle

A System

Code	Decode
A1	A
A2	AH
A3	D

B System

B3	B01
B16	B01Y2D'
B22	B03Y1E'3G'P'Q'G"(I")
B39	G2Y2E'1Q'
B45	01Q'
B46	01A'(I")
B78	I2Y2E'1Y'
B79	Y1E'3G'Y'G"
B82	Y2
B85	E'1
B89	I'Q'(I")
B90	E'30'
B92	A'P'
B96	O'
B111	G3TY1A'E'3G'G"(I")
B144	01E'3
B202	I2
B206	I2E'1
B233	E'30'G"(I")
B296	01E'1P'
B306	I'
B307	Q'
B330	A'
B331	01(I")

Blood Group System Phenogroups in Angus Cattle (Continued)

C System

Code	Decode
C1	C1
C2	C1E
C3	C1EW
C13	C2
C14	C2E
C16	C2EW
C21	C2W
C22	E
C23	EW
C27	W
C29	WX2
C30	WX2L'
C32	X2
C33	X2L'
C34	C1X2
C39	C2EWX2
C45	C1W
C51	C1EX2

F-V System

F1	F
F2	V

J System

J1	J

L System

L1	L

M System

M1	M1
M2	M2

R'-S' System

R1	R'
R2	S'

Blood Group System Phenogroups in Angus Cattle (Continued)

S System

Code		Decode
S1	SH'	SH'
S2		UH'
S4		U'
S6		H'
S12		SH'S"

Z System

Z1	Z

Transferrins

Tf1	A
Tf2	D
Tf3	E

Method of Analysis

The analyses of these data have been divided into five major procedures. The first procedure was used to test for homogeneity among blood phenogroup frequencies within blood group system of the cattle present over the ten-year period. This procedure was described by Snedecor and Cochran (1967), and the chi-square formula used was:

$$X^2 = \Sigma(n_i(p_i - \bar{p})^2/\bar{p}\bar{q})$$

where: n_i = the total number of blood phenogroups present within blood group system in the i^{th} year

p_i = the frequency of the blood phenogroup being tested in the i^{th} year

$\bar{p}$ = the mean frequency (over 10 years' time) of the blood group being tested

$\bar{q}$ = the mean frequency (over 10 years' time) of all blood phenogroups within system not being tested

These chi-square values with 9 degrees of freedom for each blood phenogroup represent a measure of the change in frequency of blood phenogroups over a ten-year period and were used as a measure of random genetic drift of blood phenogroups within blood group systems. Since the B and C blood group systems are large and several of the blood groups occur at very low frequencies, blood groups occurring in less than 20 animals in the B system and 10 animals in the C system were pooled to reduce sampling error.

The Plateau Experiment Station Angus herd was tested for Brucellosis in November, 1976 and several animals reacted positively to the test. From November 1976 to April 1980 the herd was quarantined and tested at regular intervals. A total of 391 females were present in the herd during this time, 199 reacted to the test and 159 did not react to the test. Of these 391 females, blood type data were not collected from 33 animals. A chi-square "goodness of fit" test was used to compare blood group frequencies within blood group system of reactors to the Brucellosis test to those of all non-reactors that were present in the herd during the period of quarantine. Blood groups within the B and C blood group systems with expected values less than two were pooled to reduce sampling error.

The next procedures used were analyses of variance, performed on the data to obtain least-squares means used in comparison of blood groups within blood group systems to identify differences in several quantitative variables. Weaning average daily gain (AADG), previously adjusted for age of dam and sex of calf, and 205-day adjusted weaning weight (AWW), adjusted to remove differences due to age of dam and sex

of calf (ACFWW), were considered dependent variables and the following model was fitted:

$$Y_{ijkl} = \mu + sr_{ij} + b_k + e_{ijkl}$$

where: Y_{ijkl} = dependent variable

μ = overall mean

sr_{ij} = the effect of the i^{th} sire in the j^{th} year

b_k = the effect of the k^{th} blood group within blood group system

e_{ijkl} = residual error

Post-weaning average daily gain (PADG), representing the average daily gain from weaning to the time of post-weaning data collection, and lifetime average daily gain (LADG), representing the average daily gain from birth until the post-weaning data collection date, were considered dependent variables and fitted to the following model:

$$Y_{ijklmno} = \mu + d_i + s_j + g_k + sr_{lm} + b_n + e_{ijklmno}$$

where: $Y_{ijklmno}$ = dependent variable

μ = overall mean

d_i = the effect of the i^{th} age of dam

x_j = the effect of the j^{th} sex of calf

g_k = the effect of the k^{th} age of calf

sr_{lm} = the effect of l^{th} sire within the m^{th} year

b_n = the effect of the n^{th} blood group within blood group system

$e_{ijklmno}$ = residual error

Yearling weight, adjusted to 365 days (APWT) was considered a dependent variable and fitted to the following model:

$$Y_{ijklmn} = \mu + d_i + x_j + sr_{kl} + b_m + e_{ijklmn}$$

where: Y_{ijklmn} = dependent variable

μ = overall mean

d_i = the effect of the i^{th} age of dam

x_j = the effect of the j^{th} sex of calf

sr_{kl} = the effect of the k^{th} sire within the l^{th} year

b_m = the effect of the m^{th} blood group within blood group system

e_{ijklmn} = residual error

Several body measurements taken at time of weaning, including heart girth (WHG), body length (WLENGTH), hip width (WHIHT), and a shape ratio (SRATIO) described by Dellmeier et al. (1979), formulated using three different body measurements to obtain a measure of overall shape of the animal, were considered dependent variables and the following model was fitted:

$$Y_{ijklmno} = \mu + d_i + x_j + g_k + sr_{lm} + b_n + e_{ijklmno}$$

where: $Y_{ijklmno}$ = dependent variable

μ = overall mean

d_i = the effect of the i^{th} age of dam

x_j = the effect of j^{th} sex of calf

g_k = the effect of the k^{th} age of calf

sr_{lm} = the effect of the l^{th} sire within the m^{th} year

b_n = the effect of the n^{th} blood group within blood group system

$e_{ijklmno}$ = residual error

Blood types within the B and C systems which occurred fewer than 15 animals were deleted due to reduce confounding. Age of dam was deleted as a main effect in all models which included the S blood group system,

also to reduce confounding resulting from extreme variation in subclass size.

These animals were divided into four major groups, as explained earlier. Since preliminary analysis of variance showed no significant effect of group upon the performance of these animals, this main effect was not included in these models for further analyses. Due to limitations of the computer facilities used in analyzing these data and to the extent in which the variable, age of calf, varies, it was entered as a covariate; all other main effects were considered discrete variables.

Analyses of variance were performed on all quantitative variables previously mentioned using the same models to determine whether differences occurred between homozygous and heterozygous blood group genotypes. All heterozygotes within blood group system were pooled together, all homozygotes within blood group system were pooled together, and least-squares means were obtained to compare these two groups. Blood types within the B and C systems that occurred in fewer than 15 animals were deleted to reduce confounding. Age of dam was deleted as a main effect in all models which included the S blood group system, also to reduce confounding.

For the final analysis, the F-V and R'-S' blood group systems were chosen for a comparison of observed and calculated heterozygosis. These two systems were chosen because in them, the heterozygote can be more accurately identified. Gene frequencies were determined by year, and gentotypic frequencies were determined from the gene frequencies, assuming random mating. Genotypic frequencies were adjusted for the average inbreeding by year and then converted to expected numbers.

Chi-square values were calculated using the observed occurrence of blood groups and the calculated numbers adjusted for inbreeding by the usual formula:

$$\chi^2 = \sum_{i=1}^{n} \left[\frac{(O_i - E_i)^2}{E_i} \right]$$

Where O_i and E_i are observed and expected numbers, respectively. These chi-square values were based on only one degree of freedom due to the fact that the expected numbers were calculated from a gene frequency calculated from the data.

CHAPTER IV

RESULTS AND DISCUSSION

Homogeneity Among Blood Phenogroups Over Time

For the convenience of the reader, references will be made in this discussion of results to papers previously cited in the review of literature. Tests of homogeneity among blood phenogroups within blood group systems of the cattle present over the ten-year period yielded significant ($P < .05$ or $P < .01$) differences in gene frequencies of blood phenogroups within blood group system, indicating considerable random genetic drift, an important factor in a study of period gene frequencies in a population. Random genetic drift is especially important with respect to the low frequency antigens since there is a greater probability of their complete elimination from the herd through their being omitted by chance from the sample of genes making up a calf crop. The analyses to determine if there is a difference between cattle blood types with respect to incidence of reactors to the brucellosis test, and the test to compare observed and calculated heterozygosis could be affected by these random changes in gene frequency, which must be kept in mind when interpreting the results of these other two analyses. In this test of homogeneity among blood groups no increasing trends are observed and only one decreasing trend, the S1 blood group within the S blood group system. These results are given in Table 6 (Appendix).

Comparison of Blood Group Frequencies of Reactors and Non-Reactors to the Brucellosis Test

Brucellosis is a serious problem in beef cattle. Efforts to eradicate the disease have required beef producers to slaughter all reactors to the brucellosis test and herds where positive reactors have been found were quarantined and retested until they can be brucellosis free. If an association could be found between tendency to react or not react to the brucellosis test and genetic markers such as blood antigens, this could be taken into consideration in the selection process or potentially susceptible animals could possibly be identified and watched more carefully. Briles et al. (1977) found a greater incidence of Marek's disease in chickens whose blood type included the B^{13} and B^{19} alleles and observed resistance to Marek's disease in chickens carrying the B^{21} allele. Shadmanov et al. (1976) found that the L and Z alleles occurred more frequently in leukemic cattle. In addition, they found that the I allele of the B system occurred more often in the healthy animals.

In the present study, chi-square analyses comparing frequencies of blood groups within blood group systems in reactors to the brucellosis test to the same frequencies in non-reactors showed indications of differences. Within the B system, 11 of the most frequently occurring blood groups (and a pooled group including all low frequency alleles) were used in a comparison. A chi-square value of 15.568 with 11 d.f. was computed and found to have an impressively low probability ($.10 < P < .16$) of chance occurrence. The individual cell chi-squares

indicated that the B89 and B233 alleles contributed most to the total chi-square value. B89 occurred 28 times among non-reactors and 36 times among reactors. B233 occurred 76 times among non-reactors and 41 times among reactors. These results are shown in Table 1 and Table 7 (Appendix), as are all other chi-square values subsequently discussed. Within the C system, ten of the most frequently occurring blood groups (and a pooled group including all low frequency alleles) were used in a comparison. The total chi-square value computed was 15.434 with 10 d.f. and a probability of chance occurrence between .10 and .12. The C1 blood group contributed the highest percentage of the total chi-square value. The C1 blood group occurred 4 times among non-reactors and 14 times among reactors to the brucellosis test. The frequency differences among blood groups within the S system in animals which reacted to the brucellosis test versus non-reactors approached the conventional significance level also ($.10 < P < .13$, chi-square = 7.093, 4 d.f.). The S1 and S4 alleles contributed most to the total chi-square value. The S1 allele appeared 8 times and the S4 allele 15 times among non-reactors, and the S1 allele appeared 10 times and the S4 allele 15 times among reactors. Differences approaching significance ($.10 < P < .19$) were found between frequencies of blood transferrins in reactors to the brucellosis test and those in non-reactors (chi-square = 3.984, 2 d.f.). The greatest contributor to this chi-square value was the Tf1 allele which appeared 173 times among non-reactors and 104 times among reactors.

These results suggest that there could be an association between blood types within the B, C, and S systems, and blood transferrins, and

TABLE 1

DIFFERENCES AMONG BLOOD GROUPS WITHIN THE B, C AND S BLOOD GROUP SYSTEMS AND TRANSFERRINS WITH RESPECT TO FREQUENCIES OF REACTORS TO BRUCELLOSIS TEST

Blood Group System	Blood Group	Non-Reactors	Reactors	Total	Chi-Square
B	B0	7	3	10	
	B1[a]	3	6	9	
	B16	58	62	120	
	B22	6	8	14	
	B39	58	57	115	
	B45	62	47	109	
	B78	7	4	11	
	B89	28	36	64	
	B111	12	9	21	
	B206	24	16	40	
	B233	76	41	117	
	B296	3	4	7	
				.10< P< .16	15.568 - df=11
C	C0	41	30	71	
	C1	4	14	18	
	C2	50	29	79	
	C3	94	81	175	
	C16	10	4	14	
	C21	12	8	20	
	C22	9	9	18	
	C27	12	6	18	
	C29	6	9	15	
	C32	38	31	69	
	C100[b]	7	3	10	
				.10< P< .12	15.432 df=10
S	S0	100	69	169	
	S1	8	10	18	
	S4	41	15	56	
	S6	91	53	144	
	S12	14	5	19	
				.10< P< .13	7.093 df=4

TABLE 1 (continued)

Blood Group System	Blood Group	Non-Reactors	Reactors	Total	Chi-Square
Trans-ferrins	Tf1	173	104	277	
	Tf2	129	105	234	
	Tf3	51	45	96	
				.10 < P < .14	3.984 df=2

[a]Pooled B blood groups with expected values <2, including B46, B92, B144, B96, B354, B390, B330, B307, B337, B3, B202, B331, B90, B82, B306, B79 and B85.

[b]Pooled C blood groups with expected values <2, including C13, C14, C23, C30, C33, C39.

tendency to react or not to react to the brucellosis test. There is no obvious physiological or immunological reason for such an association. It would be desirable if further research with other herds could be done to see if the same or similar results would be obtained.

Associations Between Quantitative Variables and Blood Groups within Blood Group Systems

Many researchers have studied associations between blood groups and milk production and fat percentage. Associations have been found with blood groups in the B system (Neimann-Sorenson and Robertson, 1961; Rendel, 1961; Brum et al., 1968), the M system (Mitseterlick et al., 1959), L and J systems (Rendel, 1961), S system (Brum et al., 1968) and alleles within the blood transferrins. Hargrove et al. (1980) found relationships between reproductive performance in Holsteins and blood groups of the S and F-V blood group systems and alleles of the blood transferrins. Limited research has been conducted with beef cattle production traits and blood group systems. Makarechian and Howell (1967) found small, non-significant differences between the serum transferrin types in a study of feedlot gains and carcass characteristics. Salerno (1964) found significant differences in the F-V, S, L and M blood group systems with respect to weight gains in cattle from birth to 24 months of age at six month intervals.

The results of the analyses to determine if relationships exist between Angus cattle blood types within blood group systems and quantitative performance variables will be reported by blood groups within blood group system and divided into two major divisions, weights and

average daily gains, and body measurements including the SRATIO. In the interpretation of these results, an important point to keep in mind is the large diversity in numbers of observations in blood-type-within-blood-group-system subclasses, even though the least-squares analyses performed supposedly remove much of the confounding resulting from inequality and disproportionality of subclass numbers.

The S blood group system yielded results suggesting a relationship between this blood group system and average daily gains and adjusted weaning and postweaning weights. Significant differences were found between blood groups within the S system with respect to PADG ($P < .03$) and LADG ($P < .01$) and AADG ($P < .06$). Mean separation procedures (Student-Newman Kuel) showed that animals of the S12/S6 blood type had significantly higher PADG than did animals of S6/S0, S4/S6, S1/S4, S1/S0 and S0/S0 blood types and significantly higher LADG than did animals of S12/S4, S4/S6, S1/S4 and S0/S0 blood types. Animals of the S1/S4 type had significantly lower PADG than did animals of S1/S0, S4/S0, S6/S0 and S12/S0 blood types. Animals of the S12/S4 blood type had significantly lower PADG than did animals of S6/S0 or S4/S0 blood types within the S blood group system. Animals of the S6/S0 blood type had significantly higher LADG than did animals which apparently did not possess an antigen within the S system (S0/S0). Differences among AADG means approached significance ($P < .06$). Significant differences were found among blood groups within the S system with respect to APWT. Animals of the S12/S6 blood type had significantly higher APWT than did animals of the S1/S4, S0/S0, S4/S6 or S12/S4 blood types. Animals of the S6/S0

blood type had significantly higher APWT than did animals of the S1/S4 or S0/S0 blood types. Differences with respect to ACFWW among blood types within the S blood group system approached significance ($P < .16$). These results and those to be subsequently discussed are shown in Table 2 and Table 8 (Appendix).

The results of Brum et al. (1968) illustrated that Holstein cattle with the $S^{H'}$ (S6) allele were superior in fat yield. The significantly higher average daily gains found in this study in the S system were among animals with S6/S0 blood type. Significant ($P < .05$) differences were found between blood types within the Z system among least-squares means of ACFWW. Cattle apparently not possessing a Z allele (Z0/Z0) weighed significantly less than did cattle of the Z1/Z0 or the Z1/Z1 type. Differences between least-square means of AADG approached significance ($P < .12$) within the Z blood group system.

Brum et al. (1968) in their study with Holstein cattle found a trend toward superiority of the Tf^{A} allele, with the Tf^{D} allele intermediate and the Tf^{E} allele least desirable for fat yield and milk yield. Kiddy et al. (1975) found somewhat contradictory results in that bulls of the Tf^{DD} type had a higher predicted difference for milk than bulls with the Tf^{AA} type, and Tf^{AD} individuals were intermediate. Hargrove et al. (1980) found that males of Tf^{AD} type had the highest conception rates followed by Tf^{DD}, Tf^{AA} and Tf^{DE}, respectively. Makarechian and Howell (1967) found small nonsignificant differences among transferrin types with respect to gain in the feedlot and carcass characteristics.

The results of the analyses of average daily gains and weights with respect to the blood serum transferrins yielded significant results

TABLE 2

LEAST-SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS AND WEIGHTS BY BLOOD TYPE WITHIN THE S AND Z BLOOD GROUP SYSTEMS AND TRANSFERRINS

Blood Group System	Blood Type	AADG (kg)	SDM[a]	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	AFWT (kg)	SDM
		†		*		**		†		**	
S	S0/S0 (1)	.8834		.5475	9	.7008	6,9	200.812		279.950	6,9
		±.0085		±.0118		±.0066		±1.855		±2.563	
	S1/S0 (2)	.8966		.5808	3,9	.7294		202.881		290.046	
		±.0383		±.0524		±.0293		±8.326		±11.467	
	S1/S4 (3)	.8441		.3335	4,6 7,9	.6275	9	193.388		297.874	6,9
		±.0844		±.1154		±.0646		±18.318		±25.264	
	S4/S0 (4)	.9478		.6165	8	.7377		209.976		295.445	
		±.0288		±.0407		±.0228		±6.244		±8.907	
	S4/S6 (5)	.9227		.5486	9	.7233	9	209.760		287.764	9
		±.0178		±.0244		±.0137		±3.836		±5.339	
	S6/S0 (6)	.9381		.5851	8,9	.7467		212.183		298.507	
		±.0159		±.0218		±.0122		±3.463		±4.764	
	S12/S0 (7)	.9505		.6128		.7483		199.183		293.226	
		±.0499		±.0682		±.0382		±10.824		±14.921	
	S12/S4 (8)	.9293		.3973	9	.6632	9	210.464		267.220	9
		±.0684		±.0934		±.0522		±14.845		±20.412	
	S12/S6 (9)	.9614		.8474		.8646		208.940		341.775	
		±.0855		±.1169		±.0655		±18.553		±25.552	
		‡						*			
Z	Z0/Z0 (1)	.8936		.5361		.7175		203.283	2	285.432	
		±.0048		±.0129		±.0072		±1.051		±2.777	
	Z1/Z0 (2)	.9098		.5214		.7157		207.992		285.125	
		±.0077		±.0152		±.0085		±1.693		±3.280	
	Z1/Z1 (3)	.9271		.5168		.7368		206.216		289.993	
		±.0248		±.0372		±.0207		±5.457		±7.982	
		*				†		*		†	
Trans-ferrins	Tf1/Tf1(1)	.8853	2	.5251		.7099		201.342	2	281.920	
		±.0072		±.0142		±.0082		±1.596		±3.150	
	Tf1/Tf2(2)	.9079	5	.5261		.7217		206.241	5	286.251	
		±.0060		±.0130		±.0075		±1.325		±2.891	
	Tf1/Tf3(3)	.8978	5	.5200		.7134		204.554	5	283.253	
		±.0078		±.0145		±.0083		±1.712		±3.216	
	Tf2/Tf2(4)	.8996	5	.5409		.7272		204.149		289.037	
		±.0095		±.0170		±.0098		±2.103		±3.770	

Table 2 (continued)

Blood Group System	Blood Type	AADG (kg)	SDM[a]	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
	Tf2/Tf3(5)	.8751		.5239		.7094		199.396	6	282.121	
		±.0098		±.0172		±.0099		±2.165		±3.823	
	Tf3/Tf3(6)	.9137		.5724		.7472		208.941		295.520	
		±.0203		±.0293		±.0168		±4.490		±6.496	

[a] Significantly ($P<.05$) different means

† $.05 < P < .20$

* $.01 < P < .05$

** $P < .01$

also. Significant ($P < .02$) differences were found among least-squares means of AADG between blood transferrin types. Animals of the transferrin type Tf2/Tf3 gained significantly less than did animals of types Tf2/Tf2, Tf1/Tf2, and animals of the Tf1/Tf1 type gained significantly less than did those of the Tf1/Tf2 type. With respect to ACFWW, significant ($P < .02$) differences were found among least-squares means of animals of different transferrin types. Animals of the Tf2/Tf3 transferrin type weighed significantly less than did animals of Tf1/Tf2, Tf1/Tf3 and Tf3/Tf3 types. Animals of the Tf1/Tf1 type weighed significantly less than did animals of the Tf1/Tf2 type. Differences among least-squares means of LADG and APWT of animals possessing different blood serum transferrins approached significance ($P < .06$ and $P < .08$, respectively).

These results agree generally with those of Kiddy et al. (1975) and Brum et al. (1968) which showed that Tf^{DE} (same as Tf2/Tf3) dairy individuals were lower producers of milk and milk fat. The results in the present comparison of least-squares means of average daily gains and weights showed tha animals of the Tf3/Tf3 (same as Tf^{EE}) had greater least-squares means than those of other transferrin types. This is in disagreement with the results of the other researchers. The number of individuals of the Tf3/Tf3 type were much smaller than the number of individuals of the other types. Least-squares procedures should have removed most of the confounding resulting from unequal and disproportionate numbers of observations within subclasses. No obvious differences between individuals possessing the Tf1 and Tf2 alleles were observed.

These results indicate the need for more research with respect to average daily gains and weights, and transferrin types, particularly to consider the difference between individuals of the Tf3/Tf3 type and individuals of other transferrin types.

Within the C blood group system, significant ($P < .01$) differences were found among least-squares means of AADG of animals of different blood types. Blood types within the C system were too numerous to permit identifying particular significant differences among least-squares means in a complete table. Individuals of the C2/C16 and C1/C3 types gained significantly more than did cattle of most of the other C blood types. More research and analyses should be done within this system to further determine differences between least-squares means of AADG. Within the F-V system, differences among least-squares means of LADG and APWT approached significance ($P < .12$ and $P < .17$, respectively).

The second major group of quantitative variables studied were body measurements taken at weaning and shape ratio (SRATIO) calculated from them. Significant differences were found among least-squares means of WHG and SRATIO of animals of different blood types within the F-V system. Calves of the F4/F4 type had significantly ($P < .008$) smaller WHG and significantly ($P < .02$) smaller SRATIO than did calves of the F1/F1 or F1/F4 blood types. Differences among least-squares means of WLENGTH and WHIHT of calves of different F-V types approached significance ($P < .06$ and $P < .08$, respectively). Salerno (1964) found a trend toward superiority of the F^V (same as F4) allele with respect to weight at birth and at six months of age in female calves. This trend differs from the trend found in this study which indicates that calves

of the F4/F4 type tended to have smaller WHG and SRATIO than did calves homozygous F1/F1 or heterozygous F1/F4 with respect to alleles within the F-V system. These results and those subsequently discussed are shown in Table 3 and Table 9 (Appendix).

Significant ($P < .03$) differences existed among the least-squares means of WLENGTH of animals of the J0/J0 type and those of the J1/J0 type within the J system. Calves of the J1/J0 type were longer than were calves of the J0/J0 type. Differences among least-squares means of WHIWTH of calves of different J types approached significance ($P < .07$). Rendel (1961) found in Swedish cattle that the J1 allele had an increasing effect on milk fat percentage.

Within the S blood group system, significant ($P < .0001$) differences were found among least-squares means of WHIHT of calves of different blood types. Calves of the S12/S6 blood type were significantly taller than were calves of S12/S0, S4/S0, S1/S4, S1/S0 or S0/S0 types. Calves apparently possessing no S system alleles (S0/S0) were significantly shorter than were calves of the S4/S0, S4/S6 or S6/S0 types. Differences among least-squares means of WHIHT of calves of different types within the B, L, and R'-S' blood group systems and serum transferrins approached significance ($P < .14$, $P < .08$, $P < .14$, $P < .19$, respectively). Within the R'-S' system, differences among least-squares means of WLENGTH of calves of different types approached significance ($P < .10$), and and differences among least-squares means of WHG of calves of different types approached significance also ($P < .13$, Table 9, Appendix).

TABLE 3

LEAST-SQUARES MEANS AND STANDARD ERRORS
OF BODY MEASUREMENTS AND SHAPE RATIOS BY
BLOOD TYPE WITHIN THE F-V, J AND S BLOOD GROUP SYSTEMS

Blood Group System	Blood Type	WHG	SDM[a]	WLENGTH	SDM	WHIWTH	SDM	WHIHT	SDM	SRATIO	SDM
		**		†				†		*	
F-V	F1/F1(1)	139.680	3	96.078		36.911		99.480		1498.887	3
		±.431		±.338		±.300		±.290		±11.412	
	F1/F1(2)	139.880	3	96.289		36.740		99.631		1508.153	3
		±.453		±.355		±.315		±.303		±11.919	
	F4/F4(3)	137.746		95.042		36.127		98.550		1457.329	
		±.748		±.587		±.521		±.575		±20.244	
				*		†					
J	J0/J0(1)	139.668		95.875	2	36.516		99.403		1501.500	
		±.503		±.379		±.176		±.337		±13.600	
	J1/J0(2)	139.713		96.686		36.821		99.699		1511.024	
		±.601		±.452		±.210		±.411		±16.579	
								**			
S	S0/S0(1)	137.735		94.870		36.562		98.042	4,5	1465.380	
		±.466		±.343		±.466		±.289	6,9	±11.008	
	S1/S0(2)	138.663		94.615		36.536		99.564	9	1448.598	
		±2.100		±1.547		±2.101		±1.401		±53.287	
	S1/S4(3)	138.540		93.033		37.587		98.396	9	1444.858	
		±.4590		±3.382		±4.592		±2.913		±110.787	
	S4/S0(0)	138.748		96.329		36.960		100.307	9	1477.073	
		±1.618		±1.192		±1.619		±1.023		±38.895	
	S4/S6(5)	139.391		96.554		36.938		101.213		1485.591	
		±.974		±.717		±.974		±.602		±22.880	
	S6/S0(6)	140.743		96.061		37.710		101.357		1513.548	
		±.869		±.641		±.870		±.566		±21.517	
	S12/S0(7)	137.190		97.778		37.681		100.068	9	1469.439	
		±2.711		±1.997		±2.712		±1.708		±64.968	
	S12/S4(8)	136.468		98.655		35.996		99.380		1478.075	
		±3.712		±2.735		±3.714		±2.337		±88.880	
	S12/S6(9)	141.430		97.623		35.206		106.424		1464.968	
		±4.650		±3.426		±4.652		±2.932		±111.484	

† .05 < P < .20
* .01 < P < .05
** P < .01
a - significantly different means

Comparisons of Quantitative Variables of Cattle of Different Blood Groups within Blood Group Systems

Heterozygotes Versus Homozygotes

W.E. Briles and his associates have reported a considerable body of research concerning the effects of heterozygosity in the B blood group system on production characteristics in chickens. Briles et al. (1953) found that male chicks heterozygous for B blood group alleles were heavier at nine weeks of age than those homozygous for B alleles. Briles (1957a) found that 10-week-old heterozygous cockerals weighed 2.8 percent more than did their homozygous brothers, and the pullets weighed 4.8 percent more than did their homozygous sisters. In hatchability studies, Briles (1954) found the probability of heterozygous embryos hatching to be 1.7 times greater than that of homozygous embryo hatching. Briles and Krueger (1955) found livability to nine weeks of age to be greater in heterozygous individuals, and Briles (1956) found that heterozygous females consistantly outranked homozygous individuals in hen-day production. Conneally (1962) found embryonic mortality in cattle to be significantly greater in Z/Z (Z1/Z1) zygotes, and Z/z (Z1/Z0) heterozygotes significantly excelled z/z (Z0/Z0) cows with respect to milk yield, fat yield and percent butterfat.

The results of the present analyses to determine if differences exist between Angus cattle of heterozygous blood types and those of homozygous blood types within blood group systems with respect to quantitative performance variables will be reported in two major groups, weights and average daily gains, and body measurements, including the SRATIO.

In the interpretation of these results, an important point to keep in mind is the large variation in the numbers of heterozygotes observed and the numbers of homozygotes observed within blood group systems. This is particularly true in the large blood group systems such as the B, C, and S where heterozygotes greatly outnumbered homozygotes. Least-squares analyses were performed and should have reduced confounding resulting from unequal and disproportionate subclass numbers. Significant differences were found between least-squares means of AADG and ACFWW of animals heterozygous and those of animals homozygous with respect to blood type alleles within the S blood group systems. Heterozygous calves within this blood group system gained and weighed significantly ($P < .0005$ and $P < .002$, respectively) more than did homozygous calves. Heterozygotes within the S blood group system also weighed significantly ($P < .002$) more at postweaning (APWT) than did homozygotes. Differences between least-squares means of PADG of homozygotes and heterozygotes approached significance ($P < .19$), within the S system. Within the Z blood group system the least-squares mean of ACFWW were significantly ($P < .02$) greater in cattle that were heterozygous (Z1/Z0) than it was in homozygotes. The difference between least-squares means of AADG of heterozygotes and homozygotes also approached significance ($P < .10$) within the Z system. These results are shown in Table 4 and Table 10 (Appendix). Differences among least-squares means of LADG, ACFWW and APWT of heterozygotes and homozygotes within the M blood group system approached significance ($P < .11$, $P < .14$ and $P < .06$, respectively). Within the C system, the difference between least-squares means of AADG of heterozygotes and homozygotes approached significance ($P < .10$), and in the F-V system, the

TABLE 4

LEAST-SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS AND WEIGHTS WITHIN THE S AND Z BLOOD GROUP SYSTEMS

HETEROZYGOTES vs. HOMOZYGOTES[a]

Blood Group System	Blood Type	AADG (kg)	PADG (kg)	LADG (kg)	ACFWW (kg)	APWT (kg)
		**	†		**	**
S	S Homozygotes	.8819	.5434	.6991	200.708	279.202
		±.0083	±.0117	±.0065	±1.811	±2.537
	S Heterozygotes	.9283	.5679	.7324	209.392	292.001
		±.0096	±.0133	±.0074	±2.081	±2.899
		†			*	
Z	Z Homozygotes	.8950	.5354	.7182	203.405	285.605
		±.0047	±.0128	±.0071	±1.024	±2.760
	Z Heterozygotes	.9089	.5220	.7152	207.915	284.996
		±.0077	±.0152	±.0085	±1.686	±3.272

[a]S system homozygotes S0/S0
Z system homozygotes Z0/Z0, Z1/Z1

† $.05 < P < .20$
* $.01 < P < .05$
** $P < .01$

difference between the least-squares means of ACFWW of homozygotes and heterozygotes approached significance ($P < .18$). These results are shown in Table 10 (Appendix). In all cases of significant differences and differences approaching significance, the least-squares means of the heterozygotes were greater than the least-squares means of the homozygotes within blood group system.

In the second group of analyses of quantitative variables, significant differences were found within the M and S blood group systems. Within the M blood group system, calves heterozygous for the M alleles were significantly ($P < .04$) longer than were calves which were homozygous, and the difference between least-squares means of SRATIO of heterozygotes and homozygotes approached significance ($P < .08$). Within the S blood group system, heterozygotes had significantly ($P < .006$) larger WHG, significantly ($P < .02$) greater length and significantly ($P < .0001$) greater height than did heterozygotes. Differences between the least-squares means of SRATIO of S heterozygotes and S homozygotes approached significance ($P < .15$), with heterozygotes having a larger SRATIO than homozygotes. These results are shown in Table 5 and Table 11 (Appendix). Differences among least-squares means of WHG heterozygotes and homozygotes approached significance ($P < .17$, $P < .13$, and $P < .13$) in the C, F-V blood group systems and blood transferrins, respectively. Differences between least-squares means of WLENGTH of heterozygotes and homozygotes approached significance ($P < .17$, $P < .15$, and $P < .06$) in the B, F-V and R'-S' blood group systems, respectively. With respect to least-squares means of WHIHT, differences between heterozygotes and homozygotes approached significance ($P < .15$ and $P < .17$) in the B and R'-S' blood group systems,

TABLE 5

LEAST-SQUARES MEANS AND STANDARD ERRORS
OF BODY MEASUREMENTS AND SHAPE RATIOS
WITHIN THE M AND S BLOOD GROUP SYSTEMS

HETEROZYGOTES vs. HOMOZYGOTES[a]

Blood Group System	Blood Type	WHG	WLENGTH	WHIWTH	WHIHT	SRATIO
			*			†
M	M Homozygotes	139.544	95.852	36.761	99.486	1499.769
		±.467	±.357	±.360	±.294	±11.615
	M Heterozygotes	140.434	97.009	36.867	99.881	1531.314
		±.805	±.616	±.621	±.503	±19.901
		**	*		**	†
S	S Homozygotes	137.723	94.872	36.560	98.089	1465.883
		±.456	±.336	±.454	±.281	±10.596
	S Heterozygotes	139.712	96.103	37.206	100.986	1490.968
		±.524	±.386	±.522	±.342	±12.905

[a]M system homozygote - M0/M0
S system homozygote - S0/S0

† .05 < P < .20
* .01 < P < .05
** P < .01

respectively. With respect to least-squares means of WHIHT, differences between heterozygotes and homozygotes approached significance ($P < .15$ and $P < .17$, respectively) in the B and R'-S' blood group systems. Finally, within the F-V blood group system and the blood transferrins, differences between least-squares means of SRATIO of heterozygotes and homozygotes approached significance ($P < .08$ and $P < .15$, respectively). In all cases of significant differences, the least-squares means of heterozygotes were larger than the least-squares means of homozygotes within blood group system. Among comparisons in which mean differences "approached significance" ($.05 < P < .2$), in most cases, the least-squares means of heterozygotes were larger than least-squares means of homozygotes within blood group system, but there were a few exceptions to this. These results are shown in Table 11 (Appendix). These results suggest that there could be associations between heterozygosis with respect to blood types and superiority in quantitative production variables. Perhaps heterozygosity of blood group alleles is an indicator of general heterozygosity, including that of genes affecting quantitative traits. Research of this kind with data sets from other herds would be desirable for assurance that these results are not simply a peculiarity of this particular herd.

A Comparison of Observed and Calculated Heterozygosis of Blood Group Genotype within the F-V and R'-S' Systems

Several researchers have been interested in gene frequencies and the degrees of homozygosity and heterozygosity of blood group

genotypes, particularly in closed or isolated groups (Larsen et al., 1974; Briles et al., 1957) Larsen et al. (1974) found that the cattle isolated on the Isle of Jersey had a higher degree of homozygosity within the B and C system than did Danish cattle which were descended from the Island Jerseys. Hardy-Weinberg tests for equilibrium revealed a surplus of homozygotes in six of eight systems of the Island cattle. Rausch et al. (1967) observed in their study of Angus cattle of heterozygotes in the F-V system (indicating non-random mating) and an excess of homozygotes in the blood transferrins.

In this study of observed and calculated heterozygosis of blood group genotype within the F-V blood group system over a ten-year period, no significant differences were found between observed and calculated values in any year. In all but two years (1973 and 1977), the observed heterozygosis was greater than the calculated value. These results are shown in Table 12 (Appendix).

The R'-S' system presents a different situation. The workers in the Texas A & M Immunogenetics Laboratory did not incorporate reliable S' reagents until 1972, and, according to them, the S' reagent has never been what they consider a reliable reagent. Our analyses indicated that the gene frequency of the R1 allele was very low (less than .2) until 1977, and the results in Table 12 (Appendix) show that the genotype R1/R1 was observed only once during a ten-year period. Significant differences were found between observed and calculated values of R'-S' blood group genotypes in 1975, 1976, 1977, 1978 and 1979. These differences seem to be due to the fact that the frequency of the R1 allele was increasing, but the frequency of the R1/R1 genotype is not increasing; hence, the

much larger observed heterozygosis than calculated heterozygosis. These results do indicate that in the years 1975-1979, there was greater than expected heterozygosis within the R'-S' system, but due to the unreliability of the blood typing procedures in this system, a definite conclusion cannot be drawn. Here again is a case in which further research needs to be conducted to determine whether these results (shown in Table 12, Appendix) are repeatable.

CHAPTER V

SUMMARY

Over a ten-year period (1970), blood types, weaning and post-weaning weights and gains and body measurements have been recorded from animals in the Angus herd at the University of Tennessee Plateau Experiment Station. Analyses of blood group frequencies revealed that either random genetic drift or changes and/or additions in blood typing procedures could be an important consideration in assessing trends in the herd. The herd became infected with brucellosis in 1976, and eradication was accomplished in 1980. Impressively low probabilities (.12 to .16) of chance occurrence of greater chi-square values were obtained in the B, C, and S blood group systems and in the blood serum transferrin system when chi-square was calculated using the observed frequency of reactors to the brucellosis test in the entire herd as a basis for calculating expected numbers of reactors in each blood group within a system. Even though these probabilities are greater than the traditional .05 significance level, they constitute reasonably strong evidence for some association of frequency of brucellosis reactors with blood type. Analyses of variance were performed on adjusted weaning and postweaning weights, average daily gains and body measurements to determine if any associations existed with blood types within a system. The effects of sire within year were removed from all analyses and, where applicable, data were adjusted to remove variation due to differences in age of dam, sex of calf and age of calf. Significant ($P < .05$ or $P < .01$)

differences were found among least-squares means of average daily gains of cattle of different types within the S system and within the blood serum transferrin system, among least-squares means of adjusted weaning weights in the Z system and transferrins and among least-squares means of adjusted postweaning weights in the S system. Significant ($P < .05$ or $P < .01$) differences were found among least-squares means of various body measurements of cattle of different types within the F-V, J and S blood group systems. Observations were divided within blood group systems into two large classes of heterozygous and homozygous blood types and analyses of variance were performed with the same quantitative variables mentioned above as dependent variables. Significant ($P < .05$ or $P < .01$) differences between homozygotes and heterozygotes were found in the S and Z systems with respect to average daily gains and adjusted weaning and postweaning weights, and, within the M and S systems, differences were found with respect to various body measurements. In a comparison of observed and expected heterozygosis within the F-V and R'-S' systems, no significant differences were found in any year with respect to the F-V system. Significant differences were found in years 1975 to 1979 within the R'-S' system, but due to unreliability of the blood typing procedures in this system, no definite conclusion can be drawn.

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APPENDIX

TABLE 6

CHANGE IN GENE FREQUENCY OVER A 10-YEAR PERIOD

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Chi-square
						A SYSTEM					
A1	.3011	.3333	.3291	.2688	.2442	.3428	.2605	.2746	.3707	.2840	18.4673*
A2	.0398	.0238	.0211	.0323	.0264	.0141	.0210	.0164	.0244	.0123	6.3175
A3	.6591	.6429	.6498	.6989	.7294	.6431	.7186	.7090	.6049	.7037	17.2250*
						B SYSTEM					
B0	.0104	.0160	.0157	—	—	.0169	.0060	.0115	—	.0245	9.9309
B1[a]	.0625	.0638	.0315	.0101	.0126	.0270	.0060	—	.0045	—	50.3518**
B16	.1615	.1489	.1811	.1515	.1707	.1858	.1377	.1832	.1312	.1224	9.1605
B22	.0469	.0319	.0079	.0370	.0479	.0034	.0180	.0153	—	.0367	25.7387**
B39	.2031	.1330	.2362	.2222	.1916	.1689	.2036	.1718	.2443	.1918	14.0469
B45	.1094	.2021	.1654	.1481	.1617	.2128	.1557	.1641	.1312	.1837	14.4498
B78	.0313	.0053	.0157	.0303	.0060	.0236	.0150	.0420	.0362	.0408	18.2302*
B89	.1563	.1383	.0945	.1010	.1078	.0777	.0988	.0992	.0498	.1265	19.1321*
B111	.0104	.0372	.0079	.0404	.0509	.0068	.0689	.0191	.0407	.0776	42.2242**
B206	.0365	.0745	.0787	.0539	.0539	.0980	.0719	.1260	.1312	.0612	29.5489**
B233	.1615	.1489	.1575	.1785	.1946	.1728	.2066	.1603	.2262	.1347	11.9897
B296	.0104	—	.0079	.0269	.0030	.0068	.0120	.0076	.0045	—	14.5836
						C SYSTEM					
C0	.1883	.1554	.1295	.1435	.1174	.1207	.0830	.1086	.1477	.0867	15.7296
C1	.0584	.1014	.0466	.0043	.0087	.0043	.1066	—	—	.0107	71.2723**
C2	.0519	.1081	.0622	.1087	.2043	.1379	.2075	.1357	.2898	.0969	73.8793**
C3	.3766	.3716	.4508	.3652	.4130	.3922	.4066	.3575	.2102	.4796	36.1773**

TABLE 6 (continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Chi-square
						C SYSTEM					
C16	.0130	.0068	.0104	.0261	.0130	.0474	.0124	.0542	.0341	—	23.1798**
C21	.0584	.0405	.0155	.0435	.0174	.0474	.0290	.0407	.0114	.0051	18.0714*
C22	.0130	.0068	.0207	.0696	.0217	.0345	.0415	.0498	.0227	.0153	22.3642**
C27	.0260	.0270	.0415	.0217	.0261	.0172	.0249	.0362	.0625	.0306	9.6147
C29	.0195	.0135	.0207	.0130	.0217	.0388	.0249	.0181	.0170	.0102	6.3842
C32	.1948	.1419	.1865	.1956	.1348	.1336	.1411	.1810	.1875	.1633	9.0384
C34	—	.0135	.0052	—	.0043	—	.0083	.0045	—	.0051	4.7437
C45	—	.0135	—	—	—	—	.0041	.0045	.0057	.0459	44.7443**
C51	—	—	.0052	—	—	.0216	—	.0091	.0114	.0255	15.5741
C100[b]	—	—	.0052	.0087	.0174	.0043	—	—	—	.0255	15.8789
						F SYSTEM					
F1	.6845	.7794	.7396	.7012	.8022	.7853	.7378	.7171	.7562	.7943	22.6416**
F4	.3155	.2206	.2604	.2988	.1978	.2147	.2622	.2829	.2438	.2057	22.6416**
						J SYSTEM					
J0	.6746	.7486	.6666	.6630	.6411	.6691	.6789	.7354	.6853	.7840	21.426**
J1	.3254	.2514	.3333	.3370	.3589	.3309	.3211	.2646	.3147	.2160	21.426**
						L SYSTEM					
L0	.9507	.9141	.8864	.9206	.9213	.9307	.9380	.8982	.8879	.9209	13.445
L1	.0493	.0859	.1136	.0794	.0787	.0693	.0620	.1018	.1121	.0791	13.945
						M SYSTEM					
M0	.9730	.9466	.8379	.8100	.8765	.8506	.8886	.8229	.8973	.8052	42.392**
M1	.0270	.0458	.1581	.1900	.1235	.1429	.1056	.1771	.1027	.1498	38.515**
M2	—	.0076	.0040	—	—	.0065	.0059	—	—	.0449	54.176**

TABLE 6 (continued)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Chi-square
						R'-S' SYSTEM					
R1	.1667	.3611	.5758	.5049	.6043	.5903	.5057	.6117	.4348	.5022	38.554**
R2	.8333	.6389	.4242	.4951	.3957	.4097	.4943	.3883	.5652	.4978	38.554**
						S SYSTEM					
S0	.6750	.5672	.4304	.4892	.4320	.4050	.3961	.3486	.4286	.4061	26.407**
S1	.2500	.1343	.0823	.0736	.0680	.0785	—	—	.0057	—	70.966**
S2	—	.0149	—	—	—	—	—	—	—	—	25.409**
S4	.0250	.0896	.1835	.1169	.0640	.1818	.1020	.1927	.0971	.1117	36.964**
S6	.0500	.1940	.2911	.3203	.4160	.3141	.4588	.3853	.4457	.4264	54.499**
S12	—	—	.0127	—	.0200	.0207	.0431	.0734	.0229	.0558	24.444**
						Z SYSTEM					
Z0	.8000	.8079	.8592	.8403	.6928	.8797	.7940	.8514	.7751	.7125	62.419**
Z1	.2000	.1921	.1408	.1597	.3072	.1203	.2060	.1486	.2249	.2875	62.419**
						TRANSFERRIN SYSTEM					
Tf1	.4663	.5000	.5044	.4939	.4298	.4345	.4727	.5405	.4188	.5504	20.999**
Tf2	.3617	.3317	.3274	.3262	.4269	.4226	.3142	.2973	.4274	.2554	41.362**
Tf3	.1718	.1683	.1681	.1799	.1433	.1429	.2131	.1622	.1538	.1942	10.289

[a]Small frequency (<20) B phenogroups pooled - B46, B92, B85, B144, B96, B354, B390, B330, B307, B337, B3, B202, B331, B90, B82, B392, B306, B79.

[b]Small frequency (<10) C phenogroups pooled - C13, C14, C23, C30, C33, C39.

* $.01 < P < .05$

** $P < .01$

TABLE 7

DIFFERENCES AMONG BLOOD GROUPS WITHIN BLOOD GROUP SYSTEMS WITH RESPECT TO FREQUENCIES OF REACTORS TO BRUCELLOSIS TEST

Blood Group System	Blood Group	Non-Reactors	Reactors	Total	Chi-Square
A	A1	97	79	176	
	A2	5	6	11	
	A3	246	196	442	
					.456
					df=2
B	B0	7	3	10	
	B1	3	6	9	
	B16	58	62	120	
	B22	6	8	14	
	B39	58	57	115	
	B45	62	47	109	
	B78	7	4	11	
	B89	28	36	64	
	B111	12	9	21	
	B206	24	16	40	
	B233	76	41	117	
	B296	3	4	7	
				.10 < P < .16	15.568
					df=11
C	C0	41	30	71	
	C1	4	14	18	
	C2	50	29	79	
	C3	94	81	175	
	C16	10	4	14	
	C21	12	8	20	
	C22	9	9	18	
	C27	12	6	18	
	C29	6	9	15	
	C32	38	31	69	
	C100[b]	7	3	10	
				.10 < P < .12	15.432
					df=10
F-V	F1	289	225	514	
	F4	109	93	202	
					.301
					df=1
J	J0	237	190	427	
	J1	104	80	184	
					.054
					df=1

TABLE 7 (continued)

Blood Group System	Blood Group	Non-Reactors	Reactors	Total	Chi-Square
L	L0	345	283	628	
	L1	38	24	62	
					.922
					df=1
M	M0	298	211	509	
	M1	40	24	64	
	M2	1	0	1	
					1.062
					df=2
R'-S'	R1	128	63	191	
	R2	94	60	154	
					1.328
					df=1
S	S0	100	69	169	
	S1	8	10	18	
	S4	41	15	56	
	S6	91	53	144	
	S12	14	5	19	
				.10 < P < .13	7.093
					df=4
Z	Z0	307	244	551	
	Z1	67	64	131	
					.893
					df=1
Trans-ferrins	Tf1	173	104	277	
	Tf2	129	105	234	
	Tf3	51	45	96	
				.10 < P < .14	3.984
					df=2

[a]Pooled B phenogroups with expected values ≤2, including B46, B92, B85, B144, B96, B354, B390, B330, B307, B337, B3, B202, B331, B90, B82, B392, B306, B79.

[b]Pooled C phenogroups with expected values ≤2, including C13, C14, C23, C30, C33, C39.

TABLE 8

LEAST-SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS AND WEIGHTS BY BLOOD TYPE WITHIN BLOOD GROUP SYSTEM

Blood Group System	Blood Type	AADG (kg)	SDM[a]	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
A	A0/A0	.8917		.4759		.6792		200.497		270.154	
		±.0347		±.0513		±.0292		±7.727		±11.277	
	A3/A0	.9358		.4897		.7138		207.585		284.493	
		±.0336		±.0489		±.0278		±7.457		±10.746	
	A1/A0	.9204		.5288		.7371		212.498		292.619	
		±.0351		±.0519		±.0295		±7.811		±11.404	
	A1/A3	.8867		.5445		.7147		202.336		284.793	
		±.0074		±.0192		±.0109		±1.641		±4.217	
	A2/A0	.9410		.4053		.6903		216.117		276.166	
		±.0762		±.1074		±.0611		±16.941		±23.566	
	A2/A3	.9459		.5524		.7435		211.615		295.767	
		±.0258		±.0394		±.0224		±5.739		±8.652	
	A3/A3	.9007		.5297		.7125		205.715		284.109	
		±.0055		±.0174		±.0099		±1.229		±3.829	
B	B0/B0	.8860		.5613		.7154		207.793		284.333	
		±.0488		±.0701		±.0393		±10.765		±15.171	
	B0/B16	.8400		.4265		.6159		175.532		250.278	
		±.0910		±.1254		±.0703		±19.908		±27.092	
	B0/B89	.9019		.6345		.7761		210.387		312.755	
		±.0809		±.1111		±.0623		±17.624		±24.059	
	B0/B233	.9142		.4146		.6819		206.762		271.885	
		±.0777		±.1027		±.0576		±16.187		±22.177	
	B16/B16	.9219		.6378		.7850		211.786		312.747	
		±.0636		±.0881		±.0494		±13.911		±19.054	
	B16/B22	.9033		.5887		.7567		211.913		300.769	
		±.0491		±.0694		±.0389		±10.822		±15.000	
	B16/B39	.8980		.5399		.7226		200.932		286.455	
		±.0147		±.0239		±.0131		±3.213		±5.071	
	B22/B39	.9263		.5552		.7313		211.221		291.281	
		±.0307		±.0455		±.0255		±6.772		±9.857	
	B22/B111	.9741		.4657		.7347		232.511		297.899	
		±.0756		±.1049		±.0588		±16.653		±22.709	
	B39/B39	.9536		.4601		.7131		220.114		283.197	
		±.0415		±.0588		±.0330		±9.136		±12.734	
	B39/B45	.9100		.5520		.7259		206.553		288.878	
		±.0124		±.0205		±.0115		±2.719		±4.436	
	B30/B111	.8826		.5324		.7124		200.548		285.846	
		±.0281		±.0411		±.0230		±6.188		±8.887	
	B39/B206	.8906		.5639		.7231		204.979		288.866	
		±.0172		±.0272		±.0152		±3.797		±5.886	

TABLE 8 (continued)

Blood Group System	Blood Type	AADG (kg)	SDM	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
B	B45/B16	.8929		.5063		.7004		203.809		278.680	
		±.0147		±.0235		±.0132		±3.235		±5.095	
	B45/B22	.9468		.5336		.7317		217.664		292.784	
		±.0437		±.0624		±.0350		±9.621		±13.467	
	B45/B45	.9251		.4742		.7308		204.016		282.551	
		±.0479		±.0671		±.0376		±10.552		±14.531	
	B45/B78	.8355		.5577		.6983		190.594		279.803	
		±.0487		±.0683		±.0383		±10.742		±14.781	
	B45/B89	.9040		.5626		.7296		206.312		291.138	
		±.0175		±.0270		±.0151		±3.858		±5.828	
	B45/B111	.9352		.6152		.7693		208.802		304.222	
		±.0263		±.0381		±.0214		±5.784		±8.259	
	B45/B206	.9055		.5614		.7401		207.070		294.334	
		±.0229		±.0336		±.0188		±5.040		±7.267	
	B45/B233	.8823		.5565		.7137		201.061		284.887	
		±.0138		±.0216		±.0121		±3.011		±4.667	
	B45/B296	1.0327		.5574		.7759		234.151		307.833	
		±.0636		±.0892		±.0500		±14.017		±19.308	
	B78/B16	.9053		.4027		.6722		203.223		263.996	
		±.0447		±.0635		±.0356		±9.860		±13.753	
	B78/B39	.9428		.5648		.7452		215.506		298.192	
		±.0277		±.0405		±.0227		±6.108		±8.774	
	B78/B111	.9049		.5980		.7570		205.604		299.315	
		±.0772		±.1078		±.0605		±17.021		±23.345	
	B82/B206	1.002		.7940		.8533		225.672		331.480	
		±.0813		±.1135		±.0637		±17.922		±24.583	
	B89/B16	.9109		.4989		.7067		207.503		281.221	
		±.0158		±.0245		±.0137		±3.482		±5.288	
	B89/B22	.8983		.4813		.6904		206.498		274.000	
		±.0399		±.0570		±.0320		±8.797		±12.350	
	B89/B39	.8861		.5345		.7090		202.959		281.030	
		±.0190		±.0287		±.0161		±4.189		±6.223	
	B89/B78	.8596		.6412		.7302		197.778		295.377	
		±.0672		±.0937		±.0526		±14.817		±20.295	
	B89/B89	.8156		.5765		.7013		191.769		279.492	
		±.0653		±.0914		±.0512		±14.401		±19.784	
	B89/B111	.9496		.5077		.7309		211.623		293.241	
		±.0398		±.0561		±.0315		±8.775		±12.137	
	B89/B206	.8953		.5530		.7272		204.236		290.441	
		±.0264		±.0383		±.0215		±5.854		±8.252	
	B89/B233	.9024		.5607		.7275		203.189		288.294	
		±.0187		±.0282		±.0158		±4.118		±6.098	
	B96/B16	.7480		.5398		.6422		166.228		262.763	
		±.0775		±.1074		±.0602		±17.077		±23.263	

TABLE 8 (continued)

Blood Group System	Blood Type	AADG (kg)	SDM[a]	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
B	B96/B39	.9045		.4076		.6895		201.731		274.322	
		±.0507		±.0717		±.0402		±11.182		±15.521	
	B96/B45	.9375		.5955		.7475		208.143		304.734	
		±.0590		±.0794		±.0445		±12.519		±17.204	
	B96/B85	.7595		.3981		.6474		224.670		254.635	
		±.0943		±.2066		±.1158		±31.736		±44.739	
	B96/B89	.7904		.4916		.6543		187.665		262.374	
		±.0638		±.1104		±.0619		±14.062		±23.901	
	B96/B233	.9308		.7009		.8126		222.610		322.296	
		±.0077		±.1071		±.0601		±17.018		±23.203	
	B111/B16	.8833		.6057		.7462		206.495		297.953	
		±.0333		±.0479		±.0269		±7.338		±10.373	
	B111/B206	.9447		.6252		.7802		219.024		310.977	
		±.0415		±.0588		±.0330		±9.137		±12.712	
	B206/B16	.9374		.5102		.7139		210.358		283.916	
		±.0230		±.0332		±.0186		±5.069		±7.192	
	B206/B22	.7904		.5087		.6657		177.529		267.798	
		±.0544		±.0764		±.0428		±11.991		±16.542	
	B206/B45	.9326		.5430		.7348		217.933		294.416	
		±.0413		±.0586		±.0328		±9.092		±12.658	
	B206/B78	1.0287		.5612		.6739		217.219		268.111	
		±.0580		±.0930		±.0522		±12.782		±20.149	
	B233/B16	.8829		.5192		.6994		199.276		277.927	
		±.0153		±.02333		±.0131		±3.378		±5.052	
	B233/B22	.8683		.4915		.6814		195.058		271.445	
		±.0368		±.0523		±.0293		±8.110		±11.323	
	B233/B39	.8922		.5459		.7165		202.620		285.931	
		±.0121		±.0207		±.0116		±2.668		±4.480	
	B233/B78	.8625		.5572		.7019		194.783		281.397	
		±.0306		±.0440		±.0247		±6.749		±9.484	
	B233/B111	.9219		.5298		.7262		213.099		288.589	
		±.0274		±.0399		±.0224		±6.028		±8,650	
	B233/B206	.8878		.5029		.6875		197.200		273.222	
		±.0197		±.0300		±.0168		±4.345		±6.499	
	B233/B233	.8767		.5811		.7354		200.524		291.104	
		±.0293		±0.420		±.0236		±6.454		±9.102	
	B233/B330	.9095		.5228		.7209		208.364		285.767	
		±.0491		±.0689		±.0386		±10.825		±14.922	
	B296/B39	.8793		.4759		.6989		203.080		279.398	
		±.0377		±.0534		±.0299		±8.304		±11.535	
	B296/B233	.8823		.6337		.7586		204.601		305.525	
		±.0493		±.0689		±.0386		±10.863		±14.919	
	B307/B45	.8796		.4946		.6733		210.612		269.697	
		±.0644		±.0899		±.0504		±14.194		±19.470	

TABLE 8 (continued)

Blood Group System	Blood Type	AADG (kg)	SDM	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
		**									
C	C0/C0	.8750		.5520		.7107		201.556		284.728	
		±.0175		±.0285		±.0163		±3.731		±6.169	
	C1/C0	.8175		.5890		.6860		186.347		277.363	
		±.0621		±.0883		±.0506		±13.270		±18.813	
	C1/C2	1.0854		.7197		.8632		260.741		346.448	
		±.0845		±.1192		±.0683		±18.058		±25.734	
	C1/C32	.9322		.6145		.7616		209.013		303.974	
		±.0411		±.0582		±.0333		±8.782		±12.562	
	C2/C0	.9393		.5337		.7270		214.923		292.407	
		±.0391		±.0560		±.0321		±8.358		±12.080	
	C2/C3	.9378		.5073		.7153		215.833		284.372	
		±.0412		±.0589		±.0338		±8.808		±12.770	
	C2/C16	1.2956		.3294		.6876		275.212		278.318	
		±.0843		±.1507		±.0864		±18.027		±32.624	
	C2/C22	.8857		.5801		.7159		187.065		284.468	
		±.0827		±.1121		±.0642		±17.658		±24.285	
	C2/C27	.9583		.7006		.8219		224.174		330.330	
		±.0889		±.1206		±.0691		±19.011		±26.081	
	C2/C29	.8842		.5241		.7114		203.655		283.303	
		±.0373		±.0534		±.0306		±7.984		±11.568	
	C2/C32	.8910		.5641		.7222		206.861		289.796	
		±.0190		±.0303		±.0174		±4.070		±6.563	
	C2/C34	.9077		.3530		.6787		212.337		268.155	
		±.0825		±.1013		±.0581		±15.454		±21.923	
	C2/C45	.9435		.4859		.7552		219.811		297.681	
		±.1144		±.1564		±.0896		±24.469		±33.875	
	C3/C0	.9071		.5386		.7199		205.313		287.177	
		±.0200		±.0324		±.0186		±4.269		±7.003	
	C3/C1	.7991		.4414		.6509		191.215		255.946	
		±.0800		±.1145		±.0656		±17.111		±24.807	
	C3/C16	.9083		.6587		.7780		212.211		311.829	
		±.0563		±.0778		±.0446		±12.032		±16.840	
	C3/C21	.7702		.6266		.6939		185.446		280.183	
		±.0635		±.0872		±.0500		±13.567		±18.893	
	C3/C22	1.067		.4141		.7033		219.785		279.491	
		±.0883		±.1219		±.0699		±18.886		±26.391	
	C3/C27	.8963		.4903		.6807		202.524		273.757	
		±.0371		±.0531		±.0304		±7.935		±11.448	
	C3/C29	.9299		.6109		.7634		211.506		303.654	
		±.0530		±.0741		±.0425		±11.338		±15.868	

TABLE 8 (continued)

Blood Group System	Blood Type	AADG (kg)	SDM[a]	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
C	C3/C32	.9242		.5158		.7146		207.556		284.970	
		±.0134		±.0253		±.0145		±2.866		±5.484	
	C3/C34	.9125		.7266		.7752		209.180		309.115	
		±.0827		±.1232		±.0706		±17.674		±26.680	
	C3/C45	.8821		.5886		.7653		210.235		301.147	
		±.1146		±.1564		±.0896		±24.502		±33.842	
	C3/C51	.9060		.5920		.7863		220.357		317.921	
		±.1271		±.1967		±.1127		±30.996		±42.574	
	C13/C27	.8456		.5293		.6752		192.075		263.090	
		±.1271		±.1718		±.0985		±27.190		±36.983	
	C16/C0	.9011		.4736		.6702		209.867		270.045	
		±.0680		±.0933		±.0535		±14.538		±20.148	
	C16/C27	.9234		.5682		.7858		226.002		317.599	
		±.0885		±.1212		±.0694		±18.922		±26.248	
	C16/C29	.8713		.5756		.7545		207.812		302.287	
		±.0917		±.1266		±.0725		±19.599		±27.415	
	C16/C32	.9189		.4822		.6973		215.234		275.287	
		±.0489		±.0687		±.0394		±10.458		±14.863	
	C21/C0	.8354		.5962		.7057		196.094		282.997	
		±.0842		±.1152		±.0660		±17.996		±29.959	
	C21/C22	.8713		.5903		.7304		209.427		291.752	
		±.0924		±.1277		±.0732		±19.767		±27.545	
	C21/C32	.8801		.4681		.6806		201.051		270.282	
		±.0339		±.0514		±.0295		±7.473		±11.127	
	C22/C0	.9930		.5193		.7541		220.216		295.191	
		±.0589		±.0817		±.0468		±12.590		±17.696	
	C22/C29	.9716		.5234		.7546		213.830		297.935	
		±.0848		±.1150		±.0659		±18.138		±24.921	
	C22/C32	.8819		.5219		.6985		203.495		278.238	
		±.0261		±.0384		±.0220		±5.495		±8.314	
	C23/C32	.8808		.5761		.7172		197.103		283.451	
		±.0843		±.1167		±.0669		±18.032		±25.038	
	C27/C32	.9523		.5413		.7155		215.441		285.299	
		±.0388		±.0588		±.0337		±8.296		±12.700	
	C27/C51	.9604		.7118		.8412		224.405		337.428	
		±.0793		±.1087		±.0623		±16.952		±23.557	
	C29/C0	.7571		.5057		.6328		172.629		260.477	
		±.0591		±.0824		±.0472		±12.643		±17.711	
	C32/C0	.9293		.6000		.7449		205.593		298.611	
		±.0337		±.0484		±.0278		±7.204		±10.495	
	C51/C32	.8134		.5819		.7004		187.648		288.778	
		±.0786		±.1075		±.0660		±16.808		±23.229	

TABLE 8 (continued)

Blood Group System	Blood Type	AADG (kg)	SDM[a]	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
						†				†	
F-V	F1/F1	.8986		.5317		.7186		203.743		285.592	
		±.0049		±.0118		±.0067		±1.0782		±2.595	
	F1/F4	.8964		.5391		.7215		205.185		286.900	
		±.0054		±.0124		±.0070		±1.201		±2.716	
	F4/F4	.8790		.5270		.6997		200.795		279.289	
		±.0131		±.0205		±.0116		±2.919		±4.495	
J	J0/J0	.8942		.5425		.7205		203.588		286.490	
		±.0054		±.0132		±.0076		±1.178		±2.938	
	J1/J0	.8988		.5525		.7268		205.128		289.914	
		±.0084		±.0158		±.0091		±1.834		±3.514	
L	L0/L0	.8981		.5295		.7173		204.454		285.038	
		±.0043		±.0117		±.0066		±.9492		±2.548	
	L1/L0	.8995		.5442		.7190		204.301		286.639	
		±.0119		±.0194		±.0109		±2.624		±4.222	
M	M0/M0	.8928		.5524		.7241		203.363		287.947	
		±.0047		±.0127		±.0073		±1.037		±2.809	
	M1/M0	.9048		.5664		.7424		207.461		296.242	
		±.0142		±.0228		±.0131		±3.134		±5.042	
	M2/M0	.8491		.4848		.7004		194.609		281.321	
		±.1083		±.1487		±.0855		±23.811		±32.992	
	M1/M2	.9385		.5609		.7489		215.488		296.478	
		±.0440		±.0612		±.0352		±9.669		±13.551	
R'-S'	R1/R1	.8139		.5668		.6567		193.221		258.702	
		±.1132		±.1601		±.0898		±24.736		±34.380	
	R1/R2	.8986		.5732		.7183		203.566		286.879	
		±.0094		±.0233		±.0131		±2.065		±4.986	
	R2/R2	.8975		.5626		.7131		204.469		285.332	
		±.0093		±.0219		±.0123		±2.013		±4.702	
		†		*		**		†		**	
S	S0/S0	.8834		.5475	9	.7008	6,9	200.812		279.950	6,9
		±.0085		±.0118		±.0066		±1.855		±2.563	
	S1/S0	.8966		.5808	3,9	.7294		202.881		290.046	
		±.0383		±.0524		±.0293		±8.326		±11.467	
	S1/S4	.8441		.3335	4,6	.6275	9	193.388		247.874	6,9
		±.0844		±.1154	7,9	±.0646		±18.318		±25.264	

TABLE 8 (continued)

Blood Group System	Blood Type	AADG (kg)	SDM[a]	PADG (kg)	SDM	LADG (kg)	SDM	ACFWW (kg)	SDM	APWT (kg)	SDM
S	S4/S0	.9478		.6165	8	.7377		209.976		295.445	
		±.0288		±.0407		±.0228		±6.244		±8.907	
	S4/S6	.9227		.5486	9	.7233	9	209.760		287.764	9
		±.0178		±.0244		±.0137		±3.836		±5.339	
	S6/S0	.9381		.5851	8,9	.7467		212.183		298.507	
		±.0159		±.0218		±.0122		±3.463		±4.764	
	S12/S0	.9505		.6128		.7483		199.183		293.226	
		±.0499		±.0682		±.0382		±10.824		±14.921	
	S12/S4	.9293		.3973	9	.6632	9	210.464		267.220	9
		±.0684		±.0934		±.0522		±14.845		±20.412	
	S12/S6	.9614		.8474		.8646		208.940		341.775	
		±.0855		±.1169		±.0655		±18.553		±25.552	
			†				*				
Z	Z0/Z0	.8936		.5361		.7175		203.283	2	285.432	
		±.0048		±.0129		±.0072		±1.051		±2.777	
	Z1/Z0	.9098		.5214		.7157		207.992		285.125	
		±.0077		±.0152		±.0085		±1.693		±3.280	
	Z1/Z1	.9271		.5168		.7368		206.216		289.993	
		±.0248		±.0372		±.0207		±5.457		±7.982	
			*				†		*		†
Trans-ferrins	Tf1/Tf1	.8853	2	.5251		.7099		201.342	2	281.920	
		±.9079		±.0142		±.0082		±1.596		±3.150	
	Tf1/Tf2	.9079	5	.5261		.7217		206.241	5	286.251	
		±.0060		±.0130		±.0075		±1.325		±2.891	
	Tf1/Tf3	.8978	5	.5200		.7134		204.554	5	283.253	
		±.0078		±.0145		±.0082		±1.712		±3.216	
	Tf2/Tf2	.8996	5	.5409		.7272		204.149		289.031	
		±.0095		±.0170		±.0098		±2.103		±3.770	
	Tf2/Tf3	.8751		.5239		.7094		199.396	6	282.121	
		±.0098		±.0172		±.0099		±2.165		±3.823	
	Tf3/Tf3	.9137		.5724		.7472		208.941		295.520	
		±.0203		±.0293		±.0168		±4.490		±6.496	

[a]Significantly ($P<.05$) different means

[b]Significant difference between means is too involved to show in this table.

† $.05 < P < .20$

* $.01 < P < .05$

** $P < .01$

TABLE 9

LEAST-SQUARES MEANS AND STANDARD ERRORS OF BODY MEASUREMENTS AND SHAPE RATIOS BY BLOOD TYPE WITHIN BLOOD GROUP SYSTEMS

Blood Group System	Blood Type	WHG	SDM[a]	WLENGTH	SDM	WHIWTH	SDM	WHIHT	SDM	SRATIO	SDM
A	A0/A0	139.362		93.814		37.227		97.758		1482.185	
		±1.903		±1.517		±1.574		±1.259		±47.909	
	A3/A0	140.611		94.234		37.195		99.947		1485.513	
		±1.810		±1.443		±1.498		±1.192		±45.384	
	A1/A0	141.199		95.006		37.706		99.647		1504.828	
		±2.018		±1.608		±1.669		±1.341		±51.048	
	A1/A3	138.861		95.693		36.635		99.303		1479.872	
		±.710		±.566		±.587		±.491		±18.705	
	A2/A0	142.547		97.811		36.099		98.887		1638.734	
		±3.972		±3.166		±3.286		±3.653		±139.022	
	A2/A3	141.363		97.195		36.822		100.128		1536.038	
		±1.456		±1.161		±1.205		±1.026		±39.044	
	A3/A3	139.255		96.078		36.742		99.510		1491.434	
		±.645		±.514		±.536		±.442		±16.820	
B	B0/B0	140.377		97.953		36.441		99.786	†	1538.551	
		±2.546		±2.044		±2.014		±1.647		±63.904	
	B0/B16	136.486		95.537		38.127		106.007		1427.531	
		±4.556		±3.657		±3.603		±5.259		±204.016	
	B0/B89	141.221		94.892		37.209		98.181		1564.336	
		±4.037		±3.241		±3.193		±3.726		±144.546	
	B0/B233	141.125		96.809		37.547		102.280		1483.856	
		±3.733		±2.997		±2.953		±3.447		±133.722	
	B16/B16	139.406		100.478		38.930		104.518		1860.997	
		±3.203		±2.571		±2.533		±3.502		±135.881	
	B16/B22	139.947		96.585		38.320		100.595		1536.792	
		±2.522		±2.025		±1.995		±1.827		±70.864	
	B16/B39	140.101		95.351		36.990		98.820		1501.536	
		±.851		±.684		±.673		±.605		±23.459	
	B22/B39	140.421		96.030		37.777		100.208		1522.924	
		±1.654		±1.328		±1.308		±1.192		±46.239	
	B22/B111	141.342		94.701		38.077		102.228		1467.843	
		±3.813		±3.061		±3.015		±2.472		±95.886	
	B39/B39	142.714		97.310		37.138		100.733		1566.923	
		±2.137		±1.716		±1.690		±1.494		±57.971	
	B39/B45	139.889		96.070		36.459		99.593		1492.625	
		±.747		±.600		±.591		±.504		±19.558	

TABLE 9 (continued)

Blood Group System	Blood Type	WHG	SDM	WLENGTH	SDM	WHIWTH	SDM	WHIHT	SDM	SRATIO	SDM
B	B39/B111	141.202		96.084		36.475		100.613		1521.698	
		±1.492		±1.198		±1.180		±1.054		±40.898	
	B39/B206	139.157		94.798		36.799		99.147		1474.555	
		±1.006		±.808		±.796		±.695		±26.982	
	B45/B16	139.368		95.615		36.514		98.372		1497.893	
		±.862		±.692		±.682		±.604		±23.446	
	B45/B22	140.404		98.019		37.502		100.149		1540.598	
		±2.268		±1.821		±1.794		±1.602		±62.169	
	B45/B45	141.305		95.236		37.836		103.252		1521.759	
		±2.439		±1.958		±1.929		±2.536		±98.383	
	B45/B78	138.535		90.587		36.855		96.433		1482.758	
		±2.480		±1.991		±1.962		±1.773		±68.784	
	B45/B89	140.134		96.455		37.483		99.389		1523.633	
		±.982		±.789		±.777		±.685		±26.578	
	B45/B111	140.795		98.176		37.657		100.352		1542.318	
		±1.387		±1.113		±1.097		±.924		±35.866	
	B45/B206	140.529		96.454		36.789		99.601		1512.602	
		±1.245		±.999		±.984		±.808		±31.337	
	B45/B233	139.095		95.473		36.386		98.613		1498.206	
		±.785		±.630		±.621		±.550		±21.334	
	B45/B296	140.676		102.075		37.524		103.466		1544.428	
		±3.242		±2.603		±2.564		±2.494		±96.765	
	B78/B16	138.573		95.060		37.002		99.188		1440.052	
		±2.308		±1.853		±1.826		±1.832		±71.070	
	B78/B39	141.927		95.488		37.471		101.256		1513.580	
		±1.472		±1.182		±1.165		±.991		±38.444	
	B78/B111	144.854		96.680		36.215		99.707		1605.775	
		±3.917		±3.145		±3.098		±2.535		±98.357	
	B82/B206	144.737		93.346		35.184		—		—	
		±4.124		±3.311		±3.262		—		—	
	B89/B16	139.927		95.613		38.429		99.016		1499.588	
		±.894		±.718		±.707		±.650		±25.230	
	B89/B22	139.337		95.263		36.413		99.404		1465.913	
		±2.072		±1.664		±1.639		±1.708		±66.256	
	B89/B39	138.147		95.961		35.890		98.740		1464.484	
		±1.058		±.850		±.837		±.791		±30.697	
	B89/B78	138.211		91.445		35.178		99.454		1392.319	
		±3.405		±2.734		±2.693		±2.578		±100.033	
	B89/B89	134.324		91.828		35.163		96.699		1166.642	
		±3.320		±2.666		±2.626		±3.593		±139.404	
	B89/B111	143.402		95.802		37.012		99.756		1586.862	
		±2.039		±1.637		±1.613		±1.538		±59.653	

TABLE 9 (continued)

Blood Group System	Blood Type	WHG SDM	WLENGTH SDM	WHIWTH SDM	WHIHT SDM	SRATIO SDM
B	B89/B206	140.437	96.329	36.974	99.863	1485.115
		±1.391	±1.117	±1.100	±1.008	±39.104
	B89/B233	138.639	97.349	36.350	99.517	1511.861
		±1.033	±.829	±.817	±.721	±27.974
	B96/B16	130.398	93.235	35.394	97.807	1252.690
		±3.903	±3.133	±3.087	±3.580	±138.871
	B96/B39	142.152	98.473	37.604	98.938	1575.123
		±2.606	±2.092	±2.061	±2.546	±98.755
	B96/B45	141.809	98.431	37.623	100.998	1431.133
		±2.887	±2.318	±2.283	±3.583	±138.988
	B96/B85	138.674	91.231	39.315	—	—
		±7.509	±6.029	±5.939	—	—
	B96/B89	135.444	95.275	37.825	—	—
		±4.011	±3.220	±3.172	—	—
	B96/B233	142.535	95.100	35.117	99.739	1566.016
		±3.894	±3.126	±3.080	±3.498	±135.707
	B111/B16	141.077	96.667	36.343	98.660	1546.339
		±1.742	±1.398	±1.378	±1.136	±43.977
	B111/B206	142.259	95.840	36.628	99.993	1528.081
		±2.136	±1.715	±1.690	±1.487	±57.672
	B206/B16	139.820	96.004	36.384	100.043	1481.368
		±1.247	±1.001	±.986	±.828	±32.105
	B206/B22	138.700	91.312	34.978	96.779	1435.866
		±2.776	±2.229	±2.196	±1.798	±69.743
	B206/B45	143.243	95.747	37.939	101.259	1546.862
		±2.490	±1.999	±1.969	±1.617	±62.717
	B206/B78	135.789	94.679	34.396	92.530	1473.048
		±3.381	±2.714	±2.674	±2.565	±99.521
	B233/B16	138.581	96.072	35.938	99.213	1482.263
		±.848	±.681	±.671	±.592	±22.968
	B233/B22	137.359	95.236	36.856	98.575	1419.747
		±1.904	±1.529	±1.506	±1.612	±62.543
	B233/B39	139.385	95.800	36.699	99.918	1487.716
		±.754	±.606	±.597	±.506	±19.640
	B233/B78	137.904	96.257	36.668	99.023	1481.830
		±1.599	±1.284	±1.265	±1.074	±41.658
	B233/B111	139.937	97.472	37.220	98.952	1536.976
		±1.489	±1.195	±1.177	±.973	±37.753
	B233/B206	137.094	94.219	36.590	97.011	1440.535
		±1.092	±.877	±.864	±.766	±29.727
	B233/B233	137.893	97.256	36.965	99.863	1461.911
		±1.527	±1.226	±1.208	±1.197	±46.450

TABLE 9 (continued)

Blood Group System	Blood Type	WHG	SDM	WLENGTH	SDM	WHIWTH	SDM	WHIHT	SDM	SRATIO	SDM
B	B233/B330	142.584		97.952		37.826		100.746		1569.972	
		±2.512		±2.017		±1.987		±1.627		±63.113	
	B296/B39	138.306		98.778		37.000		99.840		1500.181	
		±1.940		±1.558		±1.535		±1.258		±48.815	
	B296/B233	138.824		95.699		36.375		100.847		1427.452	
		±2.504		±2.010		±1.980		±1.788		±69.380	
	B307/B45	134.870		95.809		36.309		96.389		1434.206	
		±3.269		±2.624		±2.585		±2.117		±82.113	
C	C0/C0	141.112		95.910		36.645		99.348		1557.165	
		±1.056		±.892		±.376		±.810		±32.828	
	C1/C0	136.111		91.629		35.186		102.191		1317.630	
		±3.252		±2.747		±1.157		±3.853		±156.220	
	C1/C2	144.879		102.923		38.825		103.528		1837.886	
		±4.385		±3.703		±1.560		±3.727		±151.110	
	C1/C32	141.167		99.347		37.416		101.742		1604.569	
		±2.138		±1.806		±.761		±1.762		±71.467	
	C2/C0	142.640		97.228		38.089		103.767		1541.633	
		±2.185		±1.845		±.777		±1.621		±65.741	
	C2/C3	141.720		96.926		38.512		102.354		1511.024	
		±2.172		±1.835		±.773		±1.771		±71.809	
	C2/C16	145.402		95.504		36.805		98.959		1633.205	
		±5.534		±4.674		±1.970		±3.526		±142.978	
	C2/C22	135.209		95.685		37.031		97.136		1449.963	
		±4.117		±3.477		±1.465		±2.643		±107.163	
	C2/C27	142.889		102.513		39.169		105.845		1578.213	
		±4.432		±3.744		±1.577		±2.869		±116.340	
	C2/C29	139.537		95.366		37.405		101.200		1462.313	
		±1.995		±1.685		±.710		±1.480		±60.019	
	C2/C32	139.364		96.004		36.929		99.799		1504.239	
		±1.125		±.950		±.400		±.818		±33.168	
	C2/C34	142.503		98.810		38.621		99.065		1528.426	
		±3.725		±3.146		±1.326		±2.720		±110.305	
	C2/C45	140.863		97.050		39.880		95.918		1623.300	
		±5.745		±4.852		±2.044		±3.640		±147.593	
	C3/C0	140.160		97.769		36.883		99.313		1564.894	
		±1.211		±1.023		±.431		±.991		±40.168	
	C3/C1	138.593		94.686		35.873		97.654		1510.325	
		±4.208		±3.554		±1.498		±2.714		±110.049	
	C3/C16	142.529		97.060		38.839		101.168		1581.587	
		±2.882		±2.434		±1.026		±1.865		±75.639	
	C3/C21	139.503		91.375		36.506		97.871		1529.732	
		±3.209		±2.710		±1.142		±2.278		±92.376	

TABLE 9 (continued)

Blood Group System	Blood Type	WHG	SDM	WLENGTH	SDM	WHIWTH	SDM	WHIHT	SDM	SRATIO	SDM
C	C3/C22	142.803		91.689		39.603		98.506		1545.657	
		±4.481		±3.785		±1.595		±2.870		±116.379	
	C3/C27	139.824		96.453		36.706		100.441		1520.893	
		±1.950		±1.647		±.694		±1.401		±56.789	
	C3/C29	142.791		95.954		36.627		100.435		1577.733	
		±2.725		±2.302		±.970		±1.765		±71.586	
	C3/C32	139.954		96.768		37.077		99.934		1530.738	
		±.936		±.791		±.333		±.727		±29.467	
	C3/C34	138.423		97.683		34.884		99.083		1474.033	
		±4.524		±3.820		±1.610		±3.376		±136.890	
	C3/C45	141.952		92.260		38.061		96.628		1554.294	
		±5.748		±4.855		±2.046		±3.640		±147.587	
	C3/C51	143.461		102.537		39.823		100.009		1708.036	
		±7.226		±6.103		±2.571		±4.571		±185.331	
	C13/C27	130.319		92.746		35.337		92.330		1363.473	
		±6.311		±5.330		±2.246		±4.032		±163.494	
	C16/C0	139.731		94.340		37.008		100.746		1459.654	
		±3.459		±2.921		±1.231		±2.238		±90.731	
	C16/C27	140.942		102.972		39.164		102.297		1590.488	
		±4.454		±3.762		±1.585		±2.849		±115.542	
	C16/C29	142.077		97.817		37.990		101.585		1545.534	
		±4.730		±3.995		±1.683		±3.036		±123.097	
	C16/C32	139.778		97.024		36.751		99.551		1525.631	
		±2.543		±2.148		±.905		±2.007		±81.400	
	C21/C0	127.166		98.727		34.891		96.898		1327.143	
		±5.680		±4.797		±2.021		±3.646		±147.822	
	C21/C22	143.400		101.506		37.786		102.945		1620.469	
		±4.695		±3.965		±1.671		±3.002		±121.746	
	C21/C32	137.003		97.114		37.351		98.928		1448.287	
		±1.898		±1.603		±.675		±1.466		±59.451	
	C22/C0	143.086		96.542		37.436		97.104		1710.745	
		±3.004		±2.537		±1.069		±2.756		±111.764	
	C22/C29	147.581		101.258		37.232		100.528		1759.237	
		±4.227		±3.570		±1.504		±2.699		±109.423	
	C22/C32	138.897		95.616		37.056		98.638		1526.113	
		±1.436		±1.213		±.511		±1.008		±40.870	
	C23/C32	138.473		96.936		37.512		97.443		1504.958	
		±4.289		±3.623		±1.527		±2.731		±110.724	
	C27/C32	140.525		97.103		37.271		96.939		1572.125	
		±2.160		±1.824		±.769		±1.500		±60.832	
	C27/C51	149.646		97.620		40.205		101.107		1726.077	
		±4.172		±3.523		±1.485		±2.742		±111.191	
	C29/C0	132.456		93.919		35.374		99.195		1279.864	
		±3.033		±2.562		±1.080		±2.689		±109.050	

TABLE 9 (continued)

Blood Group System	Blood Type	WHG	SDM	WLENGTH	SDM	WHIWTH	SDM	WHIHT	SDM	SRATIO	SDM
C	C32/C0	141.212		97.072		36.190		100.618		1676.632	
		±1.783		±1.506		±.634		±1.807		±73.288	
	C51/C32	135.376		95.674		35.437		100.576		1400.795	
		±3.951		±3.337		±1.406		±2.537		±102.861	
		**		†		†				*	
F-V	F1/F1(1)	139.680	3	96.078		36.911		99.480		1498.887	3
		±.431		±.338		±.300		±.290		±11.412	
	F1/F4(2)	139.880	3	96.289		36.740		99.631		1508.153	3
		±.453		±.355		±.315		±.303		±11.919	
	F4/F4(3)	137.746		95.042		36.127		98.550		1457.329	
		±.748		±.587		±.521		±.515		±20.244	
				*		†					
J	J0/J0(1)	139.668		95.875	2	36.516		99.403		1501.500	
		±.503		±.379		±.176		±.337		±13.600	
	J1/J0(2)	139.713		96.686		36.821		99.699		1511.024	
		±.601		±.452		±.210		±.411		±16.579	
								†			
L	L0/L0	139.521		96.106		36.852		99.365		1498.802	
		±.424		±.333		±.301		±.284		±11.255	
	L1/L0	139.775		95.914		36.407		100.124		1493.793	
		±.702		±.551		±.498		±.474		±18.802	
				†							
M	M0/M0	139.552		95.845		36.766		99.482		1499.879	
		±.468		±.358		±.361		±.294		±11.626	
	M1/M0	140.267		97.146		36.760		99.978		1527.946	
		±.838		±.640		±.646		±.525		±20.753	
	M2/M0	139.485		94.319		35.163		99.855		1473.638	
		±5.502		±4.206		±4.241		±3.419		±135.201	
	M1/M2	142.201		96.086		38.166		98.981		1571.534	
		±2.251		±1.721		±1.735		±1.397		±55.238	
				†				†			
R'-S'	R1/R1	129.084		90.963		38.929		92.972		1298.764	
		±5.657		±4.114		±6.159		±3.584		±137.186	
	R1/R2	137.650		95.952		36.791		98.660		1480.970	
		±.826		±.600		±.899		±.527		±20.162	
	R2/R2	138.005		95.058		36.034		98.142		1484.230	
		±.774		±.563		±.843		±.491		±18.789	
								**			
S	S0/S0	137.735		94.870		36.562		98.042	4,5	1465.380	
		±.466		±.343		±.466		±.289	6,9	±11.008	

TABLE 9 (continued)

Blood Group System	Blood Type	WHG	SDM	WLENGTH	SDM	WHIWTH	SDM	WHIHT	SDM	SRATIO	SDM
S	S1/S0(2)	138.663		94.615		36.536		99.564	9	1448.598	
		±2.100		±1.547		±2.101		±1.401		±53.287	
	S1/S4(3)	138.540		93.033		37.587		98.396	9	1444.858	
		±4.590		±3.382		±4.592		±2.913		±110.787	
	S4/S0(4)	138.748		96.329		36.960		100.307	9	1477.073	
		±1.618		±1.192		±1.619		±1.023		±38.895	
	S4/S6(5)	139.391		96.554		36.938		101.213		1485.541	
		±.974		±.717		±.974		±.602		±22.880	
	S6/S0(6)	140.743		96.061		37.710		101.357		1513.548	
		±.869		±.641		±.870		±.566		±21.517	
	S12/S0(7)	139.190		94.778		37.681		100.068	9	1469.439	
		±2.711		±1.997		±2.712		±1.708		±64.968	
	S12/S4(8)	136.468		98.655		35.996		99.380		1478.075	
		±3.712		±2.735		±3.714		±2.337		±88.880	
	S12/S6(9)	141.430		97.623		35.206		106.424		1469.968	
		±4.650		±3.426		±4.652		±2.932		±111.484	
Z	Z0/Z0	139.791		96.059		36.805		99.492		1506.263	
		±.453		±.354		±.346		±.306		±12.285	
	Z1/Z0	140.298		96.233		36.837		99.532		1517.863	
		±.535		±.418		±.408		±.379		±15.228	
	Z1/Z1	141.298		95.692		36.643		100.003		1542.551	
		±1.304		±1.018		±.996		±.914		±36.702	
			†						†		
Trans-ferrin	Tf1/Tf1	139.124		96.041		37.045		99.395		1491.786	
		.531		±.418		±.378		±.351		±13.776	
	Tf1/Tf2	140.358		96.125		36.681		100.065		1511.631	
		±.486		±.383		±.347		±.324		±12.704	
	Tf1/Tf3	139.460		95.972		36.846		99.325		1495.590	
		±.540		±.426		±.385		±.360		±14.129	
	Tf2/Tf2	140.018		96.603		36.888		99.900		1514.391	
		±.639		±.504		±.456		±.423		±16.591	
	Tf2/Tf3	139.570		95.855		36.722		99.775		1500.934	
		±.643		±.507		±.458		±.433		±16.985	
	Tf3/Tf3	139.624		97.335		37.186		99.304		1502.937	
		±1.091		±.861		±.778		±.730		±28.651	

† .05 < P < .20
* .01 < P < .05
** P < .01

a - Significantly (P < .05) different means

TABLE 10

LEAST-SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS AND WEIGHTS BY BLOOD GROUP SYSTEM

HETEROZYGOTES vs. HOMOZYGOTES[a]

Blood Group System	Blood Type	AADG (kg)	PADG (kg)	LADG (kg)	ACFWW (kg)	APWT (kg)
A	A Homozygotes	.8999	.5277	.7114	205.471	283.654
		±.0054	±.0174	±.0099	±1.205	±3.817
	A Heterozygotes	.8938	.5411	.7171	203.549	285.704
		±.0068	±.0187	±.0167	±1.520	±4.119
B	B Homozygotes	.8997	.5339	.7254	206.407	286.823
		±.0179	±.0275	±.0153	±3.953	±5.902
	B Heterozygotes	.8981	.5324	.7138	204.022	284.111
		±.0042	±.0124	±.0069	±.9169	±2.686
		†				
C	C Homozygotes	.8741	.5597	.7148	202.154	286.048
		±.0172	±.0267	±.0152	±3.625	±5.801
	C Heterozygotes	.9060	.5504	.7215	206.657	288.198
		±.0067	±.0170	±.0097	±1.415	±3.699
F-V	F-V Homozygotes	.8963	.5310	.7162	203.385	284.764
		±.0046	±.0116	±.0066	±1.009	±2.535
	F-V Heterozygotes	.8968	.5392	.7217	205.250	286.980
		±.0054	±.0124	±.0070	±1.199	±2.717
				†	†	†
M	M Homozygotes	.8928	.5525	.7241	203.350	287.962
		±.0047	±.0127	±.0073	±1.036	±2.805
	M Heterozygotes	.9069	.5648	.7424	207.767	296.052
		±.0135	±.0219	±.0126	±2.983	±4.851
R'-S'	R Homozygotes	.8969	.5626	.7128	204.383	285.169
		±.0092	±.0219	±.0123	±2.002	±4.695
	R Heterozygotes	.8991	.5732	.7188	203.635	287.111
		±.0093	±.0232	±.0130	±2.057	±4.974
		**	†		**	**
S	S Homozygotes	.8819	.5434	.6991	200.708	279.202
		±.0083	±.0117	±.0065	±1.811	±2.537
	S Heterozygotes	.9283	.5679	.7324	209.392	292.001
		±.0096	±.0133	±.0074	±2.081	±2.899

TABLE 10 (Continued)

Blood Group System	Blood Type	AADG (kg)	PADG (kg)	LADG (kg)	ACFWW (kg)	APWT (kg)
		†			**	
Z	Z Homozygotes	.8950	.5354	.7182	203.405	285.605
		±.0047	±.0128	±.0071	±1.024	±2.760
	Z Heterozygotes	.9089	.5220	.7152	207.915	284.996
		±.0077	±.0152	±.0085	±1.686	±3.272
Trans-ferrins	Tf Homozygotes	.8922	.5328	.7179	202.835	285.109
		±.0057	±.0131	±.0075	±1.265	±2.906
	Tf Heterozygotes	.8993	.5229	.7166	204.545	284.438
		±.0046	±.0120	±.0069	±1.019	±2.664

[a]A system homozygotes - A3/A3
B system homozygotes - B0/B0, B16/B16, B39/B39, B45/B45, B89/B89, B233/B233.
C system homozygotes - C0/C0
F system homozygotes - F1/F1, F4/F4
M system homozygotes - M0/M0
R'-S' system homozygotes - R1/R1, R2/R2
S system homozygotes - S0/S0
Z system homozygotes - Z0/Z0, Z1/Z1
Transferrin homozygotes - Tf1/Tf1, Tf2/Tf2, Tf3/Tf3

† $.05 < P < .20$
* $.01 < P < .05$
** $P < .01$

TABLE 11

LEAST-SQUARES MEANS AND STANDARD ERRORS OF BODY MEASUREMENTS AND SHAPE RATIOS BY BLOOD GROUP SYSTEM

HETEROZYGOTES vs. HOMOZYGOTES[a]

Blood Group System	Blood Type	WHG	WLENGTH	WHIWTH	WHIHT	SRATIO
A	A Homozygotes	139.246	95.992	36.754	99.476	1489.698
		±.643	±.513	±.530	±.440	±16.739
	A Heterozygotes	139.189	95.708	36.701	99.429	1484.222
		±.644	±.553	±.572	±.478	±18.207
			†		†	
B	B Homozygotes	139.455	96.890	37.143	100.341	1508.852
		±.988	±.796	±.767	±.773	±29.692
	B Heterozygotes	139.374	95.878	36.766	99.281	1491.518
		±.450	±.363	±.349	±.311	±11.954
		†				
C	C Homozygotes	140.977	95.823	36.583	99.168	1539.331
		±1.008	±.842	±.355	±.703	±28.928
	C Heterozygotes	139.663	96.766	36.912	99.625	1522.068
		±.637	±.532	±.224	±.502	±20.647
		†	†			†
F-V	F-V Homozygotes	139.426	95.942	36.808	99.357	1993.417
		±.422	±.331	±.293	±.283	±11.142
	F-V Heterozygotes	139.908	96.304	36.752	99.640	1508.580
		±.454	±.356	±.315	±.304	±11.938
			*			†
M	M Homozygotes	139.544	95.852	36.761	99.486	1499.769
		±.467	±.357	±.360	±9204	±11.615
	M Heterozygotes	140.434	97.009	36.867	99.881	1531.314
		±.805	±.616	±.621	±.503	±19.901
			†		†	
R'-S'	R Homozygotes	137.949	95.033	36.052	98.108	1483.025
		±.775	±.563	±.841	±.491	±18.791
	R Heterozygotes	137.732	95.990	36.764	98.707	1482.634
		±.866	±.599	±.896	±.527	±20.149

TABLE 11 (continued)

Blood Group System	Blood Type	WHG	WLENGTH	WHIWTH	WHIHT	SRATIO
		**	*		**	†
S	S Homozygotes	137.723 ±.456	94.872 ±.336	36.560 ±.454	98.089 ±.281	1465.883 ±10.596
	S Heterozygotes	139.712 ±.524	96.103 ±.386	37.206 ±.454	100.986 ±.342	1490.968 ±12.905
Z	Z Homozygotes	139.847 ±.451	96.045 ±.352	36.799 ±.344	99.513 ±.304	1507.757 ±12.195
	Z Heterozygotes	14.256 ±.534	96.243 ±.417	36.842 ±.407	99.520 ±.379	1516.996 ±15.204
		†				
Trans-ferrin	Tf Homozygotes	139.439 ±.489	96.308 ±.385	37.011 ±.347	99.524 ±.322	1499.389 ±12.608
	Tf Heterozygotes	139.936 ±.447	96.013 ±.352	36.744 ±.318	99.763 ±.295	1504.097 ±11.578

[a]A system homozygote - A3/A3
B system homozygotes - B0/B0, B16/B16, B39/B39, B45/B45, B89/B89, B233/B233
C system homozygote - C0/C0
F system homozygotes - F1/F1, F4/F4
M system homozygote - M0/M0
R'-S' system homozygotes - R1/R1, R2/R2
S system homozygotes - S0/S0
Z system homozygotes - Z0/Z0, Z1/Z1
Transferrin homozygotes - Tf1/Tf1, Tf2/Tf2, Tf3/Tf3

† .05 < P < .20
* .01 < P < .05
** P < .01

TABLE 12

COMPARISON OF OBSERVED AND CALCULATED HETEROZYGOSIS OF BLOOD GROUP GENOTYPES WITHIN THE F-V AND R'-S' SYSTEMS OVER A 10-YEAR PERIOD

Blood Group System	Year	Blood Type	Observed	Expected	Chi-Square
F	1970	F1/F1	44	45.5606	.05346
		F1/F4	41	37.8787	.25720
		F4/F4	9	10.5607	.23067
				Total =	.54133
	1971	F1/F1	59	60.4173	.03325
		F1/F4	33	30.1657	.26630
		F4/F4	4	5.4170	.37065
				Total =	.67020
	1972	F1/F1	74	78.2978	.23591
		F1/F4	58	51.9236	.71109
		F4/F4	8	12.2979	1.50202
				Total =	2.44902
	1973	F1/F1	80	77.1585	.10464
		F1/F4	56	61.6829	.52357
		F4/F4	20	17.1585	.47054
				Total =	1.09875
	1974	F1/F1	118	119.1292	.01070
		F1/F4	54	51.7414	.09859
		F4/F4	8	9.1293	.13969
				Total =	.24898
	1975	F1/F1	97	100.8418	.14636
		F1/F4	60	52.3163	1.12850
		F4/F4	6	9.8418	1.49967
				Total =	2.77453
	1976	F1/F1	97	100.8061	.14370
		F1/F4	74	66.3878	.87284
		F4/F4	11	14.8061	.97839
				Total =	1.99493
	1977	F1/F1	82	78.9783	.11561
		F1/F4	49	55.0433	.66350
		F4/F4	17	13.9783	.65318
				Total =	1.43229

TABLE 12 (continued)

Blood Group System	Year	Blood Type	Observed	Expected	Chi-Square
F	1978	F1/F1	67	70.4094	.16510
		F1/F4	48	41.1811	1.12911
		F4/F4	5	8.4094	1.38229
				Total =	2.67650
	1979	F1/F1	87	88.4780	.02469
		F1/F4	46	43.0440	.20303
		F4/F4	6	7.4780	.29212
				Total =	.51984
R'-S'	1970	R1/R1	0	.1323874	.132387
		R1/R2	1	.7352250	.095353
		R2/R2	1	1.1323874	.015477
				Total =	.243217
	1971	R1/R1	0	1.4044604	1.404460
		R1/R2	8	5.1911366	1.519843
		R2/R2	5	6.4044604	.307990
				Total =	3.232293
	1972	R1/R1	0	1.1438658	1.143866
		R1/R2	10	7.7125851	.678406
		R2/R2	23	24.1435450	.054163
				Total =	1.876435
	1973	R1/R1	0	.3489642	.348964
		R1/R2	6	5.3025462	.091737
		R2/R2	48	48.3484840	.002512
				Total =	.443213
	1974	R1/R1	0	1.568241	1.568241
		R1/R2	15	11.863632	.829156
		R2/R2	39	40.568210	.060614
				Total =	2.458011
	1975	R1/R1	0	3.0365068	3.036501
		R1/R2	23	16.9274450	2.178470
		R2/R2	35	38.0360280	.242335
				* Total =	5.457306
	1976	R1/R1	0	2.9189082	2.918908
		R1/R2	26	20.1626880	1.689964
		R2/R2	52	54.9183880	.155084
				* Total =	4.763956

TABLE 12 (continued)

Blood Group System	Year	Blood Type	Observed	Expected	Chi-Square
R'-S'	1977	R1/R1	0	8.2345752	8.234575
		R1/R2	33	16.5306020	16.408420
		R2/R2	3	11.2348150	6.035896
				** Total =	30.678891
	1978	R1/R1	1	19.4670290	17.518397
		R1/R2	86	49.0659680	27.801809
		R2/R2	22	40.4669690	8.427341
				** Total =	53.747547
	1979	R1/R1	0	12.2711420	12.271142
		R1/R2	62	37.4572080	16.080980
		R2/R2	26	38.2716220	3.934840
				** Total =	32.286962

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

VITA

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