COMPARATIVE PROTEIN METABOLISM IN BUNAJI (WHITE FULANI) AND FRIESIAN CATTLE IN NIGERIA

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DEDICATION

This thesis is dedicated to my sister Mrs. B.O. Oduwaiye who has been my source of inspiration and in many ways a strong leader in the family to which I am happily committed.

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ABSTRACT

INTRODUCTION

The world human population rises about 70 million annually and there are predictions of sharper rises in the years ahead. Shortage of food for man and his animals will become more critical with population increases.

With regards to food, supply is perhaps most dramatically evident at inadequate protein levels available to people especially in low income countries. Malnutrition is a more insidious consequence of inadequate diets; the most important and widespread nutritional deficiency is protein[1].

In Nigeria, there is an increasing impetus to import Holstein-Friesian cattle for crossbreeding with local cattle to improve milk production and thus improve the amount of milk available for human consumption and as such lower the cost of protein.

This effort in Nigerian livestock production is not unrelated to developments in other parts of the

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[1]Kriesberg, 1968 - Food for Freedom with some implications. J. Dairy Sci. 51: 245-250.

world. Since the first world war, America has gained 40% more beef per cow, 20% more pork per sow, and 30% more milk per cow[2]. Yet less than 9% of America's population is engaged in farming, producing more than enough to feed her population compared to 80% engaged in farming in developing countries.

To achieve the goal of increased protein production, the basic physiological adaptation of indigenous and exotic cattle within the environment must be understood so that maximum advantage can be obtained from this natural selection process.

There have been reports suggesting that Bos indicus has a slightly higher nutrient digestibility than Bos taurus[3]. Blood studies have also shown higher blood urea nitrogen in the Zebu compared to other breeds[4].

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[2]Hamilton, T.S. (1963) - The Contribution of Animal Agriculture to Human Nutrition in Symposium on Protein and Metabolism. Uni. Illinois Agric. Expt. Sta. Urbana. pp.28-36.

[3]Elliot, R.C. and J.H. Topps (1963) - Studies of Protein Requirements of Ruminants. 1. Nitrogen Balance Trials on two Breeds of African Cattle given Diets Adequate in Energy and in Protein. Brit. J. Nutr. 17: 339-544.

[4]Olbrich, S.E., F.A. Martz, M.E. Tumbleson, and H.D. Johnson (1971) - Serum Biochemical and Hematological Measurements of Heat Tolerant (Zebu) and Cold Tolerant (Scottish Highland) Heifers. J. Anim. Sci. 3: 655-658.

Studies on hematological data of Zebu breeds around Shika have indicated similar findings[5]. These differences have been attributed to a more efficient digestion of protein in these breeds. It has also been suggested that Zebu cattle probably have a better ability to re-utilize nitrogen than European or other exotic breeds[4].

Studies in the Northern half of Nigeria have indicated that forage in the dry season has low levels of protein, less than 4%, which rises again during the rainy season[6]. Even in Southern Nigeria the protein content of grasses declines from 12 to 6%[7].

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[4]Olbrich, S.E., F.A. Martz, M.E. Tumbleson, and H.D. Johnson (1971) - Serum Biochemical and Hematological Measurements of Heat Tolerant (Zebu) and Cold Tolerant (Scottish Highland) Heifers. J. Anim. Sci. 3: 655-658.

[5]Saror, D. and E.H. Coles (1973) - Serum Biochemical Parameters in White Fulani (Zebu) and White Fulani/ Friesian (Crossbred) Cattle in Nigeria. Bull. Epiz. Dis. Afr. 21: 489-493.

[6]Hans, G.T. van Raay and Peter N. deleeuw (1971) - I.S.S. Occasional Papers, Fodder Resources and Grazing Management in a Savanna Environment: an Eco. System Approach. Institute of Social Studies, the Hague, Netherlands.

[7]Olubajo, F.O. and V.A. Oyenuga (1971) - The Measurement of Yield, Voluntary Intake and Animal Production in Tropical Pasture Mixtures. J. Agric. Sci. U.K. 77: 1-4.

Despite this fluctuating level of protein in the forage from season to season, Zebu breeds are able to survive on what is available. Some metabolic traits may have developed with time to assist the Zebu's adaptation to it's environment by allowing conservation of the little protein available.

Another perennial problem confronting livestock owners in Nigeria is parasites. Helminthiasis usually runs a chronic course and its manifestations clinically are similar to other diseases which are difficult to distinguish from those of management and nutrition. Heavy losses are often sustained by producers. The relationship between nutrition and parasitism is complex and factors that can be used to measure these effects, apart from visual observations and weight loss, are numerous. With concentrated efforts being directed at eradication of the major infectious diseases of cattle, the effects of intestinal parasites are bound to become increasingly obvious. Poor nutrition lowers the resistance of the host to a wide range of diseases especially parasitism. Gastro-intestinal parasites in turn cause considerable depression in food intake in addition to lowering the efficiency of the digestive tract and leak-

age of the host's protein reserves.

In Nigeria, undernourishment and nutritional deficiencies in livestock are problemsthat fluctuate with seasons of plenty (rainy season) and season of scarcity (dry season). Since man and his animals have learned to live with this problem, along with the accompanying parasitism, it is necessary that the degree to which these factors interplay in livestock production be investigated.

This research project was designed to investigate protein metabolism by Bunaji (White Fulani), Friesian, and Friesian-Bunaji cattle and the effect of internal parasitism on protein depletion at various levels of feeding. The objectives were to determine:

1. Serum biochemical and mineral values.
2. Effect of various protein levels on growth and nutrient digestibility.
3. Comparative nitrogen utilization.
4. Blood and urinary urea in relation to protein utilization.
5. Effect of varying protein levels on helminth infection.

PART I

REVIEW OF LITERATURE

A. NITROGEN METABOLISM IN RUMINANTS

1. Protein Utilization

1) Adaptation in Ruminant Nutrition

The clinical appearance of animals has been a part of the science of nutrition together with other considerations such as growth and maintenance. Gradually the sciences developed into a more detailed study of the effects of food intake upon the overall body metabolism(Mitchell, 1959). Baldwin (1948) put forth the striking concept that there exists a common chemical ground plan of body composition, digestion and metabolism to which all animals and probably all living organisms conform, having secondary, specific and adaptational variations distinguishing one species from another. This might have been the result of natural selection by survival of the fittest established by Darwin in his classical hypothesis "Origin of the Species".

Digestion in higher forms of animal life is promoted by extracellular and intracellular hydrolytic

enzymes. They are, however, all deficient in digestion of cellulolytic materials and so are dependent on bacteria and other microorganisms in the segments of the digestive tract favoring this degradation (Mitchell, 1963).

Ruminants harbor these symbiotic microorganisms in the reticulorumen which digest dietary protein yielding amino acids and other nitrogenous compounds. The amino acids produced are broken down to ammonia and resynthesized into bacterial proteins which are then available after hydrolysis by the host's proteases (Church, 1969).

The assimilation of bacterial amino acids may involve oxidation with release of energy for physiological work, synthesis into nitrogenous constituents of the tissues to replace those that are undergoing metabolism or synthesis into new tissue proteins in the various processes of growth and development. Replacement of endogenous loss of nitrogen represents the maintenance requirement for protein as measured by the lowest intake of dietary protein compatible with nitrogen equilibrium. Accumulation of nitrogen in tissues, represents a requirement for growth, both

before and during maturity. Utilization of amino acids absorbed from the digestive tract is ordinarily measured by the nitrogen balance since dietary protein is the predominant source of nitrogen and also amino acids.

The solubility of protein in the feed is an important factor in the rate of its breakdown and eventual ammonia accumulation in the rumen (El-Shazly, 1958). Improvement of protein utilization has been carried out by various means. Heat has been used to reduce solubility and improve utilization (Tagari et al., 1962). The effect is thought to be due to a more gradual breakdown in the rumen, resulting in less ammonia absorption and less urinary nitrogen loss. Tagari et al. (1962) obtained a relative increase of about 10% in apparent nitrogen digestibility with heated versus unheated soybean. Other additional effect of heating was attributed to possible destruction of enzyme inhibitors. They found that excessive heating, however, binds nitrogen in the non-enzymic reaction thus reducing the amount of digestible nitrogen.

Another source of rumen nitrogen is saliva (Scheunert and Trautman, 1921). McDonald (1948)

demonstrated the presence of salivary urea, the concentration was found by Lewis (1957) to increase with increasing rumen ammonia levels. Urea nitrogen in cattle, represents about 77% of the total nitrogen in mixed saliva. Higher salivary concentrations of total nitrogen resulted in higher percentages of urea nitrogen (McDonald, 1948). In such mixed saliva the urea content can be as much as 65% of plasma urea concentration which ranges from 4-19 mg% urea nitrogen. Somers (1961) found that the concentration of urea nitrogen in mixed saliva increased with increasing rate of saliva secretion. Further nitrogen for protein synthesis by the ruminant is urea influx from the blood across the rumen wall. Gartner (1961, 1963) performed in vivo and in vitro studies to show that passage of urea into the rumen was independent of blood urea concentration. Coccimano and Leng (1966) however, found that this total endogenous urea flow into the rumen was dependent primarily on blood urea concentration. This inflow was referred to as the sum of that from the saliva and blood. However, the total urea degraded was not a constant percentage of dietary nitrogen.

Variable results have been obtained on nitrogen

fractions present in total rumen contents. Weller et al. (1962) compared two levels of forage protein and included a feed nitrogen fraction in the rumen in their sheep trials. When they fed the forage ration with a higher nitrogen content, the total nitrogen concentration increased in the rumen with the soluble feed nitrogen forming the greater percentage. Protozoal nitrogen formed a greater percentage of microbial nitrogen at lower nitrogen intakes.

When casein was fed the total nitrogen was lower than it was in equivalent total forage protein intake (Gray et al., 1958). Also protozoal nitrogen was higher than bacterial nitrogen during casein feeding. Microbial nitrogen, however, was higher in forage protein feeding. These results could be due to differences between the type of forage protein and casein. Experimental measurements indicate that protein output from the rumen may be greater than or less than the input (Gray et al., 1958). The output can be reduced below input by excessive ammonia production and absorption, especially when the nitrogen content of the diet is high. By contrast, when the nitrogen content of the diet is low, passage of non-protein nitrogen (NPN) to

the rumen from the tissues provides an extra source of nitrogen for microbial growth and the total protein output is thereby increased above input. Thus microbial activity has some levelling effect in ruminant nutrition. It could enhance survivability for longer periods on low-protein diets. Franklin et al. (1967) found that sheep maintained their body weight for six months on roughage rations containing only 7.6% crude protein while both sheep and cattle survived for some months on diets with about 5% crude protein. At the other extreme, ruminants appear to be less efficient than monogastric animals in utilising high-protein diets. Hence the biological value (BV) of a protein for ruminants is considered as the BV of nitrogen in a given ration rather than, as defined for monogastrics, the BV is the amount of essential amino acids in the protein which is in greatest deficit relative to the animal's requirements (Annison and Lewis, 1959). With the assumption that ruminant tissues need assemblages of amino acids similar to those required by non-ruminant tissues, McDonald (1968) predicted, on the basis of amino acid composition, that microbial and leaf proteins would have a BV of about 75 (com-

pared with whole egg protein of nearly 100).
He indicated that the sulphur containing amino acids, methionine and cystine, were the first limiting amino acids. The proteins of the usual concentrates fed to ruminants such as cereal grains, industrial by-products and oil seed meals, have a more varied amino acid composition and hence no statement was made about the probable BV of the fraction of digestible feed protein escaping microbial breakdown in the rumen. For low protein diets, there is enhancement of the protein value of low quality rations by rumen microbial activity. This is an essential advantage for ruminants but leads to little increase in productivity.

2) Factors Affecting Protein Utilization

a. Rumen Nitrogen Level

Utilization of protein (nitrogen) by ruminants greatly depends on the balance between the amount and availability of nitrogen and energy. Minson and Pigden (1961) determined the effect of continuous infusion of urea on utilization of low quality forages and found a

reduction in feed intake. This may be attributed to factors other than palatability. However, Campling et al., (1962) fed oat straw with 0.46-0.53% nitrogen to cows while continuously infusing 70 or 150 mg% urea solution and found increased feed intake, increased rate and extent of fiber digestion, and increased rate of passage of stained particles.

Moir and Harris (1962) reported a negative nitrogen balance, decreased crude fiber digestion, decreased dry matter intake, and a reduced rate of cotton thread digestion in sheep fed rations with less than 0.74% nitrogen. Rumen ammonia nitrogen was 1-2 mg%. Glover and Dougall (1957) found that rations containing less than 0.96% nitrogen reduced fiber digestibility. Elliot et al. (1965) found that steers maintained body weight when rumen liquor contained about 60 mg% total nitrogen which was 2.4 to 9.5% ammonia, whereas in sheep Elliot and Topps (1964) found that if rumen liquor had 34 mg% total nitrogen they were able to maintain body weight.

b. Protein and Carbohydrate Interaction

Apart from low rumen nitrogen levels which can affect nutrient utilization, the quantity of carbohydrate also has its effect. When energy is inadequate or too slowly available for rapid utilization of nitrogen, there is an overall reduction in efficiency of protein utilization. Ferrando and Catsaounis (1966) indicated that such a situation might occur when feeding hay silage. Crampton (1965) proposed that nitrogen requirements be expressed relative to energy as grams digestible protein per Megacalorie of metabolizable energy (DP/Mcal ME). Based on this system he found that the requirement for maintenance was 24 compared to 32 for lactating animals. Arthur et al. (1967) found that during in vitro fermentations, between 50 and 80 mg of glucose were utilized for each mg of nitrogen absorbed.

From this it can be said that nitrogen metabolism in ruminants cannot be considered separately from carbohydrate digestion. The relative levels of carbohydrate and nitrogen have effects on nitrogen utilization, feed intake, and carbohydrate utilization.

Inadequate nitrogen retards fiber digestion which in turn reduces feed intake. Excessive nitrogen intake, on the other hand, can produce high rumen ammonia concentration which would also reduce feed intake. Thus the form of dietary nitrogen and the level of intake, as compared to the form of dietary carbohydrate and its level, constitutes the primary factor affecting ammonia concentration in the rumen.

Rumen concentrations of about 7mg% ammonia nitrogen results in blood absorption through the rumen wall equal to the endogenous inflow from blood urea via saliva and rumen wall transfer. At higher concentrations, there is a net absorption of nitrogen, conversion to urea, and loss via urinary excretion. With most ruminant feeds the apparent digestible nitrogen is highly and positively related to the carbohydrate level in the ration. Thus a major factor influencing utilization of ruminal ammonia is carbohydrate availability to rumen microorganisms. As early as 1943, Pearson and Smith indicated that in <u>in vitro</u> fermentation experiments, urea was better utilized when carbohydrates were available.

From feeding experiments, another conclusion, apart

from the fact that there is better utilization of proteins in the presence of added carbohydrate, there is a more rapid attack upon fibrous components of the ration as the protein intake is increased (Annison and Lewis, 1959). These authors noted that, since the exact control of conditions is difficult in feeding experiments, it is not easy to interpret these findings in metabolic terms.

Annison and Lewis (1959) suggested that, since it is known that certain branched-chain volatile fatty acids are required for rapid cellulose digestion, the protein supplements that improve the rate of attack upon fibrous constituents may act by increasing the concentrations of these acids. On this assumption Hungate and Dyer (1956) fed valeric and iso-valeric acids to steers but were unable to demonstrate any appreciable increase in straw utilization. Amos *et al.*, (1968) however, found that addition of protein to a rumen suspension stimulated cellulose digestion. It resulted in a marked increase in valeric acids levels with about 47% of the labelled carbon being recovered in volatile fatty acid after 24 hours. Radioactivity was also found in the protein and lipid

fractions of the bacterial cells.

Other metabolic studies have contributed to the understanding of protein and carbohydrate interrelationships (McDonald, 1952). These studies indicated that the value of various protein or carbohydrate supplements to ruminants lies in producing a more balanced and complete system for encouraging microbial synthesis. Thus ingested protein and carbohydrate give a ready supply of simple nitrogen containing compound and energy, respectively, to support microbial growth. McDonald (1953) demonstrated a fall in rumen ammonia concentration when starch was added and an increase in the rate of volatile fatty acid production from starch when small amounts of casein were also added. Annison (1956) confirmed that the rate of disappearance of ammonia and amino acids from the rumen, after feeding casein hydrolysate, was increased by additional carbohydrate supplements. A complete examination of the fermentation by-products of carbohydrate and protein materials, alone or together, was performed by Lewis and McDonald (1958). They confirmed that active fermentation was encouraged by the presence

of both supplements and that growth and synthetic reactions were increased by a more balanced system. They observed also that protein supplements added to the diet of ruminants are best utilized when carbohydrate is fermented at a comparable rate. With casein, they determined that levan and starch were more effective than glucose or xylan and that cellulose was ineffective.

Arias et al., (1951) reported that a variety of soluble carbohydrates improved nitrogen utilization in vitro and suggested that a small amount was necessary since ruminal bacteria probably needed a readily available energy source until cellulose was partially digested. Robertson and Hawke (1965) observed that infusion of starch into the rumen of cows on high nitrogen pastures resulted in consistently lower rumen ammonia levels than in the negative control cows. This indicated that, with readily available carbohydrate, the high protein content of the diet was being well utilized to the point that excessive nitrogen waste in the form of ammonia was reduced. Robertson and Hawke (1965) also found that ammonia production in vitro was

reduced by addition of galactose, sucrose, lactose or glucose.

Mills et al., (1944) were able to demonstrate that there was greater nitrogen retention in animals receiving urea in addition to soluble carbohydrates.

c. Protein and Lipid Interaction

Other nutrients have some effect on protein metabolism especially in the rumen. The effects of lipids on rumen ammonia is variable. Waldo (1968) reported that several workers found that if the dietary nitrogen level is up to 3% addition of oils depressed rumen ammonia. This was attributed to the reduced flow rate of materials from the rumen and resultant dilution. With dietary nitrogen greater than 3%, added oils increased the rumen ammonia (Robertson and Hawke, 1965). These authors studied the effect of plant oils or whale oil on aspects of rumen metabolism and reported that, in general, adding oils to the rumen or in vitro fermentations resulted in depression of digestibility of fibrous components, increased ammonia formation, reduction

in acetate, and an increase in propionate concentration. Czerkawski et al., (1966) found a lower urinary nitrogen and a greater nitrogen retention when glycerides or fatty acids were added to a diet containing slightly less than 3% nitrogen. Thus although there is possibly greater nitrogen retention with the addition of lipids to the diet up to a certain limit, depression of fiber digestibility may limit the practical use of this method of improving nitrogen utilization (Waldo, 1968).

d. Protein and Mineral Interaction

Among nutrients having effect on nitrogen metabolism are mineral elements and the relationship is attributed to their effects on urea metabolism (Tillman and Sidhu, 1969). Urea is an end-product of ammonia metabolism in the liver. It is re-cycled to the rumen through saliva and passively reabsorbed by the kidney into the blood (Church, 1972). It is also the most commonly used non-protein nitrogen source for ruminants. Hydrolysis of both exogenous and endogenous urea by urease is the first step in its utilization. Urease activity is found in ruminal mucosa, contents, and

microflora. Jones et al., (1964) observed that ruminal urease prepared from mixed rumen microflora was stimulated by manganese, magnesium, calcium, strontium and barium but was inhibited by sodium, potassium and cobalt. Later they found that urease produced from isolated ruminal bacteria was inhibited by manganese, stimulated by maganesium and no effect was observed with calcium. Since the above results showed varying effects of manganese, magnesium and calcium on urease activity of single and mixed rumen microorganisms, Jones and coworkers suggested that bacterial species responsible for ruminal urease activity may differ in their response to divalent cations.

2. Role of Protein in the Body

Protein is the principal constituent of the organs and soft structures of the animal body. A liberal and continuous supply is needed throughout life for growth and repair and thus transformation of food protein into body protein is a very important part of the nutrition process (Maynard and Loosli, 1962).

1) Growth

When food is provided, growth dominates the activities of the newborn and creates the greatest demand for proteins, minerals and calories. In all mammals, the neonatal or suckling period is characterized by an anabolic tendency which is never equalled later in life. This can be demonstrated even when there is insufficient food available to allow anabolism to take place. McCance and Strangeways (1954) showed that a starving newborn infant derived only 4-5% of its total caloric requirements from protein breakdown, whereas the healthy adult male utilized protein about four times as much as his metabolic requirements.

Bunge (1898) related the rate of growth of the young to the percentage of protein in the dam's milk. McCance and Widdowson (1964) revised the form compiled by Blaxter (1961). They considered the volume of milk secreted by the dam and the kilocalorie: protein ratio of the milk. They pointed out that kilocalories (kcal) derived from milk protein varied from 9% of total human milk to 20% in cow's milk, 25% in milk of rats and pigs,

and in some cases like the reindeer, the milk contained so little carbohydrate that some of the protein may become glucogenic and thus available for growth.

Nitrogen retention for purposes of growth varies with species. In some, like the piglet or puppy, as much as 90% of the nitrogen from their mother's milk is retained during the first day or two of life (McCance and Widdowson, 1956). In human babies 50% of the nitrogen from breast milk is retained at 6-8 days of age and an average of about 22% over the first six months (Slater, 1961). He found that increasing the nitrogen intake in human babies, especially by supplementation of cow's milk formulas, resulted in more nitrogen retention. However, Slater observed that they did not grow i.e. gain weight, any faster than babies fed on human milk. It was concluded from these observations that additional nitrogen supplies to the neonate of some species beyond the mother's capacity results in neonatal nitrogen retention while the supply lasts. This may not result in weight increases if there is no concurrent caloric supply but lead to more rapid maturation of the soft tissues and skeleton.

Protein supply is not only essential during periods of growth but during pregnancy. Indeed protein metabolism is put to a severe test during fetal development. Albumin serves as a major amino acid pool. Dunlap and Dickson (1955) found that ewes had a decreased concentration during the first half of pregnancy but the albumin levels returned to near-normal at term. They related this to its requisite usage as protein precursors. They also found that, in the latter half of pregnancy, there was a decrease in globulin concentration. This was thought to be due to the production of globulin - rich colostrum. A similar observation was made in cows by Larson (1958) who found a decrease in the concentration of total protein and especially $beta_2$ and $gamma_1$ globulins. Bedrak et al. (1964) observed that yearling heifers on low protein diets had no embryos or fertilized ova at slaughter when compared to those on normal diets. Those on normal diets also had heavier average ovarian weights, had larger follicles, and less atretic follicles. Low protein intake was thus confirmed as affecting reproductive performance of growing heifers. They

found delayed puberty, a long anestrous period, weak manifestations of estrus, and short estrus periods. Early embryonic resorption and estrus without ovulation, may also occur. Similar findings have been reported in laboratory animals (Guilbert and Goss, 1932), and in sheep (Hart and Miller, 1937). The phenomena are said to be due, in part, to the lack of luteinizing hormone and the general physiological stress in heifers as a result of protein deficiency. This was confirmed by Bedrak *et al.* (1964) who found that cattle on pastures with low protein intake had reduced reproductive performance.

During a three-year period, protein was fed to cows at deficient levels for the first five to six months of gestation and while they were nursing (Church, 1969). This resulted in the birth of small weak calves. When the digestible protein content was increased during dry and lactation periods, there was a marked improvement in the calf crop. Calf survival also improved from 68% on deficient protein levels to 95% of adequate levels. Ewing (1959) reported that cows fed a protein supplement gave birth to heavier calves than those fed no protein supplement. Church

(1969) reported lighter birth weights in calves from cows on a low plane of nutrition compared with calves from cows on an adequate level. He concluded that the protein content of rations for pregnant cows must be adequate for normal gestation and calf survival.

2) Nutrient and Protein Balance

Apart from the use of protein for growth, Blaxter and Martin (1962) pointed out that any diet given to ruminants with more protein above the needs for maintenance and growth, was converted to energy. They quoted work by Kellner and Kohler (1905) with steers, and Heim (1956) with sheep, who found that when protein supplements were given, 86 and 93% were digested, respectively, and that for every 100 kcal of protein energy given in addition to maintenance requirements, 33 and 35 kcal were retained in the body of cattle and sheep, respectively.

Despite the possible use of protein for energy during periods of excess, it has been found by Blaxter and Martin (1962) that protein is not utilized efficiently for energy by ruminants. Their results suggested that the lower energy value of protein for lipogenesis

in ruminants compared with non-ruminants, is the result of fermentative changes in the rumen.

Protein utilization for milk production involves absorption of balanced amino acids and acetic and propionic acids in a ratio of 2.5:1. Milk protein synthesis is assumed to occur from an almost perfect balance of amino acids and a metabolic efficiency of about 84% with propionate serving as the energy source(Church, 1969).

Various amino acids have been fed to cows to increase the protein content of milk. Broderick et al. (1970) reviewed the substances used. They quoted Griel et al. (1968) and McCarthy et al. (1968) who reported significant increases in milk production by feeding DL-alpha hydroxy-gamma-methylmercapto-butyrate calcium (methionine hydroxy analog) to lactating cows. Broderick et al. (1970) found that commercial casein infused directly into the abomasum significantly increased milk protein content as well as milk production. McCarthy et al. (1970) emphasized that there was increasing evidence that many potentially high producing animals experienced amino acid insufficiency, and that availability of amino acids influenced maximum

milk production. In such cases available substrate rather than the rate of enzymatic reaction in the secretory tissue determined the quality of milk produced.

Jacobson et al. (1970) reported that cows receiving no protein supplementation had milk production of 89-96% of that of supplemented groups, and that protein does not affect the quantity of milk production. It was found that dietary levels of about 10 to 20% crude protein resulted in small differences in milk production as the crude protein content increased. Theoretically, cows fed 30% above their protein requirement will produce the same amount of milk when the 30% is substituted by another protein of different quality. Apparently, the prime reason for feeding high levels of protein (NRC 1970 and higher) is to encourage greater voluntary consumption of net energy and, therefore, increased performance and increased efficiency of feed conversion to milk.

The part played by protein in the body is more obvious during periods of inadequate protein nutrition. Protoplasm may be broken down to meet certain other nitro-

genous needs of the body or to supply energy. If sufficient protein is supplied, a protein reserve is formed by increasing the size of the muscles. This serves as a source for synthesis of plasma proteins as well as hemoglobin (Whipple, 1942). The principal plasma proteins are albumin, globulin and fibrinogen.

Heifers fed low levels of dietary protein developed borderline signs of anemia (Bedrak et al., 1964). They found 30% reduction in hemoglobin concentration within three months with a daily consumption of 8.1 lbs. total digestible nutrients and 0.08 kg. crude protein. There was a lag period between the first and third month when this decrease occurred and this was thought to be related to the life span of erythrocytes and to the labile protein stores of the heifers. Hematocrit readings declined during the same period from 41.4 to 28.4%. Bedrak et al. (1964) reported that protein deprivation also lowered serum protein levels by 20% within a three-month period; serum albumin levels decreased but not globulin. They also discussed the effects of prolonged protein deficiency and referred to the findings of Whipple

and Maden (1944) and Yamamoto (1951). They showed that protein deficiency induced anemia and leukopenia because the hemopoietic organs were deprived of amino acids necessary for cell formation and hemoglobin production.

Kehrar and Murty (1945) reported similar protein findings. This was attributed to serum protein being the most labile protein which can be depleted from the body stores. Bedrak et al., (1964) found no significant differences in the various globulin fractions. The values of alpha$_2$ and beta globulin were not influenced by diet. Alpha globulin level increased as dietary protein level decreased, and gamma globulin level significantly increased at the lower protein levels similar to findings in protein-depleted dogs (Zieldis, 1945). Marked declines occurred in liver and blood serum protein levels with protein deficient diets.

Ruminants require nitrogen for the rumen microorganisms or in other words, dietary nitrogen is used for microbial nutrition and through them to the ruminant. Ultimately, nitrogen is used for maintenance and for tissue and milk synthesis. The degree of

The difference between daily amount of nitrogen passing from the rumen and the daily incoming feed nitrogen results from endogenous nitrogen inflow and nitrogen absorption from the rumen. This endogenous input is primarily urea which is readily hydrolyzed to ammonia and absorbed. This is the primary form of nitrogen absorption.

Ammonia absorption is one pathway whereby digested protein nitrogen disappears from the rumen. This was first demonstrated by McDonald (1948). Lewis (1957) later demonstrated that the portal blood ammonia concentration increased as a curvilinear function of ruminal ammonia content. Gartner (1961) found greater ammonia absorption at higher rumen levels, and considered that the process was by diffusion. He suggested also that permeability of the ruminal wall to ammonia was inversely related to urine flow. Hogan (1961) found that ammonia absorption was dependent on concentration gradient at pH 6.5 but that ammonia loss was nil at pH 4.5 Bloomfied et al. (1963) also found that ammonia absorption decreased as the rumen pH decreased. Ammonia absorption increased with increasing pH; this increasing rate of absorption with increasing pH is

important in urea toxicity (Coombe et al., 1960).

Ammonia can accumulate in high concentrations in the rumen due to deamination of amino acids (McDonald, 1952; Warner, 1964). Nitrates in forages are reduced through nitrite to ammonia. Wright and Davison (1964) reported that nitrite produced in this way was toxic. Ammonia itself is toxic but there is no record of ammonia intoxication in ruminants consuming natural feedstuffs. Ammonia is absorbed from the rumen and transported via the portal blood to the liver where it is converted to urea (McDonald, 1948). The peripheral blood normally has a low ammonia concentration. As rumen ammonia concentration rises the rate of absorption rises to a point where the liver's capacity to convert ammonia to urea is exceeded, and the concentration in the peripheral blood rises (Lewis et al., 1957). This critical level for intoxication is probably about 10ug NH_3/ml (McDonald, 1958).

3) Amino Acids and its Breakdown Products

Absorption of amino acids is the second pathway for nitrogen disappearance from the rumen. Absorption

of amino acids from the rumen has a less favorable concentration gradient than ammonia. Amino nitrogen in the blood ranges from 2-8 mg% in contrast to 0.1-10 mg% in the rumen (Annison, 1956; Cook *et al.*, 1965). Amino acids absorption from the rumen was thought not to occur or that absorption was small compared to ammonia. The latter fact was borne out by Tsuda (1956) who found that there was a 20% decline in glycine concentration in the immature rumen in four hours. Lewis and Emery (1962) observed lysine absorption from the rumen. Cook *et al.* (1965) found by ion exchange separation that there was absorption of several acidic and neutral amino acids and thought that the amino acids compete with each other for absorption. In spite of the strong proteolytic activity in the rumen, the amino acid concentration in rumen fluid is low (Annison, 1956). This has been ascribed to deaminases in many microbial species and to the fact that deaminase activity increases with increasing protein content in the diet (Warner, 1956). The amino group are split off with formation of ammonia.

Information on fermentation of mixtures of amino acids was provided by *in vitro* studies (El-Shazly, 1952).

He found that amino acids were undoubtedly intermediates in protein fermentation in the rumen. He found that amino acids of an acid hydrolysate of casein were attacked under anaerobic conditions by washed suspensions of rumen organisms. The end-products were ammonia, carbon dioxide and volatile fatty acids (VFA's) in roughly equimolecular amounts. Acetic acid was the main VFA with smaller amounts of C_3, C_4 and C_5 straight and branched-chain fatty acids. He observed good correlation between the concentrations of ammonia, C_4 and C_5 branched-chain fatty acids in the rumen after ingestion of protein-rich foods. From the protein hydrolysate work, he demonstrated that d-amino valeric acid was a reduction product of proline. He suggested that the Stickland reaction was important in the breakdown of amino acids in the rumen. This reaction is a coupled deamination of two amino acids, one of which functions as a hydrogen donor and the other as a hydrogen acceptor. The available evidence suggests that isobutyric, isovaleric and 2-methyl-butyric acids arise from deamination of valine, leucine and isoleucine, respectively. Annison and Lewis (1959) suggested that 2-

methyl-butyric and isovaleric acids were ketogenic. This was based on the fact that ketosis in dairy cows results in increased branched-chain VFA's from protein in the rumen, since the condition often arises during periods when high protein diets are consumed. Annison and Pennington (1954) investigated absorption of branched-chain C_4 and C_5 acids from the rumen and their metabolism by ruminal epithelium. They found that the acids were non-toxic at levels of 100 m-moles, were absorbed in the same manner as straight chain VFA's, and did not increase the level of blood ketones. This eliminated their primary involvement as causal agents of ketosis.

In further work on amino acids as degradation products of protein, Sirotnak et al. (1953) found that only a small number of amino acids were individually attacked; aspartic acid, glutamic acid, serine, arginine, cysteine and cystine. The main end-products were ammonia, carbon dioxide, and VFA's. The optimum pH for deamination was 6.9 which is close to the usual hydrogen ion concentration in the rumen.

Other data on amino acids have been furnished by Lewis (1955) when he investigated amino acid metabolism

by placing the solutions directly in the rumen of sheep. He indicated that when DL-glutamic acid was added it produced the greatest amount of ammonia followed by glycine, DL-alanine and DL-methionine. When different feeds were given in conjunction with the amino acids the order of highest ammonia production varied. When sheep were fed hay and casein hydrolysate, D-alanine gave the highest rumen ammonia concentration whereas when hay and grass were fed, DL-glutamic acid produced the highest. Studies with *in vitro* suspensions indicated that aspartic acid resulted in the greatest ammonia production. From these studies it could be inferred that amino acid metabolism in the rumen depended on the type of ration and other unexplained factors.

Church (1971) stated that soluble proteins can be degraded by rumen microorganisms with resultant production of ammonia, VFA's, carbon dioxide, and other metabolites. However, he asserted that there was some question as to how degradation of natural feedstuffs occurred and their value. Protein breakdown studies in ruminants are complicated by the passage of urea into the rumen via saliva and also

ammonia through the ruminal epithelium and these may not be direct breakdown products of the most recent protein or amino acids ingested. Concurrently, there is also absorption of ammonia and other nitrogenous compounds by the ruminal epithelium which may depend on the concentration gradient.

Another point in protein breakdown is re-cycling of bacterial and protozoal proteins in the rumen. This is obvious from the work by McDonald (1952) in which he fed zein and casein to sheep. He attempted to calculate the rate and amount of bacterial and protozoal proteins. Since zein from corn is known to be relatively insoluble in rumen liquor, it is a good choice to study while the relatively soluble casein is readily degraded. The results indicated that about 40% of zein was converted to microbial protein compared to 90% of casein. Unfortunately, McDonald's work was based on some faulty assumptions. He assumed that all dietary protein left the rumen either as microbial protein or undigested food, that protein other than zein consisted of microbial protein only, and that the rate of flow of ingesta from the abomasum was constant such that any sample taken could be used for calculation. All assump-

tions seem unlikely apart from the fact that no allowance was made for ammonia formation from zein. This is borne out by the different results obtained by Ely et al., (1967) who estimated that 24-30% of zein was converted to microbial protein depending on the ration fed and the method used to estimate the amount of microbial protein.

Annison and Lewis (1959) suggested that some decarboxylation of amino acids occurred in the rumen. They considered that the quantities involved were not large since some of the amines produced would have marked pharmacological effects such as histamine. Dain et al., (1955) identified histamine and tryptamine in rumen contents of experimentally over-fed sheep. They found histamine values as high as 70 ug per ml. As expected, the extent of amine production was considerably increased when the rumen pH fell below 5 since decarboxylases are known to be active in the acid range. They concluded that, under normal circumstances, there was little reason to suppose that amino acid decarboxylation is of quantitative significance in protein breakdown in the rumen.

Reports of occurrence of indole and skatole in

rumen content have been made but little reference about their mechanism of production (Maynard and Loosli, 1962). They pointed out that certain amino acid structures are not completely broken down. They gave the ring of tryptophan as an example of one which is excreted in the feces as indole and skatole. Annison and Lewis (1959) reported findings of about 1mg% of indole and skatole in rumen contents.

It has been indicated that free amino acids in rumen contents usually have such a low concentration that they do not form an important source of nutrients to ruminants either by absorption from the rumen or abomasum (Church, 1969). Further more, many studies have been conducted on the fate of protein and other nitrogenous materials consumed by ruminants. It is usually considered that nitrogenous materials which leave the rumen are digested similarly to nitrogenous constituents in the diets of non-ruminants. Ammonia is a waste product, so that the animal depends on food proteins escaping ruminal digestion and on proteins synthesised by rumen microbes (Mitchell and Hamilton, 1960).

Proteins escaping ruminal digestion andthose of

microbial source are of primary interest in protein metabolism of ruminants (Mitchell and Hamilton, 1960). They pointed out that the ratio of these two sources was difficult to measure. This was because of concurrent proteolysis of feed proteins and synthesis of protein by microbial growth. Later work by McDonald (1954) using purified protein, found that proteins such as zein passed into the abomasum unchanged while McDonald and Hall (1957) found that casein was nearly all degraded and replaced by microbial protein. Weller et al. (1958) found in sheep on a diet of wheaten hay that 80% of the output from the rumen was microbial nitrogen.

Microbial protein synthesis in the rumen is a function of organic matter fermented in the rumen and thus of the amount of energy available to the microbes for their growth. Hogan and Weston (1967) calculated that a little less than 15g microbial protein was synthesised for each 100g organic matter digested in the rumen.

3) Creatinine Production

Another product of protein degradation is creatin-

ine. The absolute amount of creatinine excreted by an individual per unit time is a direct function of the amount of muscle mass in the body (Muldowney et al., 1957). Creatinine excretion per unit of time does not hold under certain pathological conditions such as renal disease and excessive muscular wastage (Arroyave, 1963). Excretion is also modified by the diet as shown by Best et al. (1952) who found that with a protein-free diet, creatinine renal excretion was lowered by 10% by the following day.

In man, it is found that there is a constancy to daily creatinine excretion. In most instances, individual variation in 24 hour creatinine from day-to-day usually has an average coefficient of variation of around 10% or less (Folin, 1905 a,b; Shaffer, 1908; Hegsted et al., 1956; Vestergaard and Leverth, 1958). Urinary creatinine excretion has been used as an estimate of muscle growth and development of children related to their protein nutritional status (Stearns et al., 1958). Daniels and Hejinian (1929) reported figures for 24-hour creatinine excretion of infants under one year of age expressed in centimeters of body height. This was interpreted as an index of relative

lean body mass development uninfluenced by adipose tissue. This was confirmed by Standards et al. (1959) and Arroyave and Wilson (1961). It is concluded from these studies that urinary creatinine excretion measurements in man are useful as an indirect biochemical estimate of muscle mass development.

4) Purine Metabolism

Other products discussed along with protein metabolism include uric acid and allantoin. Uric acid is the principal end-product of purine catabolism in man and protein catabolism in birds and reptiles. Urates and uric acid form the principal nitrogenous excretory products in insects (Maynard and Loosli, 1962). Apart from man, all other domestic animals including the dog, cat, rabbit, sheep, cattle, horse, and pig are capable of converting uric acid to allantoin in the liver. Allantoin is the oxidative product of uric acid and consequently only a small amount of uric acid is found in the urine of ruminants.

It has been reported by Kaneko and Cornelius (1970)

that the ratio of allantoin to uric acid is in the order of 10:1. Blaxter and Martin (1962) fed protein to determine the efficiency of its utilization for energy processes in sheep. They found that there was more allantoin nitrogen and more hippuric acid nitrogen excreted when casein was infused into the rumen. They thought that this was due to the consistent bacterial fermentation and hydrolysis of the casein.

Topps and Elliot (1965) observed that urinary excretion of allantoin and uric acid ranged from 76-187 ug/ml. Temler-Kucharski et al., (1966) found that there was substantial amounts of nucleotides in duodenal contents of calves that were higher than that of the diet fed. They concluded that nucleotides must be synthesised in the rumen by microbial activity hence their degradation and the presence of uric acid and allantoin in the excretory products.

Vercoe (1967) measured uric acid and allantoin in different breeds of cattle on various dietary levels and found that uric acid and allantoin responded differently and both increased at higher feeding levels.

Being purine derivatives he considered that they reflected production of nucleic acids by rumen microflora. This confirmed the work by Temler-Kucharski et al. (1966).

Nitrogen, as protein breakdown products, occurs in the rumen in various forms; free amino acid (Gutowski et al., 1960); diffusible peptides (Lewis, 1955); protein nitrogen per se (William and Christian, 1956); and as nucleotide nitrogen (Ellis and Pfander, 1965).

In conclusion, the end-products of protein metabolism are highly varied and are influenced by several factors, all of which indicate that ruminants are distinct from other animals in their adaptive mode of handling protein.

B. SERUM BIOCHEMICAL PARAMETERS IN CATTLE

1. Use of Parameters in Diagnosis

Proteins and protein metabolites are parameters that have long been recognised in the body system. Their function, especially those of plasma proteins,

makes them an intergral part of the metabolic system in mammals and of interest in investigations dealing with the physiology of growth, nutrition and development. Several hematological characteristics are studied routinely as diagnostic aids in cases of human and animal disease.

Indeed, in the tropics environmental physiologists are searching for an index or a combination of indices which might measure the effect of hyperthermia on cattle or other livestock. Clinical pathologists attempt to classify hematological data which can be termed "normal" for various classes of livestock as a basis for clinical diagnosis (Gutierrez-de La et al., 1974).

2. Protein Metabolites

Measurements of various protein metabolites based on the qualitative and quantitative compositions in plasma or serum have been used for diagnosis of specific diseases (Dimopoullos, 1970). There are many so called "normal values" for plasma proteins. However, it has been found that various factors

influence the normal values.

It is well-known that serum protein values for the human infant are lower than those for the adult (Garner, 1952). The difference being due to lower values for both the albumin and globulin fractions. Adult levels are reached by 18 months. As pointed out by Garner (1952), cattle appear to differ from man in that the increase in the total protein with age is associated with an increase in the globulin fraction only. The rate of increase of total protein and globulin decreased slowly until approximately five years of age. He pointed to data which indicated that albumin levels gradually decrease throughout life. Kekwich (1959) presented a review on the serum proteins of fetal and young mammals. He observed that it is generally accepted that the concentration of total serum protein and albumin increase during fetal stages of development whereas there was no change in the concentration of globulins especially beta globulin; the concentration of alpha globulins was variable while gamma globulin was absent. Pierce (1955) studied the development of serum proteins in calves from birth to weaning. He demonstrated that

pre-colostral calf serum contained no gamma globulin. Other workers showed that after a calf ingests colostrum, gamma globulin appears in the serum within a few hours. Its absorption through the gut occurs only for about 48 hours after birth (Polson, 1952).

Dimopoullos (1970) reported that in colostral-fed calves, the concentration of albumin increased but that of beta globulin did not change significantly up to 80 days after birth. He cited numerous investigations on the significance of age and the concentration of serum proteins. Generally, there was a decrease in albumin and an increase in globulin fractions and total serum protein concentration with age. Forstner (1968) suggested the necessity of considering the age of the animal when interpreting data.

Garner (1952), investigating variations in serum protein levels in cattle, found that in an adequately fed herd, bulls had significantly higher total and differential serum protein levels than cows. Earlier, Edwards (1944) suggested that there may be a sex difference in serum protein content in cattle. Using the tyrosine method, he found that the total protein con-

tent varied between 7.5 to 9.5 g/100 ml. The higher values were obtained in bullocks. Garner (1952) observed that the significant differences in the total protein level was in the albumin and globulin values.

Plasma proteins are extremely sensitive to nutritional influences (Kaneko and Cornelius, 1970). They indicated that vitamins, growth factors and related substances which affect protein, lipid and carbohydrate metabolism would consequently be expected to make their influence felt in the plasma protein profile. Factors affecting protein metabolism may manifest themselves by influencing the total protein concentration of serum or plasma or just the fractions of individual proteins. Apart from the direct effects on serum proteins, the effect could also be extended to plasma lipoproteins.

Erwin (1960) reported a direct relationship between vitamin A and albumin concentration of bovine serum. With avitaminosis A, he found a deficiency in albumin concentration. The serum albumin levels returned to normal levels within 10 days after infusing

carotene.

Bedrak et al. (1954) reported a significantly lower serum protein content in cattle on protein-deficient diets. Dimopoullous (1970) reviewed work on protein depletion and referred to the results obtained by Weriner (1959) who found that, in rats, there was a decrease in the concentration of albumin and alpha$_1$ globulin. He quoted other workers who found that, in chicks and rats, the concentration of total serum protein was largely influenced by the amount of dietary protein and that the changes were mainly observed in the albumin fraction. In dogs, Allison (1957) reported that when protein reserves were depleted by a low nitrogen or protein-free diet, a hypoproteinemic condition developed with a decrease in albumin levels.

Watt et al. (1970) produced depletion of circulating gamma globulin in sheep by selective plasmapheresis without affecting the other globulin fractions. Repletion occurred within four days.

C. PROTEIN METABOLISM AND HELMINTHIASIS

1. General Interaction between Protein and Disease

A large volume of data is available on diseases related to specific nutrient deficiencies. However, there is comparatively limited information on the effects of nutrients on disease processes. It has been recognised from ancient times that a well-fed individual was less subject to almost any type of disease.

There are two types of interaction between nutrition and disease. First, the antagonistic effect of nutrition where, nutritional deficiency on the infectious agent is more critical than on the host thus protecting against infection such as with viral and protozoan parasites. Second, synergism where a combination of malnutrition and infection results in a greater severity than the sum of the two individual disease processes, with each exacerbating the other, for example, in chickens where undernourishment makes them more susceptible to fowl sarcoma virus.

Munro and Allison (1964) stated that certain pathological conditions may affect the general course of protein metabolism at several points. In health, proteins and other nitrogenous body constituents are maintained at constant levels by an intergrated series of reactions in which the amino acids derived from dietary protein are distributed to the tissues for anabolic purposes and the unwanted amino acids undergo catabolic reactions leading to excretion of their nitrogen.

Generally, effect of bacterial infections and dietary deficiencies are usually synergistic. Scrimshaw et al. (1959) made a list of disease conditions in various animals where several authors reported this type of interaction. He pointed out the work of Watson et al. (1938) where multiple nutrient deficiency including protein produced synergistic interaction in mice. Single nutrient deficiencies rarely occur in nature. Metcoff et al. (1948) failed to confirm a relationship between protein deficiency of moderate duration and resistance to salmonellosis in rats.

Other studies indicated a more or less proportional loss of resistance with severe protein deficiency. Tuberculosis was pointed to as one disease with a dominant synergistic effect. Hedgecook (1955) found mice fed lard as the only source of fat that there was no protein deficiency effect on tuberculosis but when a mixture of five essential fatty acids were given in addition to protein, there was statistically significant protection.

In viral infections, antagonism is a common and well-defined reaction associated with nutritional disorders (Scrimshaw et al., 1959). Protein deficiencies ordinarily have little or no effect on viral infections. However, Vilter and Thompson (1951) reported in their clinical observations on infectious human hepatitis in West Africa, that adequate protein nutrition limited the sequelae of chronic cirrhosis. On the other hand, Kearney et al. (1948) found that tryptophan deficiency gave almost complete protection to mice from the paralytic effect of Theiler virus, whereas all the controls were paralyzed. Virus titer were as high in the brains of tryptophan deficient non-paralyzed animals as in the

normally fed controls.

Studies on the interaction of malnutrition with rickettsial infection indicated synergism. The most prominent was that by Fitzpatrick (1948) with murine typhus in protein-deficient rats. Severity of murine typhus increased as the level of protein decreased.

The relationship between protein or amino acid deficiencies to antibody production or anamnestic mechanism in general has been discussed extensively (Munro and Clark, 1959). Madden and Whipple (1940) demonstrated that dogs depleted of protein by being fed a low protein diet and subjected to repeated plasmapheresis had a reduced ability to elaborate specific antibodies and that these dogs were more susceptible to infection. This was reversible by protein feeding. Cannon et al. (1943) observed a decreased ability in protein-depleted rabbits to produce agglutinins to Salmonella typhosa and S. paratyphii. They explained this on the basis of insufficient protein for synthesis of gamma globulin. Wissler (1947) reported a decreased resistance in protein-deficient rabbits to pneumococcal infection which could be restored by passive immunization.

He showed that amino acids mixture when substituted for part of the carbohydrate in the diet resulted in recovery in the capacity to produce antibodies. These and other studies led to firm conclusions that protein deficiency, not only interfered with antibody production, but also affected phagocytosis, quantitatively.

Evidence to support this latter findings was reviewed by Munro and Allison (1964). They referred to findings by Asirvadham (1948) and several others that severe protein depletion resulted eventually in marked atrophy of liver, spleen and bone marrow where most phagocytic cells originate and hence interference with normal production of phagocytic cells. Scrimshaw et al. (1959) cited work which showed that children with severe protein deficiency (kwashiokor) often had little or no leukocytic response even to serious infections.

Other areas in which protein nutrition relates to disease include collagen formation. Dumphy (1957) found that protein deficiency especially methionine, not only interfered with conversion of the precollagens but also with the tensile strength of collagen fibers.

Nonspecific protective substances like lysozyme are affected by protein deficiency (Dawson and Blagg, 1950). Properdin is euglobin associated with complement in the resistance to many diseases of various etiological agents and protein deficiency affects its protective activity and even production (Keller et al., 1957; von Wiss et al., 1957; Scrimshaw, 1964).

In another work with chicken, Bhargwa (1971) studied the effect of specific amino acids on growth and antibody production when birds were infected with living or killed Newcastle disease virus. They reported that low protein or imbalanced diets may contribute to failure to respond to vaccination.

2. Helminth Infection and Protein Interrelationship

Farmers and shepherds have long believed that well-fed sheep are troubled less with worms. Hunter (1953) reviewed work on nutrition and host-helminth relationships and stated that several nematode parasites of sheep appear to thrive when their hosts are poorly fed. Fraser and Robertson (1933) found fewer Haemonchus contortus in lambs given a supplement of

skim milk and concentrates than the controls. However, Ross and Gordon (1933) had difficulty in establishing H. contortus infection in aged sheep on a poor diet which was just sufficient to maintain their weight.

Several workers indicated that protein deficiency usually appears to benefit parasitic helminths in various species of animals. Riedel and Ackert (1950) studied the effect of protein in the diet on Ascaridia galli infection in poultry and suggested that the quality, as well as the quantity of the protein, is important in limiting establishment of the parasites. They found that chicks fed a diet containing 18.75% protein had fewer ascarids than chicks on a diet containing 11.83 or 24.36% protein. The former being low in all essential amino acids except tryptophan and the latter being low in arginine.

Donaldson and Otto (1946) found more Nippostrongylus muris in rats on a diet with 9% protein than those on a diet of 22% protein. Dewitt (1957) working with mice on a diet deficient in vitamin E and cystine found that Schistosoma mansoni infection was more severely affected.

Sheep on diets inadequate to support their full growth potential habored more worms and had higher fecal egg counts than more adequately fed sheep (Bawden, 1969). Hunter (1953) concluded that specific dietary deficiences of protein and vitamin A were often associated with increased host susceptibility to infection with nematodes. Gordon (1964) indicated that inadequate nutrition indirectly affected the epidemiology of trichostrongyliosis chiefly by influencing the free - living stages of the life cycle, the direct effects being the lowering of the host's ability to resist infection. Gibson (1955) indicated that infection with Trichostrongylus axei depressed the appetite of sheep once the developing worms reached maturity which occurs in the acute stage of the disease. He proposed that appetite depression was an important factor in the causation of disease by T. axei. Andrews (1939) and Laurence et al. (1951) published similar findings although they considered that the depression of appetite was associated with abdominal pain possibly due to abomasal lesions. Gibson (1955) also pointed out that there were factors other than appetite depression involved

in the pathogenesis of T. axei disease despite the observed decreased in digestive efficiency.

Work with helminthosis in calves have been similar to those in other species. The ability of 16% dietary protein supplementation to counterbalance increased exposure of calves to mixtures of gastrointestinal nematodes was evaluated by Leland et al. (1966). Although the crude protein level prevented clinical signs of parasitism it did not completely counterbalance the influence of the helminth infection on some of the parameters used as the measure of parasitism. They surmised that the calves might even have been in a state of "subclinical parasitism" in which only slight additional stress might lead to clinical manifestations.

3. Diagnostic Methods in Helminthosis

Parasitic diseases of livestock especially helminthoses, present many problems in diagnosis. Martin et al. (1957) reported outbreaks of severe chronic diarrhea and emaciation in young dairy cattle

due to Ostertagia ostertagi as "atypical parasitic gastritis". This outbreak was referred to by Ross (1963) as being typical. While the history of such an outbreak is helpful, diagnosis can be difficult based on clinical signs. Clinical signs may, in many cases, lead to a diagnosis without recourse to other procedures. Soulsby (1965) emphasized that it is essential that the clinical signs be regarded as an intergal part of the diagnostic procedure. Confirmation can be sought by fecal examination to determine the number of eggs per gram of feces.

Most conclusions or studies on parasitic gastroenteritis, especially the occurrence and epidemiology, have been based on data provided by fecal egg counts. Roberts et al. (1951) stated that the value and significance of fecal egg counts is a subject of much controversy among helminthologists. They indicated a number of factors which influence egg counts such as regularity of oviposition, the number of worms and their age, regularity with which fecal material enters and is discharged from the rectum, food, bulk, resistance, and food intake of the host, and anthelmintic treatment. They also

asserted that fecal egg counts fail to give any measure of the number of males or immature worms present and that there is considerable variation in the count from hour to hour and from day to day. Ross and Armour (1960) confirmed the observations of Roberts and his coworkers when they found that the mean Haemonchus and Cooperia egg estimates had wide variations in single fecal egg counts from an individual animal. They advocated that the degree of infection was closely represented by a series of counts taken over several days.

Soulsby (1965) pointed out that larval differentiation was essential in the interpretation of fecal egg counts and that differential egg counts were only of use provided several individual animals were sampled. This gives the incidence, and the extent of pathogenicity.

As a criterion for pathogenicity, serum albumin levels have been suggested (Ross and Armour, 1960). Kutler and Marble (1960) observed that there were significant differences in the albumin and alpha-2 globulin fractions between non-parasitized and clinically parasitized animals. In clinically parasitized

lambs, the total serum protein was decreased; albumin fraction was decreased and alpha-1 globulin, alpha-2 globulin, beta-globulin and gamma globulin fractions were increased. This confirmed earlier observations by Leland et al. (1958) who reported extensive and prolonged hypoproteinemia with hypoalbuminemia and an increase in the alpha-2 globulin in calves experimentally-infected with T. axei. Kutler and Marble (1960) reported the use of paper electrophoresis as an aid to diagnosis. They found that serum protein fractionation by paper electrophoresis is a reliable method for studying changes as a result of various pathologic processes.

Wilson and Turner (1965) observed higher albumin/globulin ratios and lower gamma globulin percentages in lambs raised parasite-free in comparison to those moderately or heavily parasitized. Ross and Armour (1960) also noticed that serum albumin levels and packed cell volume (PCV) percentages gave a fair indication of the condition of cattle infected with H. contortus. They considered that these might be useful aids to assessing pathogenicity. In Africa, they pointed out that the use of PCV might be authentic

provided that the normal range of healthy cattle values is known for the area. However, all these diagnostic methods become complicated when the "selfcure" phenomenon takes place and therefore the parameters used have to be carefully evaluated in light of this.

A diagnostic method described which is receiving considerable attention in research studies is the plasma pepsinogen determination (Armour et al., 1973). Determination of plasma pepsinogen is used as an adjunct to the diagnosis of helminths especially those of abomasal origin and specifically in the diagnosis of O. ostertagi. It involved emergence of the 4th larval stage from the gastric glands and subsequent damage such as cell hyperplasia, loss of cellular differentiation particularly of the parietal cells. This leads to an increase in abomasal pH from the normal 2 to 6.3 or more. The increased pH of abomasal fluid leads to failure to activate pepsinogen to pepsin. Since the pepsinogen secreted into the gastric lumen is not activated in the alkaline medium it passes from the lumen via open epithelia cell junctions into the circulation. Normal levels of plasma pepsinogen is less than 1,000

milli-units of tyrosine but in severe cases of helminth infection it could rise as high as 3,000 milli-units or more.

Measurements of plasma pepsinogen in conjunction with those of plasma proteins, seasonal incidence of disease, clinical appearance, fecal egg counts, and blood profiles have been the most useful and the most widely used techniques in diagnosis of helminth infections.

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B. SERUM BIOCHEMICAL PARAMETERS IN CATTLE

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C. PROTEIN METABOLISM AND HELMINTHIASIS

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PART II

A SURVEY OF SERUM BIOCHEMICAL LEVELS IN CATTLE IN NORTHERN NIGERIA

INTRODUCTION

Measurements of biochemical parameters in cattle in Nigeria have been carried out only within the past two decades (Garner, 1952; Ross et al., 1959; Ross, 1960; Oduye and Fansanmi, 1971; Saror and Coles, 1973). Prior to this, conclusions were extrapolated from data obtained from Bos taurus breeds under temperate conditions.

Basic differences in serum biochemical values between the Zebu and Scottish Highlander cattle were reported by Olbrich et al., (1971). Interbreed differences in cattle have been found in Nigeria (Oduye and Fasanmi, 1971; Saror and Coles, 1973). These workers concluded that the use of blood values in assessing the significance of disease conditions in tropical countries such as Nigeria differed in some important aspects from those in temperate environments. Furthermore, separate baselines are needed to be established for each breed and any seasonal variations determined.

This paper reports the range and variation in selected serum biochemical and mineral values of the Zebu (White Fulani), Friesian/Zebu crossbred, and Friesian cattle.

MATERIALS AND METHODS

Blood samples were collected from clinically healthy male and female cattle at the Shika Research Station, Ahmadu Bello University during the wet season (June to September, 1975) and the dry season (January to March, 1976). Blood samples were also collected from abattoirs in Zaria, Kaduna and Kano.

Blood (20 ml) was taken via the jugular vein, into vacuum tubes[1] without anticoagulant. The blood was allowed to clot at room temperature and serum separated within three hours of collection. The serum was frozen at -5°C until used for biochemical determinations.

Estimation of total protein and albumin was performed by the Biuret method (Coles, 1974). The values were determined colorimeterically at 450 nm[2]. Globulin value was determined by deducting the albumin value from that of the total protein.

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[1]Venoject - Jirtan Terumo Co. Ltd., Tokyo, Japan.

[2]Bausch and Lomb Spectronic 20.

Serum calcium and magnesium were determined with an atomic absorption spectrophotometer[3] by the method described by Willis (1960 a,b, 1961). Strontium chloride was used as the diluent in a ratio of 1:50.

Inorganic phosphorus levels were determined by the modified method described by Fiske and Subarow (1925) and estimated colorimeterically at 680 nm[2].

Serum sodium and potassium were determined by flame photometry (King and Wooton, 1959).

Chloride was determined by the method described by Schales and Schales (1941).

Hemoglobinconcentration was determined by the cyanmethemoglobin method and the values read in a spectrophotometer[4] at 540 nm.

Packed cell volume (PCV) was determined by the hematocrit method (Coles, 1974).

Blood urea nitrogen was determined by the method

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[2]Bausch and Lomb Spectronic 20.

[3]Model 306 Perkin Elmer Corp., Norwalk, Connecticut, U.S.A.

[4]Beckman D.S. Spectrometer Model 140.

described by Chaney and Marbach (1962).

Creatinine was determined by the method described by Hare (1950).

RESULTS

One hundred and fifty-four Zebu (White Fulani), Friesian/Zebu cross, and Friesian cattle varying in age from one to ten years were used; 78 from Shika Research Station and 76 from the abattoirs (Zaria 32, Kaduna 14, and Kano 30).

Mean serum electrolyte and biochemical values are shown in Tables 1 and 2 and the individual values in Appendix 1. Friesian cattle had significantly lower serum magnesium levels than the Zebu and Friesian-Zebu cross ($t = 8.25$; $P<0.01$). Significantly lower difference in calcium was found in the Zebu cattle ($P<0.01$). Serum potassium and sodium levels were higher in the Zebu than in the Friesian and Friesian cross.

Urea nitrogen in the Zebu was significantly lower in the Zebu ($P<0.05$). Serum albumin was significantly

higher in the Zebu ($P < 0.05$). There were no statistically significant differences in serum total protein, globulin and inorganic phosphate between the breeds.

Variations in seasonal serum biochemical and electrolyte findings are presented in Tables 3 and 4. There was a significantly higher difference in magnesium levels in Zebu in the dry season than the wet season ($P < 0.05$) but no significant seasonal variations in the other breeds. Magnesium levels were higher during the wet season than the dry season for the Friesian and Friesian cross. However, magnesium levels in the White Fulani during the dry season was higher than for the other breeds. There was no significant seasonal differences in calcium levels within and between the breeds. Higher values for sodium were obtained in the Zebu during the dry season; however, no statistically significant differences were found between the seasons for each breed ($P > 0.05$). Chloride values during the wet season were significantly higher compared to the dry season in all the breeds except the Zebu ($P < 0.05$).

Blood urea nitrogen (BUN) values for the Zebu

was significantly lower in both seasons. No. significant differences were found for the total protein values within and between the breeds or between seasons. Creatinine values were significantly lower in the Zebu during both seasons (P 0.05). There were no significant differences in creatinine values in the Friesian and Friesian/Zebu cattle.

Tables 5 and 6 present a comparison of serum biochemical and electrolyte levels reported for Nigerian cattle, the findings in this study, and the values reported for temperate zone breeds.

DISCUSSION

The mean serum biochemical values found were in agreement with values reported earlier (Garner, 1952; Bradish et al., 1954; Ross, 1960; Perk and Lobl, 1961; Oduye and Fasanmi, 1971; Olbrich et al., 1971; Saror and Coles, 1973; Coles, 1974). The lower values for creatinine in the Zebu were in contrast to the findings of Olbrich et al. (1971). They reported a higher value, which coupled with the slightly higher values of albumin, globulin and total protein, was

used to indicate basic metabolic differences between the Zebu and Friesian or Friesian cross. The findings in the present study support a metabolic difference. Values for serum globulins were lower and albumin higher than the reported normal values of Nigerian cattle (Oduye and Fasanmi, 1971). Serum protein values can be influenced by nutritional, immunological, physiological and pathological conditions (Saror and Coles, 1973); one or the other of these factors might have affected the measurements in this study.

BUN values, though within the range reported by Coles (1974), were inconsistent with those reported by Olbrich *et al*. (1971). Possible variation might be due to the breed of *Bos indicus* used in the survey since the BUN values obtained for the *Bos taurus* agreed with their findings. The slightly higher BUN values in the Zebu during the wet season compared with the constant levels in the other breeds during both seasons could be due to availability of more protein during that period and better recycling in the Zebu as indicated by McDonald (1948). Similar findings were made by (Saror and Coles, 1973) and

they attributed the seasonal differences to nutritional factors.

Chloride values obtained are similar to the findings by Dittmer (1961). There is no explanation for the significantly lower values for the Zebu. The higher chloride values obtained during the wet seasons cannot be explained or attributed to simple nutritional intake or environmental influences. It is noticed that there is a reciprocity in the values of sodium and chloride between the breeds; the lower the chloride values, the higher the sodium value. A similar correlation with season and breed was observed with potassium and chloride values.

The slightly lower calcium value for the Zebu was similar to the findings by Oduye and Fasanmi (1971) who reported lower serum calcium levels for both White Fulani and N'Dama breeds compared with European breeds. Lack of difference in inorganic phosphate values between breeds confirmed earlier findings by Oduye and Fasanmi (1971).

SUMMARY

Serum biochemical and electrolyte measurements were determined in 78 Zebu (White Fulani), Friesian and Friesian/White Fulani crossbred cattle and compared according to breed and season (wet and dry). Seventy-six blood samples were also collected from abattoirs. The values for sodium, potassium, total protein, and globulin were higher in the Zebu than the other two breeds. Blood urea nitrogen, creatinine, and chloride values were higher in the crossbred cattle. Calcium, magnesium, albumin, and PCV values were similar in both Friesian and Friesian-Zebu cross. Seasonal variations were found in the chloride, sodium, potassium, creatinine, and blood urea nitrogen levels in all the breeds. No differences were found between the breeds for inorganic phosphate values.

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Table 1. Mean and standard deviation of selected serum electrolyte levels in Nigerian cattle.

Breed	Magnesium mg/100ml	Calcium mg/100ml	Potassium mEq/l	Sodium mEq/l	Inorganic Phoshate mg/100ml	Chloride mEq/l
White Fulani	2.26	9.79	4.35	146.03	5.76	99.61
Friesian	1.68	10.38	3.89	143.33	5.60	106.13
Cross	2.36	10.76	3.98	142.68	5.77	106.11
S.E	0.24	1.38	0.38	34.13	1.21	6.38

S.E. = Standard error of difference

Table 2. Mean and standard deviation of selected serum biochemical values in Nigeria cattle.

Breed	BUN mg/100ml	Total Protein g/100ml	Globulin g/100ml	Albumin g/100ml	Creatinine mg/100ml
White Fulani	8.81	7.75	2.47	5.17	0.92
Friesian	10.86	7.41	2.43	4.79	1.18
Cross	11.11	7.54	2.47	4.99	1.39
S.E.	3.86	1.00	1.22	1.42	0.08

BUN = Blood Urea Nitrogen

S.E. = Standard error of difference

Table 3. Comparison of the means and standard deviation of normal electrolyte values in Nigerian cattle.

Breed and No. of Animals	Season	Magnesium mg/100ml	Calcium mg/100ml	Potassium mEq/l	Sodium mEq/l	Inorganic Phosphate mg/100ml	Chloride mEq/l
WF 37	Dry	2.65 ±0.44	10.17 ±2.93	4.18 ±0.55	146.69 ±27.63	5.25 ±2.17	99.68 ±12.04
38	Wet	1.90 ±0.09	9.44 ±1.95	4.50 ±0.50	145.42 ±13.82	6.24 ±0.72	99.55 ±31.01
F 10	Dry	1.62 ±0.07	9.99 ±1.42	3.71 ±0.23	143.11 ±12.11	4.79 ±0.62	102.80 ±26.18
14	Wet	1.72 ±0.13	10.64 ±1.16	4.00 ±0.11	143.47 ±29.98	6.21 ±0.80	108.50 ±17.96
WF/FC 27	Dry	2.02 ±0.19	10.96 ±1.51	4.04 ±0.31	144.16 ±21.31	5.02 ±0.86	101.27 ±20.84
28	Wet	2.47 ±0.30	10.57 ±1.46	3.93 ±0.22	141.36 ±27.28	6.12 ±1.14	110.61 ±17.80

WF = White Fulani F = Friesian WF/FC = White Fulani/Friesian Cross

Table 4. Comparison of the means and standard deviation of selected serum biochemical values in Nigerian cattle.

Breed and No. of Animals	Season	BUN mg/100ml	Total Protein g/100ml	Globulin g/100ml	Albumin g/100ml	Creatinine mg/100ml
WF 37	Dry	8.00 ±3.28	7.18 ±0.22	1.74 ±0.39	5.46 ±0.55	0.96 ±0.04
38	Wet	9.65 ±3.74	8.28 ±2.25	3.23 ±2.56	4.87 ±3.25	0.89 ±0.01
F 10	Dry	10.95 ±5.57	7.52 ±0.98	3.08 ±1.73	4.28 ±0.78	1.11 ±0.03
14	Wet	10.80 ±2.66	7.33 ±0.25	1.93 ±1.00	5.18 ±1.07	1.23 ±0.13
WF/FC 27	Dry	11.17 ±4.89	7.51 ±0.87	2.50 ±1.09	4.96 ±1.06	1.28 ±0.11
28	Wet	11.05 ±3.77	7.56 ±0.75	2.43 ±0.51	5.02 ±0.89	1.48 ±0.17

WF = White Fulani; F = Friesian; WF/FC = White Fulani/Friesian Cross
BUN = Blood Urea Nitrogen

Table 5. Comparison of findings with reported normal electrolyte values.

Breed	No. cattle (Age)	Mg mg%	Ca mg%	K mEq/l	Na mEq/l	PO4 mg%	Cl^- gmEq/l	Reference
Not Stated	-	2.20 ±0.37	10.26 ±2.13	4.14 ±0.42	144.41 ±36.42	5.74 ±1.45	102.99 ±40.03	Akerejola[a]
White Fulani	147 (1mth-11 yrs.)	-	9.81 ±1.52	4.47 ±0.86	134.80 ±19.00	5.08 ±1.05	102.37 ±13.70	Oduye and Fasanmi 1971
Not Stated	-	2.05 -2.30 ±0.17	11.08 ±0.67	3.9 -6.9	126-152	5.5 -8.9	94-112	Coles, 1974
Zebu	-	-	10.5	4.4	151.0	8.2	114.2	Olbrich et. al., 1971
Scottish Highland	-	-	10.5	4.5	148.2	8.0	114.7	"

a = Mean values (Table 1).

Table 6. Comparison of findings with reported normal biochemical values.

Breed	No. cattle (Age)	BUN mg/100ml	Total Protein g/100ml	Globulin g/100ml	Albumin g/100ml	Creatinine mg/100ml	Reference
Not Stated	154 (1-10 yrs.)	9.97 ±5.30	7.62 ±1.14	2.46 ±1.51	5.05 ±1.48	1.13 ±0.12	Akerejola[a]
White Fulani	(1-12 mths.)	-	5.91	4.08	1.83	-	Ross, 1960
	54 (1mths.-6yrs.)	-	6.95	4.45	2.50	-	" "
White Fulani	Dry Season 54(63 mths.)	10.96 ±3.82	8.06 ±1.49	3.95 ±0.90	4.10 ±1.14	-	Saror and Coles, 1973
	Wet Season 63(63 mths.)	14.46 ±4.65	8.11 ±0.89	4.16 ±0.78	3.94 ±0.55	-	" "
Cross	Dry Season 72(19 mths.)	12.75 ±4.63	7.18 ±1.09	3.54 ±0.89	3.65 ±0.71	-	" "
	Wet Season 106 (23 mths.)	12.25 ±4.13	7.22 ±0.86	3.25 ±0.52	3.96 ±0.99	-	" "

a = Mean Values (Table 2).

PART III

EFFECT OF FEEDING DIFFERENT LEVELS OF PROTEIN ON GROWTH AND NUTRIENT DIGESTIBILITY IN BUNAJI (WHITE FULANI) FRIESIAN, AND FRIESIAN - BUNAJI CROSS CATTLE

INTRODUCTION

In most developing countries of the world, production of meat at the cheapest cost to consumers and at the fastest rate is the aim of meat producers. Knowledge of nutrient requirements would play a major role in furthering this aim. Feed intake increases and overall performance improves when preformed supplemental protein is fed or replaces non-protein nitrogen in cattle rations (Anon., 1970a). Emaciation and production in cattle grazing pastures low in protein are observed in Nigeria (Olubajo and Oyenuga, 1973).

On most livestock farms in Nigeria, either Morrison's (1959) or the nutrient requirements of beef cattle (Anon., 1970a) feeding standards are followed. These recommendations are based on nutrient requirements for cattle under temperate zone conditions and may not be suitable for Zebu breeds (French, 1940). Attempts have been made to compare the relative capacity of tropical and temperate zone cattle to digest and utilize feedstuffs (French, 1940; Duckworth, 1946; Karue et al., 1972; Talpada et al., 1973). Cattle performance under

varied protein levels have been studied (Zemmelink et al., 1973; Knudsen and Sohael, 1970; Harbers et al., 1972; Umunna and Dankintafo, 1976).

The purpose of this experiment was to investigate the effect of feeding different levels of protein on performance and nutrient digestibility in White Fulani (Zebu), Friesian, and White Fulani - Friesian cattle.

MATERIALS AND METHODS

Experimental Animals

Eighteen steers, averaging 162.55 kg., aged from seven months to one year, were obtained from institutional farms at Vom and Shika: six purebred Friesian, six Friesian White Fulani 3/4 grade cross, and six purebred White Fulani. The steers were kept in isolation for six weeks and pretreatment included: fecal egg count for worms; anthelminthic[1] treatment on arrival and repeated three weeks later; daily rectal temperatures; and blood smears taken from steers with

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[1]Thiabenzole - Thiabendazole, Merck Sharp & Dohme Ltd. Hoddesdon, U.S.A.

pyrexia and treated according to blood parasite present.

The 18 steers were divided into three equal groups. They were fed in 3 x 3 factorial pattern with two replications in a completely randomized design.

Growth Trial I.

Feed consisted of Gamba hay which provided 60% of the ration and sorghum and groundnut cake provided the remianing 40% on dry basis. Using the nutrient requirements of cattle (NRC) report (Anon. 1970a) three protein levels were chosen: the recommended 12% crude protein and a 4% difference below and above this level (Tables 1 and 2). Each steer was fed 2.73 kg. concentrate and hay. Each steer was kept in a metabolism stall and fed individually for 54 days (Appendix II). Individual weights were determined at the beginning and the end of the experiment. Blood samples (10ml) were obtained from the jugular vein with disposable polyethlene syringes every seven days.

Each sample was centrifuged[2] at 3000 rpm for 10 minutes and the serum stored at -5°C for later analysis.

Balance Trial

The first 21 days the steers spent in the individual metabolism stalls receiving their allotted diet served as the adjustment period and was followed by the 10 day collection period.

Feces from each steer were collected daily, mixed thoroughly, weighed, 5% was placed in individual polythylene bags, identified, and then immediately frozen at -5°C. Total daily urine volume from each steer was determined, 10% was placed in acid washed bottles, and stored at -5°C. Twenty-five ml. of 50% reagent grade concentrated hydrochloric acid[3] was added to the urine collecting containers to prevent ammoniation.

At the end of the digestion trials, the fecal samples from each steer were pooled, dried in a

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[2]Clinical Centrifuge - International Equipment Co. Needham, Massachusets, U.S.A.

[3]Analar - Supplied by Naafco Sci. Equip. Supply Ltd., Lagos.

forced draft oven at 70°F to a constant weight, ground, and stored in airtight containers for analysis.

Proximate analysis of the fecal samples and determination of urinary nitrogen were conducted according to the official methods of the Association of Official Analytical Chemists (Anon., 1970b).

Growth Trial II.

A second growth trial was conducted after an interval of 120 days. Fifteen of the 18 steers were re-randomized and allotted to the three levels of protein supplementation. Initial and final weights were determined.

RESULTS

Data on performance of steers in the growth trials are presented in Tables 3 and 4. Analysis of variance, interaction means of initial, final weight, and weight gains in the first trial are presented (Appendix III). The Friesians had a significantly

higher weight gain and lower initial weight than the other two breeds ($P<0.05$). In the first growth trial, daily gain was better at the 12% and 16% crude protein levels than 8%, although efficiency of feed utilization was better at the 8% level. In the second growth trial there was a significantly higher difference in efficiency of feed utilization at the 12% than either the 8% or 16% crude protein level ($P<0.05$).

Digestibility coefficients are presented on Tables 5 and 6. Significantly higher differences were found in digestibility between 16% crude protein level and the other levels ($P<0.01$). The digestibility of protein at 8% and 12% level was significantly lower ($P<0.05$). At the 16% level the digestibility of all nutrients was higher than at the other two protein levels.

There was no significant difference in dry matter (DM), nitrogen-free extract (NFE), and organic matter (OM) digestibility between the Friesian and the White Fulani Cattle. The White Fulani had a significantly higher crude fiber (CF) and ether extract (EE) digestibility than the Friesian or the Zebu Cross at 8% level of crude protein ($P<0.05$). The DM and protein

digestibility were significantly higher in the Friesian than the other breeds ($P < 0.05$).

At the 12% crude protein level, DM and CF digestibility were significantly lower ($P < 0.05$) in the crossbred but the protein digestibility was significantly higher than the other two breeds ($P < 0.05$).

At the 16% crude protein level, no significant differences were found between breeds in the nutrient digestibility coefficients.

DISCUSSION

Weight gain differences between the Friesians and White Fulanis in the growth trials may have been due to management as reported by Knudsen and Sohael (1970). Similar observations were by Zemmelink *et al.* (1973) who found that crossbred Friesians gained weight faster under confinement conditions than White Fulanis.

No adequate explanation can be found for the higher weight gain and difference in feed utilization efficiency obtained at the lower protein level

in the first growth trial. The better average daily weight gain observed with the 12% crude protein diet confirmed the finding by Umunna and Dankintafo (1976).

Nutrient digestibility coefficients found were within the range reported in other studies (French, 1940; Duckworth, 1946; Philips, 1961). The digestibility coefficient of ash had little significance in this study.

The higher digestibility of nutrients found at the 16% crude protein level is similar to the findings by Talpada et al. (1973) that lower levels of protein give lower digestibility.

Observations on digestibility of DM at 8% and 16% protein levels were similar to those of Karue et al. (1972) when they fed 7% and 14.4% protein containing hay and cottonseed or urea supplement, respectively. They reported similar digestion coefficients of DM in both breeds at either level of feeding. However, the present study does not support the finding that there is no significant difference in protein digestion coefficient at low

and high levels of protein feeding. Observations of no significant difference for organic matter digestibility at all levels of protein feeding between breeds and within breeds confirmed earlier work by French (1940).

The results obtained demonstrated that there was no appreciable difference in digestibility between the Zebu and the other two breeds. The results indicated that, for the cattle used, 12% crude protein in dietary dry matter is adequate for good performance. No improvement in growth rate or efficiency of food conversion resulted when the crude protein level was increased to 16%. Similar observations have been recorded in other cattle breeds (Robertson et al., 1970).

SUMMARY

Two growth trials were performed with Zebu (White Fulani), Friesian and Zebu x Friesian crossbred steers using three levels of dietary crude protein. No significant differences were found in weight gain between the low (8%), medium

(12%), and high (16%) levels of crude protein in the first trial. Higher weight gain and efficiency of feed utilization was found with 12% crude protein. Friesian steers performed better under the management system used. On low protein feed, the Zebu had a higher significant coefficient of digestibility for crude fiber and ether extract ($P<0.05$) At the 16% protein level, no significant differences were found between breeds in digestibility of the nutrients ($P<0.05$). Significant higher differences ($P<0.05$) were found in the nutrient digestibility at the 16% crude protein level of feeding when compared to the other two levels.

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Table 1. Percentage composition of the daily basal ration for the steers.

Item	Crude Protein		
	8%	12%	16%
Salt	1.25	1.25	1.25
Trace minerals[1]	+	+	+
Vitamin A[2]	+	+	+
Bonemeal	1.00	0.9	0.7
Sorghum	87.10	56.19	9.49
Groundnut cake	10.61	41.65	88.53

[1]Pfizer mineral block; Calcium 8.5%, Phosphorus 4% Magnesium 108.2 ppm, Iron 346.1 ppm, Copper 86.5 ppm, Manganese 64.9 ppm, Cobalt 21.6 ppm, Zinc 21.6 ppm, and Iodine 5.4 ppm.

[2]Vitamin A - 200,000 IU/head/day

Table 2. Percentage chemical composition of the protein supplements and hay (dry matter basis).

Protein Level %	Crude Protein	Ether Extract	Crude Fiber	N- Free Extract	% Dry Matter	Total Ash	Organic Matter
8	13.35	3.52	3.25	76.17	94.30	3.71	96.29
12	18.45	3.32	3.78	71.12	94.10	4.67	95.33
16	41.76	5.84	10.20	34.49	96.00	7.71	92.29
Gamba hay	2.08	0.89	41.50	49.33	96.30	6.20	93.80

Table 3. Performance data of steers during growth trial 1.

Item	Crude Protein		
	8%	12%	16%
No. Steers	6[a]	6	6
Time on feed (days)	54	54	54
Initial weight, kg.	160.23	165.53	161.88 ±9.24
Final weight, kg.	181.59	176.52	174.09 ±11.32
Daily gain, kg.	0.40	0.20	0.23
Daily feed supplied kg.	6.98	6.98	6.98
Feed conversion	17.45	34.90	30.35

[a]One animal had a fracture and was removed from the group.

Table 4. Performance data of steers during growth trial 2.

Item	Crude Protein		
	8%	12%	16%
No. Steers	5	5	5
Time on feed (days)	27	27	27
Initial weight, kg.	214.09	220.45	204.18 ±4.79
Final weight, kg.	235.73	256.73	226.36 ±4.60
Daily gain, kg.	0.80	1.34	0.82
Daily feed supplied, kg.	6.98	6.98	6.98
Feed conversion	8.73	5.21	8.51

Table 5. Effect of three protein levels on nutrient digestibility in steers (mean values).

Digestibility	Crude Protein			
	8%	12%	16%	SE
No. animals	6	6	6	
Dry matter	58.88^{b}	60.05^{b}	68.09^{a}	1.88
Protein	47.39^{c}	61.85^{b}	85.39^{a}	3.96
Crude Fiber	65.47^{b}	63.01^{b}	72.53^{a}	1.53
Ether Extract	71.91^{b}	72.09^{b}	89.44^{b}	1.28
Nitrogen-free Extract	62.77^{b}	66.56^{b}	93.14^{a}	2.20
Organic matter	64.48	66.10	75.60	6.53

a,b,c = Significant difference (P 0.05) between a and b, a and c, and b and c; no significance between b and b.

Table 6. Digestibility coefficient obtained with steers of three breeds fed three levels of crude protein ration.

Constituents	Friesian*	White Fulani	Cross	SE
No. animals	6	6	6	
8% Crude Protein				
Dry matter	63.23^{b}	59.92^{b}	53.50^{a}	3.25
Protein	51.93^{a}	48.16^{b}	42.07^{b}	6.86
Crude fiber	67.30^{b}	68.98^{b}	60.12^{a}	2.66
Ether extract	72.20^{c}	78.19^{b}	66.30^{a}	2.21
Nitrogen free - extract	67.57^{b}	62.47^{b}	58.28^{a}	3.80
Organic matter	69.26^{b}	64.74^{b}	59.44^{a}	4.01
12% Crude Protein				
Dry matter	63.41^{b}	61.19^{b}	55.55^{a}	3.25
Protein	60.76^{b}	58.49^{b}	66.32^{a}	6.87
Crude fiber	68.85^{b}	62.29^{b}	57.90^{a}	2.66
Ether extract	72.23	72.80	71.23	2.21
Nitrogen free - extract	67.94	68.09	63.65	3.80
Organic matter	69.36	66.47	62.47	4.01
16% Crude Protein				
Dry matter	67.51	65.27	71.49	3.25
Protein	86.63	82.45	87.10	6.86
Crude fiber	75.64	69.10	72.87	2.66
Ether extract	89.46	89.07	89.79	2.21
Nitrogen free - extract	96.16	90.64	92.63	3.80
Organic matter	79.21	71.30	76.29	4.01

* One animal had a fracture and was removed from the group. a,b,c, = Significant difference ($P<0.05$) between a and b, a and c, and b and c; no significance between b and b.

PART IV

COMPARATIVE NITROGEN UTILIZATION BY THE BUNAJI (WHITE FULANI), FRIESIAN AND FRIESIAN - BUNAJI CROSSBRED CATTLE

INTRODUCTION

Differences in nitrogen metabolism between various breeds have been observed under grazing conditions and confinement (Vercoe, 1966). Studies comparing the digestive ability of Bos indicus and Bos taurus breeds have given variable results (Vercoe, 1967; Karue et al., 1972; French, 1940; Warwick, 1958). Ashton (1962) compared two Zebu breeds with the Hereford and found better nitrogen digestibility with the Zebu and more fecal nitrogen excretion by the Hereford. Karue et al. (1971) found that the Zebu (Boran) excreted more urea nitrogen in the urine than the Hereford and they considered this to be an adaptive nitrogen conserving mechanism in the Zebu. There is little information available on nitrogen balance and comparative studies in the Zebu (White Fulani) and Friesian.

This study was undertaken to compare the effect of diet on the nitrogen components in the feces, urine and plasma of Zebu, Zebu - Friesian, and Friesian steers.

MATERIALS AND METHODS

The 18 steers from the growth trials were used and

the management and feeding were the same as described previously (Part III).

The data on nitrogen balance was collected during the balance trial (Part III). Fecal and urinary samples were collected, handled and analysed as described in Part III. Blood samples were taken at the beginning of the first growth trial and at the end of the balance studies.

At the end of the balance studies, the protein levels of the feed changed; 8% and 12% to 16%, and 16% to 8%. The new levels were fed for 10 days and the feces, urine and blood were collected and analysed as described previously.

RESULTS

Data on nitrogen balance are presented in Table 1. At 8 and 12% crude protein level of feeding the White Fulani/Friesian steers had a significantly higher urinary and fecal nitrogen output than the other two breeds but a lower absorbed and retained nitrogen, and a lower percent retention of nitrogen intake and absorp-

tion ($P<0.05$). The Friesian at 8% level had a significantly lower fecal and urinary nitrogen output, greater nitrogen absorption and higher percent retention of nitrogen intake and absorption compared to the White Fulani ($P<0.05$).

At 12% crude protein level, the Friesian had a significantly higher retained nitrogen and higher percent nitrogen retention of intake and absorption compared to the White Fulani ($P<0.05$).

At 16% crude protein level, the crossbreds had a lower fecal and urinary nitrogen output but a higher nitrogen absorption and retention, and a higher percent retention of nitrogen intake and absorption ($P<0.05$).

Table 2 lists the values for serum metabolites in the steers at each level of protein feeding at the beginning and end of the trial period. Decreases were observed in total protein, albumin and globulin values in all steers. Significant increases in urea were observed in steers fed 16% crude protein ($P<0.05$). Significant increases in creatinine were observed at 8% and 16% protein levels but not at 12% ($P<0.05$).

Table 3 shows the nitrogen balance data after changing to two levels of protein feeding. Analysis

of variance of individual parameters giving daily and breed comparisons are tabulated in Appendix IV.

Significant higher differences were found in fecal and urinary output between the crossbreds and the other two breeds; lower values were obtained for nitrogen retention, percent retention of nitrogen intake and absorption ($P<0.05$). The Friesian had higher absorbed and retained nitrogen and percent retention of nitrogen absorbed than the White Fulani.

Effect of feed level on urinary nitrogen output was significant ($P<0.01$). The effect of feed or breed had no significant difference on daily urinary output. Fecal and urinary output was affected by the number of days on feed. Significantly lower differences were found between the pooled values for the first five days and the other days ($P<0.05$).

Nitrogen intake and absorption were significantly lower at the 8% crude protein level than 16% ($P<0.05$). The Friesian had a significantly higher retention of nitrogen and the White Fulani had higher value than the crossbred. ($P<0.01$).

Nitrogen digestibility coefficient was significantly higher at 16% level than at 8% and differed significantly

from day to day (P 0.05). The digestibility coefficient decreased with time.

Percent retention of nitrogen intake and absorption were significantly lower in the crossbreds but was unaffected by the feed level or day of feeding.

DISCUSSION

The higher total nitrogen output obtained in the crossbreds over the other breeds at 8% crude protein level supports the findings of Ashton (1962) and Vercoe (1967). The significantly higher nitrogen output of the White Fulani over the Friesian is similar to that found by Karue et al. (1972). Apparently, the low protein intake did not trigger the emergency nitrogen conserving mechanism in the Zebu steers compared to Friesian indicating a possible interbreed difference in nitrogen metabolism.

Similarities in the decreased levels of serum proteins in the three breeds supports the findings by Karue et al. (1972). Increases in serum urea with increased protein intake confirmed the dependency of

urea excretion on nitrogen intake (Schidmt-Nielson et al., 1957; McDonald, 1968). This may be related to increased microbial ammonia production and subsequent blood urea increase. The significantly higher serum creatinine values at 8% and 16% crude protein levels are similar to findings by Vercoe (1967) who referred to creatinine excretion as a function of catabolism affected by feeding level.

Nitrogen values were calculated for 10 days after changing the levels of protein supplementation because reports indicated that this was the minimum period necessary to achieve maximal nitrogen utilization (McLaren et al., 1959).

Daily nitrogen output of the steers indicated rapid adjustment to the three levels of protein feeding; approximately seven days for each group to stabilize. The crossbred steers with consistently higher nitrogen output confirmed the work by Ashton (1962). He found that nitrogen output and nitrogen digestibility coefficient were influenced by the number of days on feed. Differences in absorbed and retained nitrogen between the Friesian and the Zebu further supported the basic metabolic variation in

these breeds (Vercoe, 1966; Ashton, 1962; Karue et al., 1972).

SUMMARY

Nitrogen balance studies, serum proteins and creatinine determinations were conducted to compare the Zebu (White Fulani), Friesian and Friesian-White Fulani cross fed three levels of crude protein (8%, 12%,and 16%). Total nitrogen output was highest in the crossbreds fed 8% and lowest in the Friesians. There was no significant response in the White Fulani indicating a possible difference in nitrogen metabolism. No significant changes were found in serum proteins but significant increases were observed in urea and creatinine values at 16% crude protein intake.

Daily variations, effect of breed, and crude protein level were evaluated in the nitrogen balance data collected after changing the protein feed levels: 8% and 12% to 16%, and 16% to 8%. Re-adjustment to the new levels took approximately seven days. Signi-

ficant differences were found in values of absorbed and retained nitrogen between the Friesian and the White Fulani which supported the possibility of breed differences in metabolic handling of protein nitrogen.

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Table 1. Nitrogen balance studies with steers of three breeds fed three levels of crude protein*.

Constituents	White Fulani	Friesian	Cross	S.E.
No. Steers	6	6	6	-
8% Crude Protein Level:				
Intake	63.66[a]	66.66	66.66	-
Fecal	33.00[a]	30.60[a]	36.80[b]	1.48
Urinary	12.44[a]	5.31[b]	13.37[a]	0.87
Retained	18.22[a]	27.75[b]	13.43[c]	1.78
% N. Retained of Intake	28.63[a]	43.59[b]	21.10[c]	1.96
% N. Absorbed of Intake	59.25[a]	83.94[b]	49.29[c]	1.57
12% Crude Protein Level:				
Intake	84.39	84.39	84.39	-
Fecal	34.11[a]	33.23[a]	42.85[b]	1.48
Urinary	38.67[a]	33.39[b]	41.26[a]	0.87
Retained	11.11[a]	18.07[b]	2.73[c]	1.98
% N. Retained of Intake	13.17[a]	21.42[b]	3.24[c]	1.96
% N. Absorbed of Intake	22.14[a]	33.33[b]	6.57[c]	1.57
16% Crude Protein Level:				
Intake	183.60	183.60	183.60	-
Fecal	32.24[a]	24.56[b]	23.68[b]	1.48
Urinary	94.32[a]	92.27[a]	88.00[b]	0.87
Retained	57.04[a]	66.79[b]	71.92[c]	1.98
% N. Retained of Intake	31.07[a]	36.38[b]	39.17[b]	1.96
% N. Absorbed of Intake	37.62[a]	42.08[b]	45.29[b]	1.57

* From Part III.

Table 2. Effect of protein level on serum protein metabolites in cattle (Mean values).

Constituent		Protein Level 8%	12%	16%	S.E.
Total Protein	- Initial	6.70	7.00	7.27	0.35
	- Final	6.17	6.55	6.76	0.20
Albumin	- Initial	5.42	5.23	5.67	0.35
	- Final	4.65	4.97	5.12	0.25
Globulin	- Initial	1.28	1.93	1.67	0.47
	- Final	1.52	1.75	1.48	0.35
Urea	- Initial	9.33	9.27	9.80	1.01
	- Final	8.80	9.07	12.00	1.01
Creatinine	- Initial	0.96	0.95	0.88	0.13
	- Final	1.20	0.91	1.35	0.36

Table 3. Nitrogen balance data in steers fed 8% and 16% crude protein.

Constituents	Friesian	White Fulani	Crossbred
Nitrogen Intake	143.21	142.44	146.48
Fecal	30.96	33.16	35.53
Absorbed	113.00	109.28	110.94
Urinary	40.00	41.70	66.04
Retained	73.00	67.52	44.90
Intake % N. Retained	47.73	45.06	31.38
" " " Absorbed	91.70	87.16	60.47

PART V

STUDIES ON BLOOD AND URINARY UREA CONCENTRATION IN CATTLE IN RELATION TO PROTEIN UTILIZATION

INTRODUCTION

Balance studies to determine nitrogen requirement and utilization in ruminants rely on measuring nitrogen retention. This is the difference between the amount of nitrogen ingested and excreted. It is generally accepted that urea is the most important nitrogenous waste product in mammalian urine (Livingstone et al., 1962). Ingested protein is broken down by ruminal microorganisms to ammonia and the majority reconverted to microbial protein and some absorbed (McDonald, 1948). The ammonia absorbed is converted to urea in the liver, returned to the rumen primarily via saliva or lost through the urine. It has been reported that the efficiency of utilization of protein consumed by ruminants is dependent upon the quantity of ammonia produced in the rumen, which in turn is indicated by its concentration in the blood (Annison and Lewis, 1959). Blood urea levels reflect the overall changes in ammonia production in the rumen and this is diet-dependent (Lewis et al., 1957). Schmit-Nielsen and

Osaki (1958) found that sheep on low protein diets reduced urea loss in the urine. Lewis (1957) proposed that the ratio of blood urea concentration to rumen ammonia and urinary urea be used as a supplementary test for the efficiency of protein utilization in ruminants.

This study investigated the relationship between blood and urinary urea in White Fulani (Zebu), White Fulani/Friesian, and Friesian cattle.

MATERIALS AND METHODS

Experimental Animals

Five steers, 11 to 16 months of age with an average weight of 260 kg., were used; two White Fulani (Zebu), two White Fulani - Friesian, and one Friesian. The Friesian was obtained from the Federal Veterinary Institute, Vom and the remainder from the University herd. The steers were kept under close observation for seven months. Rectal temperatures were monitored daily, hemograms were determined fortnightly, and fecal samples checked monthly for internal

parasitism.

Feeding

The steers were divided into three groups according to breed. Each steer was placed in a metabolism stall and individually fed. They were all fed the same diet comprising 60% Gamba hay and 40% concentrates as basal to provide a dietary crude protein level of 12.1% on a dry basis (Table 1). They were given 1.82 kg. concentrates and 2.74 kg. of hay at 7.30 a.m. daily. The concentrates were consumed within five minutes. This feeding regimen was continued for 14 days.

Sampling Procedures

Blood samples were collected daily from each steer 30 minutes before feeding and five minutes after consuming the concentrates. Blood samples were also take every two hours for the first two days of the experiment and then every four hours for the next 12 days. Blood was taken from the

jugular vein into vacuum tubes without anticoagulant, allowed to clot at room temperature, centrifuged at 3,000 rpm[1] for 10 minutes, and the serum separated. Serum urea was determined immediately after separation.

Urine samples were collected into plastic containers (containing 10 ml 50% reagent grade concentrated sulfuric acid[2] to prevent ammoniation) placed under the elevated metabolism platform (Appendix II).

Total volume of urine from each steer for each period was measured and 10% placed in washed bottles for immediate urinary urea determination.

Analytical Procedure

Blood and urinary urea was estimated by the method described by Chaney and Marbach (1962).

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1 Clinical Centrifuge - International Equipment Co., Needham, Massachusets, U.S.A.

2 Analar - Supplied Naafco Sci. Equip. Supply Ltd., Lagos.

RESULTS

Mean values, standard deviation and ranges of urea in the blood and urinary samples are presented in Tables 2 and 3. Individual values are presented in Appendix V. The hemograms were within normal limits. There was no significant breed difference in the blood or urinary urea values ($P<0.05$). The postprandial (PP) urea changes in blood and urine are summarized (Figs. 1-3). Blood and urinary urea levels in White Fulani and crossbred cattle were similar. Differences were found at the higher levels of urinary urea in the White Fulani compared to the crossbreeds; the highest increase in urinary urea occurred 12 hours PP. There was a sharp drop in urinary urea levels four hours PP in all the breeds examined. In the Friesian, blood urea concentration reached a peak at eight hours PP in contrast to four hours in the White Fulani and the crossbred. This level continued till the 12th hou" then decreased. Peak of blood urea levels in all breeds corresponded to lowest levels of urinary urea excretion after which increases were noticed. This pattern of urinary excretion was not observed with the Friesian steer under the

same conditions.

DISCUSSION

The relationship between blood and urinary urea levels were determined to evaluate their possible use as a measure of protein utilization in Zebu breeds. The blood and urinary urea values found were within the normal range (Saror and Coles, 1973). Blood urea nitrogen (BUN) levels are affected by disease, increased dietary protein, and abnormal renal function (Coles, 1974). The steers were clinically normal by physical, parasitic and hematological examinations. Therefore BUN changes observed were due to physiological responses to increase dietary protein.

The BUN increases observed were similar to findings reported by Church (1970). Street et al. (1968) reported similar findings with other animals where increases were proportional to the amount of protein fed. Coles (1974) reported that BUN peak increases were reached between two to six hours after feeding and may continue for nine hours. Lewis (1957) reported peak blood urea levels at six to seven hours after feed-

ing following a delayed period of four to eight hours. In this work it was found that the time lag in peak BUN concentration in the Friesian was slightly different to that of the White Fulani or crossbred. The importance of this finding can only be appreciated if concurrent assessment is made of ruminal ammonia concentration with blood and urinary urea concentrations in work similar to that described. The differenoe in the pattern of urinary urea excretion between the White Fulani and the Friesian also was interesting; Friesian continued to excrete urea at higher levels 24 hours after feeding whereas urea excretion in the White Fulani dropped within normal levels by 24 hours. This finding indicates a possible difference in nitrogen conserving mechanism in the White Fulani based on the findings of Schmidt-Nielsen et al. (1958). They found that sheep placed on a low protein diet, conserved urea by reducing urinary excretion to a minimum.

Diurnal sampling placed limits on the interpretation of the results obtained. The number of daily samples proved to be inadequate although the replicated 14 day period of observation was adequate. Jugular cannul· in each experimental animals would have been

more appropriate. Two hourly samples were taken for the first three days but this number of sampling was reduced due to serious reaction to venapuncture.

Care must be taken in interpreting the results as the number of experimental animals used was small. Additional work to determine renal clearance of urea, urinary plasma urea ratio in relation to feed changes, and endogenous true creatinine/inulin clearance ratio in these breeds would be required to confirm the findings in this work.

SUMMARY

Blood and urinary urea levels were determined for 14 days in five steers; two White Fulani (Zebu), two White Fulani-Friesian, and one Friesian. There was no significant difference in the values in the three breeds (P 0.05). The White Fulani had a higher level of urinary urea and the peak occurred 12 hours postprandial (PP). Urinary urea levels dropped sharply in the three breeds at four hours PP. Blood urea nitrogen (BUN) reached a peak in the Friesian at eight hours PP in

contrast to four hours in the White Fulani and the crossbred. BUN peak in the three breeds corresponded to the lowest level of urinary urea excretion after which it increased except in the Friesian.

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Table 1. Percentage composition of supplement.

Item	Ration (%)
Salt	1.25
Trace minerals[1]	0.03
Vitamin A[2]	+
Bone meal	0.9
Sorghum	56.17
Groundnut cake	41.65

[1]Pfizer mineral block: Calcium 8.5%, Phosphorus 4%, Magnesium 108.2 ppm, Iron 346.1 ppm, Copper 86.5 ppm, Manganese 64.9 ppm, Cobalt 21.6 ppm, and Zinc 21.6 ppm and iodine 5.4 ppm.

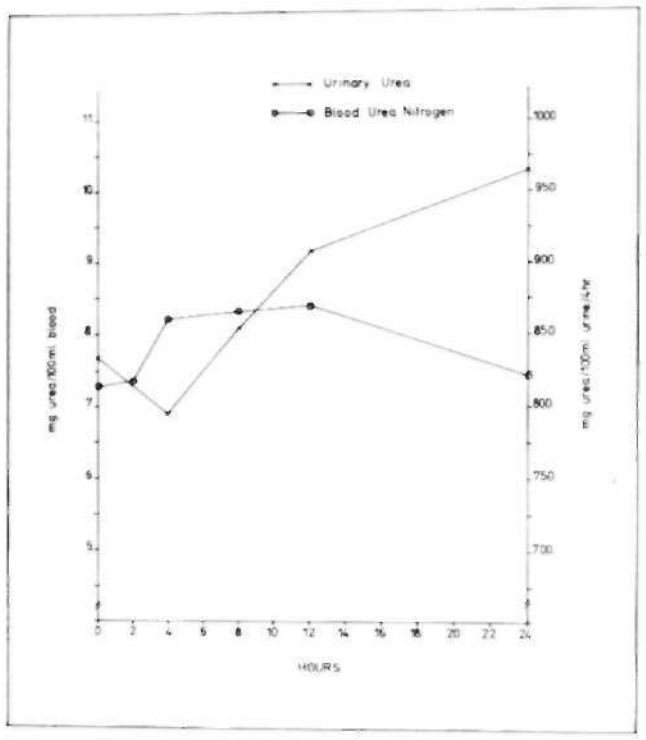
[2]20,000 IU/head/day

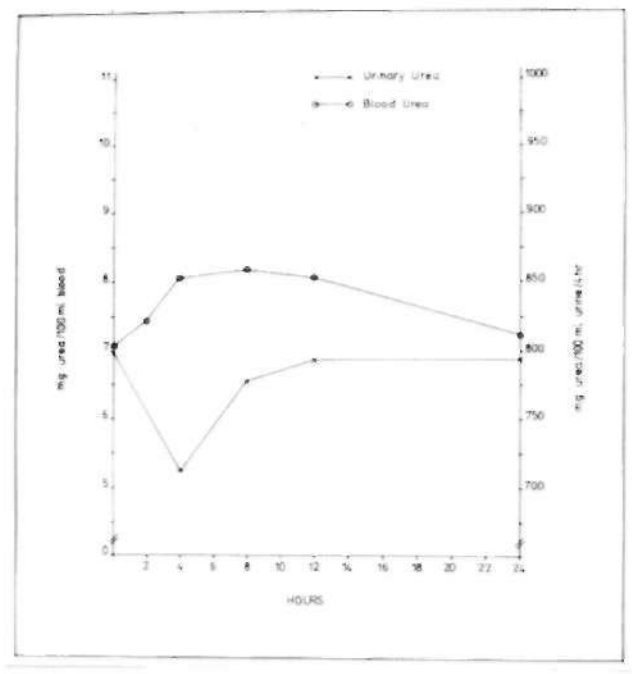
Table 2. Mean blood urea (mg/100ml) values in Zebu (White Fulani) Friesian, and Friesian-Zebu Cross fed 12% crude protein

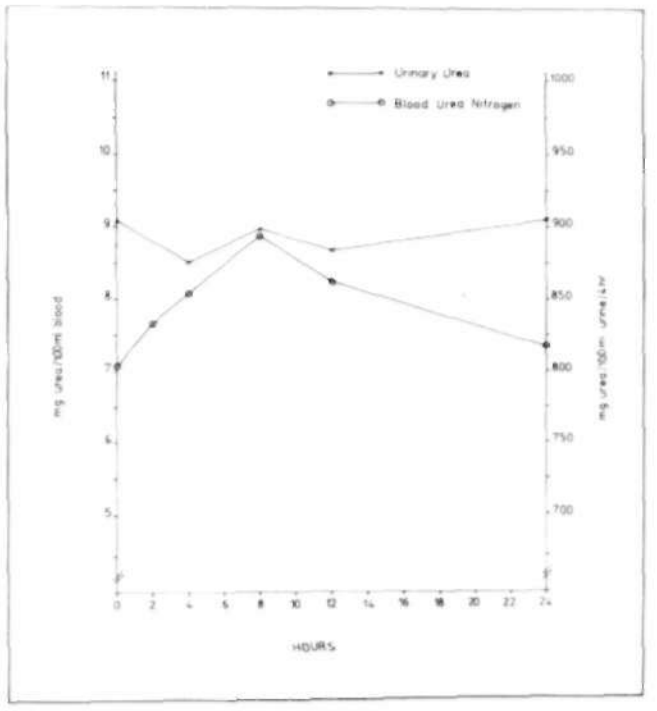
Sample Frequency (hrs.)	White Fulani	Friesian	Crossbred	Mean Values
0	7.28 ± 0.70	7.09 ± 0.94	7.08 ± 0.89	7.16 ± 0.82
2	7.34 ± 0.93	7.67 ± 1.20	7.44 ± 1.14	7.45 ± 1.06
4	8.20 ± 1.01	8.08 ± 1.02	8.05 ± 1.10	8.11 ± 1.04
8	8.30 ± 0.87	8.88 ± 1.10	8.18 ± 0.88	8.87 ± 0.91
12	8.36 ± 0.79	8.23 ± 0.93	8.06 ± 0.74	8.11 ± 0.79
24	7.44 ± 0.71	7.34 ± 1.02	7.26 ± 0.84	7.35 ± 0.82

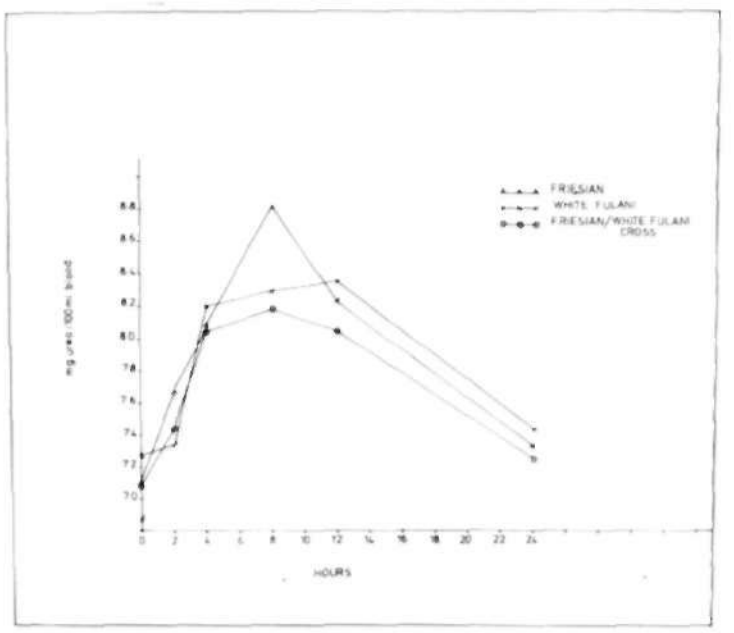
Table 3. Mean urinary urea mg/100ml values in Zebu (White Fulani), Friesian and Friesian/Zebu Cross fed on 12% crude protein level.

Sample Frequency (hrs.)	White Fulani	Friesian	Crossbred	Mean Values
0	833.02±126.33	909.75±216.76	799.83±193.33	856.03±177.68
4	795.46±141.96	825.67±154.43	710.79±215.85	767.00±181.59
8	852.30±119.43	898.08±190.88	779.84±212.34	831.80±179.82
12	908.17±224.72	883.92±171.41	793.57±217.32	857.71±187.23
24	964.28±192.77	1777.00±213.68	794.24±195.73	854.37±179.62


Urinary Urea
Blood Urea Nitrogen
mg urea/100ml blood
mg urea/100ml urine/hr
HOURS


Urinary Urea
Blood Urea
mg urea/100 ml blood
mg urea/100 ml urine/hr
HOURS


Urinary Urea
Blood Urea Nitrogen
HOURS


FRIESIAN
WHITE FULANI
FRIESIAN/WHITE FULANI CROSS
HOURS

PART VI

EFFECT OF SUPERIMPOSED NEMATODE INFECTION AND PROTEIN SUPPLEMENT ON SOME BLOOD CONSTITUENTS IN CATTLE

INTRODUCTION

Parasitism is a major problem confronting cattle production in Nigeria. The extent to which nutrient availability is affected by parasitism in Nigeria has been reported by Schillhorn van Veen (1974). The interaction between nutrition and helminth infection has been reviewed (Hunter, 1953; Scrimshaw et al., 1968; Dewitt, 1957).

The quantitative effects of rations in nematodology have also been investigated (Gordon, 1964; Roberts et al., 1951; Bawden, 1969; Kuttler and Marble, 1960). Different parameters have been used to measure the physiologic changes resulting from internal parasitism: fecal egg count (Roberts et al., 1951; Ross and Armour, 1960; Leland et al., 1959; Soulsby, 1965; Coles, 1974; Ikeme, 1975; Chiejina and Sewell, 1974), and serum protein changes (Kuttler and Marble, 1960; Leland et al., 1960; Wilson and Turner, 1965; Ross, 1962; Holmes et al., 1968). Packed cell volume has also been used to measure the extent of pathogenicity (Ross and Armour, 1960). Ross et al. (1959) investigated bovine hemonchosis in Nigeria

relative to age and environmental and genetic factors.

The objectives of this study were to determine the effect of protein supplementation on serum proteins in cattle with a mixed helminth infection.

MATERIALS AND METHODS

Experimental Animals

The 15 steers from the growth trials were used. The management and feeding was the same as described previously (Part III). The steers had been kept individually in a parasite - free environment for a least six months and monitored monthly by fecal egg counts and fortnightly by hemograms.

The steers were randomly divided into three equal groups. Body weight was determined before and after the experiment. The steers were checked clinically daily and the rectal temperatures recorded.

Inoculum

Feces from donor calves were collected from a local abattoir, cultured, and third stage larvae harvested. The steers were infected with 10,400 3rd

stage larvae followed by a second dose of 10,000 a week later. Larvae were differentiated according to sheath length beyond the tail proper (Soulsby, 1965). The mixed infection consisted of 64% Haemonchus sp., 24% Trichostrongylus sp., and 12% Oesophagostomum sp.

Blood and Fecal Examination

Feces and serum samples were taken from each steer before the start of the experiment and then weekly for 10 weeks. Analyses for total protein, globulin, albumin and hemogram were performed as previously described (Part II). Worm egg counts were carried out in a McMaster's egg counting chamber using the technic described by Whitlock (1948).

RESULTS

The mean values for serum protein fractions and egg counts in the different breeds and under the three levels of protein intake are presented in Tables 1 and 2. Weekly changes in serum protein

fractions are presented (Figs. 1 - 6). The fecal egg counts per gram (e.p.g.) did not increase sharply in any steer; least in the White Fulani and highest in the Friesian/White Fulani cross. The highest egg count was found in the 8% crude protein group, followed by 12% and 16% levels.

There was no significant difference in the serum protein changes. Decreases in serum globulin levels were most apparent by the 4th week in all steers. Albumin levels gradually dropped with time in all the breeds; the level was lowest during the last week of observation when the egg count was the highest.

There was no significant change in the packed cell volume (PCV) before and after infection in each breed or with each protein level (Figs. 7 - 8). A sharp drop in PCV value was found one week after larval challenge in the White Fulani and Cross steers but not with the Friesians.

DISCUSSION

The mean strongyle egg counts increased with time as reported by Soulsby (1965). A pathogenic level, as

described by Ross and Armour (1960), was not attained before the experiment was terminated. However, Roberts et al. (1951) indicated that conspicuous signs of hemonchosis could occur with fecal egg counts less than 100 and frequently 7 to 40 e.p.g. Ross and Armour (1960) observed that a strongyle egg count of 200 e.p.g. in cattle with 60% Haemonchus sp. in Nigeria should be cause for concern. The low fecal egg counts encountered in this study may be due to the "self-cure" phenomena (Soulsby, 1965). The steers in this study were parasite-free as indicated by fecal examination for at least six months before the start of the experiment. Prior to this time, however, they had been parasitized. Mixed infection with third stage larvae might have induced self-cure from previous sensitization.

The relatively lower e.p.g. obtained with increasing levels of protein supports previous findings (Gordon, 1964; Wilson and Turner, 1965; Leland et al., 1966). The effect, however, was not highly significant. Similar findings have been reported by Lee et al. (1959) who attributed it to the seasonal cycle in helminth development and proposed that protein supplementation would be more effective during the rainy season.

The increasing serum globulin levels in the steers with increasing e.p.g. is similar to findings by Leland et al. (1966) and may be related to an increase in protective antibodies.

The slightly lowered PCV values are similar to findings by Andersen et al. (1960) who found blood changes in calves experimentally-infected with 12,000 and 165,000 larvae of H. placei; lowered PCV and hemoglobin values but no marked parasitism or changes in serum proteins. Decreases in PCV after the first week of infection in the White Fulani and the Cross may be due to the effects of the 4th larval stage. Similar findings were reported by Andrews (1942) who found that blood loss occurred 6-10 days after infection of cattle with H. contortus. The degree of drop in PCV varied from breed to breed with the cross maintaining a more constant level.

It is concluded from this study that adequate protein supplementation may be beneficial in bovine helminthiasis.

SUMMARY

Fifteen parasite-free steers were divided into three equal groups. They were given a protein supplementation of 8%, 12% and 16% and were infected with 10,400 3rd stage larvae followed by 10,000 larvae a week later. The larvae consisted of 64% Haemonchus sp., 24% Trichostrongylus sp., and 12% Oesophagostomum sp. Fecal egg count, total serum protein, globulin, albumin, and packed cell volume were monitored weekly for 10 weeks. The mean fecal egg count was lowest in White Fulani and highest in Friesian/White Fulani Cross. The higher the fecal egg count, the lower the protein supplementation. There were no significant differences in serum protein changes between breeds or levels of protein intake. Decreased levels of albumin were lowest during the last week of the experiment when the fecal egg count was the highest. Sharp drop in PCV values was found after the first week of infection in the White Fulanis and crosses but not in Friesians. Serum globulin levels increased with increasing egg counts. It was concluded that adequate protein supplementation may be beneficial in bovine helminthiasis.

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Table 1. Mean serum protein fractions and egg count in infected steers.

Breed	Parameter	Weeks 0	1	2	3	4	5	6	7	8	8	10
WF	E.P.G.	4	0	18	6	24	28	70	-	-	220	118
	Albumin, g/100ml	5.00	5.54	4.03	-	4.95	3.82	3.68	-	4.18	3.22	
	Globulin "	2.23	2.36	2.68	-	0.95	2.42	2.60	-	2.82	3.44	-
	Total Protein	7.23	7.74	7.10	-	5.93	6.24	6.30	-	7.00	6.66	-
	PCV %	32.8	28.6	34.0	-	33.75	32.75	31.40	-	33.00	32.20	-
F	E.P.G.	4	0	18	98	38	64	84	-		-	-
	Albumin	4.70	4.43	3.30	-	4.30	3.15	3.60	-	3.33	3.05	-
	Globulin	2.03	1.80	2.80	-	1.53	2.53	2.43	-	2.83	3.45	-
	Total Protein	6.73	6.03	6.10	-	5.50	5.70	6.03	-	6.20	6.50	-
	PCV %	27.5	27	26.75	-	27.75	29.75	27.75	-	28	28.75	-
F/WFC	E.P.G.	8	4	14	38	22	76	102	-	-	142	158
	Albulin	4.72	3.66	3.88	-	3.98	3.70	4.00	-	3.60	3.14	-
	Globulin	2.00	3.44	3.00	-	2.08	2.58	2.52	-	3.32	3.52	-
	Total Protein	6.50	7.18	6.70	-	6.04	6.28	6.56	-	6.68	6.66	-
	PCV %	28	27.20	29	-	30.60	30.05	30.20	-	30.02	30	-

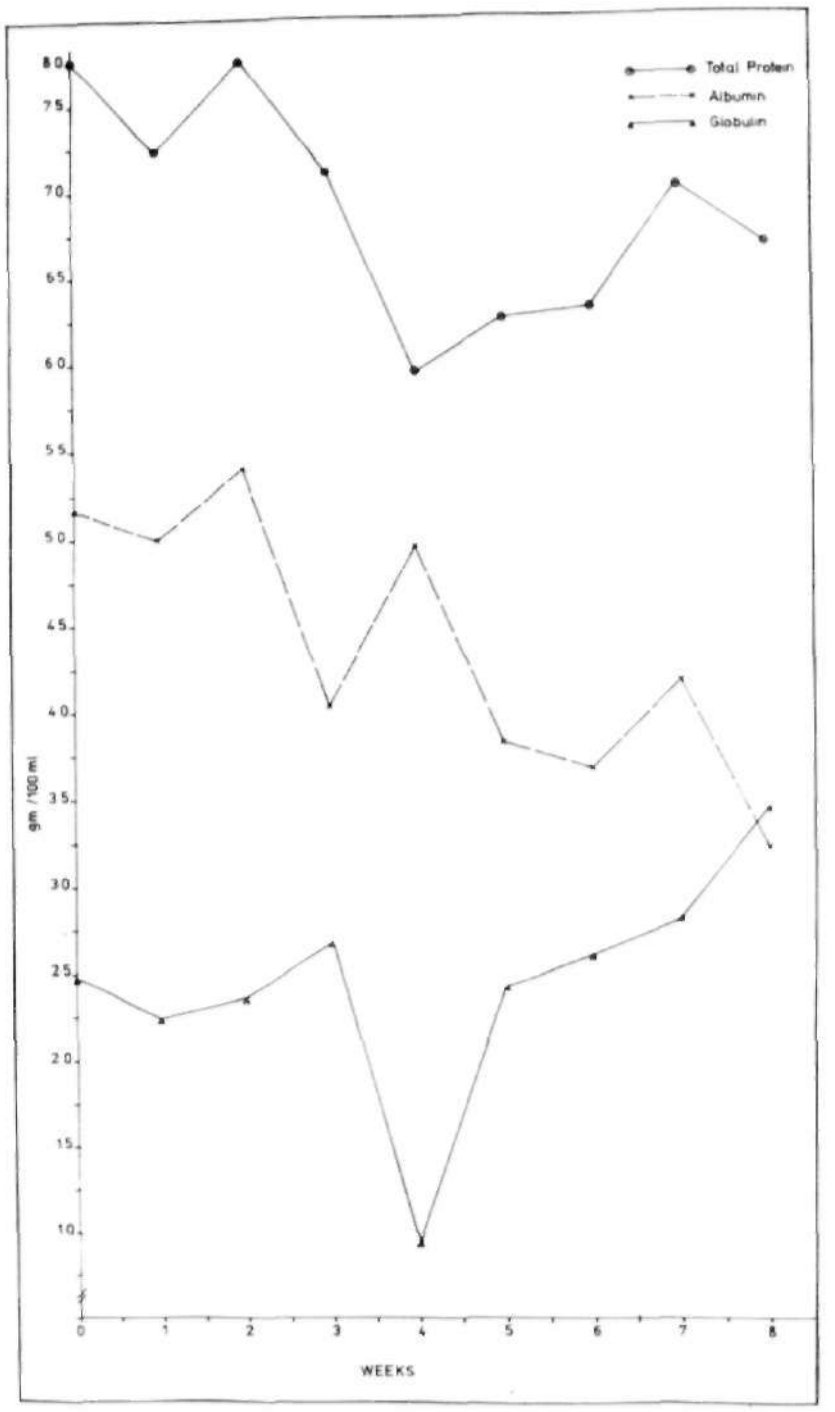
WF = White Fulani. E.P.G. = Eggs per gram of feces. F = Friesian

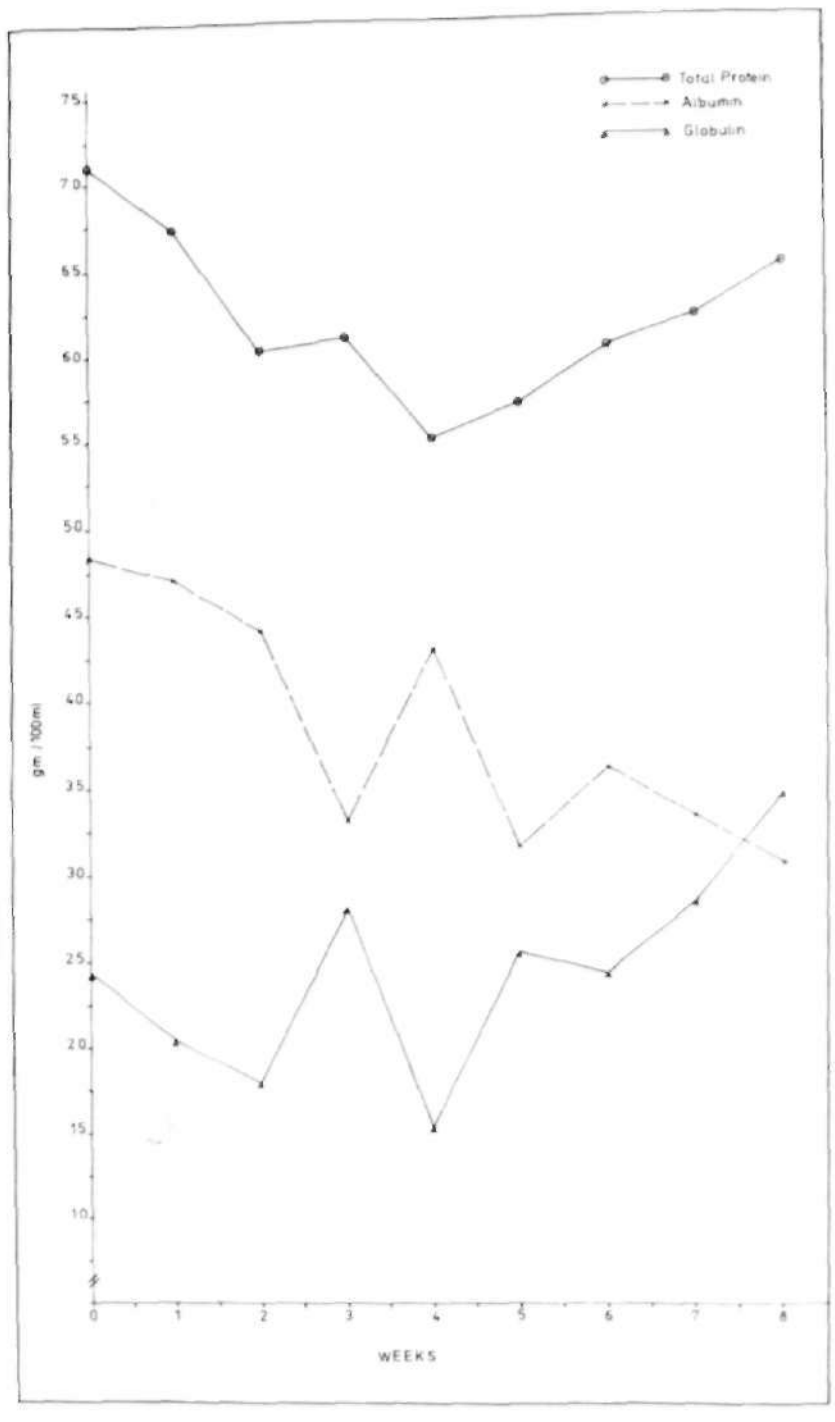
F/WFC = Friesian/White Fulani Cross

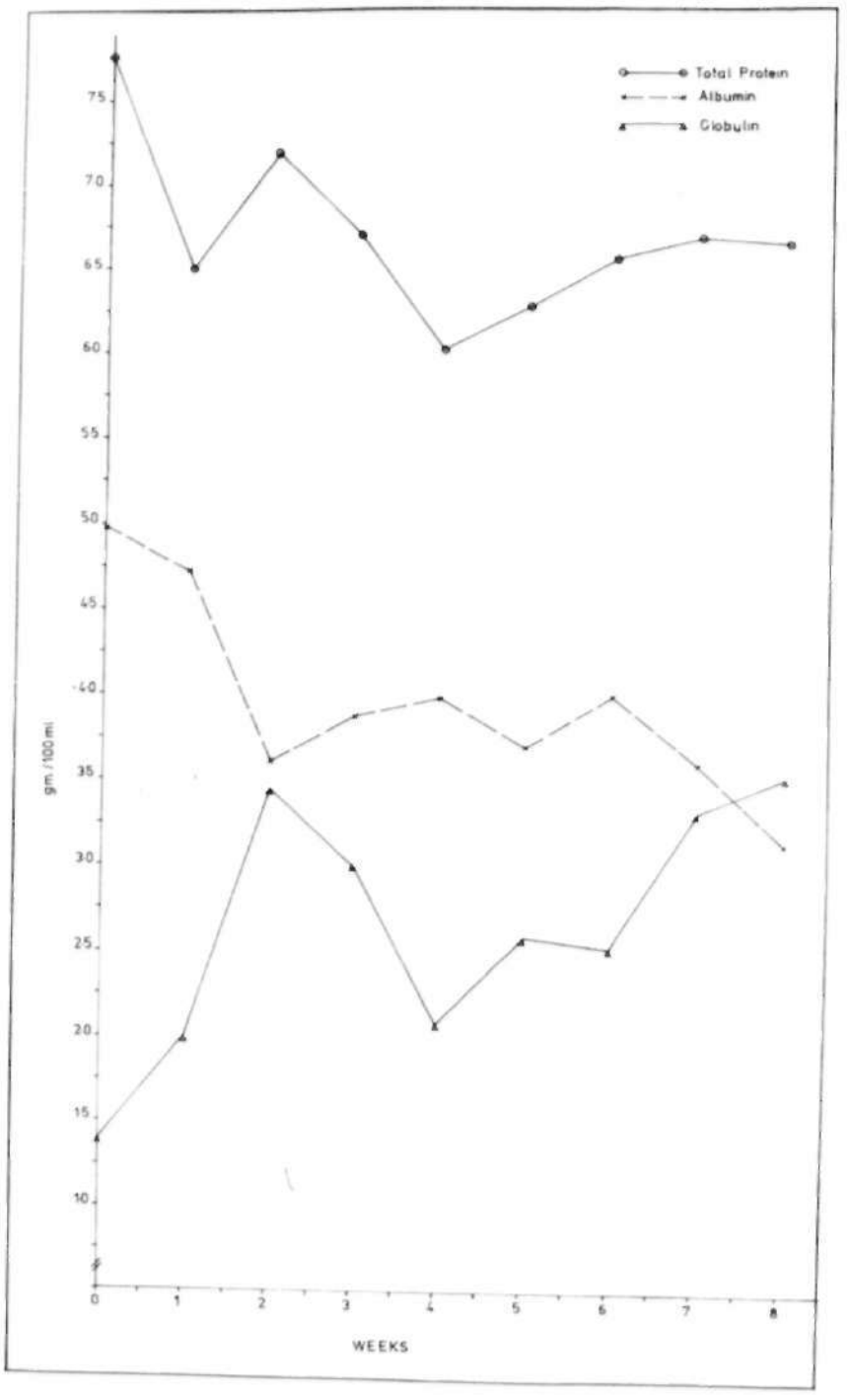
Table 2. Mean serum protein fractions and egg count infected steers on three levels of protein consumption.

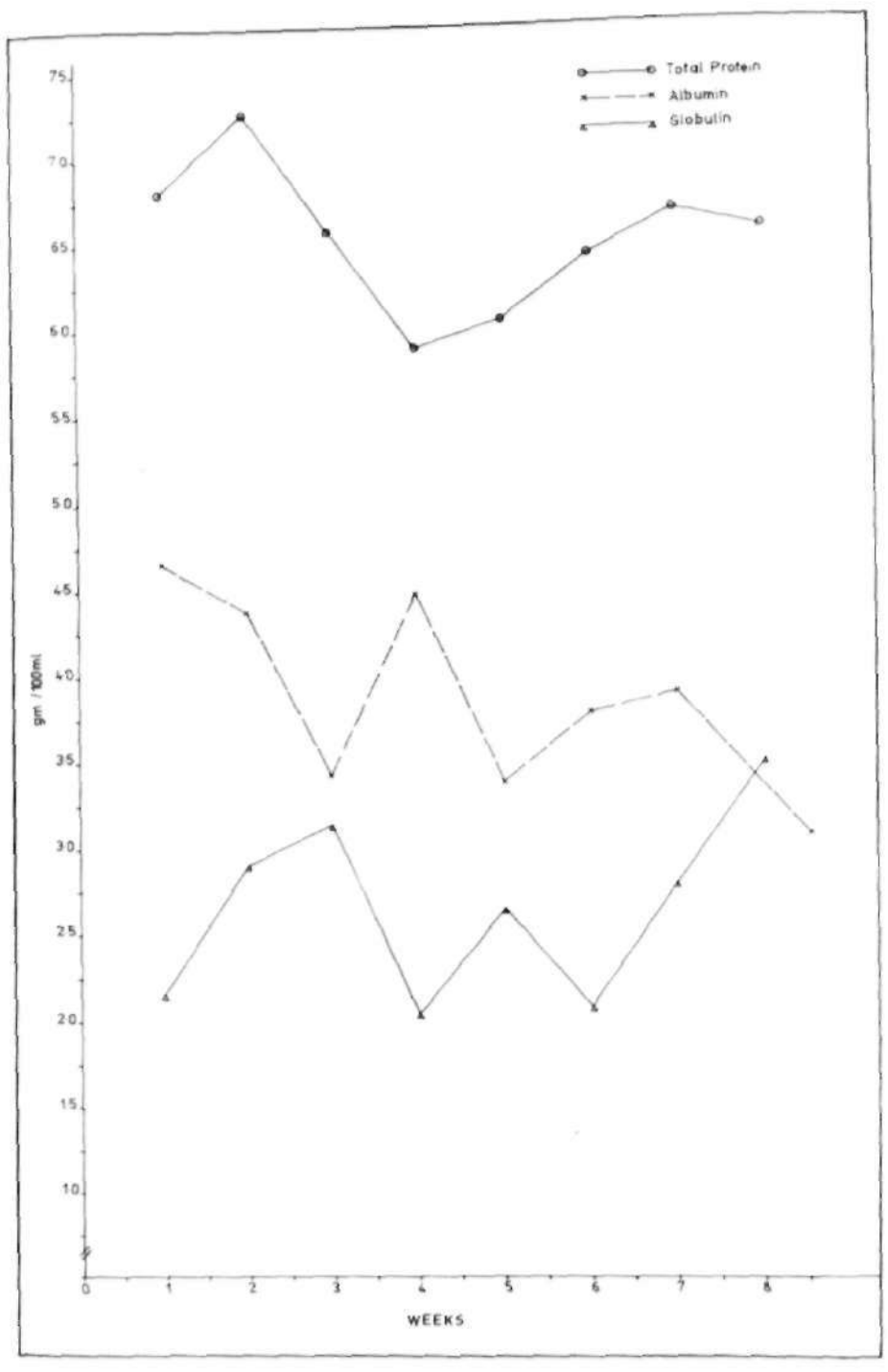
Feed	Parameter	Weeks 0	1	2	3	4	5	6	7	8	9	10
8%	E.P.G.	0	0	18	84	8	66	104	-	-	166	214
	Albumin, g/100ml	4.65	4.36	3.43	-	4.46	3.38	3.78	-	3.88	3.06	-
	Globulin "	2.15	2.90	3.13	-	2.03	2.64	2.07	-	2.78	3.50	-
	Total Protein	6.8	7.26	6.57	-	5.88	6.04	6.42	-	6.66	6.56	-
	PCV %	29.80	27.40	30.60	-	30.40	29.80	28.20	-	29.00	29.40	-
12%	E.P.G.	16	0	18	24	34	50	82	-	-	200	122
	Albumin	4.69	5.22	3.83	-	4.03	3.40	3.56	-	-	3.54	3.06
	Globulin	1.90	2.14	2.35	-	1.65	2.72	2.62	-	-	3.06	3.58
	Total Protein	6.61	7.36	6.01	-	5.68	6.12	6.24	-	-	6.61	6.48
	PCV %	26.60	24.60	28.80	-	30.00	30.00	31.20	-	31.40	31.40	-
16%	E.P.G.	4	4	14	34	42	46	72	-	-	108	132
	Albumin	4.75	4.24	3.98	-	4.38	3.90	3.90	-	3.46	3.22	-
	Globulin	2.18	3.18	3.08	-	1.23	2.26	2.42	-	3.18	3.68	-
	Total Protein	6.95	7.35	6.97	-	6.01	6.16	6.34	-	6.68	6.90	-
	PCV %	31.00	30.20	31.00	-	31.25	32.80	33	-	-	30.60	31.60

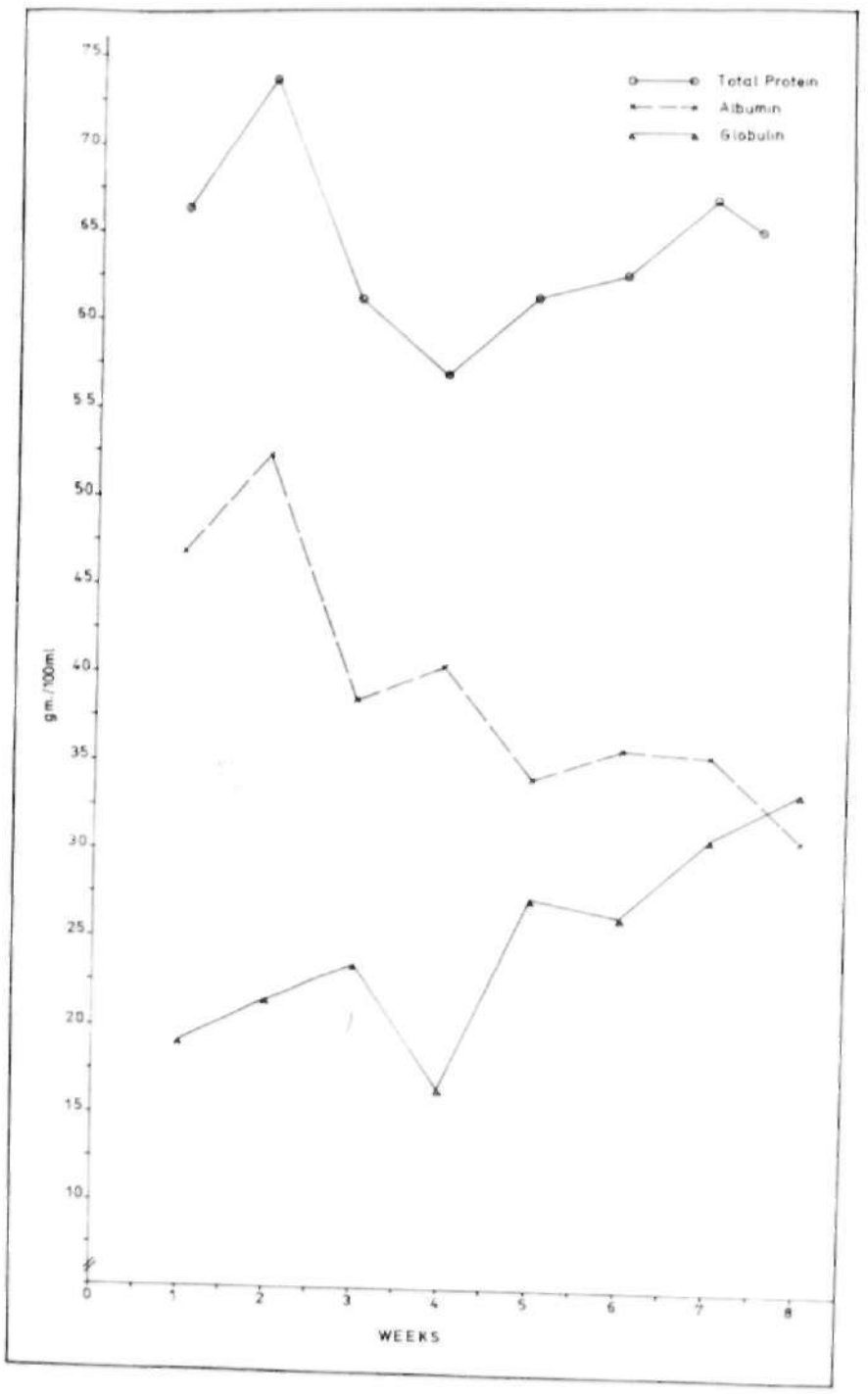
E.P.G. = Eggs per gram of feces

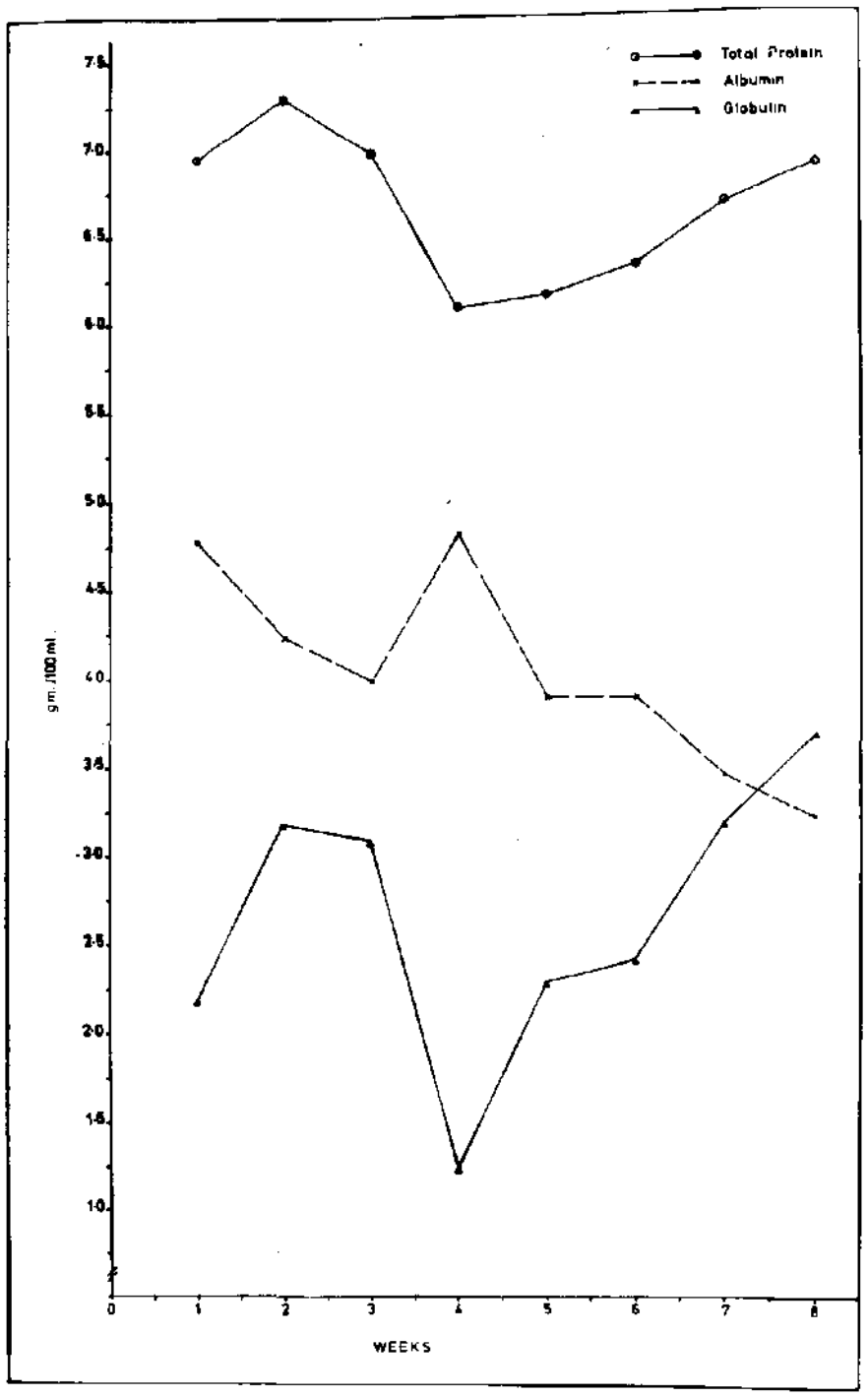

Total Protein
Albumin
Globulin
gm /100 ml
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
WEEKS

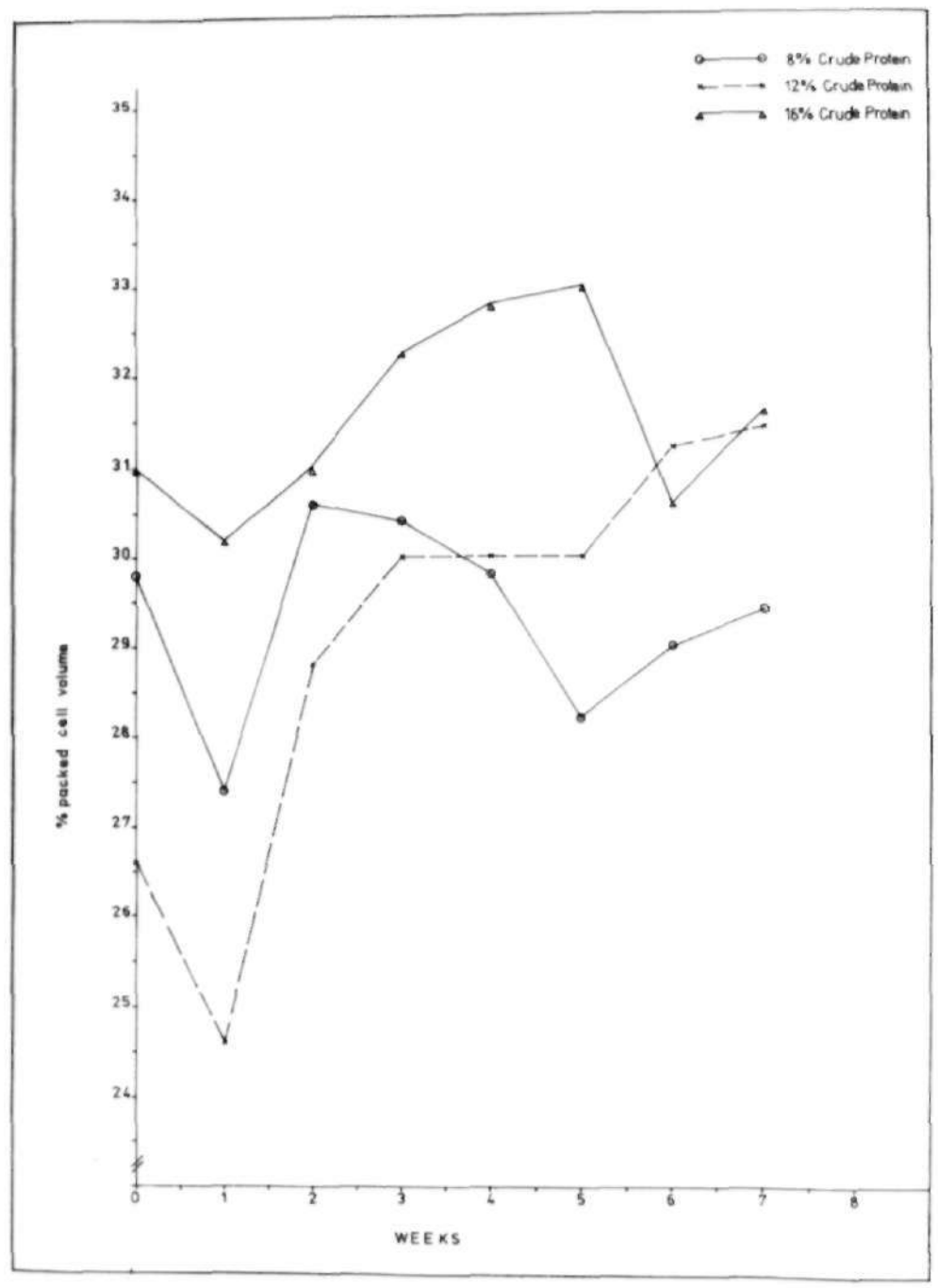

Total Protein
Albumin
Globulin
gm / 100ml
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
WEEKS

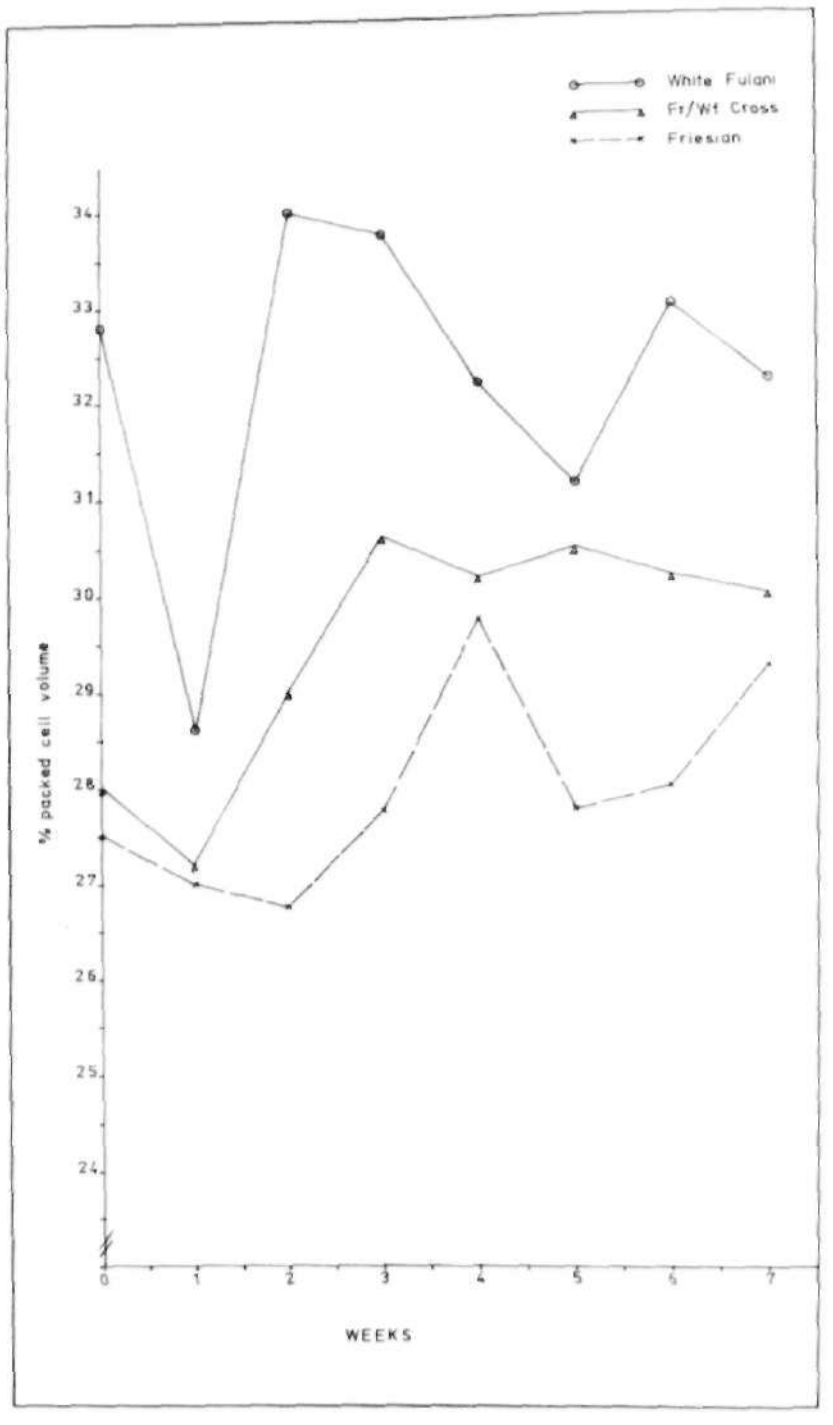

Total Protein
Albumin
Globulin
gm./100ml
75
70
65
60
55
50
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
WEEKS


Total Protein
Albumin
Globulin
gm / 100ml
75
70
65
60
55
50
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
WEEKS


Total Protein
Albumin
Globulin
gm./100ml
75
70
65
60
55
50
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
WEEKS


Total Protein
Albumin
Globulin
gm./100 ml.
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
1
2
3
4
5
6
7
8
WEEKS


8% Crude Protein
12% Crude Protein
16% Crude Protein
% packed cell volume
35
34
33
32
31
30
29
28
27
26
25
24
0
1
2
3
4
5
6
7
8
WEEKS


White Fulani
Fr/Wt Cross
Friesian
% packed cell volume
34
33
32
31
30
29
28
27
26
25
24
0
1
2
3
4
5
6
7
WEEKS

APPENDIX I

SERUM BIOCHEMICAL LEVELS IN CATTLE

TABLES 1 - 11

Table 1. Serum magnesium levels in Nigerian cattle, (mg/100ml).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
1.90	1.65	2.10	2.10	1.75	2.20
1.45	1.40	2.80	2.60	2.10	2.20
1.45	1.75	1.90	1.95	2.15	1.80
1.30	2.40	1.45	1.40	2.50	2.05
1.95	1.10	1.80	1.80	2.35	1.75
1.45	1.90	1.90	1.90	4.60	1.65
1.85	2.05	2.60	2.30	3.55	1.60
-	1.60	1.65	1.55	2.20	1.75
-	1.30	1.95	1.95	2.10	2.10
-	1.85	-	1.95	3.25	1.35
-	1.90	-	1.65	2.65	1.70
-	-	-	2.40	2.35	1.90
-	-	-	3.25	2.55	2.00
-	-	-	2.80	2.90	2.00
-	-	-	2.60	2.25	2.20
-	-	-	2.65	2.30	1.70
-	-	-	2.60	1.50	1.75
-	-	-	3.20	2.50	2.35
-	-	-	3.60	1.90	2.45
-	-	-	2.80	1.95	1.95
-	-	-	2.95	2.70	1.40
-	-	-	2.40	3.40	1.65
-	-	-	2.75	3.35	1.70
-	-	-	2.70	2.65	1.95
-	-	-	2.95	2.40	1.50
-	-	-	2.75	3.15	1.65
-	-	-	2.80	3.05	1.85
-	-	-	2.90	2.70	1.80
-	-	-	-	3.80	1.80
-	-	-	-	2.75	2.30
-	-	-	-	-	2.35
-	-	-	-	-	2.35

Table 2. Serum calcium levels in Nigerian cattle. (mg/100ml).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
10.80	10.65	11.35	10.95	8.65	10.00
11.25	10.95	11.70	11.00	9.15	10.25
9.55	10.00	10.00	10.00	8.80	8.80
8.05	12.00	9.65	10.40	8.70	10.05
9.05	10.00	10.85	11.00	7.20	8.80
10.00	12.40	10.80	10.75	13.85	9.40
11.20	8. 6	11.40	11.45	10.60	9.30
-	11.40	9.85	10.00	8.90	10.40
-	11.00	8.05	8.40	8.75	11.25
-	10.00	11.90	10.05	10.40	7.05
-	10.00	12.05	12.05	9.15	6.75
-	-	11.50	11.00	8.75	9.40
-	-	10.40	12.05	8.85	8.10
-	-	11.40	10.00	10.45	12.75
-	-	11.95	9.05	8.00	9.30
-	-	9.15	8.95	9.00	9.00
-	-	10.40	9.15	9.20	9.10
-	-	10.05	11.15	10.20	9.85
-	-	13.04	13.80	8.35	9.95
-	-	10.05	10.05	12.95	10.55
-	-	10.80	12.00	11. 8	8.10
-	-	10.70	11.95	13.15	9.50
-	-	10.90	10.40	12.60	8.40
-	-	13.60	10.46	10.40	9.60
-	-	12.55	11.05	12.25	7.60
-	-	-	9.45	11.00	9.20
-	-	-	-	11.00	9.20
-	-	-	-	11.80	9.75
-	-	-	-	10.35	11.15
-	-	-	-	9.90	9.80
-	-	-	-	11.95	12.80
-	-	-	-	-	9.10
-	-	-	-	-	7.10

Table 3. Serum potassium levels in Nigerian cattle. (mEq/l).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
3.0	3.8	4.0	4.6	4.0	4.2
4.0	4.0	3.0	4.0	3.4	4.0
4.2	4.0	4.3	3.8	3.4	4.8
3.6	4.5	4.0	3.0	4.0	5.0
3.4	3.8	3.0	4.0	4.6	4.6
3.0	4.6	3.0	3.8	3.6	4.6
4.0	3.5	4.0	3.5	4.3	5.1
4.0	3.8	3.4	4.3	4.8	4.0
4.2	3.8	3.4	3.8	4.0	4.0
-	4.0	4.8	4.0	4.0	4.2
-	4.0	4.6	3.8	4.6	6.0
-	3.6	4.3	4.6	6.0	6.0
-	4.6	4.8	4.0	3.6	4.0
-	4.0	4.6	3.6	4.0	4.2
-	4.0	4.4	4.6	4.6	3.4
-	-	4.3	3.0	3.8	5.8
-	-	4.0	3.0	3.8	4.8
-	-	4.4	4.3	4.6	4.3
-	-	3.6	4.5	3.6	5.7
-	-	4.0	3.5	3.6	4.8
-	-	4.4	4.4	4.8	4.7
-	-	4.6	4.0	4.4	4.3
-	-	3.8	4.2	4.0	3.0
-	-	4.6	4.4	4.4	3.6
-	-	3.6	3.5	3.8	3.9
-	-	-	3.6	4.0	4.8
-	-	-	4.0	3.0	4.5
-	-	-	4.3	4.6	3.8
-	-	-	-	3.6	4.5
-	-	-	-	4.6	3.8
-	-	-	-	4.0	6.0
-	-	-	-	3.4	4.3
-	-	-	-	4.3	4.5
-	-	-	-	7.0	4.8
-	-	-	-	4.0	4.0
-	-	-	-	-	4.3
-	-	-	-	-	4.3
-	-	-	-	-	4.4

Table 4. Serum sodium levels in Nigerian cattle. (mEq/l).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
146	146	144	152	140	142
146	140	138	146	138	144
142	144	148	140	108	142
142	140	146	144	140	146
138	148	138	140	148	140
144	136	140	140	150	140
144	152	144	140	142	150
148	152	146	142	156	146
138	152	142	140	144	150
-	136	148	146	144	152
-	140	130	136	140	140
-	144	144	144	160	144
-	140	150	146	148	156
-	140	148	152	146	140
-	142	144	140	150	148
-	-	150	130	148	150
-	-	148	132	148	150
-	-	144	140	150	146
-	-	138	138	144	144
-	-	144	138	144	144
-	-	146	140	154	148
-	-	146	146	148	148
-	-	142	148	144	148
-	-	148	140	154	146
-	-	148	136	152	148
-	-	-	136	140	144
-	-	-	140	146	144
-	-	-	146	156	146
-	-	-	-	144	144
-	-	-	-	156	142
-	-	-	-	148	142
-	-	-	-	144	148
-	-	-	-	150	146
-	-	-	-	160	148
-	-	-	-	150	144
-	-	-	-	-	144
-	-	-	-	-	142
-	-	-	-	-	140

Table 5. Serum phosphate levels in Nigerian cattle. (mg/100ml).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
5.2	6.0	5.3	6.1	4.0	3.5
4.9	5.0	4.6	5.0	4.0	4.9
5.2	5.0	6.3	5.8	4.2	6.1
5.2	7.1	5.8	6.1	3.4	4.9
4.2	6.8	3.0	5.2	5.0	5.1
5.8	6.1	5.2	6.5	4.0	6.8
5.2	7.1	5.6	5.5	4.0	6.1
3.2	7.0	6.0	6.0	4.0	6.3
4.2	5.2	5.6	8.6	6.0	5.8
-	6.9	4.0	6.1	6.3	6.1
-	5.2	4.9	4.4	6.3	6.5
-	7.1	4.9	6.1	3.0	5.5
-	-	4.0	5.0	5.2	7.1
-	-	-	7.4	6.5	6.5
-	-	-	5.2	5.2	6.5
-	-	-	5.0	5.2	7.5
-	-	-	5.0	6.3	5.5
-	-	-	6.1	6.0	7.9
-	-	-	6.1	7.9	5.6
-	-	-	7.0	4.2	6.8
-	-	-	5.0	8.9	7.1
-	-	-	6.1	8.9	6.5
-	-	-	8.0	7.1	6.5
-	-	-	8.0	4.1	5.6
-	-	-	7.0	4.7	6.1
-	-	-	7.0	4.7	6.7
-	-	-	5.0	3.3	7.0
-	-	-	7.0	5.0	6.7
-	-	-	-	4.1	7.3
-	-	-	-	6.0	5.9
-	-	-	-	5.0	6.4
-	-	-	-	4.1	5.9
-	-	-	-	5.9	7.0
-	-	-	-	6.0	6.4
-	-	-	-	-	5.6
-	-	-	-	-	6.9

Table 6. Serum chloride levels in Nigerian cattle (mEq/l).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
108	105	97	110	98	97
103	112	98	106	97	97
100	106	108	108	98	118
98	108	98	116	98	108
98	100	97	105	98	98
100	116	98	108	100	90
108	108	100	110	100	97
100	108	108	114	98	100
113	110	98	102	98	100
100	108	108	110	108	105
-	110	100	116	98	96
-	106	104	110	98	98
-	116	97	112	100	95
-	106	108	106	104	90
-	-	105	108	105	100
-	-	100	116	98	104
-	-	98	106	108	100
-	-	100	120	98	97
-	-	98	116	98	98
-	-	105	115	108	98
-	-	97	115	100	98
-	-	98	108	98	98
-	-	98	112	100	90
-	-	110	112	98	96
-	-	97	108	100	94
-	-	108	109	95	104
-	-	-	108	98	98
-	-	-	112	97	106
-	-	-	-	96	108
-	-	-	-	98	98
-	-	-	-	98	98
-	-	-	-	100	97
-	-	-	-	106	100
-	-	-	-	97	100
-	-	-	-	-	98
-	-	-	-	-	108
-	-	-	-	-	108
-	-	-	-	-	98

Table 7. Serum urea levels in Nigerian cattle. (mg/100ml).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
14.0	8.4	11.0	11.0	6.3	8.4
14.0	10.0	14.0	12.0	7.0	10.0
10.0	11.0	14.0	12.0	8.0	9.3
12.0	12.0	9.4	11.4	6.3	8.3
148.4	9.4	15.0	13.0	5.0	9.3
10.0	10.0	8.4	8.4	6.3	8.3
8.1	12.4	10.0	7.4	10.4	10.0
10.0	8.6	13.0	9.0	7.0	12.0
9.0	11.4	11.0	14.2	8.0	13.0
-	11.0	15.0	12.0	9.3	14.0
-	10.0	10.0	13.0	6.3	8.0
-	13.0	10.0	15.0	9.3	8.3
-	14.0	6.0	12.0	8.0	9.0
-	10.0	14.0	10.0	6.3	9.0
-	-	12.0	11.0	5.0	10.0
-	-	12.0	13.0	6.3	8.4
-	-	12.0	10.0	8.3	7.4
-	-	12.0	12.0	8.3	8.0
-	-	8.0	12.0	6.0	4.8
-	-	12.0	12.0	9.3	9.3
-	-	12.0	10.0	6.3	10.4
-	-	12.0	9.0	7.0	12.0
-	-	10.0	13.0	8.0	14.0
-	-	9.0	9.0	12.0	12.0
-	-	9.4	10.0	10.0	10.0
-	-	11.3	9.0	8.0	8.0
-	-	9.0	8.0	10.4	9.3
-	-	-	-	8.3	9.0
-	-	-	-	6.0	10.4
-	-	-	-	8.0	11.2
-	-	-	-	8.0	12.0
-	-	-	-	9.4	8.4
-	-	-	-	12.0	8.4
-	-	-	-	10.0	9.3
-	-	-	-	7.4	8.4
-	-	-	-	10.5	-

Table 8. Serum total protein levels in Nigerian cattle. (g/100ml).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
6.1	7.5	7.0	7.0	7.2	8.0
8.8	7.0	8.0	9.0	7.0	6.4
6.8	7.0	7.2	8.0	6.0	8.5
6.1	8.0	7.1	8.0	7.2	9.0
7.6	6.6	9.0	7.0	7.2	8.0
8.0	7.4	6.8	7.0	8.0	8.0
7.0	7.0	7.2	7.0	7.0	8.0
8.0	7.6	9.0	8.0	7.2	6.0
8.0	6.7	5.6	7.0	7.2	10.0
8.8	7.0	8.4	7.0	7.2	6.9
-	8.0	8.1	7.0	7.2	7.2
-	8.1	8.1	8.3	7.4	6.0
-	7.4	7.0	8.0	7.2	7.0
-	-	9.0	9.4	7.2	8.2
-	-	6.0	8.1	7.4	9.4
-	-	7.1	8.1	7.2	7.0
-	-	8.1	9.2	6.8	8.0
-	-	9.0	9.0	7.4	7.0
-	-	7.1	7.0	8.0	7.2
-	-	6.1	7.2	7.2	10.4
-	-	7.1	7.4	8.0	9.0
-	-	7.0	7.0	7.2	7.0
-	-	7.2	6.1	7.4	10.0
-	-	8.0	6.4	8.0	8.2
-	-	8.0	7.0	7.2	1.0
-	-	7.1	7.0	6.8	8.0
-	-	-	7.0	7.2	9.0
-	-	-	-	7.2	9.1
-	-	-	-	6.8	7.0
-	-	-	-	7.2	8.2
-	-	-	-	7.2	8.0
-	-	-	-	6.8	7.2
-	-	-	-	8.0	12.0
-	-	-	-	6.0	8.0
-	-	-	-	6.8	12.0
-	-	-	-	6.4	7.2
-	-	-	-	7.2	9.0
-	-	-	-	-	8.0
-	-	-	-	-	8.0

Table 9. Serum globulin levels in Nigerian cattle. (g/100ml).

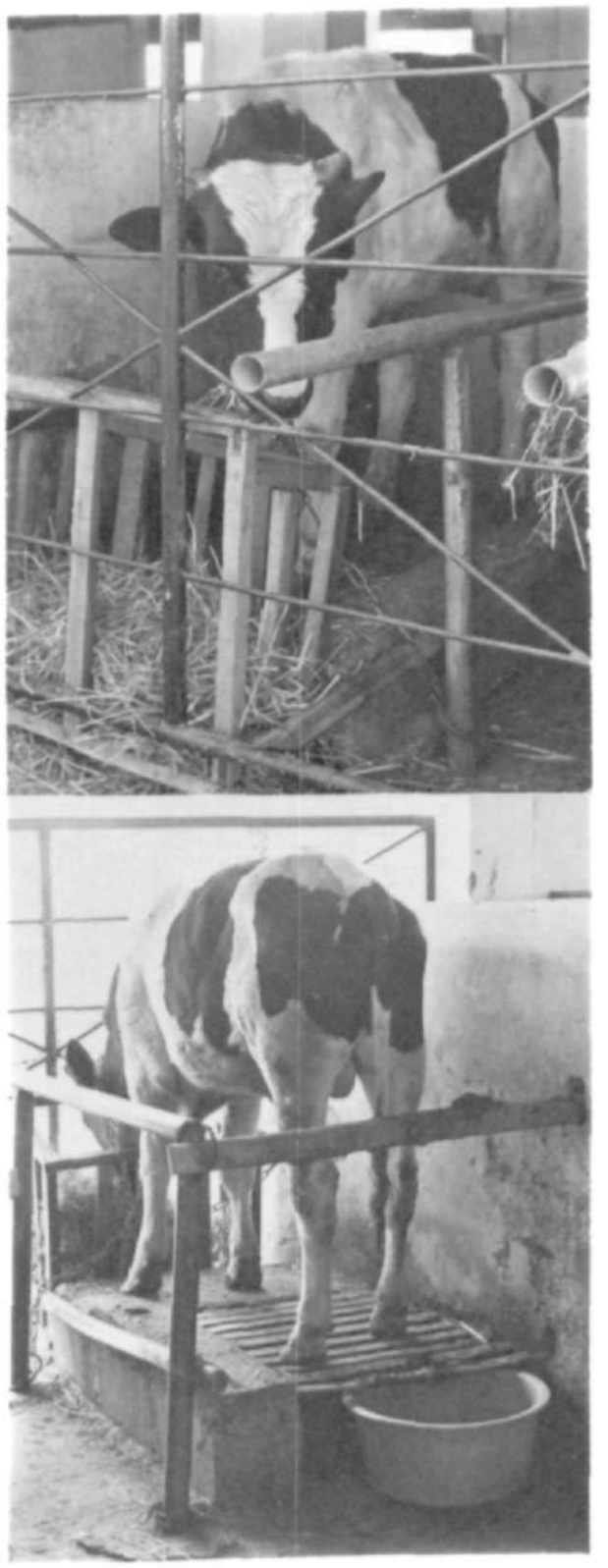
Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
2.7	2.0	2.4	2.1	1.8	4.8
1.0	1.0	2.7	2.5	2.4	2.4
5.6	2.1	3.0	3.0	0.3	4.0
2.0	4.4	1.5	2.2	2.2	4.0
2.30	1.2	1.6	1.2	1.1	2.7
3.0	2.9	4.0	1.8	1.9	0.4
3.0	1.0	4.7	3.6	1.4	4.8
3.2	1.8	3.0	2.6	1.1	2.5
3.2	2.0	0.7	1.7	1.8	3.6
4.8	2.9	0.9	2.0	1.1	0.8
-	0.9	2.4	1.6	1.1	2.3
-	1.2	0.7	1.6	1.2	2.3
-	1.7	2.0	2.9	1.8	1.6
-	-	3.8	2.2	1.8	2.6
-	-	2.8	3.0	2.0	1.8
-	-	2.4	2.1	1.8	3.8
-	-	2.9	1.7	0.8	4.4
-	-	3.0	3.6	1.3	1.40
-	-	4.0	3.0	1.2	5.3
-	-	2.0	2.8	1.1	2.1
-	-	3.0	2.3	2.6	3.8
-	-	3.4	2.2	1.8	1.6
-	-	1.6	4.0	2.0	2.1
-	-	1.6	3.1	1.2	4.7
-	-	2.4	2.0	1.8	2.50
-	-	-	-	1.8	3.70
-	-	-	-	2.2	3.0
-	-	-	-	2.2	0.6
-	-	-	-	1.8	5.9
-	-	-	-	2.3	3.7
-	-	-	-	3.5	8.4
-	-	-	-	1.8	3.2
-	-	-	-	3.0	4.5
-	-	-	-	2.3	3.0
-	-	-	-	1.8	3.0
-	-	-	-	2.2	3.8
-	-	-	-	1.4	5.0
-	-	-	-	2.2	-

Table 11. Serum creatinine levels in Nigerian cattle. (mg/100ml).

Friesian		Friesian/Zebu Cross		White Fulani	
Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
1.08	0.98	1.06	1.46	0.75	0.94
1. 4	1.98	1. 7	1.76	0.78	0.94
1. 0	1. 0	1. 2	2.00	0.95	0.86
1. 3	1.14	1.06	1.28	0.88	0.76
1. 4	1. 0	1. 8	1.76	0.95	0.76
1.02	0.96	0.90	1.96	0.85	0.98
0.98	1.14	1.06	1.96	0.95	0.95
0.98	0.98	1. 6	1.20	0.98	0.88
0.95	1.28	1.06	1.14	0.75	1.04
0.98	1.46	1.08	1.43	1. 0	1. 0
-	0.98	1.06	1. 7	0.98	0.96
-	2. 0	1. 0	1.84	0.88	0.95
-	1. 0	2. 0	1.46	0.76	0.78
-	1. 4	1.06	1. 0	0.85	0.78
-	-	1.08	1. 3	0.86	0.88
-	-	1. 8	1.74	0.98	0.78
-	-	1. 6	0.96	0.75	0.76
-	-	1. 2	2. 0	0.75	0.86
-	-	1.06	0.98	0.98	0.88
-	-	1. 6	0.98	0.70	0.96
-	-	1. 2	1.96	0.86	0.98
-	-	1. 8	2. 0	1. 6	1.00
-	-	0. 8	0.98	0.98	0.98
-	-	1. 2	0.98	0.98	0.75
-	-	0.98	1. 7	1.04	0.78
-	-	1. 2	-	0.95	0.88
-	-	-	-	0.98	1.00
-	-	-	-	1.00	0.78
-	-	-	-	1.02	0.96
-	-	-	-	1.02	0.88
-	-	-	-	1. 4	0.88
-	-	-	-	1. 0	0.78
-	-	-	-	1. 6	-

APPENDIX II

A SIMPLIFIED METABOLISM STALL FOR CATTLE IN THE TROPICS



APPENDIX III

WEIGHT GAINS FROM THREE LEVELS OF PROTEIN

FEEDING — TABLES 1 - 5

Table 1. Interaction means of initial weight.

Breed	8%	12%	16%	Mean Value
Friesian	110.91	132.05	147.45	130.19
White Fulani	184.09	189.09	175.00	182.73
Cross	185.68	175.45	163.18	174.77
Mean	160.23	165.53	161.88	

Table 2. Analysis of variance of initial weight.

D.F.	S.S.	M.S.	F.	Source
2	88.38	44.19	0.17	Feed rate
2	9642.55	4821.27	18.79	Type of animal
4	1969.29	492.32	1.92	Interaction
9	2309.39	256.60		Error
17	14009.60			Total

Table 3. Interaction means of final weight.

Breed	8%	12%	16%	Mean Value
Friesian	150.45	153.86	162.50	155.60
White Fulani	189.78	196.37	187.50	191.21
Cross	204.55	179.32	172.27	185.38
Mean	181.59	176.52	174.09	

Table 4. Analysis of variance of final weight.

D.F.	S.S.	M.S.	F.	Source
2	175.77	87.89	0.23	Feed rate
2	4377.34	2188.67	5.69	Type of animal
4	1215.13	303.78	0.79	Interaction
9	3461.81	384.65		Error
17	9230.05			Total

Table 5. Interaction means of weight gains,

Breed	8%	12%	16%	Mean Value
Friesian	39.54	21.81	15.05	25.47
White Fulani	5.69	7.28	12.50	8.49
Cross	18.87	3.87	9.09	10.61
Mean	21.36	10.99	12.21	

APPENDIX IV

ANALYSIS OF VARIANCE OF NITROGEN

METABOLISM — TABLES 1 - 7

Table 1. Analysis of variance of urinary nitrogen.

D.F.	S.S.	M.S.	F.	Source
2	57073.68	28536.84	40.21	Level of feed
2	15247.78	7623.89	10.74	Type of animal
4	9193.21	2298.30	3.24	Interaction
1	2904.43	2904.43	4.09	(Block)
8	5677.80	709.73		Error
5	9303.98	1860.80	2.38	Day
10	7444.94	744.50	0.95	Day by feed
10	2740.04	274.00	0.35	Day by breed

Table 2. Analysis of variance of fecal nitrogen.

D.F.	S.S.	M.S.	F.	Source
2	398.07	199.03	3.61	Level of feed
2	514.27	257.13	4.67	Type of animal
4	1035.56	258.89	4.70	Interaction
1	75.75	75.75	1.38	(Block)
8	440.70	55.09		Error
5	705.41	141.08	5.93	Day
10	303.86	30.39	1.28	Day by feed
10	429.51	42.95	1.81	Day by breed
65	1546.83	23.80		Within animal error
107	5449.97			Total

Table 3. Analysis of variance of absorbed nitrogen.

D.F.	S.S.	M.S.	F.	Source
2	215103.60	107551.80	677.94	Level of feed
2	249.98	124.99	0.79	Type of animal
4	573.03	143.26	0.90	Interaction
1	509.69	509.69	3.21	(Block)
8	1269.16	158.64		Error
5	3574.37	714.87	2.84	Day
10	6859.98	686.00	2.73	Day by feed
10	4179.99	417.99	1.66	Day by breed
65	16343.21	251.43		Within animal error
107	248663.00			Total

Table 4. Analysis of variance of nitrogen retention.

D.F.	S.S.	M.S.	F.	Source
2	55823.48	27911.74	54.57	Level of feed
2	15974.77	7987.38	15.62	Type of animal
4	13760.39	3440.09	6.73	Interaction
1	980.72	980.72	1.92	(Block)
8	4092.09	511.51		Error
5	12973.64	2594.73	2.49	Day
10	9888.01	988.80	0.95	Day by feed
10	7330.70	733.07	0.71	Day by Breed
65	67553.37	1039.28		Within animal error
107	188377.16			Total

Table 5. Analysis of variance digestibility coefficient.

D.F.	S.S.	M.S.	F.	Source
2	13862.83	6931.42	205.01	Level of feed
2	110.82	55.41	1.64	Type of animal
4	461.12	115.28	3.41	Interaction
1	3.67	3.67	0.11	(Block)
8	270.49	33.81		Error
5	595.74	119.15	4.04	Day
10	394.35	39.44	1.34	Day by feed
10	467.60	46.76	1.58	Day by breed
65	1918.36	29.51		Within animal error
107	18084.98			Total

Table 6. Analysis of variance of % nitrogen intake retained.

D.F.	S.S.	M.S.	F.	Source
4	5057.47	1264.37	5.59	Interaction
1	419.24	419.24	1.85	(Block)
8	1809.33	226.17		Error
5	4189.18	837.84	2.58	Day
10	2001.92	200.19	0.62	Day by feed
10	2192.96	219.30	0.68	Day by breed
65	21106.98	219.30	0.68	With animal error
107	44658.99	324.72		Total

Table 7. Analysis of variance of % nitrogen absorbed retained.

D.F.	S.S.	M.S.	F.	Source
2	45411.07	22705.54	25.77	Level of feed
2	20505.29	10252.65	11.63	Type of animal
4	15597.10	3899.27	4.43	Interaction
1	1042.72	1042.72	1.18	(Block)
8	7049.90	881.24		Error
5	17211.46	3442.29	2.26	Day by feed
10	11993.30	1199.33	0.79	Day by feed
10	9872.18	987.22	0.65	Day by breed
65	98901.00	1521.55		Within animal error
107	227584.02			Total

APPENDIX V

HOURLY AND DAILY BLOOD AND URINARY UREA LEVELS — TABLES 1 - 10

Table 1. Blood urea level in White Fulani steer (No.133) (mg/100ml).

	Hours								
Day	0	2	4	6	8	10	12	24	4
1	7.0	7.4	8.6	10.0	10.6	12.0	10.0	8.6	9.3
2	7.0	7.0	8.0	8.0	8.5	9.09	9.0	7.2	-
3	7.2	9.0	12.0	-	-	12.5	9.0	6.5	-
4	6.5	6.6	9.3	-	10.4	-	8.0	7.0	-
5	7.0	7.2	7.5	-	8.0	-	7.5	7.0	-
6	7.0	5.0	7.6	-	10.6	-	7.2	7.0	-
7	7.0	7.0	8.4	-	9.0	-	7.5	7.5	-
8	7.5	6.5	6.5	-	7.4	-	7.0	6.5	-
9	6.5	7.5	8.0	-	8.5	-	8.0	8.0	-
10	8.0	7.0	8.5	-	9.0	-	8.5	8.0	-
11	8.0	8.0	8.5	-	8.5	-	8.0	8.0	-
12	8.0	8.5	8.5	-	9.0	-	9.0	8.0	-
13	8.0	8.5	8.5	-	9.0	-	8.0	8.0	-
14	8.0	9.0	9.0	-	9.4	-	8.6	8.0	-

Table 2. Blood urea level in White Fulani steer (No.129) (mg/100ml).

	Hours								
Day	0	2	4	6	8	10	12	24	WBV
1.	6.0	6.0	6.8	6.8	8.0	9.3	6.0	5.3	8.0
2	5.3	7.0	7.0	7.0	8.0	9.1	8.3	7.4	-
3	7.4	7.0	7.5	-	-	9.0	8.0	7.0	-
4	7.0	7.0	9.0	-	11.0	-	8.0	7.0	-
5	7.0	7.0	7.6	-	9.2	-	9.0	1.0	-
6	7.0	8.0	8.0	-	9.0	-	9.0	7.4	-
7	7.4	7.0	7.4	-	8.5	-	7.0	7.0	-
8	7.0	6.5	7.5	-	8.6	-	8.0	7.0	-
9	7.0	6.8	8.0	-	8.6	-	8.0	8.0	-
10	8.0	6.5	8.0	-	9.0	-	8.5	8.5	-
11	8.5	8.0	8.0	-	8.2	-	8.8	8.0	-
12	8.0	8.0	8.4	-	8.5	-	8.0	7.5	-
13	7.5	8.0	8.4	-	8.6	-	8.0	8.0	-
14	8.0	8.6	9.0	-	9.2	-	8.0	8.0	-

WBV = Whole Blood Value

Table 3. Blood urea value in crossbred steer (No.1074) (mg/100ml).

	Hours								
Day	0	2	4	6	8	10	12	24	WBV
1	5.6	6.0	6.6	6.6	7.4	8.6	8.0	6.0	7.0
2	6.0	6.0	7.5	7.5	8.0	9.0	7.3	5.0	-
3	5.0	10.0	10.0	-	-	12.0	10.0	6.0	-
4	6.0	7.0	8.4	-	9.3	-	7.0	7.0	-
5	7.0	7.0	8.4	-	9.5	-	8.0	7.1	-
6	7.1	6.5	8.0	-	9.0	-	9.0	7.4	-
7	7.4	7.0	8.6	-	8.6	-	8.0	8.0	-
8	7.0	7.0	7.4	-	7.4	-	6.5	6.0	-
9	6.0	6.5	6.5	-	8.0	-	8.2	7.0	-
10	7.0	7.0	7.5	-	8.5	-	8.5	7.0	-
11	7.0	7.5	7.4	-	8.4	-	8.4	8.4	-
12	8.4	8.0	8.4	-	8.6	-	8.0	8.0	-
13	8.0	8.5	8.5	-	9.0	-	8.0	8.0	-
14	8.0	9.0	9.0	-	9.4	-	8.6	8.0	-

WBV = Whole Blood Value

Table 4. Blood urea value in crossbred steer (No.985). (mg/100ml).

Day	Hours								
	0	2	4	6	8	10	12	24	WBV
1	6.0	6.0	7.0	8.6	8.6	9.3	8.0	8.0	7.3
2	8.0	6.0	7.0	7.5	10.0	10.9	9.3	7.3	-
3	7.3	8.0	8.5	-	-	9.4	8.0	7.1	-
4	7.1	8.0	8.2	-	8.6	-	8.0	7.1	-
5	7.1	8.0	9.6	-	10.1	-	7.5	7.5	-
6	7.5	8.0	9.0	-	9.6	-	9.2	8.0	-
7	8.0	7.4	8.5	-	9.4	-	7.4	6.8	-
8	6.8	6.5	6.5	-	8.0	-	7.6	7.0	-
9	7.0	6.0	6.0	-	8.0	-	7.0	6.0	-
10	6.0	7.2	7.2	-	8.0	-	8.0	8.0	-
11	8.0	7.2	7.5	-	8.0	-	8.0	8.0	-
12	8.0	8.0	8.5	-	8.5	-	8.0	8.0	-
13	8.0	9.0	9.0	-	10.4	-	8.6	8.0	-
14	8.0	10.0	10.0	-	10.6	-	7.5	7.5	-

WBV = Whole Blood Value

Table 5. Blood urea values in Friesian steer (No.793). (mg/100ml).

	Hours								
Day	0	2	4	6	8	10	12	24	WBV
1	6.0	7.3	7.3	8.0	8.6	10.6	9.3	7.0	7.0
2	7.0	6.0	7.5	8.0	8.5	9.8	9.0	7.1	-
3	7.1	8.0	8.0	-	-	10.0	7.0	7.5	-
4	7.5	7.0	8.0	-	9.9	-	8.0	8.0	-
5	7.5	7.5	9.0	-	10.0	-	9.0	7.2	-
6	7.2	9.0	9.0	-	10.0	-	9.0	7.2	-
7	7.2	8.5	8.5	-	8.5	-	8.0	7.0	-
8	7.0	7.2	7.0	-	7.4	-	7.4	5.0	-
9	5.0	6.5	6.4	-	7.0	-	6.0	6.0	-
10	6.0	6.0	7.0	-	8.5	-	8.5	7.0	-
11	7.0	8.0	8.0	-	8.4	-	8.4	8.4	-
12	8.4	7.2	8.0	-	8.4	-	8.4	8.4	-
13	8.4	9.2	9.4	-	10.5	-	8.0	8.0	-
14	8.0	10.4	10.0	-	10.5	-	9.2	9.0	-

WBV = Whole Blood Value

Table 6. Urine urea level in White Fulani steer (No.129)

Day	0 hrs.		4 hrs.		8 hrs.		12 hrs.		24 hrs.	
	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml
1	-	-	-	-	340	800	460	800	770	750
2	770	750	450	680	720	740	-	-	750	1100
3	750	1100	410	533	420	850	150	1000	800	986
4	800	986	320	528	250	600	410	625	810	733
5	810	733	550	700	590	780	420	804	1150	800
6	1150	800	420	800	480	812	240	820	1180	820
7	1180	820	500	800	300	920	430	1000	440	1000
8	440	1000	280	740	320	784	220	720	850	720
9	850	720	270	800	410	800	270	800	210	760
10	210	760	170	800	110	850	480	850	620	850
11	620	850	230	800	260	840	300	840	550	820
12	550	820	180	780	340	820	120	800	100	800
13	100	800	-	-	-	-	-	-	-	-

Table 7. Urine urea level in crossbred steer (No.985).

Day	0 hrs.		4 hrs.		8 hrs.		12 hrs.		24 hrs.	
	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml
1	-	-	-	-	100	850	360	860	930	900
2	930	900	250	790	580	1067	-	-	1300	1000
3	1300	1000	320	600	50	868	260	986	1000	1000
4	1000	1000	300	400	70	402	200	600	630	600
5	630	600	400	604	210	480	110	720	850	600
6	850	600	190	500	220	500	150	512	510	520
7	510	520	210	600	320	-	1200	-	2640	-
8	2640	-	200	500	380	520	260	520	380	600
9	380	600	180	600	380	680	200	700	250	700
10	250	700	80	500	160	540	500	540	200	600
11	200	600	160	600	330	600	1810	580	550	580
12	550	580	490	600	180	620	140	600	560	600
13	560	600	200	400	200	520	180	500	610	520

Table 8. Urine urea level in crossbred steer (No.1074).

Day	0 hrs.		4 hrs.		8 hrs.		12 hrs		24 hrs.	
	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml
1	-	-	-	-	1680	750	750	750	1100	750
2	1100	750	1700	667	580	810	-	-	1500	1100
3	1550	1100	320	600	1620	700	700	1068	500	786
4	500	786	180	900	190	1026	2600	1106	1600	1000
5	1600	1000	550	900	2250	1100	800	1280	1350	1100
6	1350	1100	300	984	1170	984	160	900	520	1100
7	520	1100	200	1204	1490	926	600	900	1220	900
8	1220	900	570	950	370	800	500	680	870	600
9	870	600	190	900	480	928	100	800	730	800
10	730	800	420	600	170	780	1510	780	1510	780
11	1510	180	200	680	720	870	1310	870	680	800
12	680	800	200	980	710	1000	780	900	840	980
13	840	980	700	1000	710	1100	360	1100	780	940

Table 9. Urine urea level in crossbred steer (No.793)

Day	0 hrs.		4 hrs.		8 hrs.		12 hrs.		24 hrs.	
	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml
1	-	-	-	-	890	825	2040	767	2400	667
2	2400	667	800	768	490	800	-	-	2250	1000
3	2250	1000	340	680	1810	768	1450	1110	630	1110
4	630	1110	320	1000	370	1200	1000	1100	1720	1300
5	1720	1300	300	980	3160	1068	900	1050	1420	1100
6	1420	1100	1000	2300	1200	10440	1000	11500	1000	1000
7	2500	1000	4000	980	350	986	220	900	460	900
8	460	900	400	600	170	600	500	680	2200	700
9	2200	700	210	600	210	600	280	540	810	500
10	810	540	320	700	230	840	660	800	3740	800
11	3740	800	610	900	390	920	1320	920	820	1000
12	820	1000	470	800	220	900	300	840	1080	800
13	1080	800	280	900	240	968	350	900	730	900

Table 10. Urine urea level in crossbred steer (No.133).

Day	0 hrs.		4 hrs.		8 hrs.		12 hrs.		24 hrs.	
	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml	Vol ml	Value mg/100ml
1	-	-	-	-	690	833.3	300	733	1220	733
2	1220	733	600	600	660	867	-	-	650	1000
3	650	1000	420	666.6	300	670	250	1200	800	668.5
4	800	668.5	300	800	270	793.2	300	924	980	1000
5	980	1000	500	860	730	900	400	900	1320	900
6	1320	900	240	800	900	800	270	920	1060	900
7	1060	900	340	1000	250	1000	270	1100	810	1000
8	810	1000	250	928	210	928	230	1100	380	1100
9	380	1100	330	1000	200	1100	160	1100	1210	1000
10	1210	1000	280	1000	200	1000	230	932	780	932
11	780	932	190	720	990	740	200	820	700	820
12	700	820	300	1000	100	1100	170	1100	690	1000
13	690	1000	320	960	300	980	120	1000	880	1000

COMPARATIVE PROTEIN METABOLISM IN BUNAJI (WHITE FULANI) AND FRIESIAN CATTLE IN NIGERIA

by

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AN ABSTRACT OF A THESIS

Submitted in partial fulfillment

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Possible differences in protein metabolism, especially nitrogen conservation, by temperate and tropical cattle were investigated.

Serum biochemical and electrolyte measurements were determined in 78 Zebu (White Fulani), Friesian and Friesian/White Fulani crossbred cattle and compared according to breed and season (wet and dry). Seventy-six blood samples were also collected from abattoirs. The values for total protein, globulin, sodium, and potassium were higher in the Zebu than the other two breeds. Blood urea nitrogen, creatinine, and chloride values were higher in the crossbred cattle. Calcium, magnesium, albumin, and PCV values were similar in both Friesian and Friesian-Zebu cross. Seasonal variations were found in the chloride, sodium, potassium, creatinine, and blood urea nitrogen levels in all the breeds. No differences were found between the breeds for inorganic phosphate values.

A comparative study of growth and nutrient digestibility in steers of the three breeds was conducted using 8%, 12% and 16% levels of crude protein. Weight gains were found to be unaffected

by the low and high level of feed but higher weight gains were obtained with 12% crude protein. Friesian steers performed better under the management system used. On low protein feed, the Zebu had a higher significant coefficient of digestibility for crude fiber and ether extract ($P<0.05$). At the 16% protein level, no significant differences were found between breeds in digestibility of the nutrients ($P<0.05$). Significant higher differences ($P=0.05$) were found in nutrient digestibility at the 16% crude protein level of feeding when compared to the other two levels.

Nitrogen balance studies, serum proteins and creatinine determinations were conducted to compare nitrogen utilization at three levels of crude protein in the three breeds. Total nitrogen output was highest in the crossbreds fed 8% and lowest in the Friesians. There was no significant response in the White Fulani. Levels of feed were changed from 8% and 12% to 16%, and from 16% to 8%. Re-adjustment to the new levels took seven days and significant differences were found in values of absorbed and retained nitrogen between the Friesian and the White Fulani indicating possible differences in nitrogen metabolism in the

latter. No significant changes were found in serum proteins but significant increases were observed in urea and creatinine values at 16% crude protein intake.

Blood and urinary urea levels, as a measure of protein utilization, were determined for 14 days in five steers; two Zebu (White Fulani), one Friesian, and two White Fulani-Friesian. There was no significant difference in the values in the three breeds. The White Fulani had a higher level of urinary urea with the peak occurring 12 hours postprandial (PP). Blood urea nitrogen (BUN) reached a peak in the Friesian at eight hours PP in contrast to four hours in the White Fulani and the crossbred. BUN peak in the three breeds corresponded to the lowest level of urinary urea excretion after which it increased except in the Friesian. It was concluded that there were basic metabolic differences in the rate of absorption and efficiency of nitrogen utilization between the Zebu and Friesian.

The effect of protein supplementation on nematode infection was investigated in 15 parasite-free steers of the three breeds. The steers were supplemented with 8%, 12% and 16% crude protein and were infected with

10,400 3rd stage larvae followed by 10,000 larvae a week later. The larvae consisted of 64% Haemonchus sp., 24% Trichostrongylus sp., and 12% Oesophagostomum sp. Fecal egg count, total serum protein, globulin, albumin, and packed cell volume were monitored weekly for 10 weeks. The mean fecal egg count was lowest in White Fulani and highest in Friesian/White Fulani Cross. The higher the fecal egg count, the lower the protein supplementation. There were no significant differences in serum protein changes between breeds or levels of protein intake, Decreased levels of albumin were lowest during the last week of the experiment when the fecal egg count was the highest. Sharp drop in PCV values was found after the first week of infection in the White Fulanis and Crosses but not in Friesians. Serum globulin levels increased with increasing egg counts. It was concluded that adequate protein supplementation may be beneficial in bovine helminthiasis.

It is concluded from this investigation that the protein metabolism of the Bunaji (White Fulani) differed from that of the Friesian and that it was better adapted to the tropical environment of the Northern savannah area of Nigeria.