STUDIES ON DRY MATTER, ENERGY AND PROTEIN UTILIZATION OF THREE BREEDS OF DAIRY COWS AT IBADAN

BY

ADEBISI ADEBOWALE
B.Sc. (Hons.) in Agricultural Biochemistry and Nutrition (Ibadan)

A thesis in the Department of ANIMAL SCIENCE

Submitted to the Faculty of Agriculture and Forestry in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN
IBADAN

JULY, 1976.

ABSTRACTS

Comparative studies were conducted on exotic (German Brown and Friesian) and indigenous (White Fulani) lactating cows to assess (a) the systems of management best suited for the newly imported lactating, exotic cows for maximum production (b) the effects of seasons, stage of lactation, breeds and diets on feed dry matter (DM) intake, liveweight changes, milk yield and composition, respiration and body temperature of White Fulani (WF), German Brown (GB) and Friesian (F) lactating cows and (c) the effects of DM intake, dietary level, stage of lactation and breed on productivity, digestibility of feed, milk composition, energy and protein utilization, rumen and blood metabolites.

Results on management studies indicated that the grazed cows produced more milk, solids-corrected milk (SCM), butter-fat, ash and less milk protein than the stall-fed ($P < 0.05$). Although higher respiratory counts, water intake and body temperatures were recorded for the grazed cows than the stall-fed ones, the results were not statistically significant ($P > 0.05$)

Lactation studies showed that the exotic breeds consumed more forage DM than the indigenous, giving 5.92 ± 0.21, 5.59 ± 0.16

and 4.49 ± 0.16kg/day for the F, GB and WF cows respectively. The peak forage DM intake was attained between the 5th and 10th week of lactation. The mean milk yield and SCM were 27.55 ± 6.15 and 29.83 ± 5.26kg/week respectively for the WF cows, 40.16 ± 6.15 and 36.91 ± 3.26 respectively for the F and 41.16 ± 8.19 and 40.16 ± 5.84kg/week respectively for the GB. Peak milk production was attained between the 5th and 9th week of lactation. Generally, results showed that the milk of the WF cows possessed higher milk quality, producing higher percentage of butterfat and protein, than the exotic breeds. Although there were more forage DM intake during the dry season than the wet, higher milk yield was recorded during the latter season than the former. Liveweight losses occurred from the beginning of the experiment to about the 10th week of lactation.

The results of the relationship between rumen metabolites and milk yield showed that when the ratio of acetate to propionate was lower, there was a higher yield of milk and protein but when the ratio was higher, there was an increased butterfat. The digestible crude protein (DCP) values for maintenance were 0.39g/day/$W_{kg}^{0.734}$ (91.82g/day available protein (AP), 0.47g/day/$W_{kg}^{0.734}$ (113.28g/day AP) and 0.52g/day/$W_{kg}^{0.734}$ (121.77g/day AP) for the WF, GB and F cows respectively. The N-balance studies indicated that 6.69gDCP/day/$W_{kg}^{0.734}$ (304.80gAP/day)

were required by the WF cows to produce 3.35kg milk/day (0.51%N), 6.34gDCP/day/$W_{kg}^{0.734}$ (353.93gAP/day) by the GB cows to produce 6.17kg milk/day (0.47%N) and 6.54gDCP/day/$W_{kg}^{0.734}$ (359.20g AP/day) by the F cows to produce 7.08kg milk/day (0.49%N). The mean net efficiency of protein utilization were 27.95, 43.43 and 53.73% for the WF, GB and F cows respectively.

The metabolizable energy values for maintenance were 0.53, 0.59 and 0.61 MJ/day/$W_{kg}^{0.734}$ for the WF, GB and F cows respectively. These are 72.29, 72.75 and 73.43% of the Ministry of Agriculture, Fisheries and Food of the United Kingdom (MAFF)(1975) recommendation respectively. The gross energetic efficiencies for milk production were 10.23, 12.79 and 14.33% for the WF, GB and F cows respectively while the net energetic efficiencies were 25.47, 31.31 and 37.50% respectively. Finally, the conclusions from the trials have shown that 8.3% (WF), 10.3% (F) and 11.2% (GB) of the energy intake were contributed by the protein fraction of the DM intake.

ACKNOWLEDGEMENTS

Words are inadequate to express my profound gratitude and appreciation to my Head of Department, Professor V.A. Oyenuga and Drs. A.U. Mba, F.O. Olubajo and E.A. Olaloku for their inspiring instructions and supervision during the course of this study. I wish to thank further Professor Oyenuga for his liberal encouragement of the pursuit of knowledge and Drs. Mba and Olubajo who were magnanimous enough to provide funds from their research grants for the construction of the metabolic cages used in this study. I would like to register my heart-felt gratitude to Professor J.K. Loosli who also contributed ideas, guidance and encouragement during the early part of this study.

My thanks are extended to the staff of the Department of Animal Science, University Dairy Farm and Grassland Research Section particularly Messrs. S.B. Alade, Wale Adesuyi, S. Eweme and Idowu for the assistance and facilities extended to me.

Lastly, I am heavily indebted to my father and mother, Chief and Mrs. J.A. Adebowale, my father-in-law and his wife, Mr. and Mrs. F.A.O. Akomolede, my brother-in-law and his wife, Mr. and Mrs. Ifemidayo Adejuwon, Mrs. Oyinlola Lasebikan, and

my intimate colleague and his wife Mr. and Mrs. Francis Ogundola for their moral, financial and encouraging assistance in every phase of this work. To all those I find difficult to mention their names, not because of oversight but lack of space, I say a big thank you for your cooperation.

CERTIFICATION BY SUPERVISORS

We certify that this work was carried out by MR. ADEBISI ADEBOWALE in the Department of Animal Science, University of Ibadan.

(Supervisor)
V.A. OYENUGA B.Sc. (Agric.)
Ph.D. (Dunelm), F.R.I.C.
Professor & Head of Department.

(Supervisor)
A.U. MBA B.Sc. (Agric.)
Ph.D. (Dunelm)
Reader.

(Supervisor)
F.O. OLUBAJO B.Sc. (Illinois),
M.Sc. (Ohio), Ph.D. (Ibadan)
Senior Lecturer.

(Supervisor)
E.A. OLALOKU B.Sc. (Agric.)
M.Sc. (Nott.), Ph.D. (Ibadan)
Senior Lecturer.

July, 1976.

DEDICATION

Dedicated to ABOSEDE --------
my indispensable 'right hand'.

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CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

One of the important features that characterise Nigerian agriculture is the imbalance in the activities expended on 'crop' in relation to 'animal' production. It has been calculated from available data that 80% of the estimated agricultural output in Nigeria are derived from crops while 20% come from livestock (Oyenuga, 1973). This picture shows a sharp contrast to what exists in the agriculturally developed economies. Animal production accounts for 80% of the total value of agricultural output in Denmark, 81% in Finland, 70% in France, 76% in Ireland, 78% in the Netherlands, 77% in Sweden, 73% in Switzerland and 68% in the United Kingdom. (F.A.O., 1955) Because of this imbalance between crop and animal production, animal protein intake of an average Nigerian has been alarmingly low when compared with the F.A.O. (1966) recommended intake. According to the recent report of a committee on food crops set up by the Nigerian Federal

Ministry of Agriculture and Natural Resources, it has been shown that proteins from animal sources contribute about 17% of the total protein consumption to the average Nigerian diet compared to a corresponding estimate of 68% in New Zealand, 71% in the United States of America, 67% in Denmark and 60% in the United Kingdom (Oyenuga, 1973; Loosli and Van Blake, 1973).

A good reason why these agriculturally advanced countries attach more importance to animal production is the nutritive 'superiority' of animal protein to crop protein. Protein quality is assessed basically by its constituent amino acids and also its nutritive value. The nutritive value include factors like digestibility and absorbability of the food protein, the presence of toxic substances and inhibitors, damage by heat during cooking or processing and acidity. Vegetable proteins are less digestible and the essential amino acids less complete and less balanced to meet human body requirements than those from animal products. For example, most cereals are deficient in lysine and tryptophan, while pulses are low in methionine, cystine, tryptophan and threonine (Oyenuga, 1971). Finally most vegetable proteins have lower biological value than animal proteins. Mitchell (1927) showed that the biological value of whole egg is 94 while that of whole maize is 60.

1.1.1 <u>The Protein Gap</u>.

The F.A.O. (1966) targets for world food production in 1975 visualized a total annual consumption in human diets of about 125 million tonnes of protein of which about 38 million tonnes would be animal protein given a plant protein to animal protein ratio of about 3:1. The huge increases over the 1960 figure are to be obtained by an increase of about 13 million tonnes of animal protein. The major problem here would be the production of enough animal protein to meet the needs of those in developing countries. For instance, while Oyenuga (1975) recommended a minimum daily crude protein intake of 65g by an average Nigerian for healthy living which should include 28g from animal sources in order to obtain the desired net protein utilization (NPU) value for the ingested crude protein, it has been revealed (Oyenuga, 1975) that during 1974-1975, an average Nigerian was obtaining only approximately 25% (7.5g) of the minimum animal protein level he should consume to meet his daily requirements. This intake apart from falling short of the recommendation, falls far below the F.A.O. targets for 1975 already mentioned. It was earlier envisaged that the third National Development Plan 1975-80 will be able to tackle this problem but calculations have shown that the animal protein intake would rise to 9g/caput/day by 1980, attaining then approximately a third of minimum requirements. It is therefore necessary to re-appraise the Development Plan so as to improve this situation. It has long been demonstrated that this low protein intake is partly if not wholly responsible for the high incidence of retarded growth in children (Collins, Dema and Omololu, 1961), high incidence of the deficiency diseases known as kwashiorkor and marasmus (in adults) coupled with a high rate of child mortality (Shaw and Colville, 1950; Wilson, 1954), low level of human productivity (Platt, 1954) and short life span existing among many African communities (Oyenuga, 1967).

1.1.2 Factors affecting animal protein level.

Before there can be increase in animal protein level, there must be an increased livestock production. However, several factors have been found to militate against livestock production in the tropics. Among these are lack of properly managed pastures, disease pests, unfavourable climatic condition, poor feeding and management practices, poor economic condition of the people, land tenure system, lack of reliable livestock census, the astronomical increases in livestock feed prices, absence of the infrastructure necessary to supply the needed imputs for production, processing and distribution and low genetic potential of the indigenous animals. Highlights of these factors are discussed below.

Low productivity of the Nigerian Livestock.

Although the consumption of animal protein in the developed countries is about five times higher than in the developing countries, it has been shown (Oyenuga, 1967) that the proportion of livestock number to the human population is higher in the developing countries than in the developed countries. Furthermore, although more than half the world's cattle population are to be found in the tropics, Olaloku (1973) pointed out that milk production from so vast a cattle population accounted for only 15% of an estimated world total production of 400,932,000 metric tonnes of milk during 1970/71.

The remaining 85% came from cows in the technically developed countries most of which lie in the temperate latitudes. The problem, therefore, is not only that of increasing the number but also the productivity of the livestock in the tropical countries, like Nigeria.

While there is room for considerable expansion in the numbers of livestock, the production of these animals is very much below expectation. The milk production of the dairy cattle is very low when compared with the dairy breeds kept in the temperate countries. The mature body weight of the indigenous cattle is small, having a carcass weight at maturity of about 150kg in the White Fulani (Zebu) cattle, 100kg in the N'dama breed compared with 250kg in most of the European breeds of cattle (Mittendorf and Wilson, 1961; Loosli and van Blake, 1973). The slaughter rate is only about 9.2% in Nigerian cattle (Shaw and Colville, 1950) compared with 28% in the United States of America (Loosli and Oyenuga, 1963). Because the production seldom begins until between 3 and 4 years in the indigenous breeds (Oyenuga, 1958), the annual rate of increase of the cattle population is very low and very much below an estimated world average of 2.6% (Oyenuga, 1967).

<u>Impact of the involvement of the Government and Private Businessmen on animal production.</u>

Up till now, the only modern agriculture and livestock industry practised in the country has been provided mainly by the various State and Federal Governments. Many Governments are embarking on accelerated food production programmes which include the dairy industry in the Kano State, beef production in the various Northern States, vegetable oil production and urban dairy farm at Iwo road (Ibadan) in Oyo State and Abudu cattle ranch by the Cross River State. However, these various governments have got their shortcomings. There are growing interests in animal production but when compared with crop production, no great impacts are noticeable. The Second and Third Development Plans of the governments revealed that smaller proportion of investments in the agricultural sector is being given to the livestock industry. While ₦616.70m was voted for crop production in the second year development plan, 1970-74, only ₦24.24m or 4% was provided for the livestock industry.

Oyenuga (1971) has shown that while the capital voted for crop production represented 81% of the provision for agricultural sector, the proportion for livestock development was only 9%. The case of the third development plan, 1975-80, is only slightly better. For instance, while the Federal Government voted ₦1,645,845,000 for agriculture, only ₦344,046,171 of this is to be devoted to livestock programmes. Apart from the fact that the total money devoted to agriculture is ridiculously low (only 5% of the whole budget), that of the livestock which is only 1% of the whole budget cannot arrest the present low animal protein intake trend.

It is to be observed here that for the moment the enthusiasm shown by the private businessmen has been very appalling. It would appear that they are not reacting quickly to agricultural production, particularly livestock industry due perhaps to the land tenure system especially in the Southern States, lack of organised marketing including guaranteed market prices or to some other factors such as capitals which might militate against mechanisation of agriculture. Modern animal production requires heavy capital investments. The Agricultural Credit Bank was set up by the Federal Military Government for the sole purpose of improving the agricultural industry but the advantages taken by many businessmen have not been very encouraging. Maybe that the avenues and processes for giving out loans have been made very tight and rigorous.

Availability of livestock feeds

Feeds account for about 60-80% of the cost of raising animals depending on species, breeds and environment (Olayiwole, 1973; Jakonda, 1975). Cereal grains, such as maize, are the basic ingredients in the formulation of livestock feeds. The price of maize in 1975 has doubled that of 1969 due to very high demand on grains. It is even cheaper to purchase grains in the United States of America and United Kingdom than in Nigeria. Even at that, the grains purchased in Nigeria have no gurаranteed standards with regard to the moisture content, protein and foreign materials.

Apart from the grains, other important components of livestock feeds like groundnut cake and fish meal are very difficult to obtain. The prices of fish meal rose from about ₦140.00 per ton in 1970 to ₦700.00 in 1973/74, an increase of about 500% though it is at present much less. It is now a general practice in developing countries to substitute fish -

meal in poultry and pig diets with the cheaper soyabean meal. Soyabean meal is about the only plant protein which is high in lysine. It is deficient in methionine but this can be supplemented with sesame meal which is high in methionine or even with synthetic DL-methionine. With this fear of high feed prices, it is now becoming increasingly more difficult and less encouraging for a private businessman to plunge into livestock production. It seems to be a major obstacle militating against livestock production.

Reliable figures of livestock population.

Although agriculture has long been practised in Nigeria, yet no reliable livestock census is available. 'Guess estimates' of the number of the Nigerian cattle have ranged from 5.6m (F.A.O./I.C.A.; 1960) to a staggering figure of 15m by the Federal Ministry of Information (1964) including F.A.O.'s (1966) figures of 10.8m head of cattle. One of the difficulties adduced to this failure is the "jangali" (tax paid on cattle). Another is the transhuman system of livestock keeping in Nigeria. "Jangali" has been abolished. It is now hoped that this might lead to obtaining accurate livestock census.

1.1.3 Nutritional Importance of Milk and Dairy Products

Milk, with its products, serves as one of the most important sources of food for all nations. Milk has been known to man for centuries. Infact, the Holy Bible made a reference to the "land flowing with milk and honey" (Anonymous, 1611). Though little is known about the early history of dairy industry, archeaological excavations indicate that men of the old stone age were the first to domesticate the cow and that in prehistoric times, milk was common. Milk was evolved through the ages specifically for the nutrition of infant mammals, for bridging the gap between the dependent intrauterine and the independent adult life. Eckles (1951) pointed out that the more highly developed and prosperous the people, the greater the amounts of milk and dairy products they consume. The importance of milk to the growth and health of the world population cannot be overemphasised. For instance, dairy industry is the backbone of American agriculture and consumption of dairy products the keystone of American nutrition (Brody, 1964).

Although it is deficient in iron, copper and manganese, milk with its products is rich in body-building proteins, with a biological value of up to 78, phosphorus, calcium, vitamins, lactose and fats. The major proteins of milk is casein. Lactalbumins and lactoglobulins are present in small quantities. Casein of different species are similar but lactoglobulins and lactalbumins vary with species and differ in their composition and properties. Because milk is poor in iron and vitamin C, supplementary sources of these must be supplied in diets based wholly or substantially on milk. Vitamin A varies with the nutrition of the cow while vitamin D is affected by the amount of sunlight as well as the nutrition of the cow. Adequate calcium and phosphorus nutrition depends upon three factors namely a sufficient supply of each element, a suitable ratio between them and the presence of vitamin D. These factors are inter-related and they occur in the most available form in milk. Milk with its easily digestible fat (90-97%), high amount of Vitamin A, excellent sources of riboflavin (Vit.B_2), a fair source of thiamin (Vit. B_1), ascorbic acid and lactose are of immense importance to the health of the growing population. The ascorbic acid content in cow's milk is about one-sixth and the iron content about one-third of that in woman's milk but the riboflavin content of cow's milk is about five-fold that of woman's milk (Brody, 1964). In fact, a former President of the United States of America, Mr. Richard Nixon, has lauded the sleep-inducing, bland, soothing yet highly nourishing properties of milk (Davidson, 1974). It had been used as a virtually exclusive diet in some digestive disturbances such as ulcer (Shay, 1942). A quart of cow's milk a day furnishes an average man approximately all the needed fat, calcium, phosphorus, riboflavin, one-half of the needed protein, 25% of the needed energy, over 33.3% of the vitamin A, 20% of the thiamine and asc obic acid, considerable amounts of nicotinic acid, choline and other factors and with the exception of iron, copper, manganese, and magnesium which are low in milk, all the needed mineral (Brody, 1964).

Dairy products include skim milk, cheese, butter, evaporated and condensed milk chocolate and ice cream. Skim milk is milk whose butterfat has been removed. In the light of modern research, investigators have recommended this type of milk for the elderly adults, because of the cholesterol which is present in milk fat (containing predominantly short-chain fatty acid) and associated with atherosclerosis - a disease commonest among the elderly. In fact it has also been suggested that elderly people above the age of 50 years should limit their fat intake to between 50-70g per day almost all being vegetable oil since vegetable oil contains higher proportion of unsaturated fatty acids with characteristic phytosteroids (Kon and Cowie, 1966).

Milk powder is the milk containing no water. In cheese, the curd contains virtually all the fat, 75% of total proteins and only traces of lactose and 66.7% of calcium of the whole milk. Butter is distinguished from other dairy products because of its high butterfat content (84%) and high Vitamin E contents. Ice-cream which is particularly useful for quieting cantakerous and noisy children at homes, on the streets and used in some homes for 'cooling down' particularly after an afternoon meal consists of 24% cream, 46% whole milk, 14% concentrated milk, 15.5% sugars, 0.5% stabilizers, eggs and flavours (Adeneye, 1972).

1.1.4 The Production, Supply and Consumption of Milk in Nigeria

Olaloku (1973) has shown that cows in the tropics including those in Nigeria are low producers compared with those in the temperate countries such as Denmark, United States of America and the Netherlands. He claimed that the low production was due to low genetic improvement, poor management and nutrition.

There have been two systems of milk production in Nigeria - namely the traditional and organised systems. The bulk of the milk is produced with traditional system of dairy husbandry by the normadic Fulani and Shuwa Arabs who are located at some considerable distance from the Urban centres and are generally scattered among the rural communities. Their animals are poorly managed, most of them are dual purpose animals. To them, milk is more or less a by-product of beef production. The little milk so obtained can barely meet the needs of the producer, hence very small amounts are sold. Feed inadequacy appears to be the most limiting factor influencing the productivity of the local cows. The only feed mostly available to them are coarse herbage of the savanna land during the rainy season. In the more northerly parts where the animals are reared the rainy season is limited to four or five months in a year. For the rest of the year the cow subsists on poor quality herbage and sometimes they have to trek long distances in search of food and water. Virtually no concentrate supplement is fed. Apart from the fact that the animals are always on the move, no form of shade is provided for them to rest. All these coupled with high incidence of disease infestations and the innate low genetic capacity of the local breed tend to limit the quantity of milk produced. There is also no well organised system of marketing even the small quantity of the milk produced.

The organised system consists of large-scale operations involving considerable investments in capital and labour. This system is only practised by the various state ministries of agriculture, experimental stations, government corporations, special FAO/UNICEF projects and university research stations. Because of better management, nutrition, breed specialization and genetic improvement, these animals produce more milk than those in the hands of the nomadic herdsmen.

The animals usually used by these stations include high-yielding exotic dairy breeds like the Friesians, the German Brown and the Jersey and some selected indigenous zebu cattle and their crosses with the exotic dairy breeds. The above-mentioned stations are usually near urban centres where the milk could easily be sold. However, these stations still produce far less than the amount required by the population. Therefore milk has to be imported. In 1934, 381.8 metric tons of milk at a cost of ₦42,000 was imported into the country (Federal Office of Statistics (F.O.S.) 1951). In the first nine months of 1970, a total of about ₦10.00m (ten million naira) worth of milk was imported (F.O.S. 1970). There has been a gradual increase of milk importation since then. In view of the need to conserve valuable foreign exchange and the nutritional importance of milk, it is no wonder that ten out of the former twelve states of Nigeria are planning to produce milk in the 3rd National Development Plan.

1.1.5 Some prospects of increasing milk production in Nigeria

With increasing tendency for mass importation of exotic cows for milk production in Nigeria basic research is needed to establish the nutrient requirements of these animals in their new environments for optimal performance. Also a genetical improvement involving: (i) breeding and selection for high milk production especially among the indigenous breeds, (ii) crossbreeding programme between exotic male and indigenous female animals, and (iii) mass importation of exotic male and female for production with attendant cost of importation, maintenance of high nutritional and health standards has to be embarked upon.

Another prospect of increasing milk production is to improve the nutritional level of the livestock. Oyenuga (1958) was optimistic that given adequate nutrition, it was possible for the indigenous breed to produce more milk than its present performance. Holmes, Reid, Maclusky and

Watson (1956) and Burt (1957) have also shown that the milk yield of cows could be increased considerably by proper feeding and good management.

1.2 LITERATURE REVIEW

1.2.1 Historical Background and Adaptation of the Ruminant

Palaeontologists the world over suggest that much of the evolution of ruminants as a separate branch of mammals occurred during prolonged dry periods of the earth's history (Houpt, 1969). It is likely that special modifications of digestive tract found in present-day ruminants were developed in response to such environmental pressures and that the ability to survive a long period of semi-starvation might be as a result of these adaptations. For instance, it is well recognised that ruminants are specially well adapted to survive and even thrive under environmental condition unfavourable to other large animals. Their ability to subsist under poor nutritional conditions is particularly noteworthy.

The ruminant stomach is a physiological adaptation for biochemical and nutritional purposes. The ruminant animals depend to a large extent and by nature on vegetable feeds for their energy supply. Because vegetable feeds generally have got low calorific values, the animals must consume a large volume of the feeds. This has given rise to a development of the gut into a four well-defined compartments viz: rumen, recticulum, omasum and abomasum which develop from embryonic stomach and not from the oesophagus. The rumen, reticulum and omasum are not glandular (Schmidt, 1971) and they represent the forestomach.

While young, it is usual to compare the ruminant stomach to that of monogastric animals. McCarthy and Kesler (1956) in their investigations on the young ruminant found that at birth, and for a short time afterwards, the calf relies on glucose for its major energy needs. Later, the glucose level in the blood begins to fall while the concentration of VFAs in the blood increases. Within a year the four compartments of the ruminant stomach attain their relative permanent sizes (Jacobson, 1963). This period however varies and depends on the feed given to the animal. Wardrop (1961), Godfrey (1961), Sutton, McGilliard and Jacobson (1963) observed that the forestomach epithelia developed rapidly to adult form when roughage was given to the calves. The rumen accounts for 80% of the capacity of adult ruminant (Sutton et al, 1963). The rumen has two sacs, dorsal and ventral, each is divided into anterior and posterior portions and communicating with the reticulum over the rumen - reticular fold. The reticulum is lined with a structure like a honeycomb and both its inlet and outlet are on its dorsal surface (Houpt, 1969). Because of their connection the two together are often referred to as the reticulo-rumen. Next comes the omasum with its many laminated folds and finally there is the abomasum or the true stomach, which is more tubular than in non-ruminants. From the point where the oesophagus opens into the rumen, Phillipson (1965) has pointed out that there is at the cardia the oesophaeal groove which runs to the opening between the reticulum and the omasum. While feeding, the drier and the more fibrous materials tend to collect in the dorsal sac and the posterior region (Craplet, 1963), while the fluids and small particles collect in the ventral sac, the anterior region and in the reticulum, there is gas above the solid and liquid materials.

Apart from this complex stomach, there is the phenomenon of rumination which has been developed as a further relation to the biochemical reactions taking place in the stomach in the ingested vegetable material. Rumination which is the 'chewing of curd' consists of a number of reflex actions namely, (i) regurgitation which is a sort of controlled vomitting and is peculiar to ruminant digestion (ii) remastication - a process which increases the surface area of the vegetable feeds simply by decreasing the particle size of feed (iii) reinsalivation and (iv) deglutition which is the reswallowing of the remasticated vegetable feeds (Tyler, 1964).

The most important nutrients needed in quantity by mammals are organic compounds which can supply carbon bond energy, water and nitrogen compounds. The greatest source of bond energy is the cellulose of plants and these are broken down in the rumen by the cellulases produced by the ruminal micro-organisms. Some ruminants which are subjected in their natural habitat to paucity of water have been shown to use special mechanisms to conserve body water. On the other hand, ruminants can also conserve body nitrogen or tap sources of nitrogen unavailable to other mammals. While the nitrogen content of mature vegetation falls drastically in dry season the cellulose content of the plant is still relatively high. In fact, there is some evidence that nitrogen or protein availability is the critical factor in the survival of some groups of ruminants subjected to natural starvation during dry season (Dasmann, 1956). In 1953, some observations put forward earlier were confirmed in camels in the Sahara on low-protein diets and evidence showed that this ruminant conserved body nitrogen and probably could utilize endogenous urea.

The protein in the vegetable feeds can be extensively degraded in the reticulo-rumen and this depends upon the physical condition and solubility of the protein. The products are usually amino acids which in turn yield ammonia and various fatty acids. These degraded products can be used to build up microbial protein. Some of the ammonia which is produced is absorbed into the blood stream and converted to urea (Mba, 1972). Some of this urea is secreted in the saliva and thus finds its way back to the reticulo-rumen. In most cases, it is used to build microbial protein. The utilization of urea is increased by increasing level of starch and inorganic sulphur and by a low level of total nitrogen in the ration (Loosli, Williams, Thomas, Ferris and Maynard, 1949; Lewis, 1974).

1.2.2 Ruminant feeds and feeding standards

After more than two centuries of concerted efforts, nutritional chemists are still striving to evolve more suitable methods to determine which among the numerous chemical substances present in the various natural foods are significant in animal physiological and biochemical processes in the body. It has long been shown that the animal body consists of water, fats and small amounts of carbohydrates largely in the form of glycogen. In addition small quantities of accessory growth substances, vitamins and hormones, are present in the body. The water, protein, carbohydrates, fats, minerals and vitamins are present in the feeds and are known as nutrients (Oyenuga, 1967). Feeding standards are tables or statements showing the amounts of these feed nutrients which should be provided in the rations of different species for different purposes such as growth, fattening and lactation. Feeding standards or nutrient requirements have been set at various levels at different times (Woodman, 1948; N.R.C., 1958, 1966; Evans, 1960; A.R.C., 1965; MAFF, 1975). These tables of requirements are used solely for conditions prevalent in the temperate countries. Energy requirements are based on either Starch Equivalent (SE) system (Kellner's net energy system), Total Digestible

Nutrient (TDN), Metabolizable Energy (M E) or the Scandinarian Feed Unit (FU).

The first two systems are assigned to individual feeds of constant nutritive values which are independent of the other ingredients of the diet, the amount of the diet which is given or the type of production the diet is designed to support (A.R.C., 1965). The ME system involves the estimation of the efficiency with which the energy is likely to be retained by the animal. Although the ME value of food is relatively constant for a particular specie of animal (Maynard and Loosli, 1969), the efficiency with which ME is utilized varies according to the purpose for which it is utilized by each animal. The NE system in the scientific rationing of the animals has an advantage over the ME in that it allows both energy requirements and feed value to be expressed in the same unit (Mba, 1972). The NE system is mostly used in the Commonwealth countries while the ME is used in the Western world, East European countries and Union of Soviet Socialist Republic.

All these systems have been criticized. For instance, Kessler and Spahr (1964) believed that high producing cows may require increased gross energy (GE) per unit of milk as a result of decreased digestibility of the diet when fed in sufficient amounts to support high milk production. Forbes, Fries, Braman and Kriss (1926) reported that ME provided in excess of maintenance is used for milk production and body weight increase at 98.5% and 76% respectively.

1.2.3 Feed Intake in Dairy Cows

A general pattern of feeding the dairy cow derived primarily from the feeding standards is for the animal to graze *ad libitum* and in addition to be given 0.45kg of concentrate for every litre of milk produced (Caro-Costas and Vincente-Chandler, 1969). The concentrate is assumed to be responsible for milk production. A number of investigators (Hodgson and Sweetman, 1947; Glover and Dougall, 1961) have called attention to the fact that feeding of forage alone can be used for both maintenance and production purposes especially when dairy cows are fed on good pasture.

Hodgson and Sweetman (1947) pointed out that milk production from good pasture in England and U.S.A. may be up to sixteen litres per day depending on amount of fat in the milk and apetite of the animal. Glover and Dougall

(1961) working in East Africa have got similar results. Aryshire of average apetite could give thirteen and half litres of milk at 4% fat; Jersey cow of 365kg liveweight and of average apetite could produce about nine litres of milk at 5% fat.

Reid (1956) referred to studies which showed that when roughage alone was fed at increasing levels, there was no decline in the TDN value. He compared this with maize silage containing maize grain in which there was a decline in TDN and also with mixed ration containing large proportion of concentrates in which the decline in TDN with increased levels of feeding was quite pronounced. Morrison (1961) showed that Jersey cows fed only on roughage produced an average of 2636kg milk and about 155kg butterfat per year in the U.S.A.. Caro-Costas and Vincente-Chandler (1969) also pointed out that a Holstein cow produced over 2730kg of milk in an 8-month lactation period on an all-grass ration in Pueto Rico.

So many factors have been shown to influence total roughage intake of cows. Some of these include feed, management, animal factor (breed of animal) and weather characteristic . Payne (1962) pointed out that high water content of feeds prevents sufficient high dry matter intake. Mather (1959) found out that type and quality of roughage, frequency of feeding and amount of grain offered may affect feed intake. Animal factors include the capacity of the cow which is referred to as 'effective capacity' since the maximum may be reduced by several factors; the desire of the animal to fill that capacity could be defined as the apetite. Effective capacity may be affected by the encroachment of fat, previous feeding history and the rate of digestion and passage of feed. Temperature and humidity particularly when at the extremes will also affect forage intake (Payne, 1962).

Glover and Dougall (1961), Rogerson, Ledger and Freeman (1968) observed that *Bos taurus* animals generally could consume more forage than *Bos indicus* cows. Also it has been shown that cows receiving no grain reached their peak consumption six weeks after calving whereas cows on medium and high grain did not reach their peak consumption until about the 9th week or later (Mather, 1959).

1.2.4 Importance of Supplementary Concentrate

A forage may be said to be adequate when it is supplied in such a quantity of high palatability and its per unit concentration of usable nutrients is also high enough to permit the animal to meet its nutritional requirements concurrent with the satiety bulk. At present most of Nigeria's pastures are uncultivated and unselected and they are unable to meet this definition. Again from the point of view of efficient animal production there is a limit to which the nutrient requirements can be supplied in the form of roughage.

It is pertinent to infer here that temperate grass forages are low in energy (Blaxter, 1964) and that tropical grass forages are slightly higher (Mba, Oke and Oyenuga, 1973). This is in fact the basis for the stomach modification in ruminant animals to cope with large volume of forage with low energy content. It is often shown that a good quality grass would provide crude protein for the production of up to 22.70 litres of milk but the energy content could not meet the requirements for maintenance and production of up to 13 litres of milk. (Mba, 1972).

A number of nutritionists have come out to support or oppose the use of supplementary concentrate.

Hancock (1953) supported the idea of supplementary concentrate with forage whereas MacLusky (1955), Seath, Dowden, Brown, Jacobson and Rust (1959) were of the opinion that supplementary concentrate feeding was uneconomic. Castle, Drysdale and Watson (1960), Castle (1964) also showed that it was uneconomic to feed supplements at the prices that feeds were being sold particularly if the cows were on good leafy pastures. Kresler and Sparh (1964) in a review of the effects of feeding various levels of concentrate on feed intake, milk production and composition concluded that although feeding high level of concentrate usually resulted in increased milk production especially with cows having high potentials of milk production, unlimited concentrate feeding did not always increase production.

It is now known that increased milk production is due to high energy content of the diet. In support of this concept, Elliot and Loosli (1959) fed diets in which the level of estimated net energy (ENE) intake above maintenance was held constant and showed that production of FCM was not different on diets containing 40, 60 or 80% of the ENE in the form of concentrates. Also a number of relatively recent studies have indicated that high concentrate feeding resulted in increased milk production whereas other workers have indicated no advantage in that respect.

Broster, Ridler and Foot (1958), Ronning (1960), Rook and Line (1961), Boyd and Mathew (1962), Murdock and Hodgson (1962), Bernett and Olson (1963), Bishop, Loosli, Trimberger and Turk (1963) and Rumery and Plum (1963) have expressed various opinions on the use of supplementary concentrate. It would appear that all of them agreed that in cases where supplementary concentrates was not necessary, the cows were on good pasture. Therefore in cases where there is no improved pasture as in this country, it is reasonable to suggest that feeding of supplementary concentrate is of paramount importance. Concluding from an experiment on the importance of supplementary concentrate, Hancock (1958) was of the opinion that pasture herbage was not a perfect diet for dairy cattle since concentrate are capable of giving a substantial lift in the milk yield when added to an *ad libitum* diet of high quality forage. It seems likely that this effect is due mainly to the fact that dairy cows are capable of consuming some concentrates even when they appear to have satisfied their apetite from pasture herbage because of high energy content of the concentrate. If this is true, it is obvious that one of the limiting factors to a maximum milk production grassland is the volume of grass with low energy content which cows can consume even of good quality material. Finally, Murdock (1967) has given reasons for the use of supplementary concentrate as to encourage milk ejection, supplement the quantity and quality of the grass, improve milk production, increase total nutrient intake and energy, expedite 'tie-up' of cows and serve as a source of varying the nutritional level of free-grazing cattle. It is therefore advisable that milking cows should be given a certain amount of concentrate supplement to forage eaten _ad libitum_ so as to increase total intake and digestibility of feed.

1.2.5. Effect of feed on ruminal volatile fatty acids

Barcroft, McAnally and Phillipson (1944) found that the energy available for maintenance and production of milk and body weight increases are derived largely from the end products of microbial fermentation in the rumen. Quantitatively the most important end-products of ruminant digestion are the steam volatile fatty acids (VFAs). Acetic, propionic and butyric acids form more than half of total energy supply of ruminants (Leng and Leonard, 1965; Warner, 1964; Rook and Storry, 1964). The mixture of acids produced in the rumen varies with the chemical composition and physical nature of the diet (Rook and Storry, 1964; Armstrong, 1968).

Donefer, Lloyd and Crampton (1963), Raymond, Hinders and Ward (1961) and Stanley, Morita and Ueyema (1964) showed that in supplemented feeds the acetic acid production was just over half of the total acid produced. The ratio of acetate to propionate was just over 2. In highly fibrous feeds more acetate was produced, level of propionate and perhaps that of butyrate fell. The ratio of acetate to propionate would be as high as 7 in a highly fibrous and unsaturated feed (Armstrong, 1964). With increasing maturity of pasture, animals tend to increase their feed intake and this increase causes a reduction in digestibility and increased feacal loss (Armstrong, 1964; Armstrong, Blaxter and Waite, 1964). In general, Balch and Rowland (1957) put the mean molar percentage of these acids which varied with the different diets as follows: acetic acid 40.6-73.7%, propionic acid 16.5 - 39.1%, butyric acid 6.6 - 13.9% and higher acids at 2.5 - 12.7%. Owing to the fact that the crude fibre content of tropical forages are usually high while the crude protein contents are generally low (Oyenuga, 1958) it is usual to get high acetate level in the rumen of the ruminants in the tropics. High crude fibre in the feed favour high acetate production (Adebanjo, 1972). Leng (1969) pointed out that while the crude protein of the temperate pastures was high, that of tropical pastures at the same age was extremely low. Although it has been shown that there was a negative correlation between crude fibre and crude protein contents of the pasture grasses, Oyenuga (1966) and Olubajo (1969) showed that with proper management, the crude protein content could be very much increased to support a rapid liveweight increase and perhaps milk production in the livestock as the crude fibre fraction was very highly digested.

Results from a considerable variety of feeds have been presented by Bath and Rook (1963, 1965) and Rook (1964). The general picture which emerged from these findings was that as the proportion of structural carbohydrate in the total feed decreased the proportion of acetic acid expressed as a molar percentage of total VFA would also decline (Armstrong, 1968). Where the depression in structural carbohydrate content in the total feed was due to the feeding of an increased proportion of cereal or cereal-based concentrate then the decline in the molar proportion of acetate might be associated with an increased concentration of propionate or of butyrate or of both. When flaked maize was fed, the decline in acetate was associated with a marked rise in propionate (Storry and Rook, 1966), whereas with barley, a compensatory increase in butyrate but little change in propionate was found (Donefer, Lloyd and Crampton 1962; Sutton and Johnson 1969; Iizuka and Yonemura, 1964). Increases in intake of roughages fed singly have little effect on the molar proportion of the acids present (Williams and Christian, 1957, Bath and Rook, 1963) but with hay-concentrate mixtures where the proportions were kept constant as intake rose there was evidence that the acetic to propionic acid ratio narrows when the plane of energy nutrition was increased by feeding an increased proportion of concentrates (Bath and Rook, 1963). The general effect was to narrow the ratio of acetic to propionic acid. The same effect was induced by grinding the roughage or by heat treatment of cereal before feeding (Balch, Broster, Rook and Tuck, 1965).

Mba (1973) working with different breeds of tropical goats have also concluded that those rations which tended to depress the molar concentrations of acetic acid in the rumen resulted also in the corresponding increase in propionic acid. He pointed out that the consumption of grass-legume mixture always resulted in the high concentration of the acetic acid in the rumen of the goats. Butyric acid did not follow any general pattern.

Armstrong and Blaxter (1957) working with sheep pointed out that the measurement of butyric acid in the rumen was complicated by the fact that it is actively metabolised by the rumen epithelia. It is well known that when a ruminant is abruptly changed from high forage to high carbohydrate concentrate, lactobacilli (lactate producing bacteria) rapidly increase in number and lactate accumulates in large amounts, pH is lowered, protozoa are inactivated and the animal may go off feed (Armstrong and Prescott, 1970).

When the change is gradual, lactobacilli multiply rapidly but so do lactate fermentors hence lactate does not accumulate and high levels of propionate are observed in the rumen fluid (Armstrong, 1968).

1.2.6 Absorption and Utilization of VFA

A considerable amount of effort has been devoted to the study of absorption of acetic, propionic and butyric acids from the rumen of the ruminants. The importance of this effort is justified when it is known that VFA is an energy source and the possible relationship between their absorption and the absorption or exchange of other substances across the rumen wall. The early studies of Barcroft (1944) showed that most of the VFA produced in the sheep rumen was directly absorbed from its contents. It was also found that butyric, propionic and acetic acids were the principal acids present (Elsden, 1945; El-Shazly, 1952; Warner, 1964; Leng and Leonard, 1965; Armstrong, 1968) and that these were absorbed from the rumen at a rate which increased with chain length. Danielli, Hitschcock, Marshall and Phillipson (1945) showed that the increased absorption of VFA from rumen was associated with a decrease in the pH of rumen contents. They also demonstrated greater permeability of the tissues to the undissociated form of the acids.

At a slightly alkaline pH the absorption of a mixture of the three acids was accompanied by accumulation within the rumen of one equivalent of bicarbonate ion (HCO_3) per two equivalents of VFA absorbed. It was shown by Stevens (1969) that lowering the pH of the rumen bath from 7.4 to 6.4 increased the rate of absorption of all the three acids and resulted in a slight increase in acetate transport, a two-fold increase in propionate and a four-fold increase in butyrate transport was due to increased absorption with no increase in the rate of metabolism to ketone bodies.

In effect, it has been established that the fatty acids produced by fermentation are directly absorbed into the blood stream from the reticulo-rumen. Acetate and butyrate are lypogenic whereas propionate is glycogenic (Armstrong, 1957; Maynard and Loosli, 1969). Both acetate and butyrate are rapidly metabolised and serve the energy needs of the body. Both can enter the metabolic cycle of fat and thus form body fat. Acetate can be utilized by the mammary gland to form the short-chain fatty acids of milk (Armstrong, 1968). It is also utilized in the tricarboxylic acid (TCA) cycle in the same mechanism by which the end-products of carbohydrate and protein are metabolised to furnish energy (Barcroft *et al*; 1944).

1.2.7. Ammonia absorption and utilization in the rumen

It has been established that ammonia is absorbed from the rumen carried from blood in the portal vein to the liver where it is converted to urea which is subsequently excreted in the urine. Level of ammonia in the rumen is highly correlated positively with level of ammonia in the portal vein. Estimates of ammonia absorption from sheep rumen ranges from 4-13g per day (Mba, 1972). The rate of absorption depends on the pH of the rumen, being much more absorbed in the unionised form (Mba, 1972). Houpt (1969) pointed out that the lowering of the rumen pH by a soluble carbohydrate fermented would decrease the rate of absorption because ammonia is rapidly absorbed in an unionised form at neutral or alkaline pH. Therefore this could explain the nitrogen retention observed when large amount of carbohydrate in addition to nitrogen source is fed to ruminants. The nitrogen is quickly converted to ruminal ammonium ion which remains long enough in the rumen to be utilized for microbial protein synthesis. Ammonia is a weak base with a pKa in the vicinity of 8.80 - 9.15. An increase in pH near neutral or alkaline level causes the NH_4^+ ion to be converted to NH_3 which is rapidly absorbed (Hogan, 1961). The level of blood urea has been shown to be a good index of protein utilization (Preston, Schnakenberg and Pfander, 1965). Under some circumstances when the rate of absorption of ammonia from the rumen is high, toxic effects are associated with blood level of urea and ammonia (Lewis, 1975). The clinical symptoms observed are changes in electrolyte balance, ammonium carbamate formation in the rumen and disturbance of the acid-base status.

Also, at high ammonia concentrations, some ammonia could pass into the systemic circulation. It has been suggested that a hepatic ammonia threshold exists in the sheep and that if this threshold is exceeded, the liver can no more cope with the high level of ammonia brought to it and therefore the ammonia concentration in the peripheral blood rises sharply (Houpt and Houpt, 1968). Carroll and Hungate (1954) have shown that when ammonium acetate was used to induce varying levels of ruminal ammonia, no significant changes in arterial ammonia concentration took place until the portal blood contained about 0.8m - mole NH_3 per litre of blood. Above this level, it was shown that the arterial blood ammonia concentration increases at almost the same rate as the portal blood. When the arterial ammonia concentration reached 0.4 to 0.5m - mole NH_3 per litre, respiratory difficulties arose in the animals, and beyond this, death occurred probably due to a disturbance in acid-base equilibrium caused by excessive NH_4^+ ions. Acid administration usually prevents urea toxicity by preventing ammonia-carbamate formation. A high rate of absorption of ammonia from the rumen is certainly a great disadvantage as neither ammonia nor urea can be utilized for essential amino acid synthesis. It is estimated that the amount of ammonia carried to the liver per day is about 14g (Packett and Groves, 1965). Even if a portion of this is returned to the rumen via the saliva and through the rumen epithelia as urea, the nitrogen loss still represents an appreaciable proportion of the total nitrogen intake (Houpt and Houpt, 1968).

On a low dietary nitrogen intake, the addition through the rumen from the blood would be very considerable. This urea recycling is of considerable importance to the animal under conditions where nitrogen is in short supply as it could act greatly on the animal chances of survival under such adverse conditions (Lewis, 1975).

1.2.8 Chemistry of milk constituents

The nutritive value of milk depends on its composition which in turn is influenced by several factors. Milk is in three physical stages, viz., solution, emulsion and colloidal suspension (Markley, 1960). These are so intimately associated that changes in any of the three are bound to have profound effects on one or both of the others. Numerous substances like phospholipids, steroids, carotenoids and fat soluble vitamins are dissolved in the fat or held at the fat globule surface (Kon and Cowie, 1961). The aqueous solution holds in solution lactose, water soluble vitamins and some of the minerals. Proteins and the other minerals are held in colloidal suspension (Kon and Cowie, 1961).

Milk Protein

Kon and Cowie (1961) classified milk protein into two parts, casein and the milk serum protein. The milk serum protein was subdivided into the heat-stable and heat-labile fraction. The former consisted of proteose - peptone while the latter consisted of albumin and globulin. Casein is the predominant protein of milk, making up to 80% of the total protein fraction of milk. Casein exists in milk as a colloidal suspension containing calcium both bound to the protein molecule and associated with it as tricalcium phosphate. Mellander (1939) classified casein into three components, viz; α, β, and γ in the proportion of 75, 22 and 3% respectively and in decreasing order of mobility. However, Cherbuliez and Baudet (1950) claimed to have separated a fourth component, δ -casein which is a proteose (a substance found after casein is treated with rennet). The respective proportions of the four casein components was then given as α (60%), β (25%), γ (10%) and δ (5%).

The milk serum protein are denatured when milk is boiled but no precipitate takes place until the pH of 4.6 is reached when they are co-precipitated with casein. The proteose - peptone forms one of the largest part of milk serum protein. It makes up about 6-10% of the total milk protein. It is heat-stable (Kon and Cowie, 1961);

The classical proteose-peptone fraction of milk consists of soluble proteins not precipitated by heat (95^{0}C, for thirty minutes) at pH of 4.6 but precipitated by 8-12% trichloroacetic acid and accounts for about 24%

of the whey proteins (Kon and Cowie, 1961). Larson and Rolleri (1955) employing the Tiselius electrophoretic technique observed discernible gradient boundaries in the filtrate from acid-precipitated, heated skim-milk which they attributed to the proteose-peptone fraction. These electrophoretic boundaries were designated as serum components 3, 5 and 8 in ascending order of electrophoretic mobility. It has been demonstrated by Kolar and Brunner (1969) that components 5 and 8 appeared to be ubiquitously distributed within the protein system whereas component 3 was restricted to the serum fraction and was thought to be a blood serum.

The albumin consists of α - lactalbumin, β - lactoglobulin and serum albumin while the globulin (immune globulin) consists of euglobulin and pseudo-globulin. The β - lactoglobulin constitutes the major portion of the milk serum protein (Mba, 1972). It is of special interest as being the main source of sulphydryl groups which are liberated when milk is heated. β - lactoglobulin may be crystallised from the conventional albumin fraction subjected to prolonged dialyses at pH 5.2 (Markley, 1960). Aschaffenberg and Drewry (1955) discovered that there are two fractions of β - lactoglobulin namely β_1 and β_2 but they later found out that the capacity to produce the different types of β - lactoglobulin was genetically controlled, both fractions became known as β - lactoglobulin A and B. Experiments showed that β- lactoglobulin B was denatured at a more rapid rate than β - lactoglobulin A (Aschaffenberg and Drewry, 1955).

Although not identical with the albumin of blood serum , lactalbumin resembles it closely in amino acid composition. It contains approximately two and a half times as much sulphur as does casein. It contains no free sulphydryl groups though its cystein content is high. It contains 7% tryptophan. The serum albumin of milk is the same as blood serum albumin and has probably got into milk by direct infiltration from the blood (Kon and Cowie, 1961).

The globulin fraction otherwise referred to as the immune globulins are present in ordinary milk in small concentration but occur in much larger amounts in colostrum (Schmidt, 1974). They are of extreme importance to the new-born. Crowther and Riastrick (1916) described two fractions of immune globulins - the euglobulin which is insoluble in water and pseudoglobulin which is soluble in water. Both globulins do not however differ too much in their physical properties as well as in chemical composition. They both contain 2.5 - 3% hexose and 1.3% hexosamine (Crowther and Riastrick, 1916).

Carbohydrates

Lactose, (a disaccharide, known as glucose -4- β galactoside) is the most abundant carbohydrate of milk. Glucose, another milk carbohydrate, appears in trace amounts (Kirchgessner, Friesecke and Koch, 1967). Lactose is peculiar to, or characteristic of, milk and exists in α and β forms, with 1 part of α to 1.65 parts of β. The α-form is more active than the β- form. The α and β forms have specific rotation of +89.4 and +35.0 respectively. The osmotic pressure of milk is essentially the same as that of blood and this is maintained by concentrations of lactose and mineral matter such as k, Na, cl. The lactose together with these salts are responsible, to the extent, of 75% of the osmotic pressure of the milk.

The aqueous solution of lactose reduces Fehling's solution and ammonium nitrate solution and the reducing power increases when in aqueous solution. It is soluble in alcohol or ether and dissolves in hot acetic acid (Mba, 1972)

Milk oxidation results in the conversion of -CHO group into the corresponding -COOH group. When heated to between 110 - 130^{o}C, the lactose hydrate looses its water of crystallisation, above 150^{o}C it turns yellow and at 175^{o}C it turns very brown called the lacto-caramel (Herrington, 1948).

Milk lactose is readily attacked by various organisms in milk particularly the lactic acid bacteria (lactobacilli). The faintly sweet taste of raw milk changes gradually to a more stringent flavour with characteristic odour of souring milk. The favourable temperature condition is at 37^{o}C when about 1% of the lactic acid is produced (Kon and Cowie, 1961). Suffice it to say that lactose is easily broken down by fermentation to lactic acid

$$\underset{\text{lactose}}{2C_6H_{12}O6} \longrightarrow \underset{\text{lactic acid}}{4CH_3CHOHCOOH}$$

During the conversion of lactose to lactic acid, various byproducts are produced including carbon dioxide, acetyl methyl - carbinol, diacetyl and butyric acids (Markley, 1960). The last two acids produce powerful odours. The nature and quantity of the bi-products are determined by the type of bacteria. The production of lactic acid has been shown to affect casein and mineral matter (Jordan and Lohr, 1962). With increase in the quantity of lactic acid more and more calcium is removed from casein to form calcium lactate (Markley, 1960), some of the colloidal calcium-phosphorus is converted to calcium-hydrogen-phosphate. Thus the physical equilibrium between the soluble and colloidal condition is considerably altered with the resulting increase in osmotic pressure and corresponding decrease in the freezing point of the sample (Markley, 1960).

Commercially, lactic acid may be produced by controlled fermentation of lactose in whey resulting in calcium-lactate (Kon and Cowie, 1961) from which pure lactic acid or lactic esters could be obtained. These substances may serve as raw materials for industries in the making of plastics, resin, textiles and pure chemicals. It could also be fermented to butyric acid, carbon dioxide and hydrogen. Lactose is also used for the preparation of infant and invalid food (Rook and Storry, 1964). It is an important source of galactose which itself is an important constituent of cerebroside of brain and nerve tissues. Lactose has been shown to be important in the manufacture of penicillin. Much studies are still required to elucidate the problem of lactose utilization. It is now known that galactose need not be an essential constituent of the diet as lactose is very easily converted to glucose. In congenital galactosaemia, infants are unable to metabolise galactose due to lack of galactose - 1 - phosphate uridyl transferase. The feeding of diets free of lactose and galactose is a good remedy in this instance. The feeding to rats and chicks of diets containg 40% or more lactose results in the paralysis of hind limbs (rats) and nervous disorder (chicks) (Jordan and Lohr, 1962)

All the other carbohydrates of milk occur in small quantities and may be present in the free or bound state with protein or lipids.

Milk Fat

The esters of glycerol and fatty acids are often referred to as fats and oils. The former are usually solids and the latter are liquids at room temperature. The group of compounds designated as fatty acids were so called because they were originally found to be constituents of animal and vegetable fats and fatty oils. (Markley, 1960).

The physical properties of cow's milk fat consists of its melting point at 28°C but not completely until the temperature has reached 33°C. The liquid sets over a similar but lower temperature ranging from 24°C to 19°C. As secreted, the fat globules are therefore liquid. Because of variation in the composition of milk fat, there are slight differences from sample to sample in specific gravity,ranging from 0.936 to 0.946 at 15°C. Refractive index is between 1.458 and 1.464 at 15°C. Biochemically, the bulk of fat is constituted by the true fats - glycerides of numerous saturated and unsaturated fatty acids. As pointed out by Kon and Cowie (1961), and Folley (1956), the three hydroxyl groups of glycerol may be replaced by the same fatty acids or by two or three different fatty acids. It has been calculated that at least 4,913 glycerides are possible in milk fat contained in a pint of milk (Kon and Cowie, 1961). The fatty acids of milk fat fall into well-defined groups.

Saturated fatty acids contain even numbers of carbon atoms ranging from butyric acid C_4 to eisosanoic acid C_{20}. The major components is palmitic acid or n-heptadecanoic acid (C_{16}:0) (Mba, 1972). In milk saturated fatty acids the following are present:

(a) Normal saturated acids with odd numbered carbons e.g. n-pentadecanoic and n-heptadecanoic acids predominate. This accounts for about 2% of the total fatty acids.

(b) Methyl-branced-chain saturated fatty acids with odd and even numbers of carbon atoms.

These also account for about 2%. Considering the proportion of saturated fatty acids, that of ruminants differ sharply from that of other species. The difference is also clear in its component fatty acids. For instance, human milk fat has only traces of acids below decanoic i.e. capric acid (C_{10}:0). As pointed out by Kon and Cowie (1961) with ruminant fatty acids, there is an appreciable quantity of butyric acid (C_4:0) whereas very small quantity is present in the cow's milk; that of cow is also substantial. The proportion of palmitic acid (C_{16}:0) in milk fat is fairly constant in both ruminants and non-ruminants except in the horse where it is low.

As pointed out by Smith and Jack (1954), Kon and Cowie (1961) and Riel (1963), the saturated fatty acids above C_8:0 (caprylic or octanoic acid), are solid at ordinary temperature and the unsaturated ones are predominantly liquid. This property determines some of the characteristic physical properties of milk fat such as hardness and melting point. The unsaturated fatty acid consists of:

(a) The monoethenoid acids, the most abundant being oleic acid (C_{18}:1).

(b) Diethenoid acids are mostly the C_{18} series, e.g. the linoleic acid (C_{18}:2) with double bonds.

(c) Triethenoid acids - linolenic acid has been identified as the main component of the C_{18} triethenoid acid fraction. It is an essential fatty acid (that which cannot be synthesised at sufficient rate to meet the needs of the body). The linolenic acid content of the mare is exceptionally high.

(d) Polyethenoid acid - probably arachidonic acid is a member. It is also an essential fatty acid. Traces of C_{20}:0 and C_{22}:0 have been detected in cow's milk fat. Molecular structures of these groups of acids for the cow's milk fat have been fpund by the use of ultraviolet spectroscopy.

Associated with the milk fat are the phospholipids. It is concentrated in the fat globule membrane.. It is about 1% in the cow's milk fat. The major components are lecithin, cephalin and a small amount of sphingomyelin and closely related cerebrosides. Kon and Cowie (1961) pointed out that the phospholipids are excellent emulsifying agents since they have both lipophylic and hydrophylic groups. The phospholipids of milk fat are prone to oxidation because of the notable proportions of highly unsaturated fatty acids and are believed to be responsible for initiating the changes leading to the development of oxidative taints in milk. Also associated with milk fat are the sterols which consists of the cholesterols. Cholesterols are present in milk fat to the extent of 0.014%. It is an invariable components of milk (Kon and Cowie, 1961). The percentage is however higher in women, goats, mares, ewes and sows. The other sterols are associated with ultraviolet irradiation (Markley, 1960).

Minerals and Vitamins in milk

By the mineral constituents in milk are meant those which contain only inorganic elements in their molecules or ions. The ash of milk is obtained as whitish grey powder when the liquid is evaporated and the residue incinerated in a muffle furnace at 400-500^{o}C until it turns whitish grey. The ash content is basic. The minerals in milk can be broadly subdivided into trace and major elements depending on their concentrations. The members of the former group exist is relatively smaller concentrations in milk than the latter.

The major elements in milk ash are calcium, phosphorus, magnesium, potassium, chloride, sulphur. The contents of each element is largely determined by genetic factors. This is to say that milk content of the major elements will remain constant even when the supply of individual elements and the animals requirements are very different. Where the supply is inadequate, a certain proportion of the skeletal reserves is mobilized and the concentration of the mineral in milk is thus maintained (Wright and Pappish, 1929). Even when there is extreme defficiency of one or more elements the mineral matter per volume of milk remains constant, though the milk yield will fall and with it the total secretion of mineral substances to strike a balance in the concentration. Colostrum (the first milk after parturition) contains all the major elements except potassium in higher concentrations than normal milk, and remain more or less unchanged for the greater part of the lactation period (Schmidt, 1974). It is only towards the end of lactation that some alterations occur in concentration of some of the major elements.

The trace elements consist of iron, copper manganese, aluminium. It is noteworthy that minerals of milk originate from the feeds of the lactating animal or from body stores particularly the skeletal tissues.

The vitamins can be classified into two groups - the fat and water soluble groups. Except Vit. K, the fat soluble vitamins (A,D,E) cannot be synthesised in the rumen by the microorganisms. Vit. A content of milk is positively correlated with the carotene content of feed. Fresh pasture yields milk highest in Vit. A content, followed by well preserved silage, then by hay, especially if dried by rapid-drying method (Hilton, Hange and Wilbur, 1935). Loosli (1974) demonstrated that the concentration of tocopherol in the milk fat was directly related to the Vit. E content of the ration. Tocopherol is a pale, yellow, viscous oil. It is fat soluble, dissolves readily in presence of alkali but stable in acid, to heat and alkali in absence of oxidising agents. Loosli (1949) put the requirement of tocopherol for animals as 0.23 - 0.31mg. The two forms of Vit. D which are of importance in nutrition are ergocalciferol (Vit. D_2) and 7-dehydrocholesterol (Vit. D_3). Though Vit. D molecules are fairly stable, they may be destroyed through oxidation on exposure to oxygen and at high temperature. They are much more stable to oxidation than Vit. A. Vit. D_2 melts at 114-117^{0}C while Vit. D_3 melts at 84-85^{0}C. Vit. D is fat-soluble and therefore it is present in the fat portion of milk. The vitamin D of milk varies with the Vit. D content of the feed.

Vitamin C (ascorbic acid) which is water-soluble is a white crystalline odourless substance with sour taste. It melts at 190-192^{0}C. It is soluble in organic solvent. Ascorbic acid exists in two biological forms - the L-ascorbic acid (the more stable reduced form) and the oxidised form dehydro-ascorbic acid. Thiamine(Vit. B_1) has been shown to be soluble in 70% alcohol as well as water and is readily destroyed by heat unless the pH is low. Thiamine is readily oxidised and has a melting point between 248-250^{0}C (West, Todd, Mason and Bruggen, 1970).

1.2.9 Effect of diet on milk yield and composition

Rook and Storry (1964) observed that acetic, propionic and butyric acids produced from feeds within the rumen together accounted for 70% of the energy absorbed from the ruminant digestive tract and that the mixture of acids produced in the rumen varies with the chemical composition and physical nature of the diet. In the milking cow, the continous infusion of individual volatile fatty acids into the rumen have elucidated the effect of different diets on milk yield and composition (Rook and Balch, 1961; Rook, Balch and Johnson, 1965; Storry and Rook, 1966). Further studies have revealed that infusion of acetic acid into the rumen increased milk yield and also had a specific increase on fat content while propionic acid had no effect on milk yield but decreased milk fat content and increased milk protein (Armstrong, 1968; Rook and Balch, 1961; Rook, <u>et al</u> 1965). Butyric acid is lipogenic and therefore increases milk content (Armstrong, 1968). This increase was associated with increased yields of C_4-C_{16} acids and decreased yields of stearic and oleic acids. Suffice it to say that an alteration in the end-products of rumen digestion may not only change the overall efficiency of utilization of dietary energy but also may increase one productive process at the expense of another (Rook and Storry, 1964).

Milk fat content

Fine grinding of the entire roughage in a ration or considerable reduction in roughage intake and an increase in the concentrate feed reduced the percentage and yield of fat without affecting the yield of milk (Balch et al, 1965). Furthermore, this phenomenon has been shown by Balch et al (1965) to occur also with cows on diets of kale, concentrates and small quantities of roughage and also with animals grazing on young herbage especially when supplemented with concentrate. Storry and Rook (1966) examined the effects of diets low in hay and high in flaked maize on the secretion and composition of milk fat. In the studies, the change from a normal hay-concentrate ration to the one low in hay and high in flaked maize resulted in a marked fall in milk fat content. The change from a diet high in hay to one low in hay was reflected in the rumen by a marked fall in the proportion of acetate, increase in that of propionate and little change in that of buyrate. Lactic acid increased appreciably. Abrupt re-introduction of the normal hay-concentrate ration resulted in the return of the proportion of acids in the rumen liquour to their original levels within four days although milk fat recovery took some two to three weeks (Storry and Rook, 1966).

The fall in milk fat is usually associated with an increase in the iodine value and a decrease in the Reichert - Meissl value indicating that the proportion of the unsaturated acids are increased and those of the lower VFA are decreased (Armstrong, 1968). King and Hemken (1962) demonstrated a reduction in the yield of all fatty acids from lauric up to and including $C_{18}0$ and $C_{18}1$. The most marked reductions did occur in C_{12}, C_{14}, C_{16}, and $C_{18}0$.

Milk Protein content

Response of milk protein to change of feed is not immediate and a period of 2-3 weeks is required before the full effect is observed (Rook and Storry, 1964). For a given increment of additional food,(in terms of starch energy) the increase in protein content is more marked at low than at high levels of feeding (Rook and Storry, 1964) and also when the addition is given in the form of flaked maize than as barley or as roughages such as hay or silage. This is also to say that protein content of milk increases as energy level is raised, the changes being more marked at low levels of energy than at high (Kirchgessner *et al*, 1967). The maximum variation in protein content due to variations in feeding is about 0.3 - 0.4% units that is 10-15% of the average protein content of milk (Rook and Storry, 1964). Wide variations in the level of protein feeding from 70-150% of the standard of Woodman (1948) did not however affect milk protein content (Olaloku, 1972).

In comparison with the other feeds, the feeding of flaked (cooked) maize characteristically favours production of propionic acid compared with other acids. In conformation with the apparent association between the ruminal production of propionic acid and milk protein synthesis, the intraruminal infusion of propionate in milking cows gave a specific increase in milk protein content without change in milk yield (Armstrong, 1968). Rook and Balch (1961) showed that intraruminal infusion of acetate and butyrate were without measurable effect on milk protein content.

On absorption from the rumen, propionate is metabolised in the liver and only small quantities are present in the peripheral blood (Lewis, Hill and Annison, 1957). It is unlikely therefore that propionate is directly involved in the synthesis of milk protein in the mammary gland. It has been suggested by Rook (1959) that the supply of propionate absorbed from the rumen may through the intermediary of the Kreb's cycle affect the overall degradation and synthesis of amino-acids in the liver and hence the concentration in the plasma of non-essential amino acids. In turn the plasma amino acids level might influence protein synthesis. The intraruminal infusion of propionic acid in some lactating cows have been shown to induce significant increase in blood plasma glutamic acid which is the major amino acid of milk protein and decrease in valine, isoleucine, leucine and tyrosine(Halfpenny, Rook and Smith, 1969).

Solids-not-fat (SNF) content of milk.

There is enough evidence (Rook and Line, 1961; Armstrong, 1968) that the three-carbon acids induce significant changes in SNF and casein contents of the milk. Rook *et al* (1965) observed that the intraruminal infusion of acetic acid did increase milk yield but has no effect on SNF. Rook and Line (1961) demonstrated that SNF content of the milk rose with the level of energy fed and the changes were almost accounted for by changes in content of casein, α - lactalbumin and β -lactoglobulin. Considerable reductions in the amount of physically fibrous constituents in the diet induced marked fall in milk fat content with little effect on milk yield or SNF content (Armstrong, 1968).

Milk lactose content

Underfeeding in the cow causes a depression in the lactose content of milk (Rowland, 1946) and more marked changes are observed during starvation particularly at the terminal stages (Robertson, Paver, Barden and Marr, 1960). A specific depression in milk lactose synthesis, with a corresponding fall in milk yield but a compensating increase in fat and protein content has been observed in milking cows (Storry and Rook, 1962) following the intraruminal infusion of massive amounts of butyric acid. This effect was attributed by Storry and Rook (1962) to a marked reduction in blood glucose concentration restricting lactose synthesis through a reduction in the supply of precausor glucose.

Lactose synthesis apparently is not affected by variations in the concentration of blood glucose over the normal range for milking cows of about 40mg/100ml. The dependence of the isolated perfused mammary gland of the goat on a supply of glucose for the synthesis of of lactose and maintenance of milk secretion was demonstrated by Harwick, Linzell and Price (1961).

Mineral and Vitamin Contents of Milk

Holmes, Arnold and Provan (1960), Castle, Drysdale and Waite (1961), Rook and Line (1961) showed that with increase in plane of energy nutrition there was increase in mineral content. Huber and Boman (1966) have also reported an increase in mineral-lactose fraction as energy is increased. Haenlein (1963) called attention to the possibility that vitamin and mineral requirements of dairy cows might change when dietary ratio of grain to forage was increased. Possible reasons adduced by the author included a change in pattern of rumen fermentation, a change in rate of passage, the reduced supply of certain vitamins and mineral from forages and newer concepts of vitamins and mineral metabolism. Halfpenny, Rook and Smith (1969) had shown that if carotene was limiting in the feed, there would be a low vitamin A in milk since carotene is a precausor of Vit. A in the mammary gland. Vit. K and B_{12} have been shown to be synthesised in the rumen. Finally, Coppock, Flatt and Moore (1964) pointed out that it was possible that vitamins and minerals especially trace elements might be important when concentrates make up a large part of the diet.

1.3 General Objectives

Cognizant of the fact that before systematic computations of rations for livestock could be embarked upon, basic research is needed to ascertain the nutritional requirements for maintenance and production under tropical conditions, it is the aim of this investigation to embark upon a comparative performance of the indigenous (Zebu) cows and exotic, temperate breeds of cattle in tropical environments as it affects:

(a) energy and protein requirements for maintenance and milk production

and (b) relationship between rumen metabolites and milk constituents.

The aim was also to study the effect of seasons of the year on feed intake, milk yield and composition.

CHAPTER 2

A COMPARATIVE STUDY ON THE EFFECT OF GRAZING AND STALL-FEEDING ON THE FEED INTAKE, MILK YIELD AND COMPOSITION OF THE GERMAN BROWN AND FRIESIAN COWS

2.1 INTRODUCTION

Some investigators including Huffman (1959), Stone (1959), Arnon (1960), Watson and Runcie (1960), Greenhalgh and Runcie (1962) have carried out comparative studies on the effects of strip-and zero-grazing on the milk yield and composition of lactating cows. Results and opinion, however, differ. While some investigators concluded that green-soiling reduces wastage of herbage caused by selective grazing, trampling and fouling and therefore increases milk production per acre, improves yield per cow because animals were kept in shades (Stone, 1959) particularly in a hot tropical environments and also conserves energy which grazing animals should have expended for seeking and harvesting their feeds, others agreed that strip-grazing was better because the quality of the herbage eaten by the stall-fed animals might be inferior since they have less opportunity for selecting their feeds (Baker, Richards, Haenlein and Weaver, 1960).

The performances of the exotic animals under tropical humid environments are very little known. It was therefore the purpose of the present experiment to investigate which of the systems is better suited to the tropical environments, particularly for the management of the newly imported German Brown and Friesian cows for increased milk production.

2.2 MATERIALS AND METHODS

2.2.1 Animals and their Management

Experimental Animals

A total of 16 exotic dairy cows consisting of 8 German Brown and 8 Friesian cows were used for the experiment. They weighed between 302 and 443kg and were in their first and second periods of lactation. The experiment commenced when the cows were at their peak of lactation (about six weeks after calving) as observed by Lucas (1960).

The German Brown

The German Brown (Plate 2.1) which is the indigenous Allgau breed originated from Wurttemburg and Bavaria divisions in Southern Germany. It has now been upgraded to the Brown Swiss, and until now resembles and is closely identical with the Brown Swiss breed.

The German Brown cattle has a soft, short and grayish-brown coloured coat. The colour of the hair around the muzzle is a bit lighter, with the tongue being grayish and the hard wearing hooves dark in colour with a strongly built body and nicely sprung ribs, the animal has a good proportional development.

Originally, the German Brown cattle was developed for milking and working abilities but like the Brown Swiss, it is now generally recognised for beef and milk abilities (Oti, 1966). F.A.O. (1966) put the liveweight of the animals at maturity as about 925kg for a bull, and 550kg for a cow. Heights at withers are 137cm for males and 129cm for females. The age of heifers at first calving is between 30 and 33 months (F.A.O. 1966). The weights at birth are 38kg for male and 35kg for female. The animals are active and reasonably docile. The cows have well-developed udders. Oti (1966) recorded a milk yield of 8,574kg containing 4.76% butterfat. F.A.O. (1966) recorded an 8-year average of 6,099kg milk with 4.50% butterfat.

The first batch of German Brown cattle at the Ibadan University Teaching and Research Farm were obtained from the Federal Republic of Germany. Twenty of them arrived at Ibadan in May, 1973. Some of the foundation cattle have

Plate 2.1 German Brown, White Fulani and Friesian cows grazing on the paddock.

died owing to heart-water disease, difficult calving and the outbreak of 'foot and mouth' diseasebetween August and November, 1973. As at mid-1975, there were 37 cows, 4 bulls and 12 crosses. Since the outbreak of heart-water disease in 1973, the cattle have been sprayed regularly with acaricide.

The cows and bulls used throughout this investigation were offspring of the two batches of importation.

The Friesian

The Friesian cattle (Plate 2.1) has a short, black and white hair with a soft pliable fairly thick skin. A typical Friesian is black and white in colour, the amount of black and white varying from white with a few black spots to almost black. In most cases, the black colour predominates. The body is deep, with well-sprung ribs, large abdomen and shoulders. Both the back and the hind quarters are level, long and wide and the thighs deep, straight and fairly well-filled. The head is long, narrow and straight. Not all of them have horns but when available they taper to a dark tip and pass outward from the poll forward and inward but not upward.

It is usually used as milk breed because of its high milking ability. The standard average body weight of the cows at maturity is about 567kg. They are ruggedly built with a strong constitution. Friesian calves weigh an average of about 45kg at birth and they are usually very strong, large and vigorous (Adeneye, 1972).

The cow has a well-developed strongly attached udder and by all standards a heavy producer of milk. Generally, the milk has lower butterfat and protein contents (4% and 3.1% respectively).

The first set of 15 Friesian cattle which arrived at Ibadan University Teaching and Research Farm in May 1971 were obtained from the Federal Republic of Germany. The second batch of 15 animals arrived at Ibadan in May 1973. Owing to the outbreak of 'foot and mouth' disease towards the end of that year, a number of them and the calves of the first batch died. By the middle of 1975, there were about 29 cows and 9 bulls some of which were used for this investigation.

2.2.2 Management and Health of the animals

The animals were always fed supplementary concentrate twice a day at 5.30 a.m. and 2.30 p.m. during milking. They were fed on Cynodon nlemfuensis var. nlemfuensis thrice daily. The cows used for lactation studies were housed in a large well-ventilated byre spaciously partitioned into twenty-four compartments constructed with wooden planks and teak poles.

The concrete floor of the byre was properly scrubbed once daily and washed clean. Wood-shavings were then spread on the floor of the compartments. The shavings were also disposed off every morning. The wood-shavings, apart from serving as beddings, also prevented sliding of the animals. The animals were washed clean and neat with soap fortnightly. They were allowed a two-hour exercise everyday in bare paddocks adjacent to their byre. They were also allowed free access to cool water.

All the animals were sprayed regularly with acaricide against tick infestation. Occasionally, blood samples were taken by the veterinary surgeons from all the animals for pathological examination.

2.2.3 Diets and plan of the experiment

The cows were maintained on Cynodon nlemfuensis var nlemfuensis (Cynodon IB.8) throughout these experiments. The forage was fed fresh to the animals in the stall while those grazed were left on the grazing paddock. The stocking rate was ten cows per hectare.

The Ibadan University Teaching and Research Farm, in which the experiments were conducted, is situated in the low-land rainforest vegetational zone which enjoys a two-peaked rainfall pattern with dry season varying between 3 and 5 months (November - March) (Keay, 1959). Cynodon IB8 grows luxuriantly during this rainy season, especially between April and October. The pasture which covers an area of about two hectares established in the 1969/70 session was used throughout the period of this investigation. Some chopped samples of the grass were taken at each feeding and dried daily in forced - draught oven at 105°C to estimate dry matter intake. The dried samples were then bulked weekly, ground with Christy and Norris mill to pass through 2mm sieve and stored in air-tight jars until required for analysis.

The concentrate mixture fed to the cows was compounded from maize meal, groundnut cake, palm kernel meal, rice bran and mineral and vitamin mixture (microzone); the components of the concentrate are shown in Table 2.1. They were mixed at the University Farm Feed Mill and served in the form of dried meal. Grab samples were always taken at each meal and stored until required for analysis.

Plan of the Experiment.

The sixteen experimental cows were divided into two groups. Each group comprised four sub-groups each of which consisted of two Friesian and two German Brown cows. Table 2.4 shows the feeding arrangements of the cows with their identification numbers. Table 2.5

Table 2.1.

Components of dairy concentrate ration fed to German Brown and Friesian lactating cows

Components	
Maize meal (%)	65
Groundnut cake (%)	20
Palm kernel meal (%)	15
	100
Calculated TDN (kg/100kg DM)	77.45
Calculated DCP (kg/100kg DM)	16.71
Mineral & Vit. mixture (microzone)* kg/tonne	5

* 1kg of microzone contains:

Vit. A(I.U.)	= 0.50	Cu(g)	= 4.00
Vit. D(")	= 0.25	Co(")	= 3.00
Mn (g)	= 16.00	I (")	= 1.20
Zn (")	= 12.00	Mg(")	= 200.0
Fe (")	= 6.00		

TDN = Total digestible nutrients

DCP = Digestible crude protein.

TABLE 2.2.

**Mean Chemical Composition of Concentrate ration and forage fed to German Brown and Friesian Lactating cows (on dry matter basis)

Nutrient	Ration	Forage	
		Period I	Period II
Dry Matter (g/100gDM)	88.64	38.15*	47.23*
Ash "	3.11	9.23	9.00
Organic Matter "	85.53	82.92	84.75
Crude Protein "	17.19	4.56	3.81
Crude fibre "	4.35	24.30	30.15
Ether Extract "	2.31	1.10	1.04
NFE "	61.68	52.96	49.75
Energy (KJ/gDM)"	19.83	20.96	20.67

* Determined on fresh forage samples

** Mean of eight determinations

NFE= Nitrogen-free extractives

TABLE 2.3.

Mineral contents of the ration and forage per kg DM fed to German Brown and Friesian lactating cows

Mineral	Concentrate	Forage
Calcium (g/kg DM)	19.20	5.77
Sodium "	-	0.05
Potassium "	-	15.02
Magnesium "	0.98	2.20
Manganese (mg/kg/DM)	78.74	115.40
Phosphorus (g/kg DM)	1.40	2.03
Iron (mg/kg DM)	29.53	2041.30
Zinc (")	59.06	50.80
Copper (")	19.69	13.40
Chloride (")	-	5.94
Cobalt (")	1.48	-
Iodine (")	7.87	-
Vit. A (I.U.)	2400.00	-
Vit. D_3 (")	1230.00	

- Not determined

shows the bodyweight and lactation records of the cows.

The first group comprising four Friesian and four German Brown cows were stall-fed while the other group was strip-grazed. In the stall-fed animals, their first sub-group consisting of two Friesian and two German Brown cows was fed with concentrate ration with low herbage intake while the other sub-group was fed forage *ad libitum* with low intake of concentrate ration. The same method was applied to the grazing animals except that those on *ad lib* forage were offered additional forage after they have returned to the stall. At the end of the first period, those animals on high concentrate were changed over with those on high forage intake. Each period lasted four weeks. Before switching-over to the second period, the animals were allowed to rest for a week and the following week was used as the preliminary period. This was to eliminate any 'carry over' effects.

The paddock from which the cynodon Spp was grown was divided into two. One part was gradually cut for the stall-fed animals while the other part was grazed by the strip-grazed cows.

For high concentrate ration treatment, the cows were fed 1kg concentrate DM for every 2.5kg milk produced per

Table 2.4

Feeding arrangements of cows with their identification numbers on low or high concentrates plus forage

Feeding System	Ration Treatment	Identification of animals			
		Period I		Period II	
		German Brown	Friesian	German Brown	Friesian
STALL FEEDING (Zero-grazing)	(i) High level concentrate ration + restricted forage intake.	37, 67	99, 121	56, 64	99, 123
	(ii) *Ad lib* forage feeding + restricted concentrate ration intake.	56, 64	92, 123	37, 67	99, 121
GRAZING (Strip-grazing)	(i) High level concentrate ration + restricted forage intake.	65, 66	88, 120	42, 58	90, 127
	(ii) *Ad lib* forage feeding +restricted concentrate ration intake.	42, 58	90, 127	65, 66	88, 120

High level concentrate ration: 1kg concentrate DM to every 2.5kg milk yield
Restricted " " : 1kg " " " " 4kg " "
" forage intake: 1kg forage DM to 100kg liveweight.

TABLE 2.5

Identification, Body weight (kg), Age and Lactation records of the cows used in the experiment

Breed	I.N.	Date of Birth	Days in milk at start of expt.	Initial Weight at the beginning of the experiment	Number of Lactation
German	67	4.4.71	33	350.00	1
Brown	42	7.5.71	42	333.60	1
	37	14.6.71	51	361.40	1
	58	30.11.71	46	355.00	1
	56	16.11.71	62	375.52	1
	64	10.3.71	58	327.30	1
	65	24.3.71	65	319.10	1
	66	30.3.71	41	355.90	1
Friesian	92	23.2.69	52	368.20	2
	88	13.12.68	31	416.40	2
	99	3.11.69	46	443.60	2
	90	25.12.68	56	331.80	2
	120	27.1.71	88	315.50	1
	121	2.2.71	56	302.70	1
	123	3.3.71	62	309.10	1
	127	28.5.71	30	332.70	1

IN = Identification Number.

day and limited concentrate was taken as 1kg DM concentrate ration for every 4.0kg milk yield. For high forage treatment, the animals were fed ad lib, and for limited forage, they were supplied 1kg DM forage for every 100kg liveweight.

The experiment commenced when the animals were at their peak of lactation (Lucas, 1960).

2.2.4 Water Intake of the Animals

Using water-troughs, the water intake of the experimental animals was measured. The water trough was made of cylindrical galvanised iron-sheet. It was low and large enough for the animals to drink conveniently. The volume of water in the water-trough was read on a marked glass tubing ring attached to its side (Fig. 2.1).

The experiment lasted 17 days including 3 days of preliminary period. Owing to limited number of water troughs, only 8 animals were used for the water intake experiment. The volume of water supplied was recorded in litres. One water trough was placed in the middle of the byre housing the animals or grazing paddock as a control to measure losses due to evaporation, every 24 hours. After this period, the volume of water remaining in the water-trough was recorded and this amount of water was substracted from the volume of water supplied. The water evaporated was

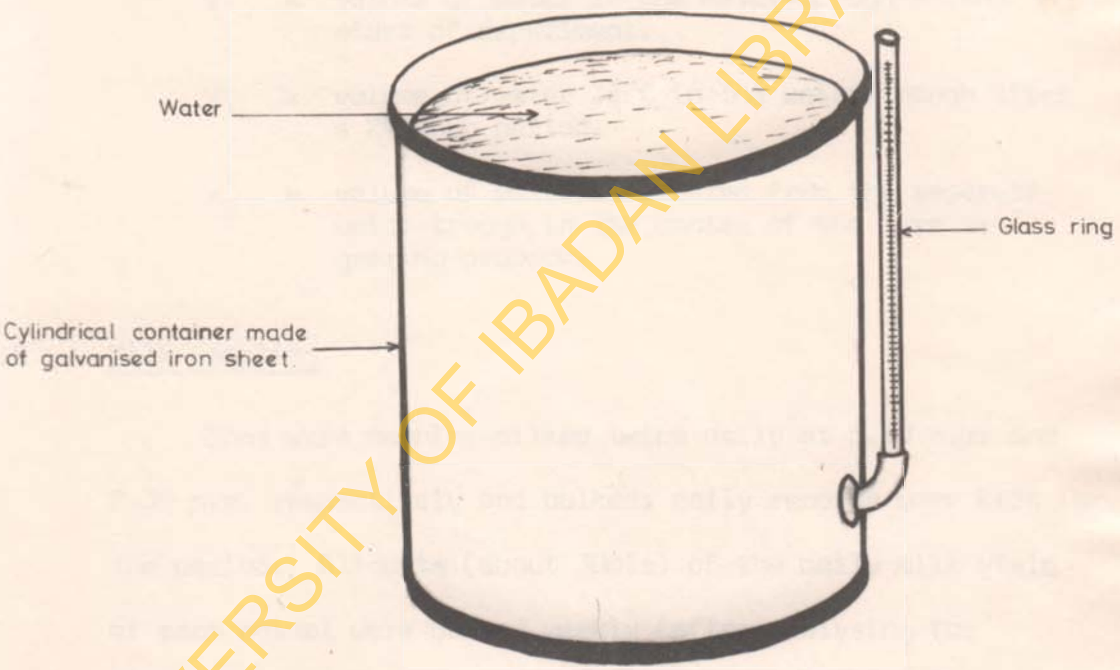

FIG. 2.1 WATER TROUGH.

substracted from the volume of water supplied. The water evaporated was substracted from the difference in volume obtained.

$Y = x - (x_1 + x_2)$ where:

Y = volume of water taken by the animals in litres

x = volume of water in the water-trough at the start of experiment.

x_1 = volume of water left in the water-trough after a 24-hour period.

x_2 = volume of water evaporated from the separate water-trough in the centre of the byre or grazing paddock.

2.2.5 Milk Sampling

Cows were machine-milked twice daily at 5.30 a.m. and 2.30 p.m. respectively and bulked; daily records were kept for the period. Aliquots (about 30mls) of the daily milk yield of each animal were bulked weekly (after analysing for milk protein and butterfat), stored in clean dried bottles with stoppers before storage in a deep freeze at -5^{0}C until required for analysis.

2.2.6 Body temperature and respiration rate

Body temperature was taken at 7.00 a.m. and 3.00 p.m. daily by inserting a previously sterilised clinical thermometer into the rectum of the cow for two minutes.

Respiration rate was taken at 7.00 a.m., 2.00p.m. and 6.00 p.m. by counting the number of flank movements in one minute.

2.3 Analytical procedure

The forage, concentrate and faeces were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), nitrogen-free extractives (NFE), gross energy (GE) and total ash as well as individual mineral content of forage and concentrate using AOAC (1970) methods. Determinations were made in duplicate. The results were expressed on dry-matter basis.

2.3.1 Moisture: 2g of each milled material was dried in an oven at 105°C overnight to a constant weight.

2.3.2 Total Ash: The dried material obtained from 2.3.1 was ignited at 600°C in a muffle furnace until grey or nearly white when ashing would have been completed.

2.3.3 Crude protein: This was determined by the macro-kjedahl digestion using sodium sulphate-copper sulphate selenium catalyst mixture followed by micro-distillation using Markham distillation apparatus. Boric acid was used as the receiving medium. By multiplying the total nitrogen content by the factor 6.25, the crude protein was obtained.

2.3.4 Ether Extract: This was estimated by extracting moisture-free milled sample with petroleum ether (Bp.40-60°C) for seven hours in a soxhlet extraction chamber.

2.3.5 Crude fibre: This was determined by the trichloroacetic acid method. The digestion reagent consisted of 500ml glacial acetic acid, 450ml water, 50ml conc. nitric acid and 20g trichloroacetic acid. 1g of the milled sample was boiled with 100ml of the digestion reagent for 40 minutes. It was filtered and washed with hot water and petroleum spirit. It was dried overnight cooled and weighed. The material was then ignited at 600°C for one hour, cooled and reweighed. The difference in the weighings divided by the weight of the milled sample taken multiplied by 100 is the crude fibre percentage.

2.3.6 Nitrogen-free extract : This was estimated by the difference between 100 and the sum of percentages of moisture, total ash, CP, EE and CF.

2.3.7 Gross energy was determined using adiabatic bomb calorimeter.

Analysis of Milk

2.3.8 Milk fat: Each sample of milk was analysed for concentration of fat by the standard Gerber method described by Davis (1959).

2.3.9 Protein: This was described for feeds and faeces in section 2.3.3 except that the results were multiplied by the factor

6.38 to obtain the protein content of milk.

2.3.10 Lactose: This was determined colorimetrically using the phenol-sulphuric acid method developed by Barnett and Tawab (1957) and modified by Marier and Boulet (1959).

2.3.11 Total solids: This was estimated by evaporating off the moisture in a known weighed sample at between 100^{o}C and 105^{o}C to a constant weight.

2.3.12 Total ash: This was determined by igniting the dried milk sample from total solids determination in a muffle furnace at 550^{o}C for 48 hours.

2.3.13 Mineral contents of feeds and milk were estimated using the modified Gomorris' (1942) method. 2g samples were wet digested using 4ml perchloric acid, 2ml conc.sulphuric acid and 25ml conc. nitric acid. The contents were transfered to 100ml flask and made up to mark with glass-distilled water. Calcium, sodium, potassium, magnesium and manganese were determined using the Atomic Absorption Spectrophotometer while phosphorus was read on Acta III Beckman at 680nm.

2.3.14 Solids-not-fat: This was estimated by substracting the percentage value of fat from that of total solids.

2.3.15 Solids-corrected milk (SCM): This was obtained by using the equation of Tyrell and Reid (1965).

Liveweight changes of the animals

Weights for three consecutive days were taken prior to the first day of each trial followed by fortnightly weightings throughout the period of the investigation. The weights were obtained in the morning before feeding and watering and just after milking in the case of milking cows.

2.4. RESULTS

Statistical analyses were carried on all the results using the methods outlined by Federer (1963) and Duncan (1955).

2.4.1 Dry Matter (DM) Intake

Adegbola's (1974) method was used to estimate the forage DM intake of the grazing animals by applying the regression equations of the DM intake of forages and metabolic size of the stall-fed cows. Table 2.6 shows the various regression equations relating DM intake (kg/day) (Y) to the metabolic size of the cows (X).

Effects of System of Management: Grazing animals consumed more forage dry matter than the stall-fed cows as shown in Tables 2.7 and 2.11 ($P < 0.05$). While grazing animals consumed an average of 7.94kg/day, the stall-fed had an average of 7.84kg/day. Expressing these data on metabolic size as shown in Table 2.8,

Table 2.6

REGRESSION EQUATIONS DESCRIBING THE RELATIONSHIP BETWEEN TOTAL DRY MATTER INTAKE (kgDM/day) (Y), AND METABOLIC SIZE (X) OF DAIRY COWS STALL-FED

BREED	TREATMENT (DIET)	REGRESSION EQUATIONS	CORRELATION COEFFICIENT(r)	STANDARD ERROR
FRIESIAN	High forage	Y=0.1056X-1.6665	0.58*	0.36
FRIESIAN	High concentrate	Y=0.0839X-0.6097	0.55*	0.16
GERMAN BROWN	High forage	Y=0.0083X+5.8127	0.51*	0.14
GERMAN BROWN	High concentrate	Y=0.0583X+0.9904	0.48*	0.18

* Significant ($P < 0.05$)

the grazing cows also consumed more total dry matter than the stall-fed animals with an average of 99.39 and 98.99g/day/$W_{kg}^{0.734}$ respectively although this was not significant ($P > 0.05$)

The intake of the forage DM alone differed from that observed for the total DM intake. The stall-fed cows and grazing animals consumed an average of 73.96 and 73.02g/day/$W_{kg}^{0.734}$ respectively.

Breed Effects: The Friesian cows consumed more forage dry matter (8.11 ± 0.19kg) than the German Brown cows (7.67 ± 0.23kg). This was statistically significant ($P < 0.05$) (Table 2.7). Mean dry matter intake from concentrate showed that Friesian cows' consumption (2.05 ± 0.14kg/day) was slightly higher than the German Brown (2.04 ± 0.22kg/day). The results were however not statistically significant ($P > 0.05$). Table 2.8 shows the dry matter intake of these cows when expressed on intake per metabolic size so as to eliminate differences in body weight . The general picture highlighted in this table differs slightly from that observed in Table 2.7. While on high concentrate feeding, forage DM intake of 95.28 and 101.82g/day/$W_{kg}^{0.734}$ (stall-feeding and grazing respectively) were recorded for the Friesian cows, and 92.60 and 88.58g/day/$W_{kg}^{0.734}$ for the German Brown, the

TABLE 2.7

+Forage Dry Matter (kg/day) intake of stall-fed and grazed German Brown and Friesian lactating cows maintained on high or low concentrate rations

PERIOD	WEEKS	HIGH CONCENTRATE								HIGH FORAGE							
		GERMAN BROWN				FRIESIAN				GERMAN BROWN				FRIESIAN			
		Stall-feeding		Grazing		Stall-feeding		Grazing		Stall-feeding		Grazing		Stall-feeding		Grazing	
		*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**
I	1	7.67	2.06	7.48	3.15	8.19	2.64	8.02	2.65	8.37	2.00	7.70	1.28	8.20	1.90	9.19	1.90
	2	7.63	2.12	7.41	3.48	8.17	2.62	7.97	2.55	8.18	1.90	7.60	1.30	7.96	1.65	9.14	1.72
	3	7.16	1.91	7.50	3.40	7.89	2.61	8.18	2.85	8.05	1.98	7.56	1.18	8.22	1.68	9.17	1.65
	4	7.20	2.06	7.42	3.10	7.45	2.73	7.89	2.55	8.76	1.90	7.75	1.35	7.91	1.65	8.83	1.61
	Mean	7.42±0.04	2.04±0.03	7.45±0.02	3.28±0.02	7.93±0.17	2.65±0.07	8.02±0.06	2.65±0.05	8.34±0.15	1.95±0.01	7.65±0.04	1.28±0.02	8.07±0.08	1.12±0.02	9.08±0.08	1.72±0.02
II	1	7.42	2.75	6.52	2.10	7.14	2.36	8.22	2.03	7.92	1.43	8.85	1.92	7.89	1.85	7.69	1.96
	2	7.62	2.33	6.37	2.25	7.19	2.28	8.36	2.10	7.91	1.35	8.35	2.00	9.03	1.65	8.06	1.77
	3	7.75	2.41	6.17	2.05	7.15	2.10	8.47	2.11	7.83	1.30	8.70	1.80	8.16	1.60	7.93	1.82
	4	7.53	2.18	6.60	1.95	6.96	1.95	8.34	1.95	8.11	1.10	8.41	1.98	8.28	1.48	8.16	1.73
	Mean	7.58±0.07	2.42±0.02	6.42±0.09	2.09±0.04	7.11±0.05	2.17±0.04	8.35±0.05	2.05±0.03	7.94±0.06	1.30±0.04	8.58±0.12	1.93±0.04	8.34±0.24	1.65±0.03	7.96±0.10	1.82±0.03

* Forage dry matter intake

** Concentrate dry matter intake

\+ Forage DM intake of grazed animals were estimated from regression equations (Table 2.6).

Table 2.8

Total dry matter of forages and concentrates (g/day/$W_{kg}^{0.734}$) consumed by exotic breeds of cows under stall-feeding and grazing conditions

DRY MATTER INTAKE	HIGH CONCENTRATE				HIGH FORAGE			
	German Brown		Friesian		German Brown		Friesian	
	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Dry Matter Intake from Forage (g/day/$W_{kg}^{0.734}$)	65.09	54.28	64.72	72.59	81.56	81.55	84.48	83.65
Dry Matter Intake from Concentrate ration (g/day/$W_{kg}^{0.734}$)	27.51	34.30	30.56	29.23	20.26	20.04	21.77	21.92
% concentrate DM intake	29.71	38.72	32.07	28.71	19.90	19.73	20.49	20.76
Total Dry Matter Intake (g/day/$W_{kg}^{0.734}$)	92.60	88.58	95.28	101.82	101.82	101.59	106.25	105.57

difference between the consumption of the two breeds was much lower under high forage feeding. The average DM intake of concentrate ration was slightly higher for the Friesian (25.87g/day/$W_{kg}^{0.734}$) cows than the German Brown cows (25.53g/day/$W_{kg}^{0.734}$).

Diet: The DM intake from the cows under high forage (HF) feeding was higher than those cows on high concentrate (HC) feeding. This is shown in Table 2.7. The average intake of the HF cows from forage was 8.25$\pm$0.16kg/day while forage DM of the HC cows was 7.54$\pm$0.21kg/day. Results were statistically significant ($P<0.05$). Concentrate DM intake of cows on HC (2.42$\pm$0.14kg/day) was statistically higher than those on HF (1.67$\pm$0.09) ($P<0.01$). When expressed on metabolic size (Table 2.8), the results obtained follow the same pattern. For example, cows under the HF consumed 103.81, 82.81 and 21.00g/day/$W_{kg}^{0.734}$ of total dry matter, dry matter intake of forage and concentrate ration respectively as against 94.57, 64.17 and 30.40g/day/$W_{kg}^{0.734}$ for those under HC. Table 2.8 also shows that while 32.30% of the total DM intake of cows on HC was contributed by concentrate supplement, the value for cows on HF was 20.22%.

.4.2 Milk yield and Solids-corrected milk (SCM)

Data used for statistical analysis were obtained by substracting milk yield produced in succeeding weeks from the one obtained a week before the start of the experiment. That is, if milk yield a week before the start of the experiment was 30kg and the milk yield recorded during the first week of the experiment was 27kg, the figure to be used for statistical analysis would be -3kg. The same procedure was adopted for the solids-corrected milk.

<u>System of Management:</u> Tables 2.9, 2.10 and 2.11 show the summary of the milk yield and SCM. Results in these tables show that the milk production of the grazed lactating cows was higher than that of the stall-fed ones. Statistical analysis (Appendix B2.1) also showed this was significant ($P < 0.01$). Table 2.11 shows that while the grazed animals produced an average of 51.40 ± 1.87kg milk/week, an average decline of 2.10kg/week, the zero-grazed ones produced an average of 46.66 ± 2.50kg/week, a decline of 6.61kg/week at the end of the experiment. The results obtained for the SCM were similar except that the differences in yield and decline were more marked.

The grazed cows produced 48.28 ± 1.51kg/week with a decline of 0.84kg/week compared with 41.80 ± 2.10kg/week, giving a decline of 7.02kg/week for the stall-fed animals.

<u>Breed Effects:</u> A close examination of the data obtained in Table 2.11 shows that the Friesian cows produced slightly

Table 2.9

Milk yield (kg/week) of the stall-fed or grazed German Brown and Friesian lactating cows maintained on high and low concentrate ration

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Before start of expt.		40.69	61.82	52.16	51.14	61.37	40.09	58.87	58.64
I	1	41.82	67.62	51.82	50.91	59.32	40.46	49.10	54.32
	2	37.73	66.82	51.59	55.92	60.68	36.59	52.26	51.36
	3	40.68	61.59	53.87	60.00	57.95	42.50	51.48	50.23
	4	45.00	60.23	57.96	62.73	55.00	42.28	46.36	40.00
	Mean	41.3±2.65	64.06±3.38	53.81±3.28	57.39±4.11	58.24±3.37	40.46±5.47	49.80±2.88	48.98±2.92
II	1	46.02	43.07	44.89	40.91	39.78	71.59	48.92	55.68
	2	47.50	39.09	40.23	41.59	40.57	56.60	48.86	57.27
	3	42.96	39.43	37.96	38.41	36.82	61.35	44.54	54.32
	4	44.55	36.14	38.64	44.86	36.14	57.50	41.82	58.19
	Mean	45.26±3.30	39.43±4.47	40.43±2.08	41.19±2.53	38.33±2.21	61.76±7.75	46.04±3.60	56.36±4.25

TABLE 2.10

Solids-Corrected Milk[a] (kg/week) of German Brown and Friesian milking cows grazed or stall-fed on high and low concentrate ration

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Before start of expt.		38.54	58.69	46.24	45.78	58.05	39.27	52.43	52.73
I	1	37.13	60.56	45.55	44.78	54.86	40.27	42.89	49.73
	2	34.74	59.47	42.19	50.20	55.74	36.57	46.47	47.89
	3	36.26	55.77	43.90	51.78	52.27	42.62	46.35	46.85
	4	39.67	52.58	45.61	54.80	49.28	42.22	41.98	38.16
	Mean	36.95±1.03	57.10±1.82	44.31±0.81	50.39±2.10	53.04±1.45	40.42±1.38	44.42±1.16	45.66±2.57
II	1	40.97	42.81	42.09	38.51	36.04	63.93	39.90	50.86
	2	42.39	38.79	36.46	39.86	37.99	54.25	43.24	52.80
	3	39.15	44.52	35.99	37.37	36.22	62.13	39.67	52.73
	4	39.83	36.88	34.73	42.35	34.82	58.63	39.37	54.29
	Mean	40.59±0.71	40.75±1.76	37.32±1.63	39.52±1.07	36.27±0.65	59.74±2.13	40.54±0.90	52.67±0.70

(a) Calculated from Tyrrell and Reid's (1965) Formula. $SCM(kg) = 12.3(F) + 6.56(SNF) - 0.0752M$

SNF = solids-not-fat (kg) M = milk yield (kg) where SCM = solids-corrected milk (kg) F = Butterfat (kg).

higher amount of milk than the German Brown cows. The Friesian cows produced an average of 49.25$\pm$1.23kg/week with a decline from the start of experiment of 5.95kg per week and the German Brown cows produced 48.82$\pm$2.01kg-/week with a decline of 2.17kg/week. However statistical analysis showed no significant difference ($P > 0.05$).

SCM production by the German Brown cows was slightly higher than that of the Friesian cows (Tables 2.10 and 2.11). While the Friesian cows produced 44.48$\pm$3.21kg/week with a decline of 4.81kg/week, the German cows yielded 45.60$\pm$4.15kg/week with a decline of 3.08kg/week. However there was also no statistical differences ($P > 0.05$).

Diet Effects: Results shown in Tables 2.9, 2.10, 2.11 and Appendices B2.1a had clearly indicated that although the two diets influenced the milk yield, the effects were statistically non-significant. Lactating cows on HC feeds produced 47.87$\pm$1.87kg/week with a decline of 3.58kg/week and those on HF feeds produced 50.20$\pm$2.18kg/week with a decline of 4.54kg/week. The SCM production also differed slightly but not significantly as that of the milk yield. The HC-fed cows produced 43.33$\pm$0.95kg/week with a decline of 3.98kg/week and the HF-fed cows produced an average of 46.75$\pm$1.02kg/week with a decline of 3.87kg/week.

Interaction: The interaction between the diet and breed, diet and system of management, breed and system of management and finally the breed, diet and system of management showed no significant differences ($P > 0.05$).

2.4.3 Milk Composition

The results of mean quality of milk obtained from the chemical analysis of samples for fat, protein, total solids, Solids-not-fat (SNF) and ash are shown in Tables 2.12, 2.13, 2.14, 2.15 and 2.16 respectively.

System of Management: Butterfat percentage of grazed animals was higher than the stall-fed ones. Results in Table 2.11 showed that the grazed animals yielded 3.93, 3.90, 4.25 and 4.04% butterfat with a mean of $4.03 \pm 0.08\%$ butterfat and the stall-fed animals produced 3.80; 3.75; 4.08 and 3.83% with a mean of $3.81 \pm 0.08\%$ showing that the butterfat per cent of the grazed cows was significantly higher than the stall-fed ($P < 0.05$).

However, the stall-fed cows produced a higher percentage of milk protein than the grazed cows. The mean protein percentage of the grazed cows was $3.25 \pm 0.06\%$ while that of the stall-fed ones was $3.52 \pm 0.05\%$. The difference was highly significant ($P < 0.01$) as shown in Appendix B2.1c.

The results in Table 2.14 also showed the effect of management over the total solids of the milk. The total solids of the grazed cows were 11.87±0.17; 11.68±0.10; 12.69±0.03 and 11.56±0.05% during the first period, and 12.57±0.08; 11.69±0.09; 12.18±0.42 and 11.94±0.17% during the second period. The stall-fed cows produced 11.73±0.39; 10.89±0.48, 11.79±0.37 and 12.02±0.16% during the first period and 11.41±0.20; 11.75±0.02; 11.84±0.23 and 11.22±0.21% during the second period. A summary of these data calculated in Table 2.11 showed that the grazed animals produced 12.02±0.36g total solids/100g fresh milk and the stall-fed cows 11.58±0.25g/100g fresh milk. Results were highly significant ($P < 0.01$).

Table 2.11 shows that the grazed animals yielded a mean of 4.04±0.02g lactose/100g fresh milk and the stall-fed animals produced 4.00±0.01g/100g fresh milk. There was no significant difference ($P > 0.05$).

The results of the solids-not-fat (SNF) in Table 2.15 showed that the yield in the first period was higher than the second period. The mean SNF content of the grazed cows' milk varied from 7.28±0.06 to 8.56±0.37 during the first period and 7.04±0.06 to 8.19±0.16 during the second period

TABLE 2.11

*Forage Dry Matter, Milk Yield and Composition of two breeds of cattle grazed or stall-fed on high and low concentrate ration

NUTRIENTS	HIGH CONCENTRATE				HIGH FORAGE			
	GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Forage Dry Matter(kg/day)	7.50	6.94	7.52	8.19	8.14	8.12	8.21	8.52
Milk yield (kg/week)	43.34	51.74	47.12	49.29	48.28	51.91	47.92	52.67
Solids-Corrected Milk(kg/wk)	38.76	48.92	40.69	44.95	44.65	50.08	43.11	49.16
Butterfat %	3.80	3.93	3.75	3.90	4.08	4.25	3.83	4.04
Milk Protein %	3.53	3.27	3.45	3.49	3.57	3.13	3.53	3.10
Solids-not-fat %	8.04	8.96	7.87	8.19	8.25	9.30	8.09	8.65
Total Solids %	11.57	12.23	11.32	11.68	11.82	12.43	11.62	11.75
Lactose %	4.16	4.18	3.84	3.96	3.94	4.08	4.01	4.04
Ash %	0.72	0.71	0.69	0.73	0.73	0.72	0.68	0.72
Energy (KJ/g freeze dried milk)	16.74	17.61	17.49	17.57	16.82	17.70	16.90	17.57

* Mean of eight determinations.

TABLE 2.12

Milk fat (g/100g milk) content of stall-fed or grazed German Brown and Friesian lactating cows' milk maintained on high and low concentrate rations

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Before start of expt.		3.71	3.20	3.17	3.28	3.35	4.10	3.21	3.76
I	1	3.67	3.13	3.18	3.20	3.45	4.08	3.48	4.05
	2	3.80	3.16	3.10	3.23	3.62	4.26	3.45	4.29
	3	3.70	3.51	3.19	3.05	3.77	4.28	3.63	4.30
	4	3.71	3.37	3.22	3.10	3.93	4.21	3.90	4.63
	Mean	3.72±0.05	3.29±0.18	3.17±0.05	3.14±0.08	3.69±0.20	4.20±0.09	3.61±0.21	4.31±0.24
II	1	3.88	4.28	4.16	4.50	3.96	3.65	3.15	3.40
	2	3.76	4.40	4.20	4.63	4.15	4.15	3.88	3.70
	3	3.83	4.52	4.38	4.78	4.70	4.60	4.10	3.96
	4	4.05	4.80	4.55	4.76	5.05	4.83	4.53	4.00
	Mean	3.88±0.12	4.50±0.22	4.32±0.18	4.67±0.13	4.46±0.50	4.30±0.52	3.91±0.58	3.77±0.28

TABLE 2.13

Milk protein (g/100g milk) content of stall-fed or grazed German Brown and Friesian lactating cows' milk maintained on high and low concentrate rations

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Before start of expt.		3.55	3.18	3.28	2.27	3.48	3.52	3.52	3.07
I	1	3.51	2.96	3.25	3.26	3.43	3.02	3.55	2.86
	2	3.47	2.97	3.27	3.15	3.50	2.97	3.49	2.90
	3	3.48	3.13	3.28	3.23	3.55	2.98	3.46	2.65
	4	3.55	3.60	3.37	3.42	3.57	2.94	3.58	3.24
	Mean	3.50±0.03	3.16±0.30	3.29±0.05	3.26±0.11	3.51±0.06	2.97±0.03	3.52±0.05	2.96±0.24
II	1	3.58	3.06	3.06	3.42	3.61	3.48	3.45	3.32
	2	3.55	3.31	3.60	3.71	3.65	3.35	3.54	3.23
	3	3.55	3.55	3.61	3.81	3.63	3.24	3.58	3.17
	4	3.54	3.58	3.62	3.87	3.68	3.12	3.60	3.20
	Mean	3.55±0.02	3.37±0.24	3.60±0.03	3.70±0.20	3.64±0.03	3.30±0.15	3.54±0.06	3.23±0.06

TABLE 2.14

Total Solids (g/100g milk) content of German Brown and Friesian cows' milk grazed or stall-fed on high and low concentrate rations

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Before start of expt.		12.34	12.83	11.91	11.95	12.64	12.88	11.87	11.65
I	1	12.22	12.04	11.53	11.79	12.23	12.71	11.78	11.57
	2	11.86	11.95	10.95	11.73	11.97	12.65	12.10	11.48
	3	11.50	11.87	10.67	11.64	11.60	12.71	12.10	11.59
	4	11.34	11.64	10.41	11.56	11.38	12.69	12.10	11.60
	Mean	11.73±0.39	11.87±0.17	10.89±0.48	11.68±0.10	11.79±0.37	12.69±0.03	12.02±0.16	11.56±0.05
II	1	11.32	12.54	11.78	11.58	11.49	11.61	11.04	11.70
	2	11.47	12.48	11.74	11.69	11.99	12.11	11.13	11.98
	3	11.66	12.65	11.76	11.81	11.95	12.55	11.19	12.12
	4	11.20	12.62	11.73	11.70	11.95	12.44	11.53	11.95
	Mean	11.41±0.20	12.57±0.08	11.75±0.02	11.69±0.09	11.84±0.23	12.18±0.42	11.22±0.21	11.94±0.17

with a pooled mean value of 8.78 ± 0.16g/100g fresh milk. The mean SNF content of the stall-fed cows' milk varied from 7.76 ± 0.51 to 8.42 ± 0.20 during the first period and 7.27 ± 0.26 to 7.55 ± 0.31g/100g fresh milk during the second period with a pooled mean value of 8.06 ± 0.25g/100g fresh milk. The SNF content of the grazed cows' milk was higher than that of the stall-fed animals ($P < 0.01$).

The ash content of the grazed animals was statistically significant to that of the zero-grazed. Though the energy value of the free-grazed cows was higher than the zero-grazed (Table 2.11), there was no statistical difference ($P > 0.05$).

<u>Breed</u>: Though there was a gradual increase of butterfat as lactation progressed towards the late stage in the two breeds, results shown in Table 2.12 clearly indicate that both the German Brown (GB) and Friesian (F) cows' milk contained mean butterfat value of 4.01 ± 0.18 and 3.88 ± 0.15% respectively with the value of the GB being slightly higher than for the F cows ($P < 0.05$). Apart from the fact that there was no well-defined trend in the milk protein percentage as the experiment progressed, there was only a little difference between protein percentage at start and end of the experiment. The mean GB protein percentage was

3.38 ± 0.02 while the F was 3.39 ± 0.02 with no breed differences in the milk protein contents of these cows.

Duncan's (1955) multiple range tests for means has revealed that both the SNF, TS and ash contents of the GB cows' milk were significantly higher than those of the F cows' ($P < 0.05$). However there was no statistical difference between the energy content of milk of the GB and that of F cows.

Diet: Duncan's (1955) multiple range tests for means revealed that the butter fat percentage of cows on high forage rations were significantly higher than those on high concentrate diet, with the mean value of 4.05 ± 0.21 and $3.85 \pm 0.18\%$ for the high forage and high concentrate diets respectively ($P < 0.05$). There were no significant differences between the milk protein and SNF% for the cows maintained on the two dietary levels. However statistical analysis showed that the TS, Ash and Energy contents of the milk (11.90%, 0.72% and 17.35KJ/g respectively) of the cows on HC were significantly higher ($P < 0.01$) than those on HF (11.70%, 0.70, 17.25KJ/g respectively).

Interaction: Significant interaction for the milk ash existed between diet and breed; and between breed and mana-

TABLE 2.15

Solids-not-fat (g/100g milk) content of German Brown and Friesian cow' Milk grazed or stall-fed on high and low concentrate rations

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Before start of expt.		8.64	9.63	8.76	8.70	9.29	8.78	8.82	7.90
I	1	8.57	8.94	8.43	8.59	8.78	8.66	8.33	7.57
	2	8.06	8.80	7.85	8.53	8.37	8.40	8.66	7.28
	3	7.80	8.37	7.57	8.59	7.85	8.46	8.50	7.29
	4	7.64	8.14	7.21	8.49	7.48	8.49	8.20	7.00
	Mean	8.02±0.41	8.56±0.37	7.76±0.51	8.55±0.05	8.12±0.57	8.50±0.11	8.42±0.20	7.28±0.23
II	1	7.47	8.29	7.63	7.08	7.54	7.96	7.59	8.30
	2	7.72	8.08	7.54	7.09	7.84	7.96	7.38	8.28
	3	7.86	8.15	7.56	7.03	7.35	7.95	7.09	8.22
	4	7.15	7.87	7.43	6.95	7.15	7.64	7.03	7.95
	Mean	7.55±0.31	8.10±0.18	7.54±0.08	7.04±0.06	7.47±0.29	7.88±0.16	7.27±0.26	8.19±0.16

TABLE 2.16

Ash (g/100g milk) content of German Brown and Friesian cows' milk grazed or stall-fed on high and low concentrate rations

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
Before start of expt.		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
		0.700	0.714	0.678	0.701	0.736	0.695	0.666	0.694
I	1	0.702	0.714	0.665	0.699	0.739	0.700	0.665	0.710
	2	0.702	0.709	0.674	0.705	0.744	0.696	0.693	0.732
	3	0.706	0.704	0.662	0.704	0.751	0.696	0.654	0.723
	4	0.704	0.711	0.664	0.711	0.751	0.696	0.659	0.738
	Mean	0.705±2.63	0.705±2.84	0.666±5.31	0.705±4.92	0.746±5.85	0697±2.00	0.667±0.02	0.726±0.01
II	1	0.747	0.700	0.691	0.744	0.721	0.721	0.656	0.712
	2	0.746	0.699	0.696	0.745	0.724	0.737	0.654	0.712
	3	0.746	0.702	0.731	0.742	0.738	0.761	0.663	0.711
	4	0.735	0.702	0.728	0.747	0.737	0.757	0.683	0.718
	Mean	0.722±0.01	0.701±1.50	0.711±0.02	0.744±2.08	0.730±8.75	0.744±0.02	0.664±0.01	0.713±3.20

gement ($P < 0.01$). There was no significant interaction ($P > 0.05$) between the diet and breed for the milk protein, SNF, TS, fat and energy. Statistical analysis showed that there were significant differences in the interaction between breed and management ($P < 0.05$) but no significant interaction among the breed, diet and management for the protein, SNF, TS, fat and energy contents of milk. Also there was no significant interaction between the breed and management for the butter-fat content of the cows' milk.

2.4.4. Liveweight changes

The summary of mean body weight changes as influenced by management practices, breed and diet are shown in Table 2.17.

System of Management: The cows under the grazing system showed the higher daily gain of 0.59kg as compared to the value of -1.30kg for the stall-fed cows. The differences were statistically significant ($P < 0.05$).

Breed: While the German Brown cows lost a mean of 0.26kg/day, the Friesian cows lost 0.45kg/day ($P < 0.05$) strongly indicating breed differences.

Diet: Cows under the high forage diet tried better to maintain their weights than those on high concentrate. Those on high forage lost 0.13kg liveweight per day and cows on high concentrate lost 0.58kg/day ($P < 0.05$).

2.4.5 Water Intake, Body Temperature and Respiration Rates

Table 2.18 shows the water intake of the cows. The mean water intake of the stall-fed animals was 32.27 ± 9.55 litres per day while that of the grazed animals was 33.80 ± 10.42 litres per day. Statistical analysis showed that any apparent differences in the mean daily water intake was not significant ($P > 0.05$).

The mean water intake of the Friesian cows was higher than that of the German Brown with the value of 38.02 ± 4.02 litres per day for the former and 28.05 ± 13.05 litres per day for the latter. The animals under high forage diets had intake higher than those on high concentrate. This was 33.58 ± 10.17 litres per day for high forage and 32.49 ± 7.56 litres per day for high concentrate.

There was also no significant difference between the mean body temperature of the grazing and stall-fed cows. The mean body temperature of the stall-fed cows was 38.92°C while that of the grazed ones was 38.94°C (Table 2.19). Respiratory counts shown in Table 2.20 indicated that the

TABLE 2.17

Liveweight (kg) of the grazed or stall-fed German Brown and Friesian lactating cows on high and low concentrate rations

PERIOD	(WEEKS)	HIGH CONCENTRATE				HIGH FORAGE			
		GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
		Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
Before start of expt.		420.58	413.92	426.12	342.32	404.18	338.84	392.47	433.88
I	1	413.50	414.22	415.00	343.28	395.11	338.53	377.30	435.70
	2	393.60	419.55	392.50	331.83	393.41	333.32	370.43	437.05
	3	385.43	431.42	385.55	332.08	391.25	328.87	366.05	441.66
	4	386.89	438.67	379.59	336.31	393.61	330.22	364.77	441.50
	Mean	394.85±6.54	425.96±5.66	393.16±8.15	335.88±3.11	393.35±1.82	332.74±3.52	369.64±1.94	438.97±2.56
II	1	396.66	331.44	368.39	444.34	383.12	444.49	373.92	338.01
	2	399.12	332.40	378.44	451.34	388.85	443.75	379.36	357.54
	3	401.21	335.33	375.53	455.39	388.99	452.15	375.59	355.38
	4	405.49	336.77	378.38	455.24	394.81	452.73	378.25	361.70
	Mean	400.62±2.18	333.98±1.62	375.18±3.15	451.58±4.16	388.94±3.52	448.28±3.50	376.78±1.85	353.16±6.76

Table 2.18

Volume of Water (litres) consumed by German Brown and Friesian cows grazed or stall-fed with high and low concentrate rations

PERIOD DAYS	HIGH CONCENTRATE				HIGH FORAGE			
	GERMAN BROWN		FRIESIAN		GERMAN BROWN		FRIESIAN	
	Stall feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing	Stall-feeding	Grazing
1	20.46	21.50	54.50	45.40	31.80	38.55	45.46	44.20
2	31.80	26.52	54.55	50.50	31.82	40.42	50.00	52.15
3	23.41	30.40	59.10	52.17	31.85	40.55	50.00	53.18
4	30.84	32.55	47.73	49.55	22.70	28.48	40.90	38.42
5	29.55	30.46	40.90	48.95	25.00	29.50	34.10	35.50
6	29.55	30.40	50.00	53.40	28.41	30.50	36.35	36.52
7	27.28.	29.55	39.78	46.55	27.28	29.50	30.70	27.28
8	26.14	28.40	30.69	36.18	28.70	31.50	27.20	27.20
9	23.87	25.80	27.20	32.40	27.28	30.00	22.75	26.50
10	23.36	23.00	28.40	30.60	27.20	31.52	31.32	28.55
11	18.18	20.00	26.14	23.15	29.55	32.60	37.50	36.55
12	23.85	25.44	18.20	20.80	27.28	27.28	36.35	38.90
13	24.00	26.00	27.40	28.50	27.30	26.80	37.50	38.40
14	24.00	25.40	28.40	30.40	27.30	28.40	37.55	39.78
Mean	25.45±3.95	26.82±3.69	38.50±13.14	39.18±11.47	28.10±2.57	31.83±4.65	37.02±7.87	37.37±8.46

± Standard deviation

Table 2.19

*Mean body temperature (^{o}C) of German Brown and Friesian cows grazed or stall-fed with high and low concentrate rations

Period (Weeks)	1st week		2nd week		3rd week		4th week		5th week		7th week		8th week		Grand Mean
	7 am	3 pm	7 am	3 pm	7 am	3 pm	7 am	3 pm	7 am	3 pm	7 am	3 pm	7 am	3 pm	
Mean of stall-fed cows	38.39	39.11	38.67	39.28	38.67	39.33	38.67	39.36	38.33	39.33	38.44	39.30	38.70	39.30	38.92
Grazed cows	38.38	39.28	38.70	39.39	38.67	39.16	38.56	39.30	38.56	39.33	38.56	39.22	38.78	39.22	38.94

* Week 6 not determined.

Table 2.20

*Body Respiration (counts per minute) of cows grazed or stall-fed with high and low concentrate rations

	3rd week				4th week				5th week				7th week				8th week			
	6 am	10 am	2 pm	6 pm	6 am	10 am	2 pm	6 pm	6 am	10 am	2 pm	6 pm	6 am	10 am	2 pm	6 pm	6 am	10 am	2 pm	6 pm
Mean of stall-fed cows	22	48.5	59	48	22	48	59	46.5	22	48	57.5	48	22	44	62.5	48	22	56	63	48
Grazing cows	22	52	65	51	22	47	65	52	22	51	64	48	21	47	60	44	21	46	61	43

• 1st, 2nd and 6th week - not determined.

highest counts were obtained at 2.00 p.m. followed by 10.00 a.m. and 6.00 p.m. and the least count was obtained at 6.00 a.m. The summary in Table 2.20 shows that the grazed cows had respiratory counts of 45.2 counts per minute and the stall-fed cows had 43.7 counts per minute.

2.5 DISCUSSION

Results tended to indicate that there was a decrease in the dry matter (DM) intake from the start of the experiment because the cows have reached their peak milk yield before the beginning of the experiment and were gradually declining in their milk yield before they were used. It has been shown by Mather (1959) that cows fed on grains reached their peak feed intake by about the 9th week after parturition and started to decrease thereafter and would appear to be in agreement with the observation in the present experiment. The regression equations obtained in Table 2.6 suggested that during lactation, intake seemed to be correlated with live-weight of the animals. This is in agreement with the results of Elliot, Fokkemma and French (1961) and Musangi (1969) that animal's liveweight is a major factor affecting its organic matter intake. The finding that the heavier animals consumed the higher feed DM intake were in good agreement with those of many investigators that the metabolic weight is an important factor influencing intake (MacLusky, 1955; Holmes and Jones, 1965).

Results obtained in the present experiment showed that those animals fed on high concentrate which contributed 32.30% on average to the total DM intake reduced their intake from grass. Indeed, similar observations were made by Mather (1960); Donefer et al, (1963); Montgomery and Baumgardt (1965); Cowsert and Montgomery, (1969). The DM intake of cows used in the present experiment were relatively low compared to the DM intakes recorded in the temperate areas. However, it is to be noted that the forage DM calculated for the grazing animals was estimated from regression equations. There is every possibility that the animals consumed more since the regression analysis used was derived from the DM intake of the stall-fed animals. The low feed intake of the stall-fed animals was likely to be due to the fact that they were unable to select the more digestible and palatable components of mature herbage (Greenhalgh and Runcie, 1962). It is also probable that the relatively high crude fibre and dry matter content of the grass was associated with more chewing, low speed of eating and consequently reduced intake. The DM content of the grass (42.68%) used in this study was for most of the time higher than the critical figure of 24-28%

suggested by Duckworth and Shirlaw (1958) when maximum DM intake could be obtained. Duckworth and Shirlaw (1958) have shown that the correlation coefficient of DM percentage and DM consumed was 0.855 ($P < 0.01$).

The milk yield was generally low throughout the experiment (6.94 and 7.04kg/day for the GB and F respectively). This might be due to two factors; firstly, the body temperature of 38.92°C and 38.94°C for stall-fed and grazed cows respectively, ambient temperature of 29°C, and respiratory counts of 43.7 and 45.2 counts per minute for stall-fed and grazed animals respectively, were very high. Blaxter et al (1959), Blaxter and Wainman (1961) have suggested that with such high respiratory counts obtained in the tropics as in the present experiment, the exotic breeds of cattle in the tropical environment might undergo any thoracic, anatomical and perhaps abdominal changes resulting from their high respiratory rates forced on them by heat stress in the tropics, might reduce their feed intake and hence milk production. The animals were often noticed to open their mouths and change positions rapidly and frequently, their breathing lacked depth and was noisy. Standing seemed to facilitate rapid respiration. The exotic cows, as pointed out earlier, are unadapted to the tropical environments, which when exposed to direct solar radiation may suffer severe stress. This has been manifested in these animals by increased respiratory rate, panting and excessive salivation. Bianca (1965); McDowell (1972); Loosli and van Blake (1973) pointed out that at such temperature and respiratory rates recorded in these studies, the milk yield of exotic cows would be lower than those cows maintained in the temperate countries. Bianca (1965), McDowell (1971), Johnson (1973) and Olaloku (1973) pointed out that temperatures above 20^{o}C decreased milk yield, butterfat and SNF. McDowell (1972) has also shown that high temperatures as recorded here increased water intake and decreased food intakes. Adeneye (1972) observed that cows maintained under the same environmental conditions as in this study often drank large quantities of water with increased volumes of urine showing that the water was used to cool their body and not to aid increased milk yield. Secondly, another reason for the low milk yield is the fact that the animals have just recovered from a widespread 'foot and mouth' disease when the experiment was started.

The grazed animals produced more milk and higher butterfat than the stall-fed ones. This was in accordance with the observations of Greenhalgh and Runcie (1962) that there is no evidence that the effects on milk production of a lower energy intake in stall-fed cows can be offset by a lower requirement of energy for muscular activity. Hardison, Reid, Martin and Woolfolk (1957) have pointed out that the digestibility of herbage grazed in the field was higher than corresponding forages eaten indoor. Topps (1962) has also concluded that materials harvested mechanically is likely to be different in digestibility from that grazed by animals because even grazed animals only graze the leaves. Baker, Richards, Haenlein and Weaver (1960) have demonstrated that there was indirect evidence that digested nutrients were metabolized less efficiently by stall-fed than by grazed animals which may eventually produce more milk yield in the latter than in the former.

Results obtained from the present study indicated that the butterfat of the grazed animals which also consumed more grass was higher than that of the stall-fed ones which consumed less grass. It is probable that the higher proportions of forage DM intake in the animals grazed have resulted in ruminal fermentation favouring the production of a greater proportion of acetic acid in the rumen liquor and thereby increasing milk fat synthesis than in those cows on high concentrate feeding (Rook and Balch, 1961; Rook and Storry, 1964; Armstrong, 1968). Butterworth (1961) reported decreased butterfat percentage at the higher level of supplementary concentrate feeding. However, the stall-fed animals produced a higher percentage of protein than the grazed. Cobble and Herman (1951) have shown that total nitrogen of milk decreased at higher environmental temperatures. McDowell (1972) have also suggested that heat stress experienced by the grazing animals in tropical fields could result in the diversion of significant amounts of protein into non-productive sources. One of such sources was the functioning of the sweat gland which could result in additional losses of protein.

The water intake of the animals reported in the present experiment was higher than those reported by Winchester and Morris (1958) in the temperate climate. The above-mentioned investigators demonstrated that animals' demand for water was variable, no reliable estimates can be made of needs unless fairly accurate information was available on the type of animal's age, level of productivity, type of feeding and the climatic environment. These same investigators also concluded that with increase in temperature, there was a corresponding increase in water intake to a certain level. Johnson (1967) estimated this level to be at 35°C. The rise in water consumption under high temperatures tends to support the well-known vital role water plays in thermal regulation. Winchester and Morris (1958) have concluded in their investigation that adequate intake of free water was a means of maintaining efficient performance in hot climates.

Higher respiratory counts than the ones recorded by McDowell (1967) were obtained in this study with those cows grazing in the field respiring faster than those fed in the pens. In domestic livestock, increased respiratory activity is an important means of increasing heat loss at high temperatures. McDowell (1967) asserted that it is the first visible sign of response to heat stress, but it has been placed third in the sequence of adaptates because the unnoticed processes of vasodilation and sweating usually occur earlier. The greater the volume of air that can be breathed in warmed and humidified climate like ours, the greater the resultant heat loss. McDowell (1967) concluded that the rate of respiration increased with increasing air temperature, the most pronounced rise occuring above 29°C. McDowell (1972) pointed out that between 18 and 20°C a cow would usually have a respiratory rate of about 20 breaths per minute and a volume of expired air of 40-60 litres, depending on body size and breed. At 40^{o}C, the same cow might breathe 115 times per minute with an expired volume of 300 litres. Kibler and Brody (1950), McDowell and Weldy (1967) had demonstrated that the Holstein cow had a higher respiratory rate under the same condition than the Zebu cow. Bianca (1965) asserted that a high respiratory rate could be an efficient means of increasing heat loss for short periods but continued high respiratory rates might interfere with feeding and rumination, add to body heat production from muscular activity, use energy that could be utilized for other purposes and lead to a reduction in the CO_2 combining capacity of the blood plasma because of hyperventilation. Respiratory alkalosis may even occur above 35^{o}C. Ragsdale et al (1951) had also demonstrated the interference with feeding of high respiratory rate. This means that with high respiratory rate, there is lower feeding resulting in lower milk yield.

In conclusion, the present study has shown that though these unadapted animals were exposed to solar radiation and other field conditions while grazing, they still tended to perform better than the zero-grazed ones. However, the practice was to 'let in' these grazed animals when the heat was becoming intolerable. The animals were observed to stop grazing during this period. Olaloku (1975) has expressed the opinion that the best practice for the newly imported lactating cows was to allow these animals to graze during the morning and evening hours but to stay indoors with free access to cool water at all times especially the hot afternoons as was practised in the present study.

In summary, the results obtained on the system of management studies seemed to indicate that:

(1) Grazing animals consumed more DM than stall-fed ones (7.94kg/day (99.39g/day/$W_{kg}^{0.734}$) for the grazed and 7.84kg/day (98.99g/day/$W_{kg}^{0.734}$) for the stall-fed.

(2) Milk production of the grazed lactating cows (51.40$\pm$1.87-kg/week and average decline of 2.10kg/week) was higher than the stall-fed ones (46.66$\pm$2.50kg/week and an average decline of 6.61kg/week).

(3) The grazed cows' milk contained higher content of butter-fat, total solids, lactose, solids-not-fat and ash but less protein than the stall-fed.

(4) Cows grazing showed a daily liveweight gain of 0.59kg compared to a daily liveweight loss of 1.30kg recorded for the

stall fed.

(5) Mean water intake of the grazed cows was 33.80 ± 10.42 while that of the stall-fed was 32.27 ± 9.55 litres/day.

(6) Mean body temperature and respiratory rate of the stall-fed cows were $38.92^{\circ}C$ and 43.7 counts/min. respectively. Results obtained for the grazed cows showed mean body temperature of $38.94^{\circ}C$ and respiratory rate of 45.2 counts/min.

CHAPTER 3

DRY MATTER INTAKE, MILK YIELD AND COMPOSITION OF WHITE FULANI, GERMAN BROWN AND FRIESIAN COWS MAINTAINED ON FORAGE AND LOW OR HIGH CONCENTRATES

3.1 INTRODUCTION

Milk production presents particularly difficult problems in tropical, developing countries like Nigeria and this has meant almost total dependence on foreign supplies of milk particularly from the temperate countries. For instance, the contribution from the local sources in Nigeria has been minimal and inadequate to meet the needs of the people in the country. Indeed, Nigeria is yet to be at the threshold of developing what can be termed a dairy industry.

In an attempt to increase milk production, basic research is needed to ascertain the nutritional requirements of dairy animals for optimal milk production and to find the effects of different dietary levels, seasons, breeds and liveweight on milk production and composition. Certain investigators have embarked on some of these studies including the relationship between milk yield and liveweight (Glesson, 1970; Olayiwole, 1973), effect of feed on milk yield (Burt, 1957; Armstrong, 1968; Olaloku, 1972) and composition (Holmes, Arnold and Provan, 1960; Rook and Balch, 1961; Castle, Drysdale and Waite, 1961; Rook and Line, 1961; Balch and Johnson, 1965; Storry and Rook, 1966; Huber and Boman, 1966; Armstrong, 1968; Armstrong and Prescott, 1970; Schmidt, 1971; Olaloku and Oyenuga, 1971; and Olaloku, 1973) effect of seasons on milk production (Rowland, 1946; Cobble and Herman, 1951; Merilan and Bower, 1959; Bianca, 1965; McDowell, 1972 and Olaloku, 1973), relationship between VFA and milk production (McDonald, 1952; 1968; Blaxter, 1956; Armstrong and Blaxter, 1957; Mba and Olatunji, 1971 and Adebanjo, 1972).

The main purpose of the present study was, firstly, to estimate the maximum voluntary intake of DM in forage to which has been added concentrate at two energy levels for milk production by the indigenous and exotic lactating cows; secondly, it was also necessary to examine the effects of these treatments on liveweight changes, milk yield and composition.

3.2 MATERIALS AND METHODS

3.2.1 Animals and their Management

Three breeds of cattle, four animals from each breed, were used in this investigation; viz.,

(a) White Fulani (Zebu) (indigenous breed)

(b) German Brown (exotic breed)

(c) Friesian (exotic breed).

The characteristics of the last two have been discussed in Section 2.2.1.

The White Fulani or Bunaji (Plate 2.1). This has been described as 'Sanga' or Zebu by various authors (Mason, 1951; Faulkner and Epstein, 1957) because its precise origin has been lost in antiquity. The breed has, in most cases, a white colour with black spots. Williams and Payne (1968) have pointed out that there are some White Fulani cattle with grey colour interspersed with black spots. Keay (1959) has also pointed out that they are available between the Sudan and Guinea Savanna vegetational zones of Northern Nigeria. The White Fulani, humped, is a fairly large animal weighing at maturity between 331.1kg (Faulkner and Epstein, 1957) and 348.1kg (Olaloku, 1972) for cows and 508kg (Ogunsiji, 1974) for bulls with an average height of 130cm behind the humb. The body is compact and fleshy. The skin is thick and pigmented. The legs are usually long which afford them to trek long distances particularly during the dry season when they are in search of forage and water (Olaloku, 1972).

The males usually have big heads with curved long horns which resemble the musical instrument - lyre hence the name 'lyre-horned'. It was first described as lyre-horned by Gates (1952). The cows have dewlaps more prominent in the bulls. The females have averagely well-developed, strongly attached udder which according to Shaw and Colville (1950) make them rank as one of the best milkers among the indigenous breeds in Nigeria, though they compare fairly low among the good exotic milkers all over the world. They produce an average of 7.45kg milk per day in 21 lactations (Oyenuga, 1967). Hill (1970) has put the milk yield of the best individual as 2241kg per 365 days or 2951kg per 427 days (Hill, 1956). Their milk also contains high fat and protein when compared with the exotic breeds. Many experiments conducted at Ibadan and Shika pointed out that they could be good beef-type. They have a birth weight of about 25kg (Oyenuga, 1967). Faulkner and Epstein (1957) put the calving age at 43 months and calving interval as 376 days while they live for about 9-10 years. Finally, Hill (1956) pointed out that they are tolerant to trypanosomiasis, to a certain degree.

The White Fulani cattle at the University of Ibadan

Teaching and Research Farm are offsprings of the first batch of cattle (4 bulls and 24 heifers and calves) purchased in June, 1950 from the Government stock Farm at Shika in the North Central State of Nigeria mainly for teaching and research purposes. After surmounting many problems, they have grown into a population of 89 cows and 41 bulls by 1975.

Management of the animals was as described in Section 2.2.2 except that the White Fulani cows were hand-milked and all the animals were zero-grazed with about two hours exercise in bare paddocks adjacent to their byre each day excluding the trekking to the milking parlour twice daily, a distance of about five kilometers.

The experimental site and housing of the animals were the same as in Section 2.2.2. The identification number, body weight, calving date and lactation records of the cows used are shown on Table 3.2.

3.2.2 Diets and Plan of Experiment

Cows were placed on the experiment five days after parturition. Since the animals calved at different times and periods of the year, they were introduced to the experiment at different periods and seasons ranging from the 21st of June 1974 to the 18th of September 1975 as indicated in Table 3.2.

All the animals were fed fresh Giant Star grass (Cynodon nlemfuensis var nlemfuesis I88) throughout the period of the experiment which was for 28 weeks except during January and February 1975 when due to shortage of fresh, green grass, they were fed silage.

Two levels of energy were supplied to the lactating cows. These levels were supplied by varying the amount of supplement given to the animals. The higher level of energy (a) was supplied at the rate of 1kg DM of concentrate ration (Table 3.1) to every 2.5kg of milk produced as practised in the Teaching and Research Farm (Alade, 1973). This level was also recommended by Caros-Costas and Vicente-Chandler (1969) and was in agreement with 115% of the Ministry of Agriculture, Fisheries and Food (MAFF) (1975) recommendation. The lower level of energy (b) was supplied at the rate of 1kg DM of the concentrate ration to every 4kg milk produced. This level also corresponded to the 75% of the MAFF (1975) recommendation.

Two animals from each breed were placed on the same energy level. This gave room for two replicates. A changeover of cows on higher energy level to a lower one and vice versa occurred at the end of the 14th week.

Table 3.1

*Components of dairy concentrate ration fed to the White Fulani, German Brown and Friesian Lactating Cows

Components	
Maize (%)	55
Groundnut Cake (%)	15
Palmkernel Meal(")	20
Rice Bran (")	10
	100
Calculated TDN (kg/100kg DM)	80.88
Calculated DCP " " "	15.35
Mineral & Vit. Mixture (microzone)* (kg/tonne)	5

*1kg of microzone contains

Vit. A (I.U.)	= 0.500	Cu (g)	= 4.00
Vit. D (" ")	= 0.25	Co (")	= 3.00
Mn (g)	= 16.00	I (")	= 1.20
Zn (")	= 12.00	Mg (")	= 200.00
Fe (")	= 6.00		

TDN = Total digestible nutrients

DCP = Digestible crude protein

Table 3.2

Identification, Liveweight (kg), Calving, Date and lactating records of the White Fulani, German Brown and Friesian cows used in the experiments

Breed	Identification Number	Calving Date	Initial Weight at start of experiment	Experimental Period	Number of Lactation
White Fulani	462	30.6.74	319.09	5.7.74 - 16.1.75	2
	430	23.10.74	230.64	29.10.74 - 12.5.75	2
	386	1.11.74	413.60	6.11.74 - 18.5.75	2
	167	26.2. 75	364.25	4.3. 75 - 18.9.75	2
German Brown	64	3.9. 74	410.00	12.9. 74 - 27.3.75	2
	32	23.9. 74	430.00	29.9. 74 - 12.4.75	2
	18	8.10.74	467.00	14.10.74 - 28.4.75	2
	58	18.12.74	410.42	23.12.74 - 14.7.75	2
Friesian	98	14.6. 74	420.00	21.6. 74 - 4.1.75	2
	118	9.9. 74	385.00	16.9. 74 - 29.3.75	2
	100	14.9. 74	440.00	21.9. 74 - 3.4.75	2
	126	16.9. 74	401.82	22.10.74 - 5.5.75	2

3.3 Analytical Procedure

The analytical procedures are the same as described in Sec. 2.3.

3.4 Results

The statistical analysis was carred out as indicated by Cochran, Autrey and Cannon (1941). However, only three parameters were possible for consideration at a time in this instance. These were effects of the breed, lactation and diet and their interactions. The fourth parameter, the effect of seasons was considered alone and separately as indicated in Appendix B3.1. The Newman-Keuls (1955) comparison between ordered means was used for comparing the means. The dry season was taken to be the period between November and February, and the wet season, between March and October. After careful consideration and study of the lactation curves, the stages of lactation, for the purpose of statistical calculations and discussion, were taken as:

early lactation	:	1st - 9th week of lactation
middle "	:	10th -18th " " "
late "	:	19th -28th " " "

Table 3.3.

Arrangement of the three breeds of cows for feeding grass ad lib and low or high concentrate rations

	White Fulani				German Brown				Friesian			
Number	1	2	3	4	1	2	3	4	1	2	3	4
Period I	a	b	a	b	a	b	a	b	a	b	a	b
Period II	b	a	b	a	b	a	b	a	b	a	b	a

1, 2, 3, 4 - number of animals from each breed

a - High energy level (High concentrate)

b - Low energy level (Low concentrate)

Period I - The first fourteen weeks

Period II - The second (last) fourteen weeks.

3.4.1 Bioclimatological data and chemical composition of the herbage, silage and concentrate supplement.

The bioclimatological data during the experimental period (June 1974 - July 1975) is shown in Table 3.4. The mean monthly chemical composition of the concentrate ration is shown in Table 3.5, while that of grass and silage during this period is shown in Table 3.6. The average annual precipitation over the period of the experiment was 133.34mm with peak periods between April and October. The highest precipitation occurred in April 1975 with 476.00mm. During the dry season, January 1974 to February 1975, vegetative growth was seriously retarded and herbage fed during this period was replaced with silage (Table 3.6).

The mean monthly minimum and maximum temperatures recorded were 63^{0}F (17.2^{0}C) and 93^{0}F (33.9^{0}C). The range between maximum and minimum temperature was greatest during the dry period especially in the months of November to February. During the months when relative humidity was highest, the lowest dry matter percentages were recorded particularly with the supplementary ration.

3.4.2 Dry Matter (DM) intake

Results of the DM intake of all the breeds while being fed on the high and low energy levels are shown in

Table 3.4.

Bioclimatological Data during the experimental period (June 1974 - July 1975) when three breeds of cows were maintained on grass ad lib with low or high concentrate supplement

Months	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Precipitation (mm)	221.70	245.91	26.70	130.00	128.15	15.80	-	-	71.00	132.90	476.00	164.34	127.25	127.00
Mean Daily minimum temperature °F	70	70	73	70	71	71	67	63	70	73	72	72	71	70
Mean Daily maximum temperature	86	83	84	83	85	90	91	93	93	93	90	88	87	83
Relative Humidity % 10.00hrs	85	87	87	88	87	81	67	54	75	80	81	85	86	89
16.00hrs	72	78	74	75	71	53	40	27	44	53	65	69	72	77

Nov - Feb. Dry season period
March - Oct. Rainy " "

TABLE 3.5

**Mean monthly chemical composition of the concentrate ration (determined on dry matter basis) fed to three breeds of dairy cows with high or low levels from June 1974 to July 1975

NUTRIENTS	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB	MARCH	APRIL	MAY	JUNE	JULY
Dry Matter (g/100g DM)	83.45	87.48	86.34	86.50	86.53	85.44	88.95	90.72	91.72	89.70	83.52	84.00	86.20	88.52
Organic Matter	78.15	82.26	82.45	82.08	82.52	81.42	85.00	86.82	87.77	85.70	78.12	79.80	81.00	83.52
Ash " "	5.30	5.22	3.89	4.42	4.01	4.02	3.95	3.90	3.95	4.00	5.40	4.20	5.20	5.00
Crude Protein " "	16.00	16.52	16.02	16.84	15.09	15.55	14.75	15.00	15.08	16.85	17.28	17.54	18.26	16.54
Crude Fibre " "	8.75	8.83	7.03	7.00	8.73	6.00	7.14	6.15	6.32	6.65	9.00	9.08	8.45	7.74
Ether Extract " "	1.95	2.01	1.54	2.00	1.44	1.35	1.33	1.35	1.30	1.36	1.32	1.62	1.41	1.82
+N F E " "	51.45	54.90	57.86	56.24	57.26	58.52	61.78	64.32	65.07	60.84	50.52	51.56	52.88	57.42
Calcium (mg/100g DM)	72.55	78.80	80.20	80.00	79.30	80.22	83.12	79.00	82.10	82.00	81.00	76.52	78.12	69.78
Phosphorus " "	63.80	64.00	62.00	63.00	63.50	62.70	56.40	55.00	58.42	63.00	68.00	65.78	66.50	60.00
Sodium " "	13.21	13.20	13.00	12.75	12.69	13.00	12.75	12.88	13.21	12.80	13.45	13.55	12.95	13.00
Potassium " "	920.55	916.50	903.00	940.80	952.08	906.00	882.10	838.00	900.00	902.40	988.50	990.00	968.50	970.00
Energy (KJ/g DM)	23.10	22.75	22.10	21.52	21.51	21.20	21.00	20.90	20.82	21.00	22.85	22.80	23.00	22.30

**Mean of four determinations except the DM which was determined daily

+Nitrogen - free extractives.

TABLE 3.6

**Mean monthly chemical composition of the grass and silage (determined on dry matter basis) fed to three breeds of dairy cows with high or low level of concentrate from June 1974 to July 1975

NUTRIENTS	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY
*Dry Matter (g/100g DM)	30.45	32.68	49.52	39.52	47.80	52.50	56.54	24.40	23.45	40.26	28.90	32.83	35.70	37.50
Organic Matter " "	83.14	83.40	85.43	83.55	84.27	86.30	86.99	86.90	86.23	86.44	85.03	83.71	83.75	83.60
Ash " "	8.38	7.39	6.36	8.45	7.56	5.52	4.87	8.10	9.25	6.00	6.56	7.28	7.00	7.28
Crude Protein " "	10.25	12.84	5.84	5.56	9.88	9.00	5.28	9.30	9.25	8.25	11.71	10.26	11.25	13.55
Crude Fibre " "	22.58	21.48	28.46	25.47	29.56	30.56	28.51	28.40	28.45	22.62	25.45	29.52	30.51	33.50
Ether Extract " "	1.00	1.14	0.52	1.15	1.50	1.30	1.00	2.01	1.92	1.84	2.80	2.88	1.95	1.10
+N F E " "	49.31	47.94	50.61	51.37	43.33	45.44	52.20	47.19	46.61	53.75	45.07	41.05	40.04	35.45
Calcium (mg/100g DM)	315.40	295.00	320.00	325.40	332.30	312.40	345.20	310.00	308.50	298.45	295.20	290.00	301.00	308.40
Phosphorus " "	125.00	138.00	130.00	128.15	125.00	120.00	120.45	108.42	102.00	104.25	144.50	132.18	130.00	132.00
Sodium " "	82.44	72.32	60.08	63.52	64.87	70.52	60.45	60.00	65.00	64.88	68.77	70.52	81.44	63.45
Potassium " "	2852.40	2572.10	2352.45	2400.00	2447.20	2000.50	1950.00	2100.00	2000.00	2500.00	2547.50	2875.00	2538.00	2450.70
Energy (KJ/g DM)	17.62	17.68	17.54	17.55	17.51	17.40	17.32	17.40	17.52	17.62	17.33	17.68	17.75	17.60

**Mean of four determinations except the DM which was determined daily. *Dry matter content of fresh grass.

Chemical composition of the silages fed (30th Dec. 1974 - 3rd March 1975). +Nitrogen - free extractives.

Tables 3.7a, b

The forage DM intake which increased with the stage of lactation reached the peak between the 5th and the 10th week of lactation. (Tables 3.7a,b and Fig. 3.1).

The White Fulani cows reached their peak DM intake on the 9th week while the German Brown and Friesian cows reached their peak on the 7th week (Fig. 3.1). When the roughage intake alone (expressed on metabolic size) was plotted against the lactation weeks (Fig. 3.2) peak feed intake was recorded for the White Fulani and German Brown cows on the 8th week and Friesian on the 6th week. After reaching the peak, there was a gradual decline in the roughage feed intake until between the 21st (White Fulani) and 23rd (exotic breeds) weeks when irregular fluctations were observed in the feed intake till the end of the experiment. Appendix B3.1(1) indicates that there were significant differences ($P < 0.01$) between the three stages with the early and the middle stages of lactation being significant to the late.

The values for the roughage DM intake of the White Fulani range from 3.26 to 5.98kg/day with a mean value of 4.49 ± 0.16kg/day. The German Brown had feed intake values

Table 3.7a **Dry matter intake (kg/Day) of the three breeds of lactating cows fed on grass with high or low concentrate rations during the 28-week experimental period (weeks 1-14)

DM Intake (kg/day)	Breed	EL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean ± SE
F	White Fulani	H	4.39	5.34	5.98	5.43	5.98	5.94	5.44	4.63	5.95	5.50	5.37	4.93	4.83	4.80	5.32±0.19
		L	3.90	3.60	3.26	4.43	3.70	3.96	4.15	4.81	4.45	4.39	3.70	3.66	3.68	4.24	4.00±0.14
	German Brown	H	4.55	5.68	5.85	6.21	6.14	5.94	6.32	6.17	6.07	5.91	5.60	5.58	5.43	5.24	5.76±0.13
		L	4.90	4.66	5.06	5.74	6.06	6.43	6.93	6.23	6.69	6.42	6.45	5.71	5.56	5.53	5.88±0.18
	Friesian	H	6.29	6.68	7.58	7.39	8.12	7.86	7.97	7.49	6.98	6.40	7.06	6.66	7.28	6.85	7.18±0.20
		L	4.99	5.15	5.38	5.57	6.36	6.38	6.50	6.83	6.86	7.14	6.64	6.10	5.73	5.16	6.06±0.19
C	White Fulani	H	1.75	1.72	2.30	2.40	2.28	2.60	2.85	2.90	2.73	2.68	2.25	2.10	2.00	2.10	2.33±0.10
		L	1.58	1.29	1.30	1.34	1.41	1.50	1.35	1.05	1.05	1.05	1.00	0.82	0.98	0.95	1.19±0.06
	German Brown	H	2.40	2.35	2.58	2.80	2.80	3.00	2.99	3.15	3.10	2.95	2.83	2.50	2.32	2.13	2.71±0.09
		L	1.68	1.98	2.28	2.55	2.80	3.03	2.64	2.25	2.25	2.10	2.08	1.78	1.70	1.60	2.19±0.12
	Friesian	H	1.75	2.08	2.75	3.41	3.50	3.68	3.88	3.63	3.50	3.45	3.15	2.68	2.25	2.30	3.00±0.14
		L	1.65	1.55	2.25	2.39	2.58	2.48	2.59	2.50	2.35	2.20	1.95	1.68	1.60	1.57	2.10±0.14
T	White Fulani	H	6.14	7.06	8.28	7.83	8.26	8.54	8.29	7.53	8.68	8.18	7.62	7.03	6.83	6.90	7.65±0.20
		L	5.48	4.89	4.56	5.77	5.11	5.46	5.50	5.86	5.50	5.44	4.70	4.48	4.66	5.19	5.19±0.12
	German Brown	H	6.95	8.03	8.43	9.01	8.94	8.94	9.31	9.32	9.17	8.86	8.43	8.08	7.75	7.37	8.47±0.20
		L	6.58	6.64	7.34	8.29	8.86	9.46	9.57	8.48	8.94	8.52	8.53	7.49	7.26	7.13	8.07±0.27
	Friesian	H	8.04	8.76	10.33	10.80	11.62	11.54	11.85	11.12	10.48	9.85	10.21	9.34	9.53	9.15	10.18±0.28
		L	6.64	6.70	7.63	7.96	8.94	8.86	9.09	9.33	9.21	9.34	8.59	7.78	7.33	6.73	8.16±0.27

F = Forage DM Intake C = Concentrate DM Intake T = Total DM Intake EL = Energy Level
H = High level concentrate (high energy level) L = Low level concentrate (low energy level)
** = Two animals within a breed were maintained on each level. Each value is also a mean of the week's DM intake.

Table 3.7b **Dry matter intake (kg/Day) of the three breeds of lactating cows fed on grass with high or low concentrate rations during the 28-week experimental period (weeks 15-28)

DM Intake (kg/day)	Breed	EL*	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Mean ± SE
F	White Fulani	L	4.84	4.49	5.00	4.15	3.89	3.60	4.08	4.80	4.34	4.18	4.55	3.86	4.33	4.33	4.32±0.11
		H	4.27	3.61	3.81	4.09	4.40	4.23	4.23	4.15	4.59	5.03	4.45	4.82	4.54	4.13	4.31±0.10
	German Brown	L	5.01	5.22	5.71	5.30	5.82	6.19	5.08	5.39	4.83	5.83	6.26	5.64	5.07	5.03	5.46±0.13
		H	5.43	5.25	5.12	5.00	5.03	4.80	4.81	5.20	5.69	5.55	5.29	5.27	5.70	5.68	5.27±0.09
	Friesian	L	6.09	6.39	5.98	5.15	5.50	5.65	5.15	4.57	5.55	5.21	4.78	4.80	4.61	4.42	5.27±0.20
		H	5.16	4.89	4.84	5.50	5.84	5.45	5.25	5.21	5.07	5.11	5.30	4.91	4.91	4.88	5.17±0.08
C	White Fulani	L	1.16	1.15	1.15	1.03	1.00	1.00	1.10	1.03	1.00	1.00	0.88	0.80	0.78	0.70	0.98±0.04
		H	1.58	1.46	1.44	1.35	1.42	1.30	1.23	1.15	1.13	1.10	0.98	1.10	1.05	0.99	1.23±0.05
	German Brown	L	1.75	1.45	1.28	1.25	1.45	1.30	1.10	1.13	1.18	1.23	1.10	1.18	1.18	1.02	1.26±0.05
		H	2.55	2.23	2.08	1.95	1.95	2.01	1.98	2.18	2.12	1.95	1.98	1.85	1.68	1.48	2.00±0.07
	Friesian	L	1.35	1.35	1.25	1.10	1.05	1.08	1.10	1.08	1.00	0.94	0.95	0.94	0.88	0.88	1.07±0.04
		H	2.08	2.38	2.34	2.13	2.38	2.00	2.01	1.98	2.07	2.33	2.05	1.98	1.60	1.50	2.06±0.07
T	White Fulani	L	6.00	5.64	6.15	5.08	4.89	4.60	5.18	5.83	5.34	5.18	5.43	4.66	5.11	5.03	5.30±0.13
		H	5.85	5.07	5.25	5.44	5.82	5.53	5.46	5.30	5.72	6.13	5.43	5.92	5.59	5.12	5.54±0.09
	German Brown	L	6.76	6.67	6.99	6.55	7.27	7.49	6.18	6.52	6.01	7.06	7.36	6.82	6.25	6.05	6.72±0.13
		H	7.98	7.48	7.20	6.95	6.98	6.81	6.79	7.38	7.81	7.50	7.27	7.12	7.38	7.16	7.27±0.10
	Friesian	L	7.44	7.44	7.23	6.25	6.55	6.73	6.25	5.65	6.55	6.15	5.73	5.74	5.49	5.30	6.34±0.23
		H	7.24	7.27	7.18	7.63	8.22	7.45	7.26	7.19	7.14	7.44	7.35	6.89	6.51	6.38	7.23±0.12

F = Forage DM Intake C = Concentrate DM Intake T = Total DM Intake EL* = Energy level change of diet
H = High level concentrate (high energy level)
L = Low level concentrate (low energy level) ** = Two animals within a breed were maintained on each level. Each value is also a mean of the week's DM intake.

Table 3.7c

Percentage concentrate DM in total DM intake

Breed	High level concentrate		Low level concentrate	
	1st period	2nd period	1st period	2nd period
White Fulani	30.46	22.20	22.93	18.49
German Brown	32.00	27.51	27.14	18.75
Friesian	29.47	28.49	25.74	16.88

1st period = The first fourteen weeks (1-14 weeks)

2nd " = The second " " 15-28 ")

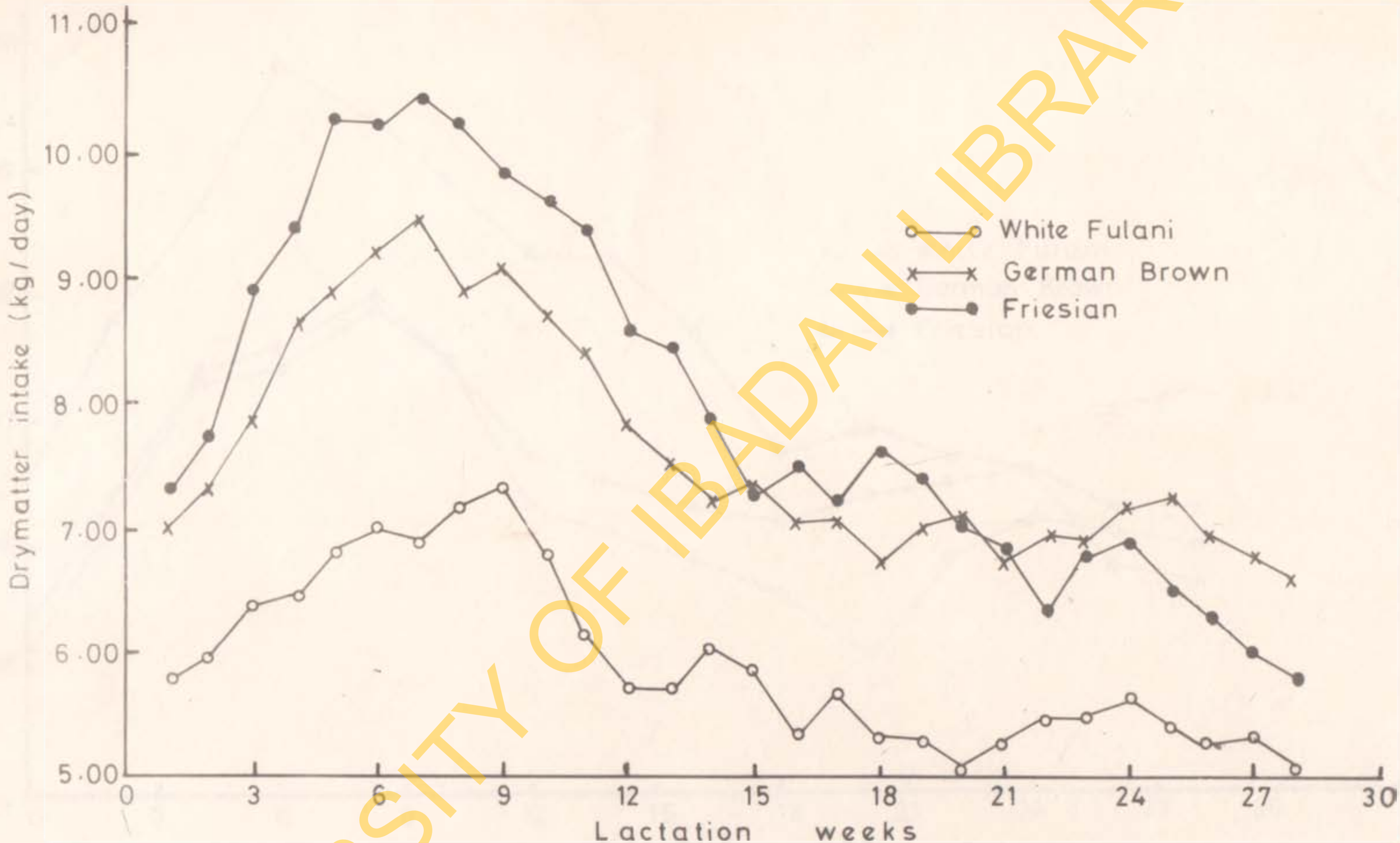

Fig. 3.1 Mean total drymatter intake. (kg/day).

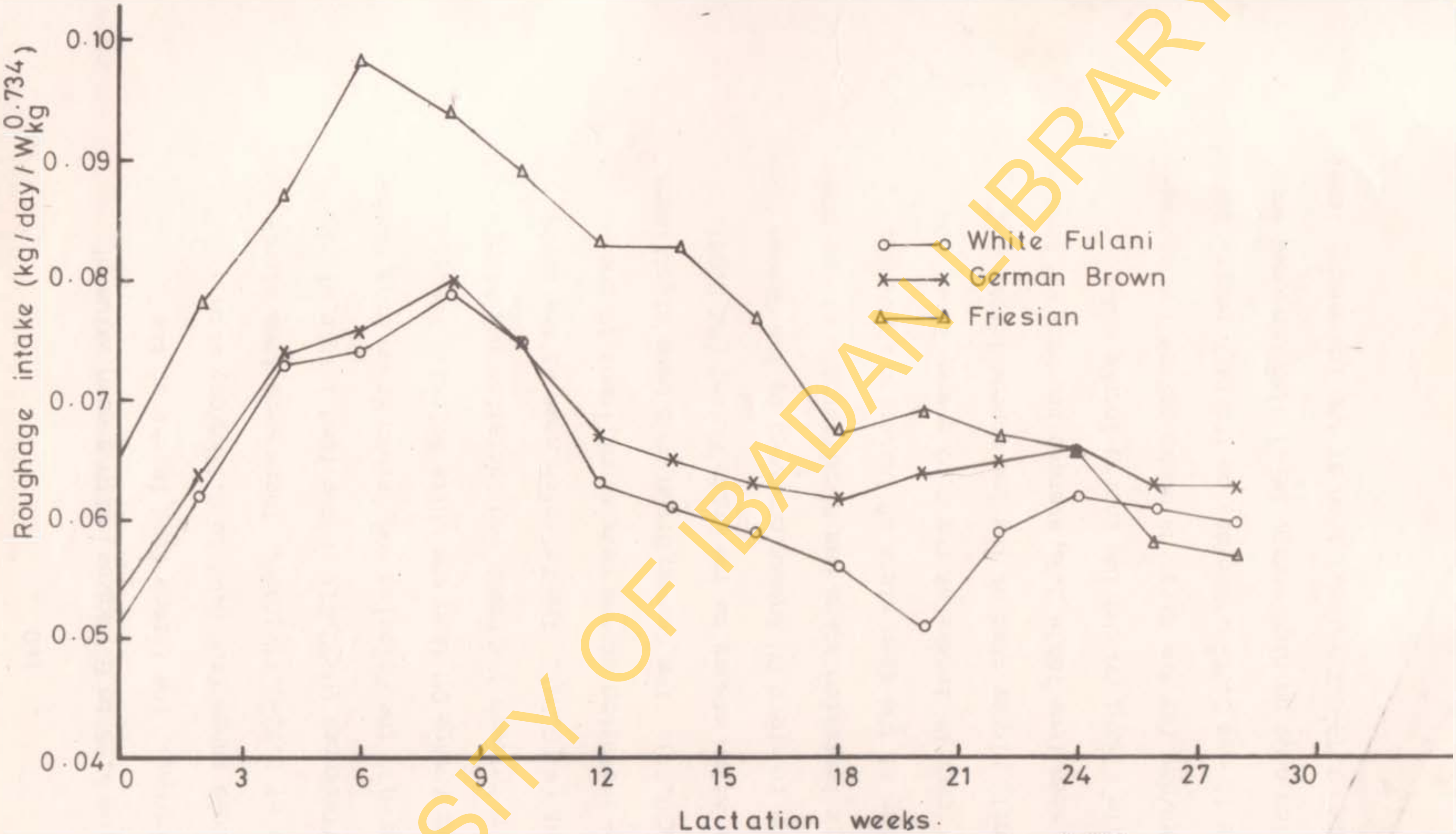

FIG. 3.2 Mean roughage drymatter intake (kg/day/$W_{kg}^{0.734}$)

ranging from 4.55 to 6.93kg/day with a mean value of 5.59 ± 0.16kg/day. The forage feed intake of the Friesian cows range from 4.42 to 8.12kg/day with a mean value of 5.92 ± 0.21kg/day. There were thus significant differences ($P < 0.01$) in the feed intake within the breeds with the Friesian and German Brown cows consuming higher forage DM than the White Fulani. The interaction between the breed and lactation was highly significant ($P < 0.01$). The Friesian cows at the early and middle lactation stages were significant to the others ($P < 0.01$). The German Brown cows were significant at all lactation stages to the White Fulani ($P < 0.01$). However the roughage DM intake consumed by the German Brown at the late lactation stage was significantly higher than the Friesian at the same stage of lactation ($P < 0.05$).

The forage DM intake at the high energy level were significantly higher than at the low energy intake ($P < 0.01$). As can be seen from Table 3.7a, average roughage DM intake of the White Fulani on the low energy intake was 4.00 ± 0.14kg/day for the first 14 weeks before the change-over while it was 5.32 ± 0.19kg/day on the high energy intake. The Friesian cows on high energy level also consumed more roughage DM (7.18 ± 0.20kg/day) than at the low energy level

(6.06 ± 0.19). The consumption of the German Brown cows was, however, unexpected and therefore difficult to explain. Animals on low energy level consumed more DM than on the high energy level (5.88 ± 0.13 to 5.76 ± 0.12kg/day). The statistical analysis of the interaction between diet and breed showed high significant differences ($P < 0.01$). While there was no statistical difference ($P > 0.05$) between the consumption of the Friesian and German Brown cows at the low energy level intake, both of them consumed more forage DM than the White Fulani cow at the same level ($P < 0.01$). The DM intake by the Friesian cows at the high energy level was higher than that of the German Brown and White Fulani cows at the same level ($P < 0.01$).

Finally, the DM intake during the dry season was higher than during the wet season ($P < 0.05$).

3.4.3 Milk Yield and Solids-Corrected Milk

The mean milk yield and solids-corrected milk (SCM) over a period of twenty-eight weeks are shown in Table 3.8 and Fig. 3.3 - 3.5. The statistical analysis is tabulated on Appendix B3.1a, b.

The influence of the stages of lactations on milk production and solids-corrected milk is shown by the fact that there was a progressive increase in milk yield until the attainment of peak production between the 5th and the 9th week of lactation. After this there was a gradual decline to the end of the experiment. Except for the Friesian cows, Fig. 3.3 - 3.5 show that animals which were first placed on low energy intake attained peak production earlier than those which were first placed on high energy intake. Cows on high energy level also maintained their peak for about two weeks before declining. However those on low energy dropped in their milk yield immediately after attaining the peak. This is very obvious in the case of the German Brown breed.

The influence of the stages of lactation on milk yield and SCM was in favour of the early lactation which was significantly higher than the middle and late lactations, while the middle lactation was significant to the late lactation ($P < 0.01$).

The milk yield of the indigenous cows were markedly lower than the exotic cows. While the White Fulani cows produced an average of 27.55 ± 6.15kg milk/wk and 29.83 ± 5.26kg SCM/wk, the German Brown cows yielded

Table 3.8 **Milk yield (kg/week) of the three breeds of lactating cows fed on grass with low or high concentrate during the 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	30.10	31.17	42.00	49.06	35.23	44.32
2	38.39	31.10	45.91	58.59	47.05	54.10
3	40.56	32.60	50.12	67.25	59.43	56.82
4	38.75	34.26	50.80	74.04	60.69	63.87
5	43.64	37.60	52.94	78.73	63.64	63.64
6	48.31	32.60	54.77	69.29	66.25	68.19
7	49.80	28.96	55.77	57.62	64.28	65.02
8	47.83	28.41	55.91	58.82	60.91	55.00
9	45.92	28.73	57.23	53.36	58.89	52.95
10	38.77	26.67	54.75	51.78	56.41	45.23
11	35.97	21.25	48.63	45.20	45.23	40.68
12	34.28	26.28	45.91	42.93	37.98	40.85
13	35.21	25.22	43.64	41.57	39.21	38.86
14	31.92	24.20	41.49	41.10	36.59	33.23
Mean	39.96±6.86	29.22±4.36	49.99±5.46	56.38±12.25	52.27±11.48	51.63±11.18
*	L	H	L	H	L	H
15	31.81	23.00	37.73	35.42	34.46	33.78
16	31.16	22.07	36.73	33.40	33.48	35.49
17	28.23	20.74	32.96	30.44	29.21	33.40
18	28.10	22.47	34.78	30.20	28.39	36.82
19	27.71	20.59	30.23	31.12	28.63	29.50
20	24.83	18.37	28.41	31.12	29.76	30.23
21	23.16	17.29	26.13	33.61	28.85	29.55
22	22.98	16.49	25.22	33.84	26.58	30.14
23	22.26	16.26	25.68	32.02	24.84	33.41
24	19.12	15.29	24.05	31.58	26.80	30.23
25	17.13	16.75	24.55	28.62	24.75	25.91
26	17.40	16.26	26.82	25.44	23.86	23.18
27	15.71	13.71	23.87	22.26	22.03	22.95
28	15.62	9.91	18.41	21.26	19.20	19.00
Mean	23.23±6.92	17.80±3.69	28.26±5.55	30.02±4.27	27.20±4.14	29.54±5.16

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

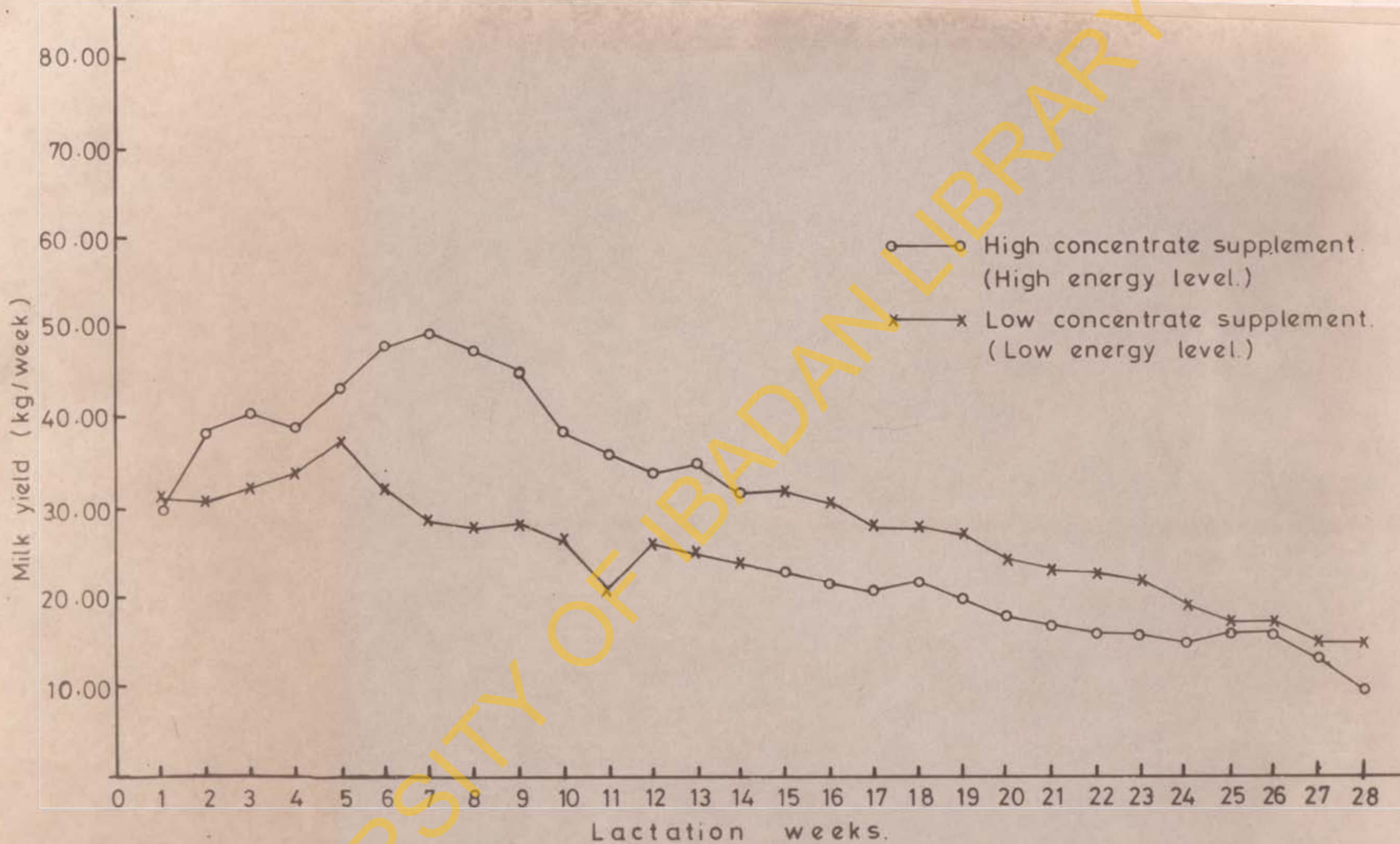

Fig. 3.3 Graph showing milk yield of the white Fulani cows.

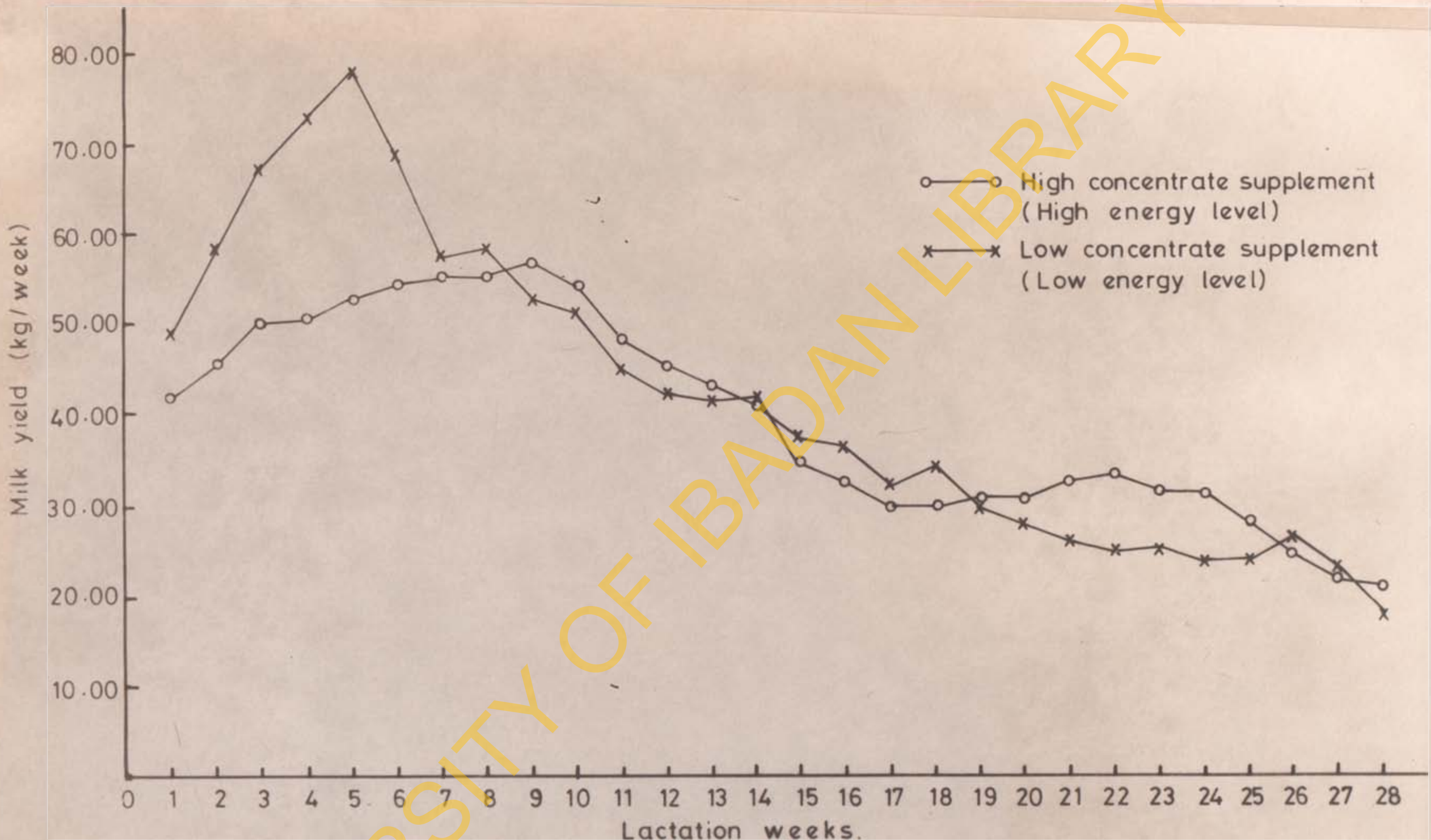

Fig. 3.4 Graph showing milk yield of the German brown cows.

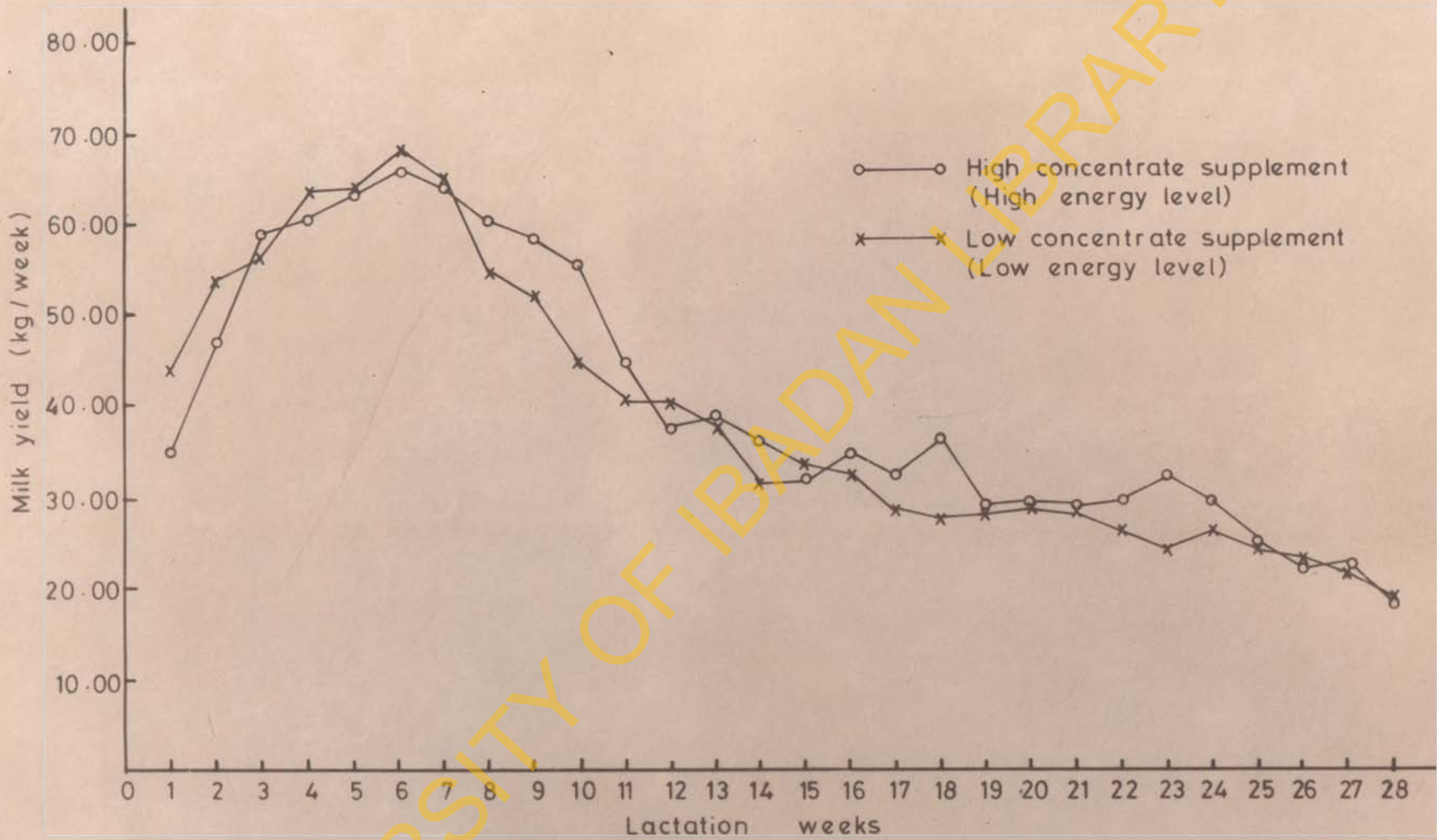

Fig. 3.5 Graph showing milk yield of the Friesian cows.

41.16 ± 8.19kg milk/wk and 40.16 ± 5.84kg SCM/wk and the Friesian cows 40.16 ± 6.15kg milk/wk and 36.91 ± 3.28kg SCM/wk. Statistical analysis showed that there were significant differences between the milk yield produced by the three breeds ($P < 0.05$). This was also true of the SCM. The milk yield and SCM of the exotic cows were significantly higher than those of the indigenous breed ($P < 0.01$). The Newman-Keuls (1955) comparison between ordered means revealed that although the milk production of the German Brown cows was higher than the Friesian, there was no statistical difference between them ($P > 0.05$).

The interaction between the stages of lactation and breed showed considerable significant differences ($P < 0.01$). Though average milk production of the German Brown cows was higher than the Friesian cows, there was no statistical difference between milk yield during the early lactation. However both breeds had their milk yield being statistically higher than the White Fulani ($P < 0.01$) at this stage of lactation. At the middle lactation, the average production of the German Brown cows was statistically significant to the Friesian, while the Friesian was statistically higher than the White Fulani

Table 3.9 **Solids-corrected milk (kg/week) of the three breeds of lactating cows fed on grass with low or high concentrate during 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	33.02	32.48	42.39	46.78	32.24	39.91
2	41.79	32.41	45.73	55.78	43.04	48.85
3	43.41	33.47	49.44	63.09	54.17	51.87
4	41.37	35.11	49.65	69.02	55.04	57.61
5	47.64	39.03	51.30	73.77	58.64	57.68
6	53.13	34.62	53.38	65.82	61.44	61.68
7	54.14	30.71	54.63	54.63	59.38	59.15
8	52.30	30.77	55.00	56.16	55.97	49.53
9	50.59	31.33	55.93	51.07	54.29	47.88
10	42.66	29.10	52.60	50.13	49.96	41.04
11	39.12	22.86	47.90	41.73	41.71	36.70
12	37.08	28.16	45.25	41.34	35.52	36.92
13	37.77	27.15	43.53	40.13	36.90	39.19
14	34.46	25.97	41.42	39.89	34.54	30.09
Mean	43.45±8.07	30.94±4.14	49.15±4.89	53.52±11.17	48.06±10.34	47.01±9.86
*	L	H	L	H	L	H
15	34.35	24.69	37.61	34.21	32.46	30.77
16	33.58	23.72	36.85	32.45	31.71	31.99
17	30.77	22.21	32.77	29.74	27.56	30.10
18	30.85	24.45	34.77	30.15	26.48	33.24
19	30.58	22.36	30.31	31.05	26.72	26.71
20	27.16	20.03	28.74	31.10	28.04	27.59
21	26.04	18.85	25.78	33.76	27.48	27.05
22	24.94	17.93	24.86	34.01	24.99	27.49
23	25.11	17.72	25.20	32.31	23.40	30.29
24	21.80	16.16	23.48	31.88	25.26	27.48
25	19.57	18.13	24.13	28.95	23.52	23.67
26	19.66	17.48	26.40	25.75	22.61	21.30
27	17.46	15.10	23.07	22.54	20.86	21.10
28	17.47	10.94	18.15	21.56	18.60	17.46
Mean	25.67±7.82	19.27±3.92	28.01±5.73	29.96±4.03	25.69±3.82	26.87±4.55

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

($P < 0.01$). At the late stage of lactation, though the milk yield of the German Brown was higher than the Friesian, there were no significant differences ($P > 0.05$) but both of them as in the early lactation stage were significantly higher than the White Fulani ($P < 0.01$). The statistical analysis of the SCM follows this pattern except that at the early stage of lactation the production of the German Brown was statistically higher than the Friesian ($P < 0.05$). This was perhaps due to the higher percentage of total solids in the German Brown than the Friesian.

Although increase in the amount of concentrate fed was accompanied by the increase in milk yield particularly during the early stage of lactation (Fig. 3.3 - Fig. 3.5) and production of milk yield by animals on high energy was slightly higher than those on low energy (36.60kg/day and 35.99kg/day respectively), statistical analysis showed that there was no statistical difference in the production of milk by the animals fed high or low energy.

The interaction between the breed and diet was significant ($P < 0.05$) for milk yield but non-significant for the SCM ($P > 0.05$). While the milk yield of the German Brown and Friesian cows under high energy level was significantly higher ($P < 0.01$) than those fed low energy level, there was no significant difference ($P > 0.05$) between the two levels for the White Fulani. The interaction between stages of lactation and diets was significant ($P < 0.05$) both for the milk production and SCM. A break-down of the analysis showed that milk production at the high energy levels were significantly higher than at the low energy level ($P < 0.05$) during the early and middle stages of lactation. There was no difference ($P > 0.05$) at the late stage of lactation. A 3-way interaction among the stages of lactation, diets and breeds were highly significant ($P < 0.01$). A summary of this as given by the Newman-Keuls (1955) comparison among ordered means showed that the milk yield and SCM of the exotic breeds at the early stage of lactation and under the high energy level were significantly higher than the other stages of lactation and at the lower energy level ($P < 0.01$). This was not the situation with the indigenous breed. While milk production at the early lactation was significantly higher than the other stages of lactation, the differences between the high and low levels of energy were not significant ($P > 0.05$).

The milk yield during the wet season was higher than that at the dry season ($P < 0.05$).

3.4.4 Milk Composition

Results of the milk quality of the breeds are shown in Tables 3.9 - 3.18. The statistical analysis are shown in Appendix B3.1.

(a) Butterfat: The butterfat content of the milk decreased slightly for the first three or four weeks before increasing progressively till the end of the experiment. This increase was more pronounced with the indigenous cows than the exotic breeds. Statistical analysis has shown a significant different ($P < 0.01$) between the three stages of lactation. The butterfat percentage at the late stage was statistically higher than that at the early and middle stages of lactation ($P < 0.01$) while the middle was significantly higher than the early stage ($P < 0.05$). The White Fulani butterfat percent was significantly higher than that of the German Brown and Friesian cows ($P < 0.01$). The White Fulani, German Brown and Friesian cows produced milk containing an average of 5.33%, 3.94% and 3.56% of butterfat respectively. The butterfat percent of the German

Table 3.10 **Milk fat (g/100g milk) content of the three breeds of lactating cows' milk fed on grass with low or high concentrate during 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	4.88	4.91	3.95	3.73	3.48	3.44
2	4.89	4.90	3.93	3.75	3.48	3.41
3	4.86	4.64	3.82	3.65	3.27	3.42
4	4.84	4.70	3.83	3.53	3.31	3.35
5	4.85	4.76	3.56	3.54	3.25	3.38
6	4.83	4.89	3.61	3.57	3.28	3.37
7	4.81	5.02	3.61	3.61	3.25	3.43
8	4.96	5.30	3.65	3.69	3.32	3.43
9	5.04	5.52	3.70	3.78	3.36	3.39
10	5.06	5.44	3.75	3.83	3.58	3.44
11	4.98	5.36	3.81	3.86	3.50	3.49
12	5.03	5.36	3.78	3.87	3.55	3.46
13	5.04	5.35	3.90	3.91	3.63	3.55
14	5.11	5.38	3.95	3.94	3.66	3.54
Mean	4.94±0.04	5.11±0.08	3.78±0.04	3.73±0.04	3.42±0.04	3.44±0.02
*	L	H	L	H	L	H
15	5.11	5.35	3.96	3.92	3.65	3.52
16	5.11	5.36	3.97	3.94	3.70	3.50
17	5.43	5.29	4.02	4.13	3.68	3.48
18	5.61	5.41	4.14	4.13	3.65	3.49
19	5.53	5.37	4.21	4.20	3.69	3.52
20	5.44	5.62	4.25	4.19	3.75	3.65
21	5.64	5.47	4.11	4.19	3.80	3.71
22	5.73	5.63	4.20	4.17	3.78	3.65
23	5.91	5.58	4.14	4.16	3.81	3.52
24	6.07	5.66	4.11	4.17	3.82	3.56
25	6.16	5.67	4.08	4.18	3.83	3.61
26	5.97	5.68	4.06	4.19	3.84	3.64
27	5.99	5.86	4.18	4.20	3.93	3.69
28	6.21	5.86	4.21	4.22	4.10	3.67
Mean	5.70±0.09	5.56±0.05	4.12±0.02	4.14±0.02	3.79±0.03	3.59±0.02

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

Brown was significantly higher than that of the Friesian ($P < 0.05$). There was no interaction between the stages of lactation and diet, and among the stages of lactation, diet and breed but there was a significant interaction between the breed and stages of lactation ($P < 0.01$) and between breed and diet ($P < 0.05$). The butterfat content during the wet season was higher than during the dry season ($P < 0.05$).

(b) Milk Protein: The protein content of milk was also influenced by the stages of lactation. Although there were irregular fluctuations from the start to the end of the experiment, statistical analysis showed significant differences between the threee stages of lactation ($P < 0.05$) with the late and middle lactations being significantly higher than the early lactation. The average protein contents of milk of the White Fulani, German Brown and Friesian cows were 3.36%, 3.28% and 3.08% respectively. The values for the White Fulani was significantly higher than that of the German Brown and Friesian ($P < 0.05$) while that of the German Brown was in turn significantly higher than that of the Friesian ($P < 0.05$). The influence of the diets was also very pronounced as the high energy level produced a higher percentage of protein than the low energy level

Table 3.11 **Milk protein (g/100g milk) content of the three breeds of lactating cows' milk fed on grass with low or high concentrate during 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	3.23	3.21	3.31	3.18	3.03	3.06
2	3.22	3.20	3.31	3.14	3.11	3.00
3	3.28	3.21	3.28	3.12	3.04	3.00
4	3.24	3.20	3.30	3.11	3.04	2.90
5	3.25	3.16	3.30	3.11	3.07	2.99
6	3.24	3.25	3.30	3.17	3.06	3.02
7	3.24	3.21	3.32	3.16	3.08	3.03
8	3.21	3.29	3.38	3.15	3.09	3.02
9	3.22	3.31	3.37	3.20	3.11	3.01
10	3.24	3.26	3.37	3.26	3.16	3.04
11	3.24	3.28	3.45	3.24	3.14	3.05
12	3.26	3.32	3.45	3.26	3.13	3.05
13	3.28	3.34	3.31	3.31	3.13	3.04
14	3.30	3.32	3.43	3.33	3.14	3.05
Mean	3.24±0.01	3.25±0.02	3.25±0.02	3.20±0.02	3.10±0.02	3.02±0.01
*	L	H	L	H	L	H
15	3.30	3.30	3.42	3.33	3.13	3.04
16	3.26	3.31	3.41	3.34	3.14	3.04
17	3.29	3.34	3.64	3.46	3.13	3.07
18	3.31	3.34	3.65	3.48	3.12	3.00
19	3.24	3.34	3.36	3.56	3.11	3.05
20	3.25	3.34	3.57	3.57	3.11	3.00
21	3.31	3.32	3.58	3.60	3.12	3.02
22	3.28	3.32	3.29	3.64	3.11	3.05
23	3.29	3.32	3.28	3.64	3.12	3.07
24	3.28	3.34	3.29	3.64	3.14	3.07
25	3.31	3.32	3.31	3.68	3.15	3.14
26	3.30	3.34	3.30	3.67	3.13	3.12
27	3.29	3.34	3.32	3.65	3.18	3.15
28	3.30	3.35	3.30	3.64	3.19	3.18
Mean	3.29±0.01	3.33±0.05	3.33±0.04	3.36±0.03	3.13±0.02	3.07±0.02

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

(3.28% to 3.16%). This was statistically significant ($P < 0.05$). There was a significant interaction between breed and lactation ($P < 0.05$), breed and diet ($P < 0.01$) and among breed, diet and lactation ($P < 0.05$). There were however no significant differences between lactation and diet ($P > 0.05$). Considerable and highly significant differences ($P < 0.01$) were found between the protein percentage during the wet season (3.38%) and dry season (3.06%).

(c) Lactose: Apart from the fact that there was a high statistical significance between the lactose content of the milk of the three breeds ($P < 0.01$), 4.78% for White Fulani, 4.55% for German Brown and 4.71% for the Friesian, there was no significant difference among the stages of lactation ($P > 0.05$) and between the two diets ($P > 0.05$). The lactose content of the White Fulani cows' milk was significantly higher than that of the Friesian ($P < 0.05$), while that of the Friesian was significantly higher than that of the German Brown ($P < 0.01$). There were no statistical differences between the milk lactose percent during the two seasons, wet and dry ($P > 0.05$).

Table 3.12 **Lactose (g/100g milk) content of the three breeds of lactating cows' milk fed on forage and low or high concentrate supplement during the 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	4.82	4.72	4.76	4.38	4.86	4.72
2	4.82	4.74	4.80	4.41	4.86	4.71
3	4.80	4.73	4.81	4.80	4.83	4.73
4	4.81	4.69	4.75	4.55	4.82	4.69
5	4.80	4.73	4.76	4.39	4.77	4.73
6	4.80	4.70	4.74	4.26	4.77	4.70
7	4.80	4.70	4.71	4.29	4.71	4.70
8	4.80	4.75	4.69	4.29	4.75	4.75
9	4.78	4.91	4.74	4.28	4.72	4.75
10	4.79	4.72	4.79	4.32	4.69	4.74
11	4.80	4.76	4.76	4.34	4.66	4.76
12	4.78	4.75	4.78	4.35	4.68	4.75
13	4.78	4.75	4.80	4.30	4.67	4.75
14	4.78	4.71	4.78	4.39	4.69	4.71
Mean	4.79±0.07	4.74±0.02	4.76±0.02	4.35±0.02	4.79±0.02	4.73±0.01
*	L	H	L	H	L	H
15	4.80	4.72	4.71	4.39	4.65	4.72
16	4.75	4.73	4.75	4.40	4.65	4.73
17	4.82	4.72	4.78	4.37	4.64	4.72
18	4.83	4.72	4.78	4.39	4.68	4.72
19	4.82	4.80	4.72	4.41	4.62	4.80
20	4.83	4.86	4.65	4.43	4.62	4.86
21	4.84	4.81	4.68	4.45	4.56	4.81
22	4.86	4.80	4.69	4.45	4.55	4.80
23	4.83	4.80	4.69	4.36	4.58	4.80
24	4.88	4.79	4.67	4.35	4.49	4.79
25	4.89	4.64	4.60	4.16	4.53	4.74
26	4.89	4.70	4.65	4.39	4.51	4.70
27	4.88	4.74	4.88	4.44	4.51	4.74
28	4.88	4.73	4.83	4.47	4.46	4.73
Mean	4.84±0.07	4.75±0.02	4.72±0.03	4.39±0.02	4.58±0.02	4.76±0.03

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

(d) Total Solids (TS): Table 3.13 shows the results of the total solids (TS) (g/100g fresh milk) of the three breeds. Apart from the fact that the pattern of values obtained were irregular as the lactation progressed, statistical analysis showed no significant differences ($P > 0.05$) between the three stages of lactation. However statistical significance existed between the values obtained from the three breeds of cattle ($P < 0.01$). The TS percent of the White Fulani cattle (12.97 ± 0.16g/100g fresh milk) was significantly higher than that of the German Brown (12.62 ± 0.08g/100g fresh milk) ($P < 0.05$) while that of German Brown was in turn significantly higher than that of the Friesian (12.03 ± 0.05g/100g fresh milk) ($P < 0.01$). TS percent obtained from cows maintained on high energy ration was statistically higher than those on the low energy ration ($P < 0.05$). There was a high statistical significance between the values obtained for the wet and dry seasons($P < 0.01$), with the wet season producing higher percentage of TS than that of the dry season.

(e) Solids-not-fat (SNF): Results obtained for the solids-not-fat (SNF) percent in Table 3.14 showed a gradual decrease from the start to the end of the experiment. Significant differences therefore existed between the three stages of

Table 3.13 **Total solids (g/100g milk) content of the three breeds of lactating cows' milk fed on grass and low or high concentrate supplement during the 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	13.38	12.70	12.85	12.48	11.95	11.83
2	13.36	12.70	12.85	12.41	12.00	11.89
3	13.15	12.72	12.80	12.27	12.11	12.02
4	13.08	12.62	12.66	12.30	12.09	11.93
5	13.47	12.72	12.76	12.33	12.32	11.96
6	13.63	12.80	12.81	12.50	12.38	11.95
7	13.38	12.79	12.88	12.46	12.35	11.97
8	13.41	12.87	12.85	12.50	12.21	11.94
9	13.46	12.79	12.77	12.43	12.22	11.88
10	13.39	12.81	12.72	12.54	12.21	11.89
11	13.29	12.78	12.77	12.50	12.10	11.86
12	13.18	12.80	12.81	12.42	12.29	11.83
13	13.02	12.81	12.88	12.41	12.31	11.76
14	13.08	12.73	12.85	12.45	12.31	11.82
Mean	13.30±0.07	12.76±0.16	12.80±0.03	12.43±0.03	12.20±0.04	11.89±0.06
*	L	H	L	H	L	H
15	13.07	12.78	12.80	12.40	12.29	11.80
16	13.01	12.81	12.82	12.46	12.31	11.78
17	12.95	12.93	12.72	12.51	12.26	11.80
18	12.93	12.97	12.74	12.60	12.13	11.80
19	13.08	13.04	12.70	12.56	12.10	11.83
20	12.94	13.03	12.51	12.61	12.18	11.81
21	12.96	13.10	12.53	12.72	12.31	11.78
22	12.52	13.04	12.45	12.75	12.13	11.80
23	12.75	13.04	12.43	12.80	12.13	11.84
24	12.97	12.48	12.38	12.81	12.13	11.85
25	12.91	12.75	12.49	12.82	12.23	11.86
26	12.95	12.86	12.52	12.84	12.20	11.89
27	12.66	12.86	12.29	12.83	12.24	11.91
28	12.61	12.88	12.52	12.83	12.32	11.90
Mean	12.88±0.08	12.94±0.17	12.56±0.07	12.68±0.04	12.21±0.04	11.83±0.06

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

Table 3.14 **Solids-not-fat (g/100g milk) content of the three breeds of lactating cows milk fed on grass with low or high concentrate during 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	8.50	7.79	8.90	8.75	8.47	8.39
2	8.47	7.80	8.92	8.66	8.52	8.48
3	8.29	8.08	8.98	8.62	8.84	8.60
4	8.24	7.92	8.83	8.77	8.78	8.58
5	8.62	7.96	9.20	8.79	9.07	8.58
6	8.80	7.91	9.20	8.93	9.10	8.58
7	8.57	7.77	9.27	8.85	9.10	8.54
8	8.45	7.57	9.20	8.81	8.89	8.51
9	8.42	7.27	9.07	8.65	8.86	8.49
10	8.33	7.37	8.97	8.71	8.63	8.45
11	8.31	7.42	8.96	8.64	8.60	8.37
12	8.15	7.44	9.03	8.55	8.74	8.37
13	7.98	7.46	8.98	8.50	8.68	8.21
14	7.97	7.35	8.90	8.51	8.65	8.28
Mean	8.36±0.06	7.65±0.07	9.03±0.04	8.70±0.03	8.78±0.06	8.46±0.06
*	L	H	L	H	L	H
15	7.96	7.43	8.84	8.48	8.64	8.28
16	7.90	7.45	8.85	8.52	8.61	8.28
17	7.52	7.64	8.70	8.38	8.58	8.32
18	7.32	7.56	8.60	8.47	8.48	8.31
19	7.55	7.67	8.49	8.36	8.41	8.31
20	7.50	7.41	8.26	8.42	8.43	8.16
21	7.32	7.63	8.42	8.53	8.51	8.07
22	6.79	7.41	8.25	8.58	8.35	8.15
23	6.84	7.46	8.29	8.64	8.32	8.32
24	6.90	6.82	8.27	8.64	8.31	8.29
25	6.75	7.08	8.41	8.64	8.40	8.25
26	6.98	7.18	8.46	8.65	8.36	8.25
27	6.57	7.00	8.11	8.63	8.31	8.22
28	6.40	7.02	8.31	8.61	8.22	8.23
Mean	7.19±0.09	7.34±0.20	8.46±0.08	8.53±0.06	8.44±0.08	8.25±0.05

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

lactation ($P < 0.01$). Values obtained for the early lactation was higher ($P < 0.01$) than those obtained for the middle which in turn was also statistically higher than those of the late lactation ($P < 0.05$). Significant differences existed between the three breeds of cows ($P < 0.01$), with the exotic breeds producing higher values than the indigenous breed. SNF% obtained from the cows on high energy level was significantly higher ($P < 0.05$) than those on low energy rations. Apart from the significant interaction ($P < 0.05$) which existed between breed and lactation, no significant interaction existed between any of the parameters. Also values obtained during the wet season were not significantly different from those obtained during the dry season ($P > 0.05$).

(f) Mineral Content of Milk: The mineral content (Tables 3.15-3.17) of the cows' milk at the late stage of lactation was significantly higher ($P < 0.01$) than those at the middle and early stages of lactation. The ash content of the German Brown cows' milk (0.719%) was significantly higher than those of the Friesian (0.708%) and the White Fulani (0.705%) ($P < 0.01$). The mean values also obtained from those animals on high energy level (0.712%) was statistically higher than those on low energy level (0.708%) ($P < 0.01$).

Table 3.15 **Ash (g/100g milk) content of the three breeds of lactating cows' milk fed on grass with low or high concentrate during the 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	0.72	0.69	0.71	0.72	0.70	0.70
2	0.72	0.68	0.71	0.72	0.70	0.71
3	0.72	0.68	0.72	0.72	0.70	0.71
4	0.73	0.69	0.72	0.72	0.70	0.71
5	0.72	0.69	0.72	0.72	0.71	0.71
6	0.73	0.69	0.72	0.72	0.71	0.71
7	0.72	0.70	0.73	0.71	0.70	0.71
8	0.71	0.70	0.73	0.71	0.70	0.71
9	0.72	0.70	0.73	0.71	0.71	0.71
10	0.71	0.69	0.73	0.71	0.71	0.71
11	0.72	0.69	0.73	0.71	0.71	0.71
12	0.72	0.69	0.73	0.71	0.71	0.71
13	0.72	0.69	0.73	0.71	0.71	0.71
14	0.72	0.69	0.73	0.71	0.71	0.70
Mean	0.72±0.02	0.69±0.02	0.72±0.02	0.71±0.02	0.71±0.02	0.70±0.01
*	L	H	L	H	L	H
15	0.71	0.69	0.73	0.71	0.71	0.70
16	0.71	0.69	0.73	0.71	0.71	0.70
17	0.71	0.69	0.73	0.71	0.71	0.71
18	0.71	0.69	0.72	0.71	0.71	0.71
19	0.71	0.69	0.72	0.72	0.71	0.72
20	0.71	0.69	0.72	0.72	0.71	0.72
21	0.71	0.69	0.72	0.72	0.71	0.72
22	0.71	0.69	0.72	0.72	0.71	0.72
23	0.71	0.69	0.72	0.73	0.71	0.72
24	0.71	0.70	0.72	0.73	0.71	0.72
25	0.71	0.71	0.72	0.72	0.71	0.72
26	0.72	0.71	0.72	0.72	0.71	0.72
27	0.72	0.71	0.72	0.72	0.71	0.72
28	0.72	0.71	0.72	0.72	0.71	0.72
Mean	0.72±0.01	0.70±0.02	0.72±0.01	0.72±0.01	0.71±0.01	0.72±0.01

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

Table 3.16 **Calcium (mg/100g milk) content levels of the three breeds of lactating cows' milk fed on forage and low or high concentrate supplements during the 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	130.65	119.30	135.18	127.73	112.98	114.45
2	132.54	119.30	131.00	127.96	117.34	113.65
3	132.13	122.62	140.76	128.44	114.53	114.15
4	132.63	119.71	139.20	129.18	116.20	122.60
5	132.48	122.00	137.20	128.74	116.05	118.90
6	131.96	116.08	136.82	128.64	122.46	115.75
7	128.16	117.34	130.53	129.67	122.45	117.70
8	126.36	118.68	127.31	127.46	122.25	120.18
9	133.46	120.00	132.17	127.65	122.00	119.27
10	133.87	116.35	135.26	128.43	129.63	120.18
11	135.26	114.60	136.60	128.35	122.73	117.68
12	133.43	114.99	138.66	128.78	122.80	119.67
13	133.70	115.18	137.10	129.75	121.00	121.65
14	133.38	115.00	139.20	130.60	120.25	127.50
Mean	132.14±1.44	117.94±0.71	135.50±1.58	128.67±0.24	120.00±1.27	118.81±1.24
*	L	H	L	H	L	H
15	132.48	116.14	139.26	130.85	116.00	117.50
16	135.35	117.13	137.98	130.	110.15	118.00
17	136.81	116.38	139.20	129.38	109.72	117.55
18	137.70	116.34	141.00	129.44	111.65	117.58
19	140.32	121.45	139.88	129.20	114.73	117.00
20	141.00	124.63	143.35	130.83	114.20	111.75
21	142.58	127.80	145.90	131.22	115.00	116.65
22	135.45	127.86	148.00	131.10	116.00	113.60
23	138.63	127.66	144.15	131.30	119.00	115.00
24	138.74	131.20	145.00	131.50	120.50	121.95
25	141.63	130.26	146.25	132.04	118.50	120.50
26	142.50	134.76	143.63	131.70	119.50	120.90
27	142.90	133.51	138.00	132.00	123.50	122.80
28	143.60	133.50	139.75	131.40	125.00	124.00
Mean	139.26±0.90	125.62±1.86	142.24±2.56	130.88±0.30	116.68±1.10	118.20±0.94

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

Table 3.17 **Phosphorus (mg/100g milk) content of the three breeds of lactating cows' milk fed on grass with low or high concentrate during the 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	73.63	69.38	87.28	92.73	70.91	63.90
2	72.88	70.46	88.76	97.24	70.12	65.60
3	65.38	70.18	90.62	96.81	69.90	65.88
4	66.63	69.62	93.89	93.76	70.50	65.78
5	70.38	70.62	98.75	95.91	73.04	66.17
6	71.20	70.10	86.38	97.13	72.52	66.72
7	72.67	70.77	88.55	97.75	73.03	66.60
8	70.61	71.28	87.71	96.50	71.13	65.10
9	71.11	70.85	83.75	95.73	76.75	65.52
10	72.62	70.71	85.38	94.25	75.00	66.16
11	72.00	69.39	85.63	95.43	74.50	71.02
12	72.10	70.26	85.75	96.25	71.05	71.80
13	70.63	69.10	89.53	97.80	71.50	71.64
14	70.00	69.05	90.54	96.86	72.04	71.40
Mean	70.90±1.24	70.13±0.58	88.75±1.43	96.07±1.25	72.28±4.15	67.60±0.96
*	L	H	L	H	L	H
15	68.57	68.86	87.52	98.70	72.70	72.50
16	69.08	69.45	88.60	98.95	72.00	67.00
17	70.12	68.48	87.55	100.28	72.72	67.74
18	71.25	69.67	89.83	99.76	71.22	72.77
19	71.50	69.30	91.13	99.90	71.00	73.15
20	70.83	70.86	86.35	99.73	78.50	73.63
21	72.49	70.61	85.10	102.00	75.52	75.16
22	70.58	71.50	84.25	101.40	75.52	73.90
23	68.88	71.63	85.10	101.45	79.25	74.82
24	69.50	72.00	86.85	102.63	78.15	75.25
25	71.47	71.72	93.00	102.55	78.60	76.28
26	71.60	72.38	89.58	102.60	78.75	76.50
27	71.00	72.65	90.60	102.88	75.35	78.51
28	71.28	72.50	90.75	102.63	78.38	78.03
Mean	70.58±2.32	70.83±0.76	88.30±0.74	101.10±0.61	73.62±3.59	73.94±0.88

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

There were no significant differences between the ash content during the wet and dry seasons ($P > 0.05$). The mean yield of calcium and phosphorus followed a similar pattern as that of the ash except that there were no significant differences among the three stages of lactation and the two dietary levels ($P > 0.05$).

(g) Energy content of Milk: Although the gross energy level of the milk of the White Fulani (22.30 ± 0.15KJ/g) was slightly higher than that of the German Brown (20.85 ± 0.09KJ/g) and the Friesian (20.75 ± 0.09KJ/g), the differences between these means were not significant ($P > 0.05$). There were also non-significant differences between the means obtained at the three stages of lactation. On the other hand, there were significant differences ($P < 0.05$) between the values obtained for the low (20.98 ± 0.21KJ/g) and the high energy levels (21.60 ± 0.18KJ/g). Though there were no significant differences between the values obtained for the two seasons, the interaction between the breed and lactation, breed and diet, there were highly significant differences ($P < 0.01$) between the lactation and diet and among the stages of lactation, breed and diet.

Table 3.18 **Milk Energy (KJ/g freeze-dried milk) content of the breeds of lactating cows' milk fed on grass with low or high concentrate during 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1	22.83	20.35	20.82	20.09	20.92	20.50
2	22.80	20.55	20.77	19.19	21.14	19.96
3	22.74	20.52	20.67	19.77	22.64	20.04
4	22.92	20.46	20.63	19.35	21.87	20.19
5	22.60	20.46	20.76	19.35	21.00	19.87
6	22.54	20.34	20.61	19.82	20.27	20.09
7	22.56	20.80	21.03	19.77	20.37	20.03
8	22.83	20.85	21.09	20.02	21.17	20.25
9	22.94	20.80	21.42	20.25	20.90	20.36
10	22.71	21.12	21.19	20.36	21.17	20.08
11	22.75	21.42	21.18	20.59	21.36	20.04
12	22.71	21.39	21.13	20.54	21.51	20.05
13	23.07	21.62	21.30	20.41	21.72	20.51
14	23.21	21.62	21.59	20.26	21.94	20.36
Mean	22.80±0.09	20.88±0.13	21.01±0.08	20.04±0.11	21.28±0.17	20.17±0.06
*	L	H	L	H	L	H
15	23.06	21.91	21.56	20.42	20.97	20.46
16	22.98	21.86	21.13	20.55	21.45	20.44
17	22.94	21.80	21.10	20.84	20.09	20.57
18	22.98	21.93	21.00	21.24	19.73	20.71
19	23.10	21.89	20.54	21.40	19.68	20.82
20	23.09	22.10	20.36	21.21	19.94	20.88
21	23.29	21.70	20.63	21.02	20.44	20.92
22	23.21	22.16	20.63	21.31	20.20	21.01
23	23.44	22.31	20.46	21.52	20.59	20.88
24	23.54	22.35	21.26	21.67	20.73	21.38
25	23.45	22.35	21.35	21.66	20.75	21.55
26	23.48	22.92	21.04	21.59	20.69	21.35
27	23.50	22.90	21.44	21.76	21.20	21.52
28	23.58	23.24	21.15	21.69	21.22	21.62
Mean	23.26±0.06	22.24±0.13	20.98±0.10	21.28±0.11	20.55±0.15	21.01±0.11

H = High level concentrate L = Low level concentrate * Change of diet
** = Two animals within a breed were maintained on each level.

3.4.5 Liveweight changes:

All cows showed liveweight losses from the beginning of the experiment which was about a week after parturition. With a few exceptions, the losses in weight persisted until about the 8th to 10th week of lactation. The summary of mean body weight changes as influenced by stages of lactation, breed, pasture and supplementary concentrate treatments are shown in Tables 3.19a, b.

Animals on the high concentrate feeding had faster weight gains than the cows fed on low concentrate. While the latter had an average increase of 35.51g/day, the former had 22.85g/day ($P < 0.05$).

It is interesting to note than on calculation the Friesian cows lost an average of 5.16g/day, the German Brown and White Fulani cows gained weight (50.20g/day and 10.51g/day respectively). A significant difference existed between them ($P < 0.05$). Statistically significant differences were found between the mean daily gain per cow during the dry and wet seasons ($P < 0.05$), with 30.51 ± 8.51g/day during the dry season and 27.85 ± 10.52g/day during the wet season.

Table 3.19a **Liveweight (kg) of the three breeds of lactating cows fed on grass forage with low or high concentrate during the 28-week experimental period

WEEKS	WHITE FULANI		GERMAN BROWN		FRIESIAN	
	H	L	H	L	H	L
1						
2	340.37	282.08	418.60	407.90	415.81	376.80
3						
4	334.45	275.26	406.59	400.20	402.07	365.45
5						
6	329.54	282.14	408.99	400.59	396.13	357.82
7						
8	328.79	274.35	406.82	403.30	389.91	349.77
9						
10	326.30	282.97	413.34	409.73	378.86	349.23
11						
12	330.45	294.30	424.77	419.35	376.82	357.05
13						
14	337.30	292.88	433.27	420.01	382.19	363.29
Mean	332.46±1.91	283.43±2.93	416.05±3.81	408.73±3.13	391.68±5.32	359.92±3.64
*	L	H	L	H	L	H
15						
16	348.50	283.58	438.86	420.48	383.41	365.68
17						
18	340.20	289.30	437.63	423.48	390.68	372.92
19						
20	338.41	282.34	443.84	423.56	397.17	387.26
21						
22	338.91	291.92	438.60	426.80	395.15	380.77
23						
24	344.90	298.83	438.37	429.21	402.71	369.55
25						
26	347.56	302.42	441.14	432.37	406.16	379.84
27						
28	350.91	302.85	441.49	437.22	407.82	383.84
Mean	344.20±1.91	293.03±3.23	439.99±0.84	427.59±2.20	397.59±3.31	377.12+2.99

H = High Level concentrate

L = Low level concentrate

* Change of diet

** Two animals within a breed were maintained on each level.

Table 3.19b

Bimonthly weight changes of the three breeds of lactating cows fed on grass forage with low or high concentrate during the 28-week experimental period

Weeks	White Fulani		German Brown		Friesian	
	H	L	H	L	H	L
1						
2	-25.98	-15.37	-19.90	-12.31	-14.19	-16.61
3						
4	-5.92	-6.82	-12.01	-7.70	-13.74	-11.35
5						
6	-4.91	+7.00	+2.40	+0.39	-5.94	-7.63
7						
8	-0.75	-7.79	-2.17	+2.71	-6.22	-8.05
9						
10	-2.49	+8.62	+6.52	+6.43	-11.05	-0.54
11						
12	+4.15	+11.33	+11.43	+9.62	-2.04	+7.82
13						
14	+6.85	-1.42	+8.50	+0.66	+5.37	+6.24
15						
Mean	-5.34	-0.56	-0.65	-0.03	-5.98	-3.77
*	L	H	L	H	L	H
15						
16	+11.20	-9.30	+5.59	+0.47	+1.22	+2.39
17						
18	-8.30	+5.72	-1.23	+3.00	+7.27	+7.24
19						
20	-1.79	-6.96	+6.21	+0.08	+6.49	+14.34
21						
22	+0.50	+9.58	-5.24	+3,24	-2.02	-6.49
23						
24	+5.99	+6.91	-0.23	+2.41	+7.56	-11.22
25						
26	+2.66	+3.59	+2.77	+3.16	+3.45	+10.29
27						
28	+3.35	+0.43	+0.35	+4.85	+1.66	+4.00
Mean	+1.70	+1.25	+1.03	+2.15	+3.20	+2.57

3.5 DISCUSSION

Keay (1959) classified Ibadan under the lowland rainforest vegetation zone with a two-peaked rainfall pattern and a dry season lasting between three to five months usually between November and March. Apart from the August 'break', the data shown in Table 3.4 were in good agreement with this observation.

The differences in the chemical composition of the concentrate supplement were not as variable as the grass forage. The crude protein, phosphorus and ash were largely dependent on rainfall as could be deduced from Tables 3.5 and 3.6. This observation was also supported by Todd (1956). Calcium was relatively stable during the dry season but fell with the onset of the rains. A possible explanation is that the uptake of calcium during the rainy season is slow in comparison with the very rapid growth made by the grasses, so that, though the total amount of calcium may be increasing, the content of the forage dry matter may fall. As for the increase during the dry season, the most likely explanation seems to be preferential translocation. As is shown by the fact that deficiency symptoms first appear at the growing point. Calcium in plants is a relatively immobile element and if translocation of other fractions of the dry matter to the root system took place, the percentage of the calcium in the above ground portions would increase. Fiske and Subbarow (1925) expressed a similar view.

Results obtained from this investigation have shown that consumption of DM after parturition was low but increased gradually until it reached a peak between the 4th and the 10th week. Hutton (1962), Mowat (1963) and Ogunsiji (1974) have observed that cows reached their maximum DM intake 6-16 weeks after parturition. The general picture emerging from the present investigation was that the DM intake by the exotic cattle was higher than that of the indigenous ones. Results of comparative studies undertaken by various investigators (Glover and Dougall, 1961; Rogerson et al, 1968; Musangi 1969 and Rogerson, 1970) have shown that the DM intake, was generally lower in the Bos indicus cattle than in their Bos taurus counterparts of European origin. Many reasons could be adduced to the lower DM intake of the indigenous. During lactation, intake seemed to be related to metabolic weight, and the exotic cows in the present study with the highest metabolic size consumed the highest amount of nutrients. This observation agreed with the findings of many investigators that the animal size was an important factor influencing intake (MacLusky 1955; Elliot et al, 1961; Holmes and Jones, 1965; Musangi, 1969). Hill (1966) hypothetically described tropical breeds of cattle as 'respiratory' types, there being a relatively greater development of thoracic region compared with the more fully developed abdominal region in the temperate breeds, leading to larger capacity in the rumen and greater appetite. However, these anatomical differences between the tropical and temperate breeds of cattle could only be regarded as one of the plurality of causes responsible for the variation in DM intake. Apart from the fact that DM intake, dictated by appetite or desire of animal to consume is partly controlled by inheritance which is described as "intensity factor" by Mather (1959); of more paramount importance however is the suggestion of Lander (1949) and Gupta and Jackson (1968) that the generally low capacity for milk production may be related more to their relatively lower total DM intake.

A general assessment of the DM intake has shown that while the intake of White Fulani animals ranged from 1.54

to 2.30kg of DM per 100kg liveweight that of the German Brown was 1.53 to 2.44 and that of the Friesian 1.59 to 2.90kg of DM per 100kg liveweight. Slightly higher DM intake than the ones reported in the present experiment ranging from 2.1 to 2.3kg DM per 100kg liveweight had been recorded by Mather and Desai (1953) for Zebu cattle in India. However a lower DM intake of 0.99 to 1.95% of liveweight among White Fulani cattle was reported by Miller (1961) in the Northern States of Nigeria. Olaloku (1972) reported a higher intake for lactating White Fulani cows. Higher DM intake than the ones recorded in the present experiment have been reported in the literature for the exotic breeds of cattle. Castle (1953) reported consumption of 2.9 and 2.5kg per 100kg liveweight for cattle grazing rye grass and cocksfoot herbage. Hashizume, Morimoto, Masubuchi, Abe and Hamada (1965) showed that the average DM intake was 2.6% of the body weight.

The absolute daily feed consumption figure reported here are generally lower than the figure from the temperate countries. Several reasons may be advanced for this. All the animals were zero-grazed. Baker, Richards, Haenlein and Weaver (1960) have agreed that stall-fed animals were likely to feed on a quality of herbage inferior to that grazed by animals in the field since they have less opportunity for selecting their forages. Duckworth and Shirlaw (1958) have suggested that crude fibre content was very crucial in controlling appetite. There is no doubt that the amount of roughage consumed could have been limited partly by the relatively high crude fibre content (21.48 to 33.50%) of the grass fed in the present experiment. Though Duckworth and Shirlaw (1958) have suggested that optimum forage DM intake was guarranteed when the grass has a DM content not higher than 24.28%, results obtained from the present study reported an average DM intake of 40.86% (ranges 23.45 - 76.54%). Finally, one cannot underestimate the influence of the high ambient tropical temperature since such temperatures have been shown to have a depressing effect on appetite (Holme and Coey, 1967; McDowell, 1972; Loosli and van Blake, 1973).

Results obtained in the present investigation have indicated that milk yield attains peak production between the 5th and the 9th week and that cows which were first placed on low energy intake attained peak production earlier than those first placed on high energy intake. Kartha (1934) observed that maximum rate of secretion of milk which preceded the decline was attained at different individuals but the large majority of animals of all breeds attained it between the third and sixth weeks after calving. The results of the investigations of Bailey (1952), Rook and Campling (1965), Olaloku and Oyenuga (1971) and Broster (1974) are in general agreement with the findings in the present investigations in which milk yields and SCM were declining as the lactation progressed.

The high energy ration fed to the animals at the receding stages of lactation (middle and late stages) did very little, if any, to improve the level of milk yield (Fig. 3.3 - 3.5). These observations were more pronounced in the high producing cows than in the low producing ones. Results obtained in the present study have shown that cows which were first placed on low energy intake attained peak production earlier than those first placed on high energy intake. These results were also in support of the observations of Eckles and Shaw (1913) that the experienced husbandry man supplies his cows with practically the same amount of roughness throughout the lactation period, but a larger amount of grain is fed in the early part of the period than towards the end.

Broster and Tuck (1964) have even observed that the pattern of yield established by the level of feeding in early lactation persisted over the whole lactation. The present study appeared therefore to suggest that to increase milk production particularly in the exotic breeds of cattle and high milk yielding indigenous cows in Nigeria, attention should be given to the possibility of not only raising their milk yield at the beginning of lactation by generous feeding but also extending the period at which lactation reaches its peak (persistency). In fact, several experiments under the temperate climates have shown that the response of the dairy animals to extra feeding is proportional to the initial yield of the cows. McCullough and Nevill Jr. (1960) and Broster (1963) have concluded that the high yielder benefited more from extra feeding particularly at the beginning of lactation than the low yielder. Admittedly, the cow's innate capacity can only be exploited by generous feeding at prepartum or early lactation only to get a good milk yield peak in early lactation and to keep the cow's rate of milk yield fall gradually throughout the lactation period thus ensuring persistency; but the productive potential of the animal cannot be extended for at any one time the milk yield of the cow is an amalgam of her genetic potential and her history including nutrition (Blaxter 1956; 1967). The increase in milk yield that occurs with increase in plane of nutrition (high concentrate feeding) is probably associated with increases in the amounts of precausors for milk yield synthesis reaching the mammary gland. For instance, Rook and Line (1961) reported significant increases in volatile fatty acids (VFA's) in arterial blood and α - amino nitrogen in venous blood with increase in energy intake. The bulk of experimental evidence from the literature (Bath and Rook, 1963; Sutton and Johnson, 1969; Mba and Olatunji, 1972) indicates that rations high in crude fibre tend to increase the molar proportions of acetic acid with corresponding lowering of the molar proportion of propionic acid while the reverse is true for the rations low in crude fibre. Mba and Olatunji (1971) postulated that such rations which severely depressed molar concentrations of acetic acid and correspondingly increased proportions of propionic acid could enhance production of meat and milk.

The explanation to the higher milk yield obtained during the wet season than the dry season despite the higher DM intake in the latter than the former in the present studies may be due to the poor quality of the roughage intake during the dry season. Armstrong, Blaxter and McC.Graham (1957) showed that rumen liquor contained greater amounts of acetic acid relative to propionic and butyric acids after feeding poor quality roughages. The above authors have also observed that a change from lower to higher proportions of acetic acid of the total VFAs and a corresponding fall in the propionic and butyric acids proportion resulted in increased heat increment and a fall in the utilization of the metabolizable energy of the ration.

The chemical composition of the milk showed that there was an increase in butterfat content as the lactation progressed. This is in agreement with the findings of Eckles and Shaw (1913), Azih (1963), Olaloku and Oyenuga (1971) and Adebowale (1972). The result of the butterfat percentage obtained in the present study showed that while there was an increase in the milk yield with increase in energy intake, exotic breeds on low energy produced higher butterfat percentage than when on high energy. Many experiments (Schultz, 1974; Armstrong and Prescott, 1970; Lofgreen and Warner, 1970) as well as field observations (Davis and Brown, 1970) have shown that fat content of milk tended to drop when concentrate levels in feeds were increased and roughage made up less than one-third of the ration DM. The butterfat percentage of the indigenous cows in the present studies was higher than those of the exotic cows. Apart from the fact that the indigenous cows have been genetically noted to produce milk of high butterfat, Ogunsiji (1974) found that in cows giving a high milk yield, the butterfat and total protein content was lower than those producing low milk yield.

The milk protein of the cows studied did not follow any well-defined trend but there were stage of lactation effects. This observation was also reported by Ogunsiji (1974) who inferred that SNF, protein and lactose of milk did not follow any definite pattern. Although statistical analysis in the present experiment showed that there were significant differences between the milk protein of those cows on high and low energy levels, Newman-Keuls' (1955) comparison between ordered means revealed that this was only during the early stage of lactation when there was high milk yield and that there were no significant differences between the percentage protein during the middle and late lactation stages. Perhaps this shows that the protein requirement during the early lactation when there was a high milk yield was higher than the amount supplied with the low energy ration. The fact that this particular phenomenon did not occur during the last two stages in the present experiment is in agreement with the findings of Rook and Line (1962) and Armstrong (1963) that dietary protein levels do not seriously affect percentage protein of milk unless intakes were considerably below the recommended requirements. The observation revealed in the present study that milk protein percentage was higher during wet season than the dry season was supported by the conclusion of Todd (1956) and Rook (1961) that protein contents of milk increased significantly with the commencement of grazing in May and June and declined during the dry season when herbage was scarce and of low nutritive value.

There were no differences throughout in the lactose percentage. Rook (1961) has pointed out that lactose is a major determinant of osmotic pressure in milk and thus a regulator for the volume of water secreted by the mammary gland and therefore not easily altered. Armstrong and Prescott (1970) have asserted that an increase in the plane of nutrition does not increase lactose content but a small decline occurs when energy content is severely restricted. The conclusion generally is in support of the results obtained in the present study.

The commonly observed increase in solids-not-fat (SNF) of milk with increase in the plane of energy nutrition (Lees, McMeekan and Wallace, 1948; Campbell and Flux, 1948; Broster and Tuck, 1967) was found in the present experiment. Rook and Line (1961) and later on Rook and Storry (1964) postulated that an increase in the plane of energy nutrition increased the amount of propionate absorbed from the rumen and consequently the plasma propionate concentration in peripheral blood. This change in turn increased the rate of mammary synthesis of both lactose and protein. To maintain isotonicity of the mammary secretion with blood plasma, an increase in the synthesis of lactose will produce an increase in the output of water and therefore in the yield of milk.

Results obtained for the ash content has shown that the phosphorus was relatively constant. Hansson (1948) showed that the content of phosphorus in cow's milk was governed chiefly by genetic factors and was therefore relatively constant for a particular breed. The increase observed in the ash content of milk however with increase in plane of nutrition was likely due to the explanation of Holmes, Arnold and Provan (1960), Castle, Drysdale and Waite (1961), Rook and Line (1961) that an increase in the mineral fraction as energy intake increased may in part be due to increase in mineral content with rise in energy intake.

The dietary energy effect was reflected in the milk energy of the cows. Expressed on the values of the energy distributed in milk in relation to the gross energy consumed the values obtained in the present study for White Fulani, 18.24% (High energy HL) and 22.81% (low energy LL); for German Brown, 14.25% (HL) and 14.94% (LL); for Friesian 12.91% (HL) and 15.18% (LL) were generally within the range of 12.9 to 18% obtained by Hashizume <u>et al</u> (1965) for Japanese Holstein cows but those of the White Fulani were outside this range, although they were very close. Flatt (1967) reported that the proportion of milk energy in relation to gross energy consumed was high in early lactation, being 34.9%, while it was 12.1% in late lactation.

It is pertinent to note that there was an appreciable decrease in liveweight up to the twelveth week of lactation. The liveweight increased after this for some few weeks and remained almost constant till the end of the experiment.

Glesson (1970) and Olayiwole (1973) have carried out experiments in which liveweight fell just after calving and thereafter regained and remained almost constant on average. This loss in liveweight during early lactation observed in the present study was in general agreement with the findings of Moe and Flatt (1969) and Moe, Tyrell and Flatt (1971) that in early lactation dairy cows may rely on body fat reserves as an energy source. They stated that milk may be produced from body tissue reserves with an efficiency of 82 - 84%. Furthermore, Moe et al (1971) stated that the amount of tissue energy used during early lactation for milk production would depend on the degree of fatness of the cow at the time of parturition, the genetic potential of the animal for milk production and feed intake during early lactation. Graves, Davison and Kpoland (1938) showed that the total digestible nutrient (TDN) intake was only 74% of TDN requirements in the first month of lactation and that the intake did not equal the requirement until the 4th month. The lactating ruminants also have got the capacity to draw upon the body energy reserves to maintain milk secretion during early lactation (Armstrong, 1968). Ogunsiji (1974) explained that there was mobilization of blood tissue substances to support milk production during the early *lactation. Flatt et al (1969) calculated the average* daily loss of tissue substance in high yielding Friesian cows during early lactation to be equivalent to 28.9MJ or 0.72kg fat. Finally, Flatt, Coppock and Moore (1965) have pointed out that good-producing cows are often unable to consume enough feed in early lactation to prevent some loss of body reserves of energy, calcium, phosphorus and protein. These findings were generally in agreement with the low feed intake, increasing milk yield and loss of weight recorded in the present study during the early part of the lactation.

In conclusion, the results obtained in these experiments seemed to indicate that:

(1) Mean roughage DM intake were 4.49 ± 0.16, 5.59 ± 0.16 and 5.92 ± 0.21kg/day for the White Fulani (WF), German Brown (GB) Friesian (F) cows respectively. DM intake was higher during the dry season than the wet season.

(2) Peak milk production for all the breeds was between the 5th and the 9th weeks of lactation and declined thereafter. Average milk yield was 27.55 ± 6.15, 41.16 ± 8.19 and 40.16 ± 6.15 kg/day for the White Fulani, German Brown and Friesian cows respectively.

Milk yield during the wet season was higher than the dry season.

(4) All cows lost weight immediately after calving until about the 8th to 10th week of lactation. While the Friesian cows lost an average of 5.16g/day, their German Brown and White Fulani counterparts gained 50.20 and 10.51g/day respectively.

CHAPTER 4

ENERGY AND PROTEIN REQUIREMENTS FOR MAINTENANCE AND MILK PRODUCTION

4.1 INTRODUCTION

Animals being fed for growth, fattening, milk production and other productive functions, need a substantial part of the food for supporting body processes, which must go on whether or not any new tissues or products are being formed. This demand for non-productive but essential function is the maintenance requirement. Maintenance need is usually determined by feeding trials. The method involves the determination of food required to keep animals at constant body weight.

Energy requirements for maintenance, growth, lactation and pregnancy are usually determined using energy balance techniques or feeding trials (Brody, 1945; Meyer and Lofgreen, 1959; Hashizume, Kaishio, Ambo, Tanaka, Hamada and Takahashi, 1963; Flatt et al, 1967; Maynard and Loosli, 1969; Neville and McCullough, 1969; Moe, Tyrrell and Flatt, 1970; Swanson, 1971; Neville, 1974; Patle and Mudgal, 1975) which facilitate the expression of requirement as Total digestible nutrient TDN; digestible energy (DE) and metabolizable energy (ME) which are some of the feeding standards commonly used for energy values. In such trials, facilities for the measurement of feed intake, urine, faecal loss and methane production are provided for the determination of ME (Maynard and Loosli, 1969).

Since it is now known that before systematic computations of rations for livestock could be embarked upon, basic research is needed to ascertain the nutritional requirements for maintenance and production under tropical conditions, the objective of this study is to compute in accordance with the conventional methods of estimating energy and protein requirements, the maintenance and milk production requirements for both protein and energy of lactating exotic and indigenous cows under the humid tropical environments using local feeds and facilities. Experiments performed on the fistulated lactating cow will also elucidate the relationship between rumen metabolites, milk and blood constituents. Finally, it will also afford the effectiveness of the new modified metabolism cages adapted for use of heavy lactating cows when results obtained from these animals without harnesses and in these cages are compared with those obtained from these animals without harnesses and in these cages are compared with those obtained from steers harnessed with collection bags.

4.2 MATERIALS AND METHODS

4.2.1 Animals and their management:

Twelve intact lactating cows, six intact steers and one fistulated White Fulani cow were used throughout the trials. The twelve lactating cows ranging in liveweights from 350 to 404kg were made up of four cows from each of the three breeds viz., White Fulani, German Brown and Friesian. The steers with liveweight range of 352-485kg were also made up of two animals from each of the above-mentioned breeds. While the lactating cows were kept in individual metabolism cages when under dietary treatments, with free access to salt licks and daily fresh water supply, the steers were fitted with locally made harnesses and collection bags and placed in a nearby byre. They were also supplied with salt-licks and fresh water. All the animals were obtained from the University of Ibadan Teaching and Research Farm.

All the animals were sprayed weekly against tick infestation. Occasionally too, blood samples were taken by the veterinarian surgeons from all the animals for pathological examination. During preliminary and resting periods, the lactating cows were let out of the metabolism cages and they along with the steers were allowed to graze on the open paddock and therefore allowed enough exercise.

4.2.2 Diets and plan of experiment

The diets fed consisted of (a) the basal diet which was *Cynodon nlemfuensis* var. *nlemfuensis* *ad lib*(Sec. 2.2.3) (b) the basal ration plus the supplement (components on Table 3.1) supplied at the rate of 1kg of dry matter (DM) to every 2.5kg of milk produced (c) the basal ration plus the supplement supplied at the rate of 1kg of DM to every 4kg milk produced. The (b) and (c) diets were supplied as described in Sec. 3.2.2. Each animal was made to gothrough the three different diets with a preliminary period of 14 days preceeding each diet and a 7-day collection period. The animals were put on the trials at the receding stage of lactation as adviced by Lucas (1960) for dairy animals.

The steers were also fed the basal ration alone *ad lib*, followed by the basal ration and the supplement. The supplement was supplied by finding the ratio of the supplement to basal diet consumed by the lactating cows of that particular breed. For example, if the White Fulani lactating cow was calculated to have consumed a 1:7 ratio of supplement to basal diet during the preliminary period and the White Fulani steer fed about 7kg basal diet, then the steer would be supplied

1kg ration. The reason for including the steers on the experiment is to ascertain the reliability of the digestibility results obtained from the lactating cows without harnesses placed in the modified metabolism cages because these were the data to be used for arriving at the final results.

4.2.3 Collection of faeces and urine

For the lactating cows, faeces and urine were collected separately during the last seven days as described by Oyenuga (1961) but the cages were subjected to certain modifications (Fig. 4.1). The dimensions were longer than that described by Oyenuga (1961) and constructed in such a way as to accommodate freely the big lactating exotic cows (Fig. 4.1 and Plate 4.1). The floor of each cage contained an irremovable tray with thick wire mesh and long, solid wide planks on which the heavy animal stood. The faeces were trapped by both the wide planks and a tier of two removable trays below that on which the cow stood. The removable trays were of closely knit mesh, reinforced with strong expanded metal grid. They could be withdrawn for collection of faeces and for cleaning and replacement at will. These removable trays retained all the faeces but permitted urine to drain freely on the aluminium tray below. This was sloped so as to allow

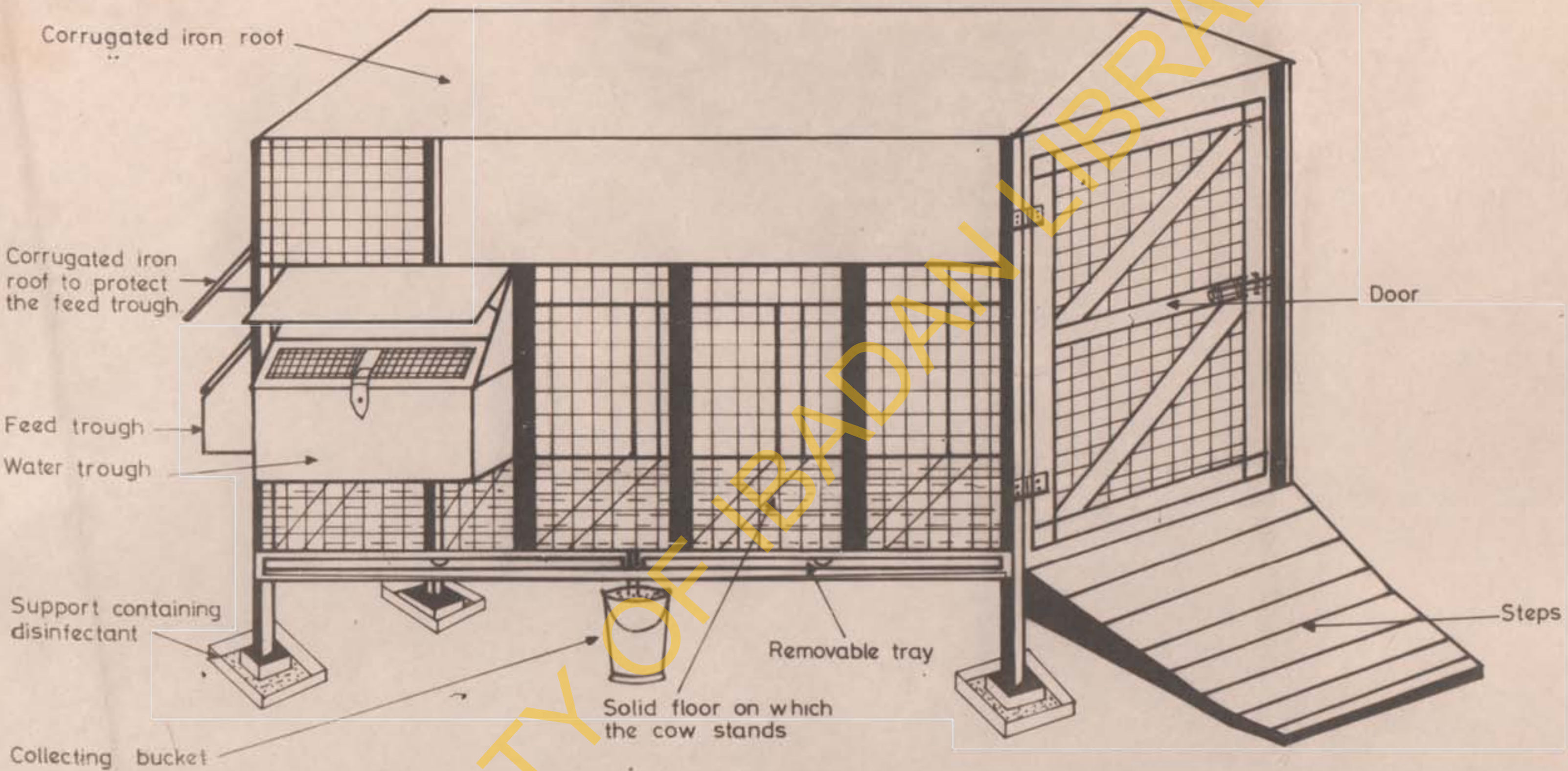

FIG. 4.1 DIAGRAM OF THE MODIFIED METABOLISM CAGE.

Plate 4.1 A lactating cow in the modified metabolism cage.

easy drainage to its tube at the centre. The tube led to a big plastic bucket placed directly below the tube into which the urine drained.

The four stands of the cage were rested on supports made of hollow-shaped cement-blocks. This was to prevent gradual sinking of the heavy cage particularly during the rainy season and also prevent rodents and ants escaping into the cage above since the hollow of the cement block contained disinfectant. Before the start of collection period and on each day, 5mls of 10% mercuric chloride solution was added to the (urine) collection bucket to prevent loss of nitrogen. The total daily urine output of each animal was measured, mixed thoroughly and 10% of it was retained. The daily samples were bulked for each lactating cow and stored in a deep freeze at $-5^{o}C$ until required for analysis. The steers were harnessed to ensure total faecal collection. The harnesses which were locally made were adapted to ensure maximum comfort to the steers and also to ensure minimum loss of moisture. During faecal collection period, the faeces were bulked in cellophane bags also to ensure minimum loss of moisture. All the faeces were collected and 10% of the daily samples were dried to constant weight at $105^{o}C$ in the hot-air oven and the dried samples bulked, milled in a Christy-Norris hammer mill and stored at room temperature until required for chemical analysis.

4.2.4 Milk sampling

Throughout the period of the experiment, all the cows were hand-milked at 5.30 a.m and again at 2.30 p.m. The daily records of milk collected throughout the experimental period were kept. Aliquots of the daily, bulked milk yield were stored in previously washed and dried sample bottles with lids before storage in a deep freeze at -5^{o}C for analysis. The aliquots were then bulked to give two samples per week, the first three days providing the first bulk and the last four days of the week the second bulked sample .

4.2.5 Rumen and blood sampling

Only one White Fulani lactating cow fitted with permanent rumen cannula was available for the experiment. The animal was fed the same diet as the other experimental lactating cows. Rumen liquor and blood samples were taken from the cow when each diet was fed. The samplings were usually during the last three days, one and two hours after feeding for the rumen liquor, and 4 and 5 hours after feeding for the blood. About 300ml rumen liquor were collected from the animal by suction through a perforated transparent polythene tubing inserted through the cannula into the ventral part of the rumen

(Plate 4.2). The liquor poured directly into clean glass bottles. The bottles were well stoppered after collection. The samples not immediately analysed in the laboratory were stored at -5^{o}C until required for analysis. About 30ml blood samples from the fistulated animal were collected each time in a heparinised centrifuge tube. The blood samples were drawn from the jugular vein. The samples were centrifuged at 2000 r.p.m. for 20min. The plasma thus collected was mixed with an equal volume of saturated $MgSO_4$, filtered and stored at -5^{o}C until required for analysis.

4.3 Analytical procedure

Some samples of the milled feeds (concentrate supplement and basal forage) and the faeces were further dried at 105^{o}C in the hot-air oven to constant weight for residual moisture determination. The dried samples of faeces, grass, supplement rations and aliquots of urine samples were analysed for nitrogen (crude protein), ether extract, organic matter, crude fibre, gross energy, dry matter and ash (for the feeds alone) using the AOAC (1970) methods. Semi-micro-kjeldahl technique with Markham distillation apparatus was used for the nitrogen determination. The milk samples were analysed ad described in Sec. 2.3.8 - 2.3.14. The gross energy values of the supplement ration, grass, faeces and urine were determined using the

Plate 4.2 Rumen liquor sampling.

Adiabatic Bomb Calorimeter (A.Gallenkamp & Co. London). A known volume of fresh urine sample from each animal was absorbed on a previously dried and weighed "ashless" filter paper (Whatman No. 540). The filter paper with the urine was dried in a desiccator containing P_2O_5 and NaOH pellets for 48 hours and re-weighed. Similar filter papers were cut out, dried, weighed and ignited in the bomb calorimeter to obtain the energy content per g of the samples of filter papers. The gross energy of the urine was obtained by substracting the gross energy of the filter paper from the gross energy of the dried filter paper with urine. Methane energy was calculated from the equation:

$CH_4 = 1.30 + 0.112D + L(2.37 - 0.05D)$ ------ (1)

where L is the level of feeding as a multiple of maintenance level and D is the apparently digestible energy at the maintenance level of feeding (Blaxter and Clapperton, 1965). The methane was first expressed in Kcal/100Kcal of the dietary gross energy and later converted to Kilojoules.

The apparent digestibilities of the dry matter (DM), organic matter (OM), Crude protein (CP), crude fibre (CF), Ether extract (EE), nitrogen-free-extractives (NFE) and Energy of the grass and ration were determined by using the equation

$$DC(X) = 100 \times \frac{X \text{ in feed} - X \text{ in faeces}}{X \text{ in the feed}} \text{ - - - - } (2)$$

where, DC(X) = digestibility coefficient of X nutrient

X = X nutrient in the feed or faeces.

The digestibility coefficient of the different nutrients in the supplementary ration was then calculated using the formula of Crampton and Lloyd (1959)

$$D = \frac{100(d_1 - d_2)}{S} + d_2 \text{ - - - - - - - - - } (3)$$

where D = percentage apparent digestibility

d_1 = coefficient of digestibility of total ration (grass and concentrate)

d_2 = coefficient of digestibility of basal ration

S = percentage of concentrate feed in the total ration.

The data obtained from these analysis and calculation were used to compute the metabolizable energy (ME).

Analysis of blood and rumen

The blood plasma was estimated for urea, total and individual VFA's and the rumen liquor was estimated for pH, ammonia, total and individual VFA's.

About 50ml of the rumen samples were squeezed through fine muslin cloth. To 5ml of the squeezed sample were added 5ml 0.1N H_2SO_4 saturated with $MgSO_4$. The solution was filtered and 2ml of the filtrate distilled in a Markham **distillation apparatus.** 350ml distillate were collected and titrated against 0.01N NaOH to obtain the total steam VFAs. For the estimation of the individual VFA a Gas Liquid Chromatograph Pye 104 using flame ionization detector was used. 25ml of each of the squeezed liquor were poured into centrifuge tube and 5ml of 25% orthophosphoric acid in 5N H_2SO_4 were added to each liquor. It was left for at least 30 minutes and then centrifuged at 2,500r.p.m. for 10 minutes. The supernatant was poured into a small bottle and well stoppered. 0.3ml of this was chromatographed in duplicate on the Pye 104 G.L.C. The column contained 20 per cent carbowax 20M plus phosphoric acid on celite (100-120mm mesh). The working temperature was maintained at 125°C and attenuation was 1 x 500. The flow rate of compressed air was at 705.8ml/min, Argon at 61.4ml/min and Hydrogen at 41.4ml/min. The separation was mainly into acetic, propionic and butyric acids and usually lasted between 75 and 90 minutes.

Calculations were done by calculation of the area of the peak from the chromatograph using the formula (height x base at

½ height). Standard mixture of VFA was also chromatographed and correction factor determined. The correction area so obtained was used to calculate the molar percentage of the individual acids as follows:

Molar percentage of individual acid:

$$= \frac{\text{Corrected area for individual acid}}{\text{Sum of total corrected area}} \times 100$$

The blood urea concentrations and rumen ammonia were determined using the methods of Fawcett and Scott (1960) and Chaney and Marbach (1962). The colour developed was read at 625nm using Beckman Acta III and the concentration expressed in mg/100ml rumen liquor or 100ml blood calculated from standard curves prepared from ammonium sulphate solutions for ammonia and urea standard solutions for urea.

4.4 RESULTS

4.4.1 Composition of the diets:

Components of the dairy concentrate supplement were the same as used in the previous study (see Sec. 3.2.2, Table 3.1). The mean chemical composition of the ration and grass (*Cynodon nlemfuensis* var *nlemfuensis*) are shown on Table 4.1. The mean crude fibre of the grasses was high and the crude protein of the ration was also fairly high.

Table 4.1

Mean Chemical Composition of Ration and Forage fed

(on dry matter basis)

Nutrient	Concentrate Ration	Forage (C.nlemfuensis)
Dry Matter (g/100gDM)	88.12	31.49*
Ash (")	4.55	10.45
Crude protein (")	17.65	9.25
Crude fibre(")	9.02	29.40
Ether Extract (")	2.05	0.51
Nitrogen-free extractives NFE (")	54.85	42.06
Energy (KJ/gDM)	22.30	20.50
Calcium (mg/100gDM)	79.30	332.30
Inorganic phosphorus (mg/100gDM)	63.50	125.45
Sodium (mg/100gDM)	12.69	64.87
Potassium (mg/100gDM)	952.08	2447.20

*Dry matter of fresh forage

4.4.2 DM intake, milk production, rumen and blood metabolites of the fistulated cow:

Table 4.2 shows the feed intake, milk yield and composition of the fistulated White Fulani cow. There was a gradual increase in the herbage DM intake from the start of the experiment to the end. Because the experiment was started at the receding stage of lactation, the concentrate ration intake when the animal was on low energy was very low compared with ration intake on high energy level. The ratio of the forage DM intake to the concentrate ration was 2.10 for high energy level and 3.49 for the low energy level indicating 32.3 and 22.3% of concentrate DM intake respectively.

The fat percentage when on grass feed alone was higher than when concentrate rations were fed along with the grass despite advancing lactation. The protein level of the milk produced by the animal when concentrate supplement was fed was slightly higher than when grass alone was fed (3.19% on grass alone, 3.23% on low energy plus grass, 3.25% on high energy level plus grass). The protein/fat ratio was highest when the animal was on high energy plus grass ration and least when it was fed grass alone. Table 4.2 also indicates that liveweight of the animal increased when low energy was fed.

Table 4.2

Feed Intake, milk yield and composition for the fistulated White Fulani cow fed on grass and high or low concentrate supplement.

		F	HC	LC
Concentrate Ration Intake (KgDM/day)		-	2.30	1.40
Forage Intake (KgDM/day)		4.44	4.83	4.89
Forage to Ration Ratio (F/R)		-	2.10	3.49
Milk yield (kg/day)		4.56	4.69	4.58
Butterfat (%)		4.96	4.70	4.74
Protein (%)		3.19	3.25	3.23
Protein/fat ratio		0.64	0.69	0.68
Body weight (kg)	Initial weight	289.15	287.24	288.15
	Final weight	287.24	288.15	292.14

HC : High concentrate (high energy level) + *ad lib* forage

LC : Low concentrate (high energy level) + *ad lib* forage

F : *Ad lib* forage intake.

The increase in liveweight may be due however to reduced milk yield as lactation advanced with increased feed intake.

Table 4.3 shows the pH, total and individual VFA's, acetic to propionic acid ratio and ammonia nitrogen of the fistulated lactating White Fulani cow's rumen liquor. Except for the low energy level, the pH of the rumen was higher when samples were taken one hour after feeding than two hours. The pH was least when high amount of concentrate was fed (pH 6.96) and highest when grass alone was fed (pH 7.50). The pH level also varied with the total volume of VFA available in the rumen; that is the rumen was most acidic when the highest volume of total VFA was recorded. This was when the animal was fed the highest amount of concentrate ration (4.64 ± 0.75 Meq%). When the cow was fed only grass and rumen liquor was almost tending towards being slightly basic, the least amount of total VFA was recorded (3.05 ± 0.48 meq%). When grass alone was fed, highest molar percentage of acetic acid was recorded 77.58 ± 0.56 molar % to the low percentage of propionic acid 19.11 ± 1.29 molar %. The lowest percentage of acetic acid and the highest percentage of propionic acid occurred when high amount of concentrate (high energy level) was fed (67.73 ± 0.53 molar % acetic acid and 27.21 ± 1.21 molar % of propionic acid). The molar % of acetic acid was

72.45±0.75 and that of propionic acid 23.22±0.78 when animal was fed low energy level. The butyric acid content was low in the three dietary levels. The relationship *between the acetic and propionic acids in the three feeds* are also shown in Table 4.3. The highest ratio of 4.06 was recorded for the grass intake alone, 3.12 for the lower energy level plus grass and 2.49 for the high energy level plus grass. A well-defined trend of ruminal ammonia nitrogen (mg/100ml rumen liquor) was noticed. Results showed that ruminal ammonia nitrogen (mg/100ml rumen liquor) was noticed. Results showed that ruminal ammonia nitrogen was highest when the animal was on the high concentrate supplement (high energy level) 14.21±2.00mg/100ml liquor, 11.87±0.99mg/100ml liquor for the low energy level and 10.88±0.13mg/100ml liquor was recorded when only grass was fed.

Table 4.4 shows the feed intake and time of blood sampling on total and individual VFA's, acetic to propionic acid ratio and urea nitrogen level of the fistulated lactating White Fulani cow's blood. These results indicate that higher total VFA in blood plasma were obtained four hours after feeding. The highest total VFA production was obtained with animals given the high energy level (2.45±0.37 Meq%). When the animal was fed low energy level 1.78±0.20 Meq% total VFA was

Table 4.3

Effect of feed intake and time of rumen sampling on the pH, total and individual VFA, Acetic/Propionic acid ratio and ammonia nitrogen content of the fistulated lactating White Fulani cow's rumen liquor fed on grass and high or low concentrate supplement

		F			HC			LC		
Rumen sampling time after feeding.		1hr	2hrs	Mean	1hr	2hrs	Mean	1hr	2hrs	Mean
pH of rumen liquor		7.64	7.35	7.50±0.15	6.98	6.94	6.96±0.02	7.02	7.06	7.04±0.02
Total VFA of rumen liquor (Meq %)		3.53	3.57	3.05±0.48	5.39	3.88	4.64±0.75	4.03	4.01	4.02±0.01
Individual VFA rumen liquor (Molar %)	Acetic acid	77.02	78.14	77.58±0.56	69.20	66.25	67.73±0.53	71.70	73.20	72.45±0.75
	Propionic acid	17.82	20.40	19.11±1.29	26.00	28.42	27.21±1.21	22.43	24.00	23.22±0.78
	Butyric acid	5.16	1.46	3.31±1.85	4.80	3.33	4.07±1.74	5.87	2.80	4.34±1.54
Acetic acid to propionic acid ratio (A/P)		4.32	3.83	4.06	2.66	2.33	2.49	3.20	3.05	3.12
Ammonia nitrogen (mg/100ml liquor)		10.75	11.00	10.88±0.13	16.20	12.21	14.21±2.00	12.85	10.88	11.87±0.99

HC = High concentrate ration + ad lib forage

LC = Low " " " " "

F = ad lib forage.

Table 4.4

Effect of feed intake and time of blood sampling on total and individual VFA, Acetic/Propionic acid ratio and urea nitrogen of a lactating White Fulani cow's blood fed on grass and high or low concentrate supplement

		F			HC			LC		
Blood sampling time after feeding		4hrs	5hrs	Mean	4hrs	5hrs	Mean	4hrs	5hrs	Mean
Total VFA in blood plasma (meq %)		0.83	0.62	0.73±0.11	2.82	2.08	2.45±0.37	1.58	1.98	1.78±0.20
Individual VFA of blood plasma Molar %	Acetic acid	89.26	90.11	89.69±0.43	84.00	76.56	80.28±3.72	82.57	86.44	84.51±1.94
	Propionic acid	10.74	9.89	10.31±0.43	16.00	23.44	19.72±3.72	17.43	13.56	15.50±1.94
	Butyric acid	ɵ	ɵ		ɵ	ɵ		ɵ	ɵ	
Acetic acid to propionic acid ratio (A/P)		8.31	9.11	8.71	5.25	3.27	4.26	4.74	6.37	5.55
Urea nitrogen (mg/100ml blood plasma)		13.20	11.10	12.15±1.05	19.10	19.50	19.30±0.20	16.14	16.25	16.20±0.06

HC = High concentrate ration + ad lib forage
LC = Low " " " " "
F = Ad lib forage
ɵ = Negligible percentage.

produced. The least total VFA produced was when the animal was fed on grass alone and the value obtained was 0.73 ± 0.11 Meq%. Only acetic and propionic acids were obtained when individual VFA of blood plasma was examined. The highest ratio of acetic/propionic acid was obtained when only grass was fed (8.71), while the least ratio (4.26) was obtained when a high energy level was fed. The higher the inclusion of concentrate ration (or energy) the lower the molar % of acetic acid available in the blood and the higher the propionic acid recorded. Urea nitrogen (mg/100ml blood plasma) which is a good index of protein utilization varied according to the nature of the feed given to the animal. When the animal was fed grass and high energy level, 19.30 ± 0.20mg urea nitrogen/100ml of blood plasma was available in the blood plasma, when it was fed low energy level plus grass 16.20 ± 0.06mg/100ml was recorded and with grass alone 12.15 ± 1.05mg urea nitrogen/100ml of blood plasma was found in the blood plasma.

4.4.3 Milk Yield and Composition of intact lactating cows

Tables 4.5, 4.6 and 4.7 show the milk yield and composition of the White Fulani, German Brown and Friesian cows used for the energy and protein requirement studies.

Table 4.5 MEAN MILK YIELD AND COMPOSITION OF WHITE FULANI COWS MAINTAINED ON GRASS AND LOW OR HIGH CONCENTRATE SUPPLEMENT

ANIMAL NO.	TREATMENT	MILK YIELD (KG/DAY)	TOTAL SOLIDS %	CRUDE PROTEIN %	LACTOSE %	FAT %	ASH %	GROSS ENERGY (KJ/G)
467	Ad lib	2.57	12.25	3.06	4.80	4.72	0.71	21.78
481	forage	3.50	11.52	3.12	4.72	4.84	0.68	21.82
242	alone	3.96	12.00	3.07	4.75	4.63	0.67	21.20
167	(F)	4.08	11.75	3.35	4.83	5.02	0.70	22.21
Mean		3.53±0.34	11.88±0.16	3.15±0.07	4.78±0.02	4.80±0.14	0.69±0.01	21.75±0.71
467	Ad lib	1.82	12.88	3.04	4.81	4.60	0.71	21.00
481	forage	3.02	11.61	3.10	4.73	4.46	0.68	21.52
242	and high	4.14	12.00	3.12	4.76	4.60	0.69	21.10
167	level	4.01	11.86	3.61	4.84	5.00	0.72	21.55
Mean	ration (HC)	3.25±0.54	12.09±0.28	3.23±0.13	4.79±0.02	4.67±0.12	0.70±0.01	21.29±0.43
467	Ad lib	2.04	12.80	3.21	4.80	4.62	0.70	21.57
481	forage	3.36	11.63	3.24	4.72	4.71	0.68	21.21
242	and low	4.60	12.00	3.12	4.76	4.64	0.69	21.25
167	level	3.15	11.90	3.58	4.86	5.20	0.72	22.15
Mean	ration (LC)	3.29±0.52	12.08±0.25	3.29±0.10	4.79±0.03	4.79±0.09	0.70±0.01	21.55±0.56

Table 4.6 MILK YIELD AND COMPOSITION OF GERMAN BROWN COWS MAINTAINED ON GRASS AND LOW OR HIGH CONCENTRATE SUPPLEMENT

ANIMAL NO.	TREATMENT	MILK YIELD (KG/DAY)	TOTAL SOLIDS %	CRUDE PROTEIN %	LACTOSE %	FAT %	ASH %	GROSS ENERGY (KJ/G)
69	Ad lib	6.20	12.00	3.00	4.70	3.95	0.69	21.61
42	forage	7.56	11.80	2.95	4.78	3.85	0.70	20.74
66	alone	7.26	11.92	2.85	4.65	3.60	0.70	21.20
57	(F)	6.24	13.24	3.10	4.62	4.00	0.68	22.02
Mean		6.82±0.35	12.24±0.34	2.98±0.05	4.69±0.03	3.90±0.08	0.69±0.00	21.39±0.48
69	Ad lib	6.35	12.20	3.10	4.70	4.00	0.70	21.78
42	forage	6.36	12.00	3.00	4.76	3.70	0.71	20.20
66	and high	5.35	12.00	3.00	4.55	3.66	0.70	20.56
57	level	6.45	12.98	3.05	4.64	3.85	0.69	21.55
Mean	ration (HC)	6.13±0.26	12.30±0.23	3.04±0.02	4.66±0.04	3.80±0.10	0.70±0.00	21.02±0.18
69	Ad lib	5.22	12.25	3.15	4.71	3.90	0.70	21.70
42	forage	5.45	11.95	3.30	4.77	3.75	0.71	20.99
66	and low	6.00	11.92	3.00	4.52	3.80	0.70	21.00
57	level	5.65	12.95	3.02	4.63	4.08	0.72	21.91
Mean	ration (LC)	5.58±0.17	12.28±0.15	3.08±0.04	4.66±0.05	3.88±0.14	0.71±0.00	21.40±0.33

Table 4.7 MILK YIELD AND COMPOSITION OF FRIESIAN COWS MAINTAINED ON GRASS AND LOW OR HIGH CONCENTRATE SUPPLEMENT

ANIMAL NO.	TREATMENT	MILK YIELD (KG/DAY)	TOTAL SOLIDS %	CRUDE PROTEIN %	LACTOSE %	FAT %	ASH %	GROSS ENERGY (KJ/G)
92	*Ad lib* forage alone (F)	8.17	11.25	2.98	4.80	3.85	0.72	21.74
117		7.13	11.84	3.10	4.93	4.42	0.69	22.59
90		7.32	13.00	3.26	4.85	3.75	0.68	20.17
127		7.36	12.40	3.00	4.56	3.63	0.70	20.00
Mean		7.50±0.23	12.12±0.38	3.09±0.06	4.79±0.08	3.91±0.25	0.70±0.01	21.13±1.20
92	*Ad lib* forage and high level ration (HC)	8.00	12.41	3.05	4.76	3.80	0.72	20.52
117		6.78	11.85	3.12	4.92	4.47	0.70	23.18
90		6.62	12.66	3.15	4.84	3.71	0.69	20.28
127		6.39	12.33	3.01	4.61	3.42	0.70	20.41
Mean		6.95±0.36	12.31±0.17	3.08±0.03	4.78±0.07	3.85±0.22	0.70±0.01	21.10±0.96
92	*Ad lib* forage and low level ration (LC)	6.58	12.32	3.14	4.78	3.78	0.72	20.07
117		6.62	11.64	3.15	4.84	4.42	0.71	22.68
90		8.15	12.85	3.40	4.80	3.92	0.69	21.32
127		5.83	12.34	3.06	4.60	3.40	0.70	20.38
Mean		6.87±0.28	12.29±0.25	3.14±0.04	4.76±0.05	3.88±0.21	0.71±0.01	21.11±0.94

The milk yield of the cows generally decreased as lactation progressed for the three breeds, though the drop was relatively low. The milk yield of the exotic cows (6.64 ± 0.62kg/day) was higher than the indigenous cows (3.36 ± 0.58kg/day). The Friesian cows produced an average higher milk yield (7.11 ± 0.38kg/day) than the German Brown cows (6.18 ± 0.27kg/day). Total solids percentage increased with the increase in energy intake. The protein percentage also followed a similar pattern except that the protein level of the milk of the indigenous cows was higher than those of the exotic breeds. Lactose was relatively constant while fat percentage decreased with increase in energy intake. Average butterfat percentage of the exotic cows' milk (3.87%) was lower than that of the indigenous cows (4.75%). The ash content was relatively constant. There was increase in gross energy of milk with increase in milk butterfat. Results also show that the higher the butterfat percentage the higher the gross energy of milk. This indicates that the average gross energy of the milk of White Fulani cows (21.53KJ/g) was higher than that of the German Brown (21.27KJ/g) and the Friesian cows (21.11KJ/g.)

4.4.4 Comparison of the digestibilities of the basal grass and supplements fed to the steers and lactating cows.

Results of the mean coefficients of apparent digestibility of the grass alone, the grass and concentrate rations and the concentrate rations alone are shown in Tables 4.8; 4.9; and 4.10 respectively. Appendix B4.1 shows statistical calculations.

(a) Dry Matter (DM) digestibility

The results of the DM digestibility showed that though digestibility coefficients (%) of the steers were higher than the lactating cows, yet there were no significant differences in their DM digestibilities for the grass alone ($P > 0.05$). The mean digestibility values of 66.74$\pm$0.52%; 65.98$\pm$0.63% and 65.19$\pm$1.18% were recorded for the German Brown, Friesian and White Fulani cattle respectively, there were no statistical differences between them ($P > 0.05$). Table 4.9 shows that the mean digestibility values of animal on high concentrate (67.88$\pm$1.52%) were higher than the low one (66.74$\pm$1.84%). Average digestibility coefficients of 66.61$\pm$2.48; 67.62$\pm$1.22 and 67.71$\pm$1.26 were recorded for the White Fulani, German Brown and Friesian cattle respectively ($P < 0.05$). Table 4.10 shows a similar pattern to the above except that higher percentages of concentrate digestibility were recorded.

Table 4.8

Mean Coefficient of apparent digestibility of grass (%) (Cynodon nlemfuensis var. nlemfuensis) fed to both the steers and the lactating cows

Nutrients	White Fulani		German Brown		Friesian	
	Steers*	Cows**	Steers*	Cows**	Steers*	Cows**
Dry Matter	65.92±2.35	64.45±1.42	67.04±0.27	66.43±0.72	65.99±0.71	65.96±0.43
Organic Matter	64.05±0.81	63.48±1.65	63.97±0.04	62.85±1.16	63.02±0.23	62.77±0.47
Crude Protein	64.64±0.55	64.45±0.60	67.97±0.56	68.19±1.00	67.67±1.14	67.60±0.41
Ether Extract	65.34±0.46	51.18±2.25	64.27±2.02	62.55±2.69	58.14±0.52	58.40±1.07
Crude Fibre	58.16±0.04	60.10±1.24	56.18±0.44	58.48±2.00	53.94±0.71	53.35±4.14
NFE	64.10±0.39	62.90±1.77	64.37±0.56	65.66±0.32	65.43±0.81	65.02±2.06
Energy	60.43±0.25	58.09±1.80	65.27±0.55	66.02±0.69	66.32±1.09	60.16±2.62

* Mean value of two animals

** Mean value of four animals

(b) Organic Matter digestibility

As pointed out for the DM digestibility, mean organic matter digestibility values of the steers and lactating cows for the grass alone showed no statistical significance ($P > 0.05$). However, results showed that the steers had higher digestibilities. Organic matter digestibility for grass and concentrate also followed a pattern similar to those of the DM, that is, animals on high concentrate ration had higher values than those on low concentrate ration. Coefficient of apparent digestibility of concentrate supplement alone as shown in Table 4.10 were slightly higher than the DM values. The highest mean values were obtained for the German Brown cattle ($74.64 \pm 1.31\%$) and the lowest for the White Fulani ($72.27 \pm 0.82\%$). The Friesian cattle had a $73.77 \pm 1.18\%$ digestibility. There were no statistical differences between the steers and lactating cows ($P > 0.05$).

(c) Crude protein (CP) digestibility

The mean coefficient of apparent digestibility of the CP for the grass alone was fairly high. The highest values were obtained for the German Brown cattle. In the case of the grass and concentrate rations, higher values of apparent digestibility were recorded for the high-concentrate-fed cattle than the low fed ones. Coefficient of apparent digestibility of concentrate supplement alone for steers and lactating cows as shown in Table 4.10 indicated no significant differences ($P > 0.05$). However the steers had slightly higher values than the lactating cows ($74.92 \pm 4.42\%$ for steers and $73.39 \pm 6.34\%$ for lactating cows).

(d) Ether extract (EE) digestibility

The mean coefficient of apparent digestibility of content of grass alone for the White Fulani steers ($65.34 \pm 0.46\%$) was higher than that of the cows ($51.18 \pm 2.25\%$) ($P < 0.05$). There was however, no statistical differences in the digestibility values between the steers and the cows in the exotic breeds ($P > 0.05$). There were also no statistical differences ($P > 0.05$) between the mean digestibilities of EE content of the concentrate alone for the steers and the cows in all the breeds. Highest digestibility coefficient of $70.77 \pm 3.49\%$ was obtained for the German Brown cattle, with the Friesian ($69.78 \pm 2.33\%$) and White Fulani cattle ($69.97 \pm 1.63\%$) having almost the same values.

(e) Crude fibre (CF) digestibility

The lowest values of digestibility coefficients were observed for the crude fibre. The reason for this may lie in the fairly high crude fibre percentage (29.40%) in the basal grass fed. Higher digestibility values for the grass were obtained for the indigenous breed ($59.13 \pm 0.81\%$) than the exotic breeds, the Friesian cattle with $53.65 \pm 5.12\%$ and German Brown with $57.33 \pm 1.82\%$. Contrary to the previous results obtained, Table 4.9 shows that addition of concentrate to the ration of the exotic breeds particularly the German Brown tended to decrease the CF digestibility. The higher the inclusion of concentrate in the diet, the lower the CF digestibility coefficient. There were significant differences in the crude fibre digestibility of the concentrate alone among the breeds and between the steers and lactating cows ($P < 0.05$).

(f) <u>Nitrogen-free extractives (NFE) digestibility</u>

Mean apparent coefficient of digestibility of the grass alone, the grass and the concentrate and the concentrate alone were fairly high and followed similar patterns as those of the DM digestibility. Statistical analysis showed that there were no differences between the values obtained for the steers and the lactating cows ($P > 0.05$).

(g) <u>Energy digestibility</u>

There were no statistical differences ($P < 0.05$) in the apparent digestibility coefficients of energy between the steers

Table 4.9 *Mean Coefficient of apparent digestibility of grass (*Cynodon nlemfuensis*) and concentrate ration fed to both the steers and lactating cows

Nutrients	White Fulani				German Brown				Friesian			
	Steers		Cows		Steers		Cows		Steers		Cows	
	b	c	b	c	b	c	b	c	b	c	b	c
DM	67.93±3.02	66.89±2.38	66.08±1.27	65.55±1.31	68.74±0.02	67.96±0.44	67.27±0.92	66.51±0.73	68.64±0.07	66.70±1.46	68.63±0.42	66.86±0.59
OM	65.53±0.83	64.97±1.02	67.42±0.63	66.23±1.23	65.87±0.34	65.39±0.35	67.48±1.41	66.76±1.54	65.24±0.10	64.67±0.45	67.35±3.34	65.67±1.01
CP	65.80±0.57	65.44±0.81	68.45±1.05	67.73±1.13	69.18±1.07	68.86±0.91	70.52±0.72	69.79±0.87	68.23±0.96	67.08±2.00	69.67±0.08	68.68±0.22
EE	68.27±0.68	67.01±0.51	66.19±2.13	64.57±2.10	68.38±0.96	66.90±0.80	68.55±0.13	63.97±2.54	61.98±2.64	63.47±0.37	64.78±2.07	62.61±1.46
CF	59.53±0.24	58.66±0.03	60.15±1.42	60.02±1.49	56.45±0.58	55.28±0.02	57.69±1.51	56.15±0.47	54.54±0.51	53.26±0.70	55.75±1.77	56.13±1.97
NFE	66.63±0.58	65.80±0.10	65.36±1.74	64.52±1.56	67.07±0.32	66.53±0.52	70.27±1.61	67.60±1.04	69.06±0.17	67.95±0.43	68.13±0.52	66.74±0.33
E	65.34±0.31	65.38±0.26	65.85±0.69	67.94±2.56	71.75±1.49	69.72±1.48	71.10±3.52	69.24±2.97	77.49±0.69	71.74±2.48	72.00±1.95	68.13±0.52

* Average of two values for steers and mean of four values for cows.

b = High level concentrate ration + *ad lib* forage.

c = Low level concentrate ration + *ad lib* forage.

DM = Dry matter
OM = Organic matter
CP = Crude protein
EE = Ether Extract
NFE = Nitrogen-free extractives
E = Energy

Table 4.10

Coefficient of Apparent Digestibility+ of Concentrate Supplement alone for Steers and Lactating cows

Nutrients	White Fulani				German Brown				Friesian			
D	Steers		Cows		Steers		Cows		Steers		Cows	
	b	c	b	c	b	c	b	c	b	c	b	c
OM	75.92±3.79	71.46±0.20	72.40±2.13	69.29±1.17	78.16±0.25	72.84±1.67	76.74±0.70	70.83±0.97	73.88±0.54	72.70±0.59	75.94±0.51	72.39±0.91
DM	69.16±0.83	68.64±1.34	70.17±0.43	68.36±0.93	69.62±0.46	68.08±0.06	72.35±1.76	70.51±1.45	68.65±0.35	68.12±0.10	69.96±2.62	68.96±0.66
CP	73.04±1.67	73.46±2.42	73.99±2.13	71.69±1.10	77.42±0.11	76.30±0.56	77.09±2.46	73.43±1.28	75.95±0.78	73.37±3.10	74.01±2.24	70.11±0.43
EE	70.67±1.25	69.11±0.89	70.71±0.67	69.38±0.43	73.28±0.70	70.60±1.02	72.12±1.17	67.08±3.59	70.56±0.58	67.76±0.30	71.97±1.56	68.83±0.85
CF	65.44±0.28	62.03±0.13	65.99±0.90	63.76±1.33	55.62±6.48	57.11±3.37	53.63±3.12	56.28±2.3	58.57±0.85	57.42±0.82	60.15±4.03	58.59±2.69
NFE	70.28±0.60	68.47±1.79	70.16±0.73	68.17±0.37	74.53±0.50	69.48±0.51	79.05±2.98	72.72±1.70	75.49±3.39	73.57±1.17	76.54±2.05	72.76±1.42
E	77.94±2.33	76.23±1.98	77.25±0.31	74.83±1.51	81.55±2.66	79.76±3.50	82.05±2.41	77.03±2.82	81.69±0.59	79.49±1.91	82.70±1.64	78.87±0.56

*Average of two values for steers and mean of four values for cows. +Estimated from Crampton and Lloyd's (1959) formula.

DM = Dry Matter OM = Organic Matter CP = Crude Protein EE = Ether Extract NFE = Nitrogen Free Extractives E = Energy.

b = High level concentrate ration + ad lib forage. c = Low level concentrate ration + ad lib forage.

and cows. Very high values were recorded for the digestibility coefficient of the concentrate supplements alone. Digestibility values for the breeds range from 76.66±3.58% (White Fulani) through 80.10±5.29% (German Brown) to 80.68±2.15% (Friesian). There were statistical differences between the values obtained for the indigenous and exotic breeds ($P < 0.05$). Values obtained for the energy digestibility of those animals on high energy level were higher than those on the low energy ones but results were not significant ($P > 0.05$).

4.4.5 Total digestible nutrient (TDN) (kg/100kg feed) and metabolizable Energy (ME) (MJ/kg feed)

Tables 4.11a, b and c show the total digestible nutrient (TDN) kg/100kg feed and metabolizable Energy (ME) MJ/kg feed intake from grass and the two levels of concentrate supplements for all the breeds. The TDN values were converted to the ME by using Jagusch and Coop's (1971) value (1kgTDN = 15.127MJ ME). In all the feeds used, highest values were observed when the animals were fed grass alone. The low energy ration values were slightly lower than the values for the high energy rations. The ME values obtained for the animals fed on the supplemented rations were statistically higher than when they were fed on grass alone

Table 4.11a.

Total Digestible Nutrient (TDN) and Metabolizable Energy (ME) intake from grass and concentrate rations fed to White Fulani Steers and lactating cows

Nutrients	Steers			Cows		
	a	b	c	a	b	c
Digestible Crude Protein (DCP)	5.98±0.06	12.89±0.33	12.97±0.48	5.96±0.07	13.06±0.41	12.65±0.22
Digestible Crude Fibre (DCF)	17.10±0.02	5.90±0.03	5.60±0.02	17.67±0.44	5.95±0.08	5.75±0.12
Digestible Ether Extract (DEE)	0.75±0.01	3.24±0.08	3.19±0.04	0.59±0.05	3.26±0.03	3.20±0.02
Digestible Nitrogen free-extractives (DNFE)	26.96±0.18	38.55±0.39	37.56±1.16	26.46±0.82	38.48±0.50	37.39±0.22
Total Digestible Nutrient (TDN) (kg)/100 kg feed	50.79±0.23	60.58±0.05	59.32±0.63	50.68±0.61	60.75±0.64	58.99±0.27
*Metabolizable Energy (ME) (MJ/Kg feed)	7.68±0.02	9.16±0.01	8.97±0.10	7.67±0.09	9.19±0.10	8.92±0.04

a = Grass alone

b = High concentrate ration

c = Low " "

*TDN was converted to ME by using Jagusch and Coop's (1971) value.

Ikg TDN = 15.127 MJ ME

Table 4.11b

Total Digestible Nutrient (TDN) and Metabolizable Energy (ME) intake from grass and concentrate rations fed to German Brown steers and lactating cows

Nutrients	Steers			Cows		
	a	b	c	a	b	c
Digestible Crude Protein (DCP)	6.29±0.03	13.47±0.02	13.47±0.11	6.31±0.11	13.61±0.48	12.96±0.25
Digestible Crude Fibre (DCF)	16.52±0.16	5.02±0.14	5.16±0.31	17.19±0.71	4.84±0.28	5.08±0.21
Digestible Ether Extract (DEE)	0.74±0.05	3.76±0.41	3.26±0.05	0.72±0.02	3.33±0.05	3.10±0.17
Digestible Nitrogen Free Extractives (DNFE)	27.07±0.95	40.88±0.32	38.11±0.33	27.62±0.15	43.36±1.93	39.89±1.10
Total Digestible Nutrients (TDN) (kg/100 kg feed)	50.62±0.80	63.32±0.88	60.00±0.09	51.84±0.68	65.14±2.48	61.03±1.24
*Metabolizable Energy (ME) (MJ/kg feed)	7.66±0.12	9.58±0.14	9.08±0.02	7.84±0.10	9.85±0.33	9.23±0.19

a = Grass alone

b = High concentrate ration

c = Low " "

* TDN was converted to ME by using Jagusch and Coop's (1971) value

IKG TDN = 15.127 MJ ME

Table 4.11c

Total digestible Nutrient (TDN) and Metabolizable Energy (ME) intake from grass and concentrate rations fed to friesian steers and lactating cows

Nutrients	Steers			Cows		
	a	b	c	a	b	c
Digestible Crude Protein (DCP)	6.26$\pm$0.08	13.41$\pm$0.16	12.83$\pm$0.61	6.25$\pm$0.04	13.06$\pm$0.44	12.37$\pm$0.08
Digestible Crude Fibre (DCF)	15.86$\pm$0.26	5.29$\pm$0.08	5.18$\pm$0.07	15.68$\pm$1.48	5.43$\pm$0.36	5.30$\pm$0.25
Digestible Ether Extract (DEE)	0.68$\pm$0.01	3.26$\pm$0.03	3.13$\pm$0.02	0.67$\pm$0.02	3.32$\pm$0.07	3.18$\pm$0.04
Digestible Nitrogen free-extractives (DNFE)	27.52$\pm$0.22	41.41$\pm$2.19	40.35$\pm$0.75	27.35$\pm$0.32	41.98$\pm$1.33	39.91$\pm$0.92
Total Digestible Nutrient (TDN) (kg/100 kg) feed)	50.32$\pm$0.21	63.37$\pm$2.45	61.49$\pm$1.45	49.95$\pm$1.44	63.79$\pm$0.98	60.76$\pm$0.68
*Metabolizable Energy (ME) (MJ/kg feed)	7.61$\pm$0.03	9.59$\pm$0.37	9.30$\pm$0.22	7.56$\pm$0.22	9.65$\pm$0.15	9.19$\pm$0.10

a = Grass alone

b = High concentrate ration

c = Low " "

* TDN was converted to ME by using Jagusch and Coop's (1971) value

Ikg TDN = 15.127 MJ ME

($P < 0.01$). There were however, differences in the ME values between the high and low energy level ($P < 0.05$).

Generally, values obtained for the steers were higher than those for the lactating cows but the differences were not significant ($P > 0.05$). The mean ME obtained for the German Brown cattle (8.87 ± 0.37) was only slightly higher than the value for the Friesian (8.82 ± 0.40). The lowest mean value was recorded for the White Fulani cattle (8.60 ± 0.30MJ/kg feed). Values obtained for the German Brown and Friesian cattle were significantly higher than the White Fulani ($P < 0.05$).

4.4.6 <u>Protein (Nitrogen) utilization and requirements for milk production</u>

Summary of nitrogen utilization data with estimates of biological value (BV), metabolic faecal nitrogen (MFN) and endogenous urinary nitrogen (EUN) where necessary are shown in Tables 4.13-4.22. Details of the statistical calculations are shown in Appendix B4.2. The dry matter (kgDM/day) consumed both from grass and the supplemented rations by the cows with their metabolic size are shown in Table 4.12.

Table 4.13 shows the summary of faecal-N(g/kgDM consumed) and nitrogen intake (g/day) for the three breeds of lactating cows. The faecal-N was highly correlated with N-intake as shown in Table 4.14 and illustrated in Fig. 4.2. The coefficient of correlation (<u>r</u>) ranged from 0.73 for the German Brown

Table 4.12 Dry Matter (DM) Intake (kg/day) and metabolic size ($Wkg^{0.734}$) of three breeds of cows maintained on basal forage and high or low concentrate supplement

TREATMENT	WHITE FULANI			GERMAN BROWN			FRIESIAN		
	No.	Dry Matter	Metabolic Size	No.	Dry Matter	Metabolic Size	No.	Dry Matter	Metabolic Size
F	467	3.60	74.99	69	4.60	88.88	92	5.77	93.50
HC		5.08(1.08)	76.21		5.23(2.18)	90.78		7.06(2.73)	93.54
LC		4.74(0.74)	77.98		4.99(1.46)	92.08		5.12(1.71)	93.52
MEAN		5.08±0.77	76.39		5.67±0.89	90.58		5.98±1.60	93.52
F	481	3.67	76.43	42	5.86	84.33	117	4.62	79.05
HC		3.98(1.20)	73.96		5.62(2.76)	85.27		5.02(1.85)	80.24
LC		4.67(0.84)	74.92		5.37(1.33)	87.10		5.65(0.85)	82.60
MEAN		4.79±0.57	75.10		6.98±0.74	85.57		6.00±0.70	80.63
F	242	4.00	72.35	66	5.01	79.25	90	5.62	81.58
HC		4.82(1.64)	73.84		4.92(1.34)	78.57		6.02(2.51)	82.15
LC		4.85(1.15)	76.76		5.65(1.00)	80.98		6.86(1.82)	84.55
MEAN		5.49±0.76	74.32		5.97±0.49	79.60		7.61±1.00	82.76
F	167	4.83	79.45	57	4.84	91.83	127	4.68	84.45
HC		5.28(1.50)	73.84		5.26(2.18)	90.20		5.21(1.72)	86.18
LC		6.27(0.72)	80.97		5.64(1.10)	90.99		7.24(0.80)	88.49
MEAN		6.20±0.69	78.09		6.34±0.78	91.00		6.55±0.99	86.37

F = Grass alone HC = High Concentrate level LC = Low Concentrate level
( ) = Figures in parenthesis are dry matter intake from concentrate supplements.

Table 4.13 Summary of Faecal N(g/kgDM consumed) and N-Intake (g/day) for three breeds of lactating cows maintained on basal forage and high or low concentrate supplements

TREATMENT	WHITE FULANI			GERMAN BROWN			FRIESIAN		
	No.	FAECAL-N	N-INTAKE	No.	FAECAL-N	N-INTAKE	No.	FAECAL-N	N-INTAKE
F	467	5.37	80.04	69	6.49	101.96	92	5.78	102.14
HC		5.94	125.44		7.73	184.45		8.00	208.56
LC		5.60	118.28		6.62	135.20		6.32	142.78
MEAN		5.64+0.29	107.92±24.41		6.95±0.68	140.54±41.50		6.70±1.16	151.16±53.70
F	481	5.69	71.20	42	5.34	80.04	117	5.64	80.39
HC		5.06	106.93		7.06	159.45		6.44	145.44
LC		5.11	107.64		6.49	141.15		5.54	125.00
MEAN		5.29±0.35	95.26±20.84		6.30±0.88	126.88±41.58		5.87±0.49	116.94±33.25
F	242	4.35	69.60	66	6.01	87.17	90	5.61	81.43
HC		6.40	135.37		6.24	127.69		6.46	144.65
LC		5.71	120.50		5.96	129.71		6.77	151.10
MEAN		5.49±1.04	108.49±34.49		6.07±0.15	114.86±24.00		6.28±0.60	125.73±38.50
F	167	5.01	84.04	57	5.47	101.62	127	5.63	97.79
HC		6.57	138.97		7.35	159.97		7.56	183.56
LC		6.25	131.71		6.02	132.68		7.40	176.51
MEAN		5.94±0.82	118.24±29.84		6.28±0.97	131.42±29.20		6.86±1.07	152.62±47.61

F = Grass alone HC = High level Concentrate LC = Low level Concentrate

cows to 0.80 for the Friesian cows; the White Fulani cows had a correlation coefficient of 0.78. They were all statistically significant ($P < 0.01$). The intercepts on the ordinate axis gave the nitrogen excreted in faeces when the dietary nitrogen intake was hypothetically zero, that is, the metabolic faecal nitrogen (MFN). These values (Table 4.14) ranged from 3.06g/kgDM consumed for the Friesian cows through 3.44g/kg DM consumed for the White Fulani cows to 3.82g/kgDM consumed for the German Brown cows. These values were taken directly from Fig. 4.2 and are therefore the mean for the respective breeds. Statistical analysis in Appendix B4.2 has shown highly significant differences ($P < 0.01$) within the breeds and treatments for the faecal nitrogen ($g/day/W_{kg}^{0.734}$) output. Duncan's multiple range tests showed that there were no significant differences ($P > 0.05$) between the German Brown and White Fulani breeds but both were significantly higher than the values for the Friesian cows ($P < 0.05$). Also animals on high energy ration produced significantly higher faecal -N than those on low energy ration ($P < 0.01$).

The summary of urinary-N ($g/day/W_{kg}^{0.734}$) and absorbed -N($g/day/W_{kg}^{0.734}$) for the three breeds are shown in Table 4.15. The urinary -N was highly correlated with absorbed nitrogen. The correlation coefficients (r) ranged from 0.76 for the Friesian cows to 0.79 for the German Brown cows; the White

Table 4.14

Regression Equations Describing the Relationship between Faecal-N (g/kgDM) Y, and N-intake (g/day) X for Lactating cows in estimating Metabolic Faecal Nitrogen (MFN)

Breed	Regression Equations	Correlation Coefficient (r)	Standard Error	Interest on Y-axis	MFN g/kgDM
White Fulani	Y = 3.4385 + 0.020X	0.78**	0.18	3.44	3.44
German Brown	Y = 3.8170 + 0.0201X	0.73**	0.34	3.82	3.82
Friesian	Y = 3.0619 + 0.0251X	0.80**	0.19	3.06	3.06

** Highly significant ($P < 0.01$)

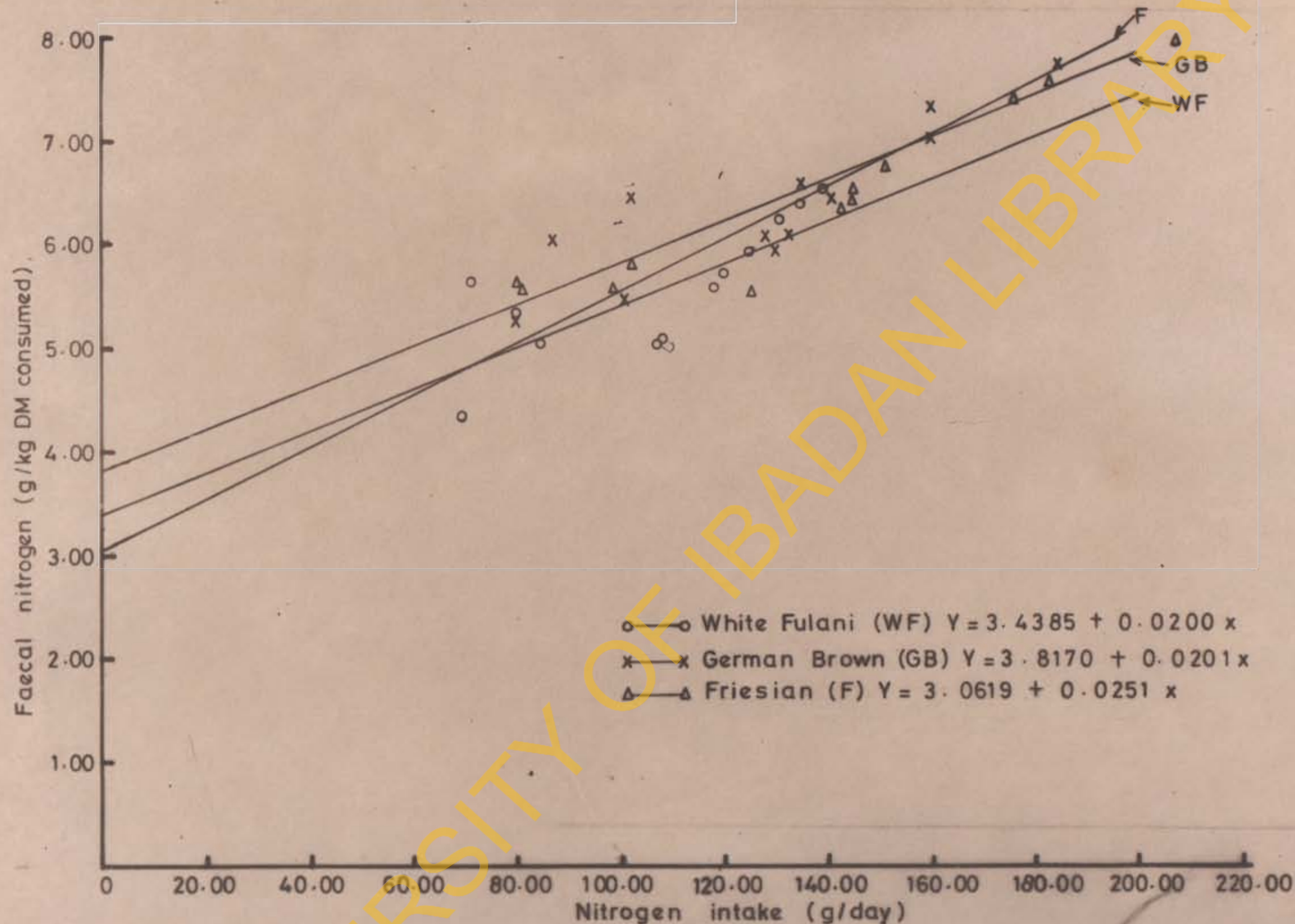

FIG. 4.2 Relationship between Faecal-N and N-Intake for three breeds of lactating cows.

Table 4.15 Summary of Urinary-N (g/day/$Wkg^{0.734}$) and Absorbed-N (g/day/$Wkg^{0.734}$) for three breeds of lactating cows maintained on grass and high or low concentrate supplements

TREATMENT	WHITE FULANI			GERMAN BROWN			FRIESIAN		
	No	URINARY-N	ABSORBED-N	No.	URINARY-N	ABSORBED-N	No.	URINARY-N	ABSORBED-N
F	467	0.35	0.80	69	0.30	0.80	92	0.34	0.78
HC		0.51	1.12		0.53	1.25		0.63	1.39
LC		0.40	1.16		0.33	1.05		0.30	1.12
MEAN		0.42±0.08	1.03±0.02		0.39±0.13	1.03±0.23		0.42±0.18	1.10±0.31
F	481	0.27	0.71	42	0.28	0.58	117	0.32	0.74
HC		0.40	1.15		0.56	1.24		0.51	1.21
LC		0.52	1.12		0.43	1.18		0.30	1.12
MEAN		0.40±0.13	0.99±0.25		0.42±0.14	1.00±0.36		0.38±0.12	1.02±0.25
F	242	0.29	0.77	66	0.31	0.77	90	0.29	0.74
HC		0.50	1.22		0.45	1.18		0.52	1.17
LC		0.40	1.17		0.40	1.16		0.40	1.20
MEAN		0.40±0.11	1.05±0.25		0.39±0.07	1.04±0.23		0.40±0.12	1.04±0.26
F	167	0.27	0.80	57	0.35	0.82	127	0.28	0.84
HC		0.58	1.23		0.49	1.22		0.62	1.44
LC		0.39	1.15		0.30	1.07		0.50	1.32
MEAN		0.41±0.16	1.06±0.21		0.38±0.10	1.04±0.20		0.47±0.17	1.20±0.32

F = Grass alone HC = High level Concentrate LC = Low level Concentrate

Fulani cows had a correlation coefficient of 0.77 (Table 4.16), and the relationships are illustrated in Fig. 4.3. They were all statistically significant ($P < 0.01$). The intercepts on urinary -N axis gave the urinary -N at zero -N absorption which is the endogenous urinary nitrogen (EUN) in g/day/$W_{kg}^{0.734}$. These values varied from 0.017 for the White Fulani, through 0.033 for the German Brown, to 0.042g/day/$W_{kg}^{0.734}$ for the Friesian lactating cows (Table 4.16). Statistical analysis has also shown that there were no significant differences in the urinary-N of the three breeds of lactating cows ($P > 0.05$) but differences occurred in the dietary levels. Animals on high-energy ration produced significantly higher urinary -N than those on the low-energy feed and on the grass intake alone ($P < 0.05$). The summary of the results on absorbed -N showed statistical differences ($P < 0.05$) between the nitrogen absorbed by the three breeds of cows. Though there were no significant differences between the absorbed -N by the White Fulani and German Brown cows, the nitrogen absorbed by the Friesian cows was statistically higher than the other breeds ($P < 0.05$). High statistical differences were recorded for the absorbed -N in the three different diets. Absorbed -N of animals on high energy ration was statistically higher than those on the low energy ration and the grass forage alone ($P < 0.01$).

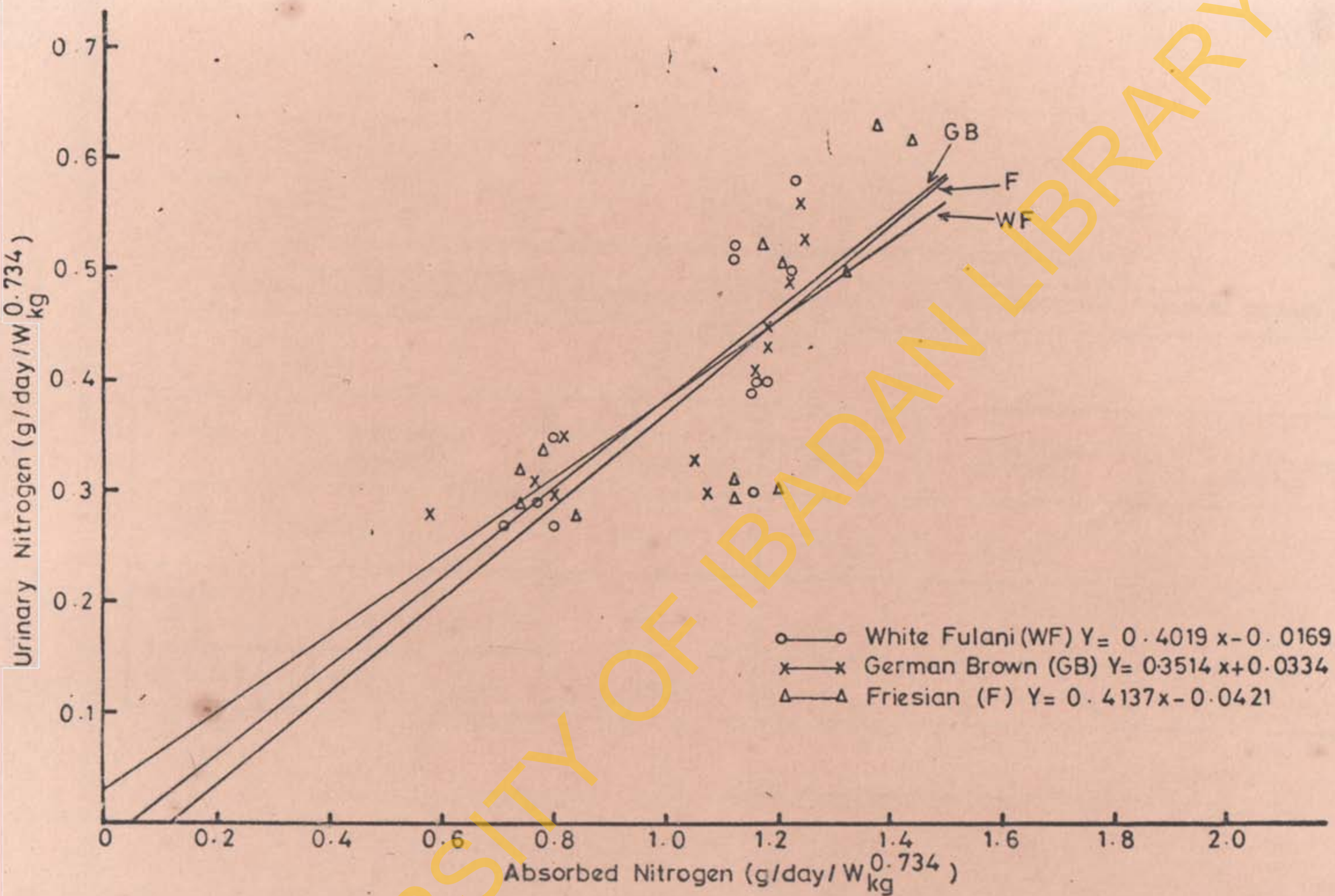

FIG. 4.3 Relationship between Urinary-N and Absorbed-N for three breeds of lactating cows.

Table 4.16

REGRESSION EQUATIONS DESCRIBING THE RELATIONSHIP BETWEEN URINARY-N($g/day/W_{kg}^{0.734}$) Y, AND ABSORBED-N ($g/day/W_{kg}^{0.734}$)X FOR THREE BREEDS OF LACTATING COWS IN ESTIMATING ENDOGENOUS URINARY NITROGEN (EUN)

BREED	REGRESSION EQUATIONS	CORRELATION COEFFICIENT (r)	STANDARD ERROR	INTERCEPT ON Y-AXIS	EUN $g/DAY/W_{kg}^{0.734}$
WHITE FULANI	Y = 0.4019 X - 0.0169	0.77**	0.0025	0.0169	0.017
GERMAN BROWN	Y = 0.3514 X + 0.0334	0.79**	0.0010	0.0334	0.033
FRIESIAN	Y = 0.4137 X + 0.421	0.76**	0.0037	0.0421	0.042

** Highly significant ($P<0.01$)

The summary of the N-balance (g/day/$W_{kg}^{0.734}$) and absorbed -N(g/day/$W_{kg}^{0.734}$) for the three breeds of lactating cows are shown in Table 4.17. The absorbed-N was corrected for MFN while the nitrogen balance was corrected for both MFN and EUN. Nitrogen balance was highly correlated with absorbed -N. High correlation coefficients (r) ranging from 0.79 for the Friesian cows through 0.84 for the German Brown cows to 0.85 for the White Fulani cows were significant ($P < 0.01$) as shown in Table 4.18. The relationships are illustrated in Fig. 4.3. The biological values which are the coefficients of X in the regression equations (Fig. 4.4) when multiplied by 100 were 60 for White Fulani, 66 for German Brown and 64 for Friesian. Significant differences were recorded for the nitrogen balance (g/day/$W_{kg}^{0.734}$) among the three diets ($P < 0.01$). The pattern was similar to that of absorbed -N. No statistical differences were recorded among the three breeds ($P > 0.05$).

Table 4.19 shows the summary of the results of N-balance (g/day/$W_{kg}^{0.734}$) and N-intake (g/day/$W_{kg}^{0.734}$) for the three breeds of lactating cows. Highly significant correlations ($P < 0.01$) were also obtained for nitrogen balance (g/day/$W_{kg}^{0.734}$) as shown in Table 4.20 and illustrated in Fig. 4.5. Correlation coefficients (r) ranged from 0.73 for the White Fulani, 0.79 for

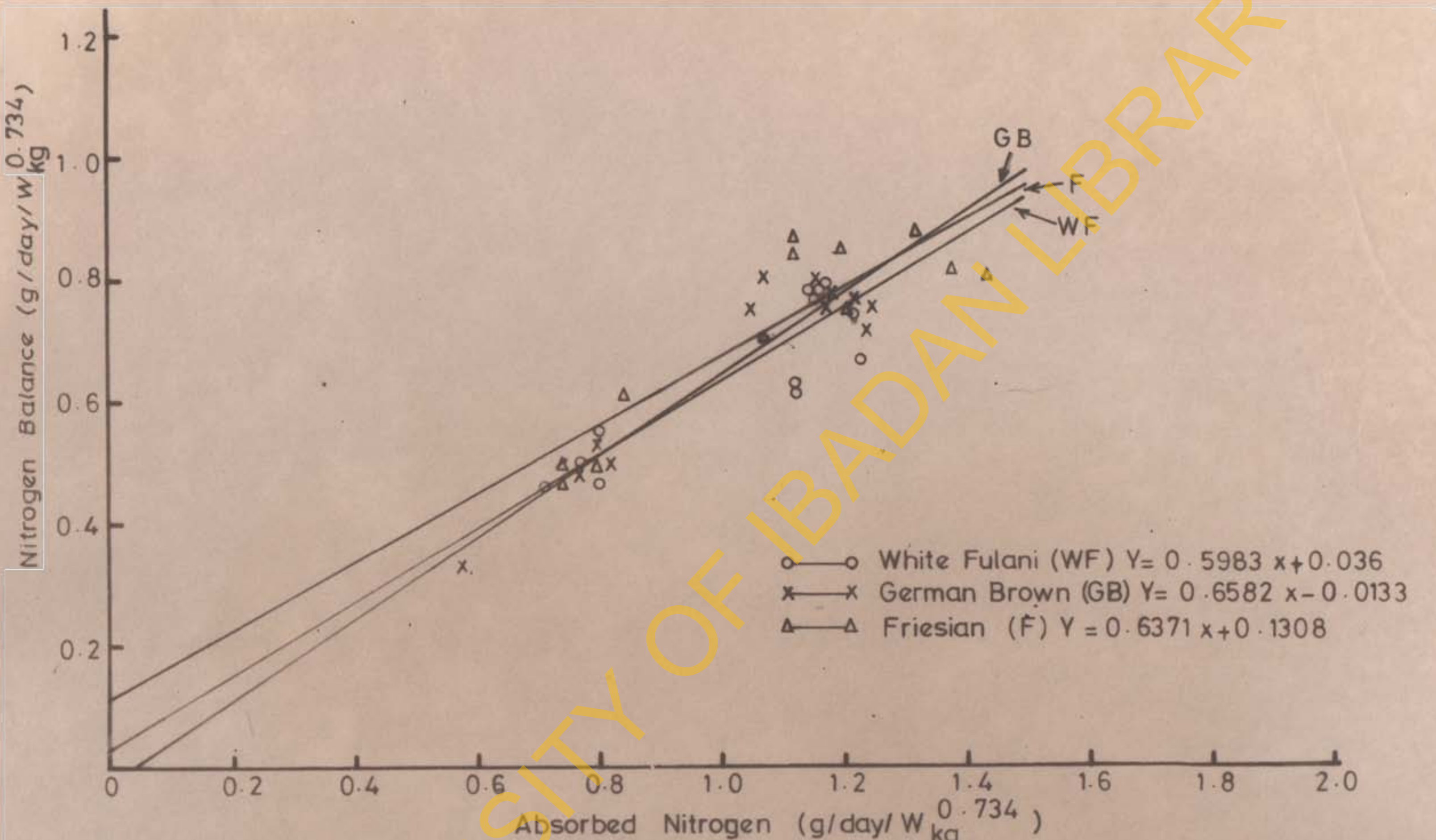

FIG. 4.4 Relationship between N-Balance and Absorbed-N for three breeds of lactating cows.

Table 4.17 Summary of **N-Balance ($g/day/Wkg^{0.734}$) and *Absorbed-N ($g/day/W_{kg}^{0.734}$) for three Breeds of lactating cows maintained on grass and high or low concentrate supplements

TREATMENT	WHITE FULANI			GERMAN BROWN			FRIESIAN		
	No.	N-BALANCE	ABSORBED-N	No.	N-BALANCE	ABSORBED-N	No.	N-BALANCE	ABSORBED-N
F	467	0.47	0.80	69	0.53	0.80	92	0.49	0.78
HC		0.63	1.12		0.75	1.25		0.81	1.39
LC		0.78	1.16		0.75	1.05		0.87	1.12
MEAN		0.63±0.16	1.03±0.20		0.68±0.13	1.03±0.23		0.72±0.20	1.10±0.31
F	481	0.46	0.71	42	0.33	0.58	117	0.47	0.74
HC		0.77	1.15		0.71	1.24		0.75	1.21
LC		0.62	1.12		0.78	1.18		0.87	1.12
MEAN		0.62±0.16	0.99±0.25		0.61±0.24	1.00±0.36		0.70±0.21	1.02±0.25
F	242	0.50	0.77	65	0.49	0.77	90	0.50	0.74
HC		0.74	1.22		0.76	1.18		0.70	1.17
LC		0.79	1.17		0.79	1.16		0.85	1.20
MEAN		0.68±0.16	1.05±0.25		0.68±0.17	1.04±0.23		0.68±0.18	1.04±0.26
F	167	0.55	0.80	57	0.50	0.82	127	0.61	0.84
HC		0.67	1.23		0.76	1.22		0.80	1.44
LC		0.78	1.15		0.80	1.07		0.87	1.32
MEAN		0.67±0.12	1.05±0.23		0.69±0.16	1.04±0.20		0.76±0.13	1.20±0.32

* Corrected for metabolic faecal nitrogen. ** Corrected for both metabolic faecal nitrogen and endogenous urinary nitrogen.

F = Grass alone HC = High level Concentrate LC = Low level Concentrate.

Table 4.18

REGRESSION EQUATIONS DESCRIBING THE RELATIONSHIP BETWEEN N-BALANCE ($g/day/W_{kg}^{0.734}$) Y, AND ABSORBED-N($g/day/W_{kg}^{0.734}$) X in ESTIMATING BIOLOGICAL VALUE

BREED	REGRESSION EQUATIONS	CORRELATION COEFFICIENT (r)	STANDARD ERROR	ABSORBED-N AT ZERO BALANCE($g/day/W_{kg}^{0.734}$)	BIOLOGICAL VALUE
WHITE FULANI	Y = 0.5983X + 0.036	0.85**	0.0057	0.036	60
GERMAN BROWN	Y = 0.6583X - 0.0133	0.84**	0.0054	0.013	66
FRIESIAN	Y = 0.6371X + 0.1308	0.79**	0.0131	0.131	64

** Highly significant ($P < 0.01$)

Table 4.19 Summary of N-Balance (g/day/$W_{kg}^{0.734}$) and N-Intake (g/day/$W_{kg}^{0.734}$) for three breeds of lactating cows maintained on grass and high or low concentrate supplements

TREATMENT	WHITE FULANI			GERMAN BROWN			FRIESIAN		
	No.	N-BALANCE	N-INTAKE	No.	N-BALANCE	N-INTAKE	No.	N-BALANCE	N-INTAKE
F	467	0.47	1.07	69	0.53	1.15	92	0.49	1.09
HC		0.63	1.65		0.75	2.03		0.81	2.23
LC		0.78	1.52		0.75	1.47		0.87	1.53
MEAN		0.63±0.15	1.41±0.30		0.68±0.13	1.55±0.45		0.72±0.20	1.62±0.57
F	481	0.46	0.93	42	0.33	0.95	117	0.47	1.02
HC		0.77	1.45		0.71	1.87		0.75	1.81
LC		0.62	1.44		0.78	1.62		0.87	1.51
MEAN		0.62±0.16	1.27±0.30		0.61±0.24	1.48±0.48		0.70±0.21	1.45±0.40
F	242	0.50	0.96	66	0.49	1.10	90	0.50	1.00
HC		0.74	1.83		0.76	1.63		0.70	1.76
LC		0.79	1.57		0.79	1.60		0.85	1.79
MEAN		0.68±0.16	1.45±0.45		0.68±0.17	1.44±0.30		0.68±0.18	1.52±0.45
F	167	0.55	1.06	57	0.50	1.11	127	0.61	1.16
HC		0.67	1.88		0.76	1.77		0.80	2.13
LC		0.78	1.63		0.80	1.46		0.87	1.99
MEAN		0.67±0.12	1.52±0.42		0.69±0.16	1.47±0.33		0.76±0.13	1.76±0.52

F = Grass alone HC = High level Concentrate LC = Low level Concentrate

Table 4.20

Regression Equations Describing the Relationship Between N-Balance ($g/day/W_{kg}^{0.734}$) Y, and N-Intake ($g/day/W_{kg}^{0.734}$) X, for three Breeds Lactating Cows

BREED	REGRESSION EQUATIONS	CORRELATION COEFFICIENT(r)	STANDARD ERROR
White Fulani	Y = 0.2233+ 0.3049X	0.73**	0.0099
German Brown	Y = 0.0980+0.3814X	0.82**	0.0085
Friesian	Y = 0.259+0.2879X	0.79**	0.0102

** Significant ($P < 0.01$)

the Friesian to 0.82 for the German Brown lactating cows. The graph relating N-balance to N-intake did not show any deviation from linearity as one would expect at about 17 to 22% crude protein level in the supplements (ARC, 1965; Maynard and Loosli, 1969). A close study of Fig. 4.5 however showed some levels of intake (between 1.4 and 2.0g/day/$W_{kg}^{0.734}$ N-intake) which corresponded to optimal nitrogen balance in the three breeds of lactating cows. These are shown in Table 4.22. Maximum nitrogen intake were 1.60; 1.45 and 1.50g/day/$W_{kg}^{0.734}$ for the White Fulani, German Brown and Friesian lactating cows respectively. Statistical results on nitrogen balance (g/day/$W_{kg}^{0.734}$) and nitrogen intake (g/day/$W_{kg}^{0.734}$) followed the same pattern. There were no statistical differences ($P > 0.05$) among the breeds. However, there were significant differences among the levels of feed intake with the high energy ration being statistically higher than low energy ration and the grass forage alone ($P < 0.01$).

Substituting for the results already obtained for MFN (Table 4.14), EUN (Table 4.16) both expressed in g/day/$W_{kg}^{0.734}$, and BV (Table 4.18), Table 4.21 shows the factorial equation culminating in the digestible crude protein (DCP) (g/day/$W_{kg}^{0.734}$) requirement for maintenance. Calculated DCP requirement (g/day/$W_{kg}^{0.734}$) was 0.39 for the White Fulani; 0.47 for the

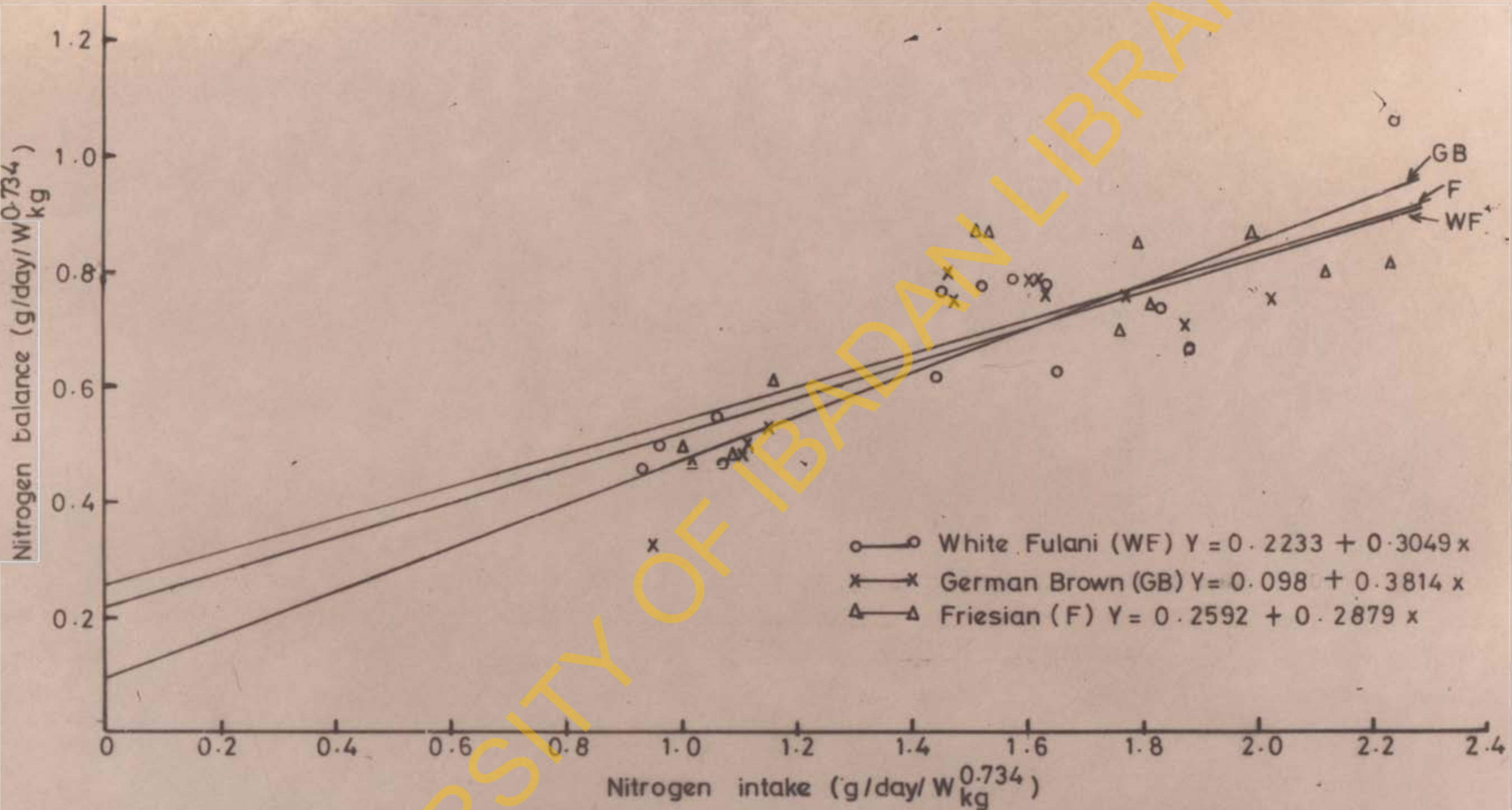

FIG. 4.5 Relationship between N-Balance and N-Intake for three breeds of lactating cows.

German Brown and 0.52 for the Friesian lactating cows. Values ranging from 91.82 for the White Fulani ,113.28 for the German Brown to 121.77g/day available protein for the Friesian cows were obtained when the above DCP requirements were converted to available protein using the coversion factor recommended by ARC (1965).

In Table 4.22, the DCP requirement for maintenance and milk production was given using the results obtained from Fig. 4.5. DCP requirement for maintenance and production was 6.69 for the White Fulani, 6.34 for the German Brown and 6.54g/day/$W_{kg}^{0.734}$ for the Friesian lactating cows. These values were obtained by multiplying with 6.25 the nitrogen intake at maximum N-balance (g/day/$W_{kg}^{0.734}$) having previously corrected these values with their respective mean digestion coefficients. These values were summarised in Table 4.22. Available protein for lactating White Fulani cows producing an average of 3.35kg/day milk was 304.80g/day. The ARC (1965) estimate was 272.14g/day showing that enough protein was available for the White Fulani cows for milk production. 353.93g/day protein were available for the German Brown cows producing an average of 6.17kg milk yield per day. The ARC (1965)

Table 4.21

ESTIMATION OF DIGESTIBLE CRUDE PROTEIN (DCP) REQUIREMENT FOR THREE BREEDS OF LACTATING COWS FOR MAINTENANCE BY FACTORIAL EQUATION

BREED	ENDOGENOUS URINARY NITROGEN G/DAY/$W_{kg}^{0.734}$	METABOLIC FAECAL NITROGEN G/DAY/$W_{kg}^{0.734}$	BIOLOGICAL VALUE	CALCULATED DCP REQUIREMENT G/DAY/$W_{kg}^{0.734}$
WHITE FULANI	0.017	0.052	60	0.39
GERMAN BROWN	0.033	0.048	66	0.47
FRIES-IAN	0.042	0.049	64	0.52

DCP (G/DAY/$W_{KG}^{0.734}$) FOR MAINTENANCE = $6.25 \left[\left(EUN \times \frac{100}{BV}\right) + MFN \left(\frac{100}{BV} - 1\right) \right]$ (Akinsoyinu, 1974)

EUN = Endogenous Urinary Nitrogen (g/day/$W_{kg}^{0.734}$)

MFN = Metabolic Faecal Nitrogen (g/day/$W_{kg}^{0.734}$)

BV = Biological Value.

Table 4.22 Estimated DCP requirement for maintenance and maintenance with milk production from relationship between N-balance (g/day/$W_{kg}^{0.734}$) and N-Intake (g/day/$W_{kg}^{0.734}$) for the three breeds of lactating cows

Breed	N-intake at Zero-balance g/day/$W_{kg}^{0.734}$	Mean Digestion Coefficient %	DCP intake for for maintenance g/day/$W_{kg}^{0.734}$	N-intake at maximum N-balance g/day/$W_{kg}^{0.734}$	DCP requirement for maintenance and milk production g/day/$W_{kg}^{0.734}$	*Available Protein g/day	Recommended available protein ARC (1965) g/day
WHITE FULANI	0.2233	66.88	0.93	1.60	6.69	304.80[1]	272.14[1]
German Brown	0.0980	69.50	0.55	1.46	6.34	353.93[2]	337.29[2]
FRIESIAN	0.2592	68.84	1.12	1.52	6.54	359.20[3]	387.04[3]

[1] Milk yield = 3.35 kg/day
[2] Milk yield = 6.17 "
[3] Milk yield = 7.08 "

$$R_{AP} = \frac{1}{BV} \; 6.25 \; (E + G) \quad \text{(Roy, 1970)}$$

Where R_{AP} = Requirement of available protein
BV = Biological value (as a coefficient)
E = Endogenous urinary N(g/day)
G = N retention (g/day)

recommended 337.29g/day. This also shows that enough protein was made available to the German Brown lactating cows. Available protein intake of the Friesian cows was 359.20g/day while producing an average of 7.08kg milk yield per day. 387.04g/day available protein was recommended by the ARC (1965) for cows producing this amount of milk.

Table 4.23 shows the calculation of the efficiency of protein utilization for milk production for the three breeds of cattle. The Friesian lactating cows had the highest percentage of net efficiency of protein utilization (53.73%) while the German Brown cows had 48.43%. The White Fulani cows had the least net efficiency of protein utilization (27.95%).

4.4.7 Energy utilization

A summary of the total dry matter intake of the animals and their metabolic weights are shown in Table 4.12. A summary of the data on energy utilization by the three breeds of lactating cows are shown in Table 4.24 while the detailed results are shown in Appendix C4.5. Both Table 4.24 and Appendix C4.5 clearly show the gross energy (MJ/day), its partition on the body, utilization and the efficiency of utilization. Average gross energy intake of the White Fulani cows was 96.74±6.06 MJ/day while the ME

Table 4.23

Efficiency of protein utilization for milk production

for three breeds of cattle

maintained on grass and low or high concentrate supplements

Variable description	Unit	Breeds WF	Breeds GB	Breeds F
Digestible Crude protein intake (DCP)	(g/day)	529.18	638.17	655.56
Digestible Crude protein for maintenance	" "	131.38	218.55	224.27
Total protein secreted in milk	" "	111.20	203.24	231.75
*Net efficiency of utilization	%	27.95	48.43	53.73

WF = White Fulani

GB = German Brown

F = Friesian

$$* = \frac{\text{Protein yield in milk}}{\text{DCP intake} - \text{DCP for maintenance}}$$

intake was 43.79±5.22MJ/day. This indicates that only 45.27% of the gross energy intake was metabolized. There was considerable loss of weight in all animals during the beginning of the experiment (early part of lactation) particularly when grass alone was fed and increasing high milk yield was produced. Towards the end of the experiment when low energy level was fed and there was increase in feed intake the animals gained weight. This recovery from weight loss occurred in most of the animals when high energy was fed. On the average, the White Fulani cows gained 0.25kg/day liveweight. The German Brown cows consumed 123.24±4.90 MJ/day and metabolized 52.35±3.48 MJ/day indicating that about 42.48% of the gross enery intake of the German Brown cows was metabolized. There was also body weight loss during early lactation and the animals lost an average of 0.65kg/day at the end of the experiment. The Friesian cows consumed an average of 123.19±9.18 MJ/day (gross energy). Their average ME was 54.66±7.98 MJ/day and only 44.37% of the gross energy intake was in fact metabolized. Table 4.24 shows the summary of the ME intake (MJ/day), liveweight changes (kg/day), milk yield (kg/day) and milk energy (MJ/day) of the three breeds of lactating cows. Comparative results of ME intake calculated from TDN intake and the conventional method

Table 4.24 Summary of Metabolizable Energy, Liveweight Change, Milk Yield and Energy of the three breeds of lactating cows maintained on grass and low or high concentrate supplements in the declining phase of lactation

Breed	Treat-ment	No. of Cows	Dry Matter Intake (kg/Day)	Metabolizable Energy (ME) (MJ/Day)	ME (MJ/kgDM)	Liveweight Changes (kg/Day)	Milk Yield (kg/Day)	Milk Energy (MJ/Day)
White Fulani	F	4	4.03	22.33	5.55	-0.61	3.53	4.76
	HC	4	6.14	48.89	7.96	+0.02	3.25	4.39
	LC	4	6.00	60.15	10.03	+0.53	3.29	4.30
	Mean	4	5.39±0.68	43.79±6.69	7.85±1.30	-0.02±0.26	3.36±0.09	4.48±0.14
German Brown	F	4	5.08	39.47	7.77	-0.81	6.82	7.50
	HC	4	7.37	60.09	8.15	+0.04	6.13	6.43
	LC	4	6.64	57.49	8.66	+0.54	5.58	6.16
	Mean	4	6.36±0.68	52.35±6.49	8.19±0.26	-0.08±0.41	6.18±0.36	6.70±0.41
Friesian	F	4	5.17	19.82	3.83	-0.98	7.50	8.12
	HC	4	8.03	67.83	8.45	+0.30	6.95	7.22
	LC	4	7.51	76.33	10.16	+0.62	6.80	6.95
	Mean	4	6.90±0.88	54.66±17.61	7.48±1.89	-0.02±0.56	7.08±0.22	7.43±0.35

F = Grass alone HC = High Concentrate + *ad lib* grass intake LC = Low Concentrate + *ad lib* grass intake.

are shown in Appendix C4.6. ME intake from TDN results are slightly higher than the conventional method in the case of the exotic breeds. The reverse is the case with the White Fulani breed.

Table 4.25 shows the summary of the regression equations describing the relationship between ME (MJ/day/$W_{kg}^{0.734}$) and liveweight changes (kg/day) for the three breeds of lactating cows. This relationship is depicted in Fig. 4.6.

There was a highly significant ($P < 0.01$) correlation between ME intake (MJ/day/$W_{kg}^{0.734}$) and liveweight change (kg/day) for the three breeds. The correlation ($\underline{r}$) ranged from 0.81 for the German Brown through 0.85 for the White Fulani to 0.94 for the Friesian lactating cows. The ME values at the point of zero liveweight change gave the ME (MJ/day/$W_{kg}^{0.734}$) required daily for maintenance. The estimates so obtained ranged from 0.53 for the White Fulani cows through 0.59 for the German Brown cows to 0.61 MJ/day/$W_{kg}^{0.734}$ for the Friesian cows.

The gross efficiency for milk production, which is the energy in milk divided by the energy intake without correction for maintenance expressed on percentage basis, was estimated by using the pooled means of the ME (MJ/day) intake for each breed and the energy of the milk produced (MJ/day). The efficiency of gross energy utilization (Table 4.26) for milk

Table 4.25

SUMMARY OF

REGRESSION EQUATIONS DESCRIBING THE RELATIONSHIP BETWEEN METABOLIZABLE ENERGY ($MJ/day/W_{kg}^{0.734}$) AND LIVEWEIGHT CHANGES (kg/day) OF LACTATING COWS

BREED	REGRESSION EQUATIONS	CORRELATION COEFFICIENT(r)	STANDARD ERROR (SE)	INTERCEPT ON Y-AXIS (a)	ME REQUIREMENTS FOR MAINTENANCE $MJ/day/W_{kg}^{0.734}$
WHITE FULANI	Y = 0.5328 + 0.4216X	0.85**	0.01345	0.5328	0.5328
GERMAN BROWN	Y = 0.5894 + 0.1531X	0.81**	0.03546	0.5894	0.5894
FRIESIAN	Y = 0.6103 + 0.3704X	0.94**	0.01392	0.6103	0.6103

** Significant ($P < 0.01$)

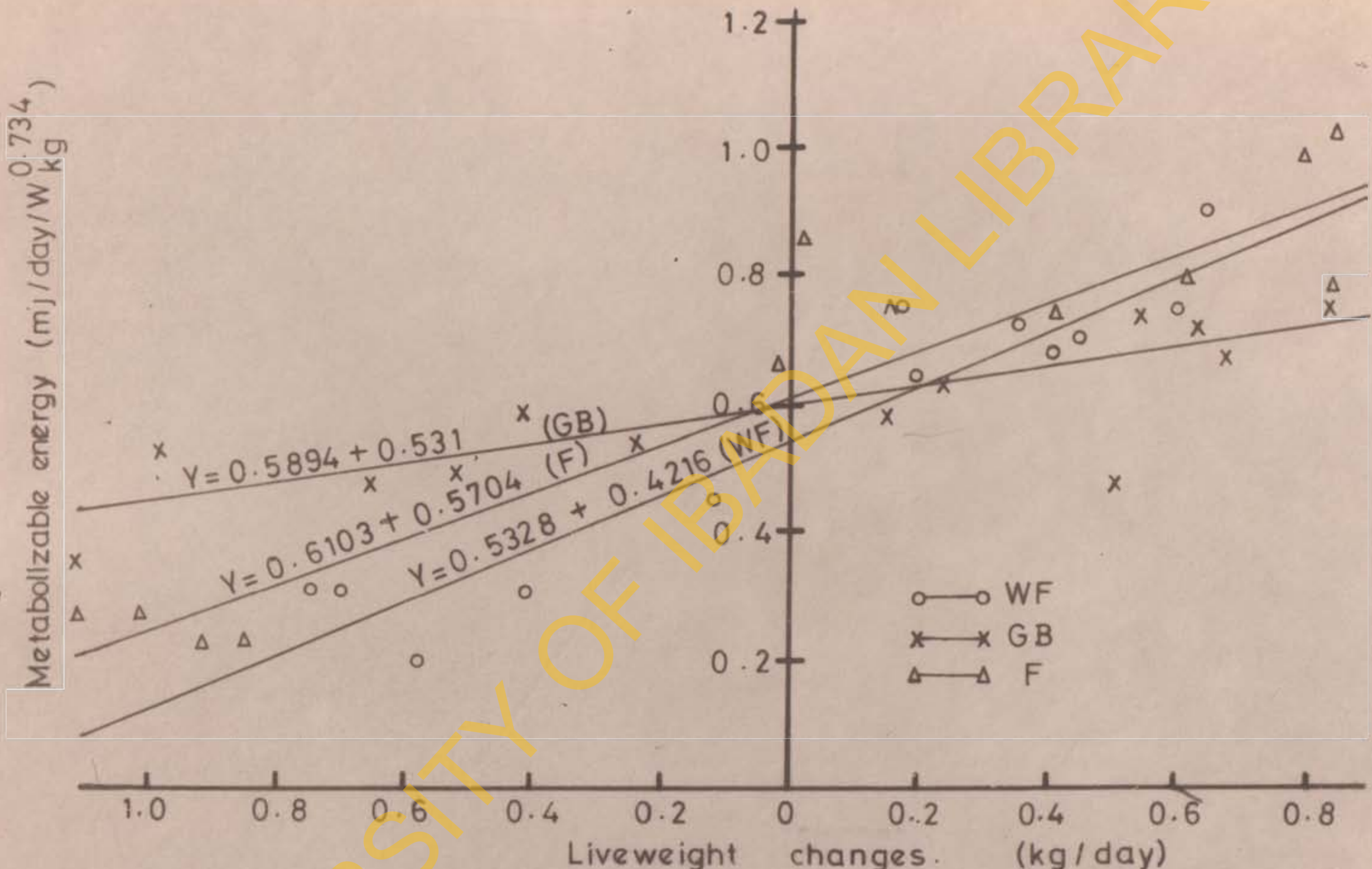

FIG. 4.6 Relationship between Metabolizable Energy (mj/day/W$_{kg}^{0.734}$) and liveweight change (kg/day) of lactating cows.

Table 4.26

**Efficiency of energy utilization for milk production

Variable description	Unit	Breeds		
		WF	GB	F
ME intake	MJ/day	43.793	52.351	54.658
ME for maintenance	"	26.196	30.971	33.777
ME available for production	"	17.597	21.380	20.881
*Energy secreted in milk	"	4.482	6.694	7.831
Gross Energetic Efficiency (a)	%	10.234	12.787	14.327
Net Energetic Efficiency (b)	%	25.470	31.310	37.503

WF = White Fulani

GB = German Brown

F = Friesian

ME = Metabolizable energy

(a) = $\frac{\text{Milk energy (MJ ME/day)}}{\text{ME Intake (MJ/day)}}$

(b) = $\frac{\text{Milk energy}}{\text{ME Intake - ME for maintenance}}$

*ME adjusted to mean milk production by multiplying by 1.102 Mcal ME/kg 4% FCM (Neville, 1974).

Fat corrected milk (FCM) was computed by using Gaine's (1928) formula

** Detailed results available in Appendix C4.5.

production ranged from 10.23% (White Fulani cows) through 12.79% (German Brown cows) to 14.33% (Friesian cows). The net efficiency for milk production, which is the energy in milk divided by the energy intake with correction for maintenance expressed on percentage basis was also estimated. Results also varied from 25.47% (White Fulani), through 31.31% (German Brown) to 37.50% (Friesian cows).

4.4.8 DPE : DE Ratio (Protein and energy interaction)

One of the difficult problems noted while defining protein requirement was to specify the energy intake. This problem arose from the observation of Black, Pearce and Tribe (1973) that nitrogen retention was always dependent on energy intake. Using Brody's (1945) method, the N- balance ($g/day/W_{kg}^{0.734}$) obtained from Table 4.19 was regressed on the contribution protein made to the digestible energy intake (DPE : DE). To obtain this, the digestible crude protein intake was multiplied by 0.0167 MJ per g DCP to obtain the digestible protein energy (Brody, 1945). The relationship is shown in Fig. 4.7.

Table 4.27 shows the regression equations. There were statistically significant correlation (r) between the N-balance ($g/day/W_{kg}^{0.734}$) and DPE : DE ratio. The correlation (r) for the Friesian (0.91) was highly significant ($P < 0.01$). The

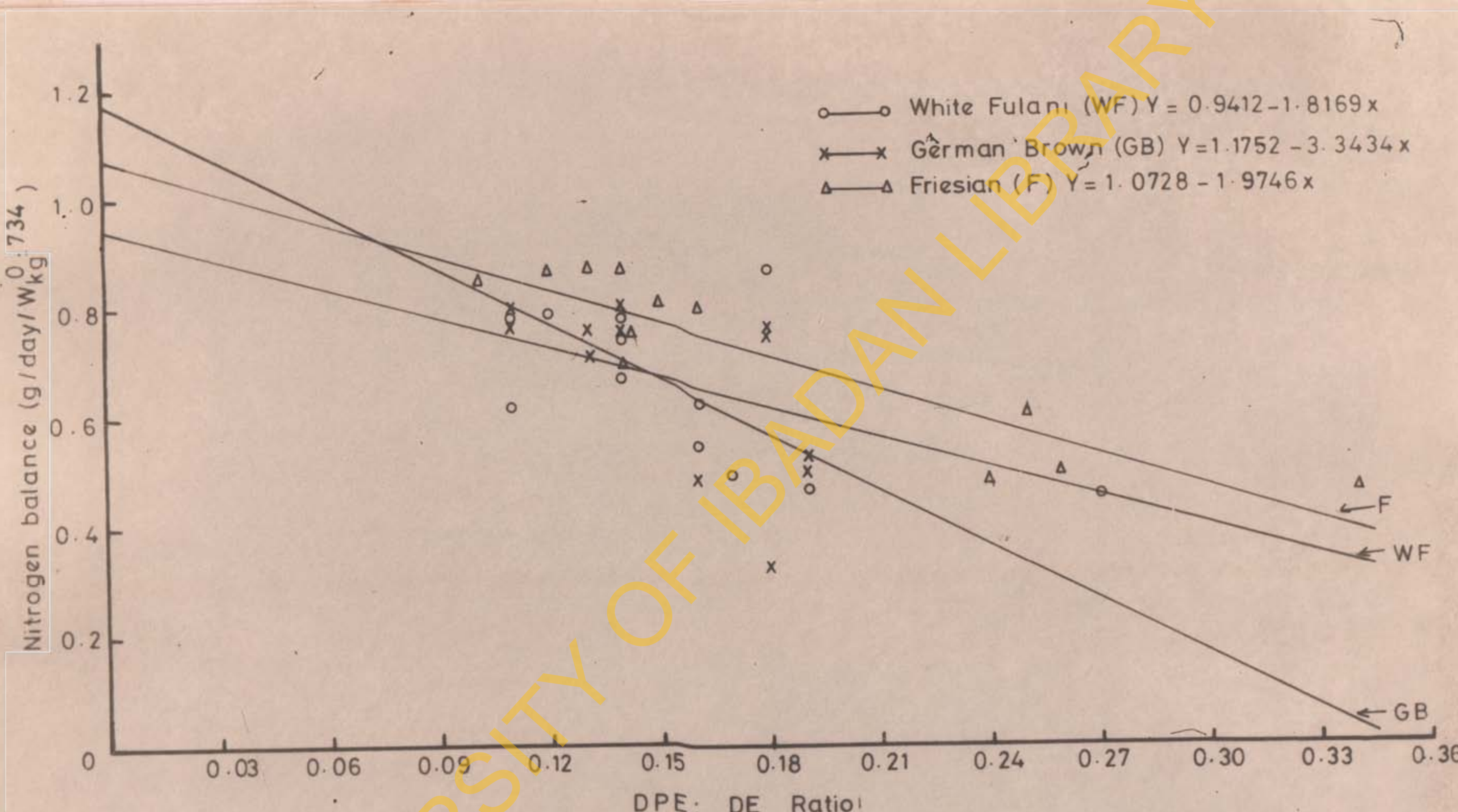

FIG. 4.7 Relationship between N-Balance and DPE to DE ratio for three breeds of cows during lactation.

Table 4.27

Regression Equations Describing the Relationship Between N- Balance ($g/day/W_{kg}^{0.734}$) Y, DPE : DE Ratio X for three Breeds of cows during Lactation

Breed	Regression Equations	Correlation Coefficient (r)	Standard Error	Maximum N-Balance	DPE : DE
White Fulani	Y = 0.9412-1.8169X	0.58*	0.014	0.79	0.083
German Brown	Y = 1.1752-3.3434X	0.64*	0.016	0.80	0.112
Friesian	Y = 1.0728-1.9746X	0.91**	0.005	0.87	0.103

*Significant difference ($P < 0.05$)

**Highly significant difference ($P < 0.01$)

DE = Digestible Energy

DPE = Digestible protein energy

White Fulani cows had a correlation of 0.58 while the German Brown cows had 0.64. Both showed statistical significance ($P < 0.05$). If the maximum N-balance was substituted for Y in the regression equations, results for DPE : DE ratio were 0.083 (White Fulani), 0.112 (German Brown) and 0.103 (Friesian). The results obtained indicate that 8.3% of the energy intake of the White Fulani, 11.2% of the German Brown and 10.3% of the Friesian cows were contributed by the protein fraction of the DM intake.

4.5 DISCUSSION

The results obtained in the present experiment (Tables 4.2 and 4.3) showed that with increase in the level of concentrate supplements in the ration, there was corresponding increase in milk yield, decrease in butterfat percentage of milk, increased percentage of milk protein, increase in the amount of total VFA's in rumen liquor, a decrease in the ratio of acetic to propionic acid, increased level of ruminal ammonia nitrogen and also a decrease in the ruminal pH values. Armstrong and Blaxter (1957) and McDonald (1968) have shown that rumen liquor obtained from ruminants fed on pasture forage was consistently higher in the proportion of acetate and lower in propionate and butyrate than in the case where animals have been fed on concentrate diets. This observation was in general agreement with the results obtained in the present study which showed that the highest percentage of acetate occurred when the animal was fed grass alone and the lowest percentage was recorded when it was fed the higher level of concentrate ration. The present study has also indicated that the highest production of VFA's was obtained when the animal was fed higher level of concentrate ration and least production when grass alone was fed. This observation would appear to be in agreement with the conclusion of Carroll and Hungate (1954) that the grain-fed animals showed the highest rate of production of volatile acids, while the hay-fed ones were intermediate and the animals fed on pasture forage showed the lowest rate of production. Results obtained from the present study have shown that there was an increase in the acetic acid proportion of the total VFA's with the corresponding increase in the butterfat content of the cows' milk and that there was also an increase in the proportion of the propionic acid in the rumen with the corresponding increase in milk protein. It has been shown by Maynard and Loosli (1969) that any ration which caused a marked lowering of the milk fat percentage would produce changes in the movements of the reticulo-rumen and in the physical and chemical composition of the digesta. In such a case they pointed out that the production of acetic acid would thus be lowered and that of propionic acid would be increased and these changes were associated with the lowering of the fat content of milk. Investigations of Armstrong and Blaxter (1957) and Blaxter (1967) have revealed that while acetic and butyric acids were lypogenic, propionic acid was glucogenic and had protein-sparing effect. This therefore explains why the cows in the present study produced the highest milk protein percentage and the lowest butterfat content while on high concentrate rations.

The pH value obtained one hour after feeding was higher than the value 2 hours after. Results also would appear to indicate that pH varied directly with the molar proportions of acetate and inversely with the proportions of the propionate. Mba and Olatunji (1971) observed that peak production of total VFA was observed one hour after feeding and the ruminal pH tended to vary directly with the molar proportions of acetic acid and also tended to be lower the higher the molar proportions of propionic and butyric acids. The results in the present study were in good agreement with this observation and that of Balch (1958) who showed that feeding high concentrate rations to ruminants resulted in a marked reduction in salivary secretion with subsequent lowering of pH in the rumen. McDonald (1952), Mba, Awoniyi and Oyenuga (1972) have demonstrated that high energy substrate favoured the lowering of ruminal pH which delayed the absorption of ammonia through the rumen wall. The ammonia eventually became available for the synthesis of microbial protein. There is abundant evidence in the literature to show that the end-products of readily available carbohydrates lower the ruminal pH (Belasco, 1954; McDonald, 1968).

When the low concentrate ration was fed, milk production in the fistulated cow was depressed and there was only a slight increase in the milk protein percentage above that obtained when grass alone was fed. There was however increased body weight both in the fistulated cow and intact ones fed the same diet, suggesting a change to a fattening metabolism with body fat synthesis increasing at the expense of milk fat synthesis. Schultz (1974) explained that when an alteration like this occurs, there is a decrease in the proportion of acetic acid and an increase in the proportion of propionic acid. This may result in the enhanced circulation of the acetate in the blood and the subsequent uptake by the mammary gland being reduced. The high propionate tends to cause small increases in blood glucose which may increase insulin secretion and stimulate body fat synthesis (Schultz, 1974).

Results in the present study have shown conclusively that the higher the energy intake, the higher the total ruminal VFA and therefore the higher the total VFA in blood plasma and urea-N in the venous blood. Explaining the reason why high energy intake was accompanied by increased milk yield, Rook and Line (1961) have demonstrated that an increase in the plane of nutrition was associated with increase in the amount of milk precausors getting into the mammary gland. Rook and Line (1961), and later on Sutton and Johnson (1969) reported significant increases in the VFA level in the arterial blood and of α-amino nitrogen in the venous blood as the dietary energy intake was increased. Mba and Olatunji (1971) have shown that rations high in crude fibre increases the acetic acid proportion of the VFA with a corresponding lowering of the molar proportion of propionic acid while the ruminal pH values were also increased. These observations were recorded in the present experiment when the animals were fed grass alone. Investigations of Elliot and Loosli (1959) have indicated that when the molar proportion of acetic acid in the rumen liquor ranges from 50-60% the efficiency of conversion of ME to milk was fairly constant at 70% but the molar proportions of acetic acid outside this range would tend to lower the efficiency. Perhaps this might explain why the fistulated cow in the present study produced more milk when it was supplemented with concentrates than when fed on the forage alone.

The milk composition of the intact cows fed the same dietary levels also followed the same pattern as the fistulated cow. The level of NH_3 - N concentration in the rumen depends on so many factors. These include the nature and level of dietary protein, availability of readily fermentable carbohydrates, the acidity of the rumen liquor, and the rate of fermentation and absorption from the rumen.

When grass was supplemented with different levels of concentrate ration in the present study, ruminal ammonia concentration increased. This is in agreement with the results of Elliot and Topps (1964) who found that ruminal NH_3-N concentration increased with increasing dietary nitrogen intake and percentage crude protein in the rations.

The increase in ruminal NH_3-N concentration recorded when grass was supplemented with concentrate ration was also observed in the case of blood urea nitrogen and this is in agreement with the results of Lewis (1957) who found that changes in ruminal ammonia concentration resulted in similar changes in the blood urea level. Increase in the concentration of blood urea was observed to increase with increasing intake of dietary protein and also percentage crude protein in ration. Preston et al (1965) suggested that blood urea-N levels could be used to assess protein utilization. From their results, they showed that blood urea-N in excess of 10mg/100ml blood plasma would indicate adequate protein intake in their ration. Results obtained from the ruminal and blood metabolites in the fistulated cow tended to indicate that adequate protein intake was made available to the intact lactating cows in their rations.

The milk yield of the intact lactating cows used for the digestibility, energy and protein utilization studies declined from the start of the experiment despite the introduction of high concentrate rations. It could be due to the fact that the experiment was started at the receding stages of lactation in which case the effect of lactation seemed to have had more overiding effects than the feed intake (Lucas, 1960). However this lowered milk yield was compensated for by the increase in liveweight. This alteration as explained inter alia in the case of the fistulated White Fulani cow could be due to the decrease in the proportion of acetic acid, increased molar proportion of propionate, giving rise to reduced acetate uptake by the mammary gland, and the consequent high propionate tending to cause increases in blood glucose which with increasing insulin secretion could stimulate body fat synthesis. This could then explain the decreasing milk yield and increasing liveweight as lactation advanced as observed in the present study. The results of the milk composition obtained in the present experiment have also shown that the higher the butterfat percentage the higher the milk energy and were in line with the conclusion of de Vleechauwer (1959) that the energy content of milk had a positive relationship with the butterfat.

Except for the crude fibre values, the digestibility coefficients of the other nutrients in the basal forage and the supplemented rations fed to the cows and steers showed no statistical differences. This would indicate that the modified cages used to separate the faeces and urine of the lactating animals were as good as those conventional ones incorporating the use of harnesses and collection bags with the steers (Oyenuga, 1961). The use of these modified cages would go a long way to facilitating balance studies of nutrients in female animals particularly the dairy cows as hitherto it has been a problem to harness female animals although such cages have successfully been used in balance studies with goats (Akinsoyinu, 1974).

Blaxter and Mitchell (1948) defined metabolic faecal nitrogen (MFN) as that portion of faecal nitrogen which is not of dietary origin but originating within the body from a variety of sources, such as epithelial cells, bacteria, mucus, residues from bile and digestive juices. The MFN values obtained in the present study 3.44 for WF, 3.82 for GB and 3.06g/kgDM consumed for F were lower than 5.5g/kgDM consumed recorded for ewes by Harris and Mitchell (1941), 4.0g/kg DM consumed for rams by Deif, El-Shazley and Abou Akkada (1968), 5.0g/kgDM consumed often quoted for ruminants by ARC (1965) and Maynard and Loosli (1969), and 4.3g/kg DM consumed for does by Akinsoyinu (1974); but these values were higher than 2.4g/kg DM consumed often quoted for lambs by Ellis, Garner, Muhrer and Pfander (1956).

Maynard and Loosli (1969) defined endogenous urinary nitrogen (EUN) as the minimum urinary excretion on a nitrogen-free energy-adequate diet. Wide variations or differences in the values obtained for EUN of ruminants have been reported in literature. For instance while in the present study values varying from 0.017 (White Fulani) through 0.033 (German Brown) to 0.042g/day/$W_{kg}^{0.734}$ (Friesian) have been obtained, Robinson and Forbes (1966) also using a regression equation obtained a negative figure of -1.81±0.50gN/day for ewes, Sotola (1930) had a figure of 0.08g/day/$W_{kg}^{0.734}$ for sheep and ARC (1965) quoted a value of 0.12g/day/$W_{kg}^{0.734}$ for cattle above 200kg liveweight. Explaining why there were wide variations in values often quoted for EUN, Packett and Groves (1965) pointed out that energy source for rumen micro-organisms stimulated ammonia uptake for microbial protein synthesis and resulted in a net transfer of endogenous urea nitrogen to the rumen. Robinson and Forbes

(1966) have also explained these large variations in the EUN values as due to urea recycling effects.

The biological values obtained in the present study ranged from 60 to 66% giving an overall mean of 63.3% for all the cows. This mean value was very much in agreement with 65% which is often quoted for ruminants (Maynard and Loosli, 1969). Digestible crude protein (DCP) intake values for maintenance ranged from 0.39 for the White Fulani breed, through 0.47 for the German Brown to 0.52g/day/$W_{kg}^{0.734}$ for the Friesian breed. When the available protein (g/day) were calculated from these figures, 91.82 (WF), 113.28 (GB) and 121.77g/day (F) were obtained. These values were slightly higher than the values recommended by ARC (1965) and those obtained by Webster and Wilson (1966).

In accordance with the customary methods of estimating protein requirements (Hegsted, 1964), the best estimate of the minimum requirement for each of a breed of the lactating cows was taken to be at the intersection of the line describing the increase in N- balance as protein intake was raised with the horizontal line representing the maximum response in N- balance. In the present study, this graph did not deviate from linearity as one would expect at about 17 to 22% crude protein ration supplement (Maynard and Loosli, 1969), that is, the graph was rectilinear. These findings were in general agreement with the observations of Hersted and Neff (1970), Velu, Baker and Scott (1971) that the line describing the increase in N-balance was essentially rectilinear when plotted against protein intake but may be curvilinear when plotted against protein concentration.

The results of the present study indicated that a value of 6.69g/day/$W_{kg}^{0.734}$ DCP was adequate for a White Fulani cow producing 3.35kg milk per day. This shows that for a White Fulani cow producing 3.35kg of milk per day containing 3.25% of protein (0.51gN), a 6.69g DCP/day/$W_{kg}^{0.73}$ is adequate. ARC (1965) using factorial method recommended 272.14g/day available protein (AP) for a cow producing this amount of milk with 3.7% butterfat, 3.35% protein (0.53gN). The present study has shown that protein available for maintenance and production for the White Fulani cow was 304.80g/day. In the case of the German Brown cows 353.93g AP/day was found to be adequate while producing an average of 6.17kg/day milk containing 3.03% protein (0.47gN). The recommended ARC (1965) available protein adequate for a cow producing this amount of milk with 3.35% protein is 337.29g/day. The Friesian cows had an average of 359.20gAP/day while producing 7.08kg/day milk with 3.10% protein (0.49gN). The ARC (1965) recommendation is 387.04gAP/day. Except for the Friesian

Table 4.29

Efficiency found in experiments with milking cows

Authors	Breed	Gross Energetic Efficiency %	Net Energetic Efficiency %	Net Protein Efficiency %
1. Brody (1945)	Jersey	14.4	60.00	-
2. Coppock *et al* (1964)	Holstein	-	65.00[a]	-
3. Hashizume *et al* (1965)	Holstein	28.3[b]	83.3	55.0[c]
4. Jumah *et al* (1965)	Holstein	40.6	60.2	66.4
5. Olaloku(1972)	White Fulani(d)	12.04	20.31[e]	19.86
6. Hohenboken *et al* (1972)	Hereford	13.00		
7. Ogunsiji (1974)	White Fulani	10.69	22.30[e]	20.25
8. Neville Jr. (1974)	Hereford	15.30[f]	33.60	-
Present study (f)	White Fulani	10.23	25.47	27.95
	German Brown	12.79	31.31	48.43
	Friesian	14.33	37.50	53.73

(a) = Assuming maintenance requirement of 0.548 MJ ME/$W_{kg}^{0.734}$

(b) = Two types of rations used

(c) = Ratio of the protein secreted in milk to the digestible protein intake

(d) = Cows supplemented and non-supplemented at pasture

(e) = Maintenance requirements based on ARC (1965) standard

(f) = Maintenance requirements calculated using regression analyses with zero order correlation coefficient

\- = Not determined.

breed with a fairly low available protein when compared with the ARC (1965), adequate protein intake was made available to the lactating cows in the present study as shown from the above results and conclusions from the fistulated White Fulani lactating cow.

The net efficiency of protein utilization for the cows ranged from 27.95% for the White Fulani breed through 43.43% for the German Brown to 53.73% for the Friesian cows. The efficiency with which the indigenous White Fulani cows in the present study utilized feed protein for milk production was lower than the values reported for the high producing temperate breeds (German Brown and Friesian) of dairy cattle (Table 4.29). However, the net efficiency obtained for the White Fulani breed in this investigation was much higher than 19.86% obtained by Olaloku (1972) and 20.25% by Ogunsiji (1974). Reasons for the differences may be due to the composition and amount of feed intake and the techniques of collecting the faecal DM in the different investigations. The net efficiency of protein utilization obtained for the exotic cows were within the range obtained by other workers. For instance, Hashizume et al (1965) working with Holstein cows had a value of 55% and Jumah, Poulton and Apgar (1965) had a value of 66.4% for the Friesian cows.

The relationship between metabolizable energy (ME) intake and liveweight change for the lactating cows was obtained in the present study. When the cows were neither gaining nor loosing weight, the White Fulani cows required 532.80KJ/day/$W_{kg}^{0.734}$ when a diet with a concentration of 8702.72KJ/kg DM (2.08Mcal/kg) was being fed. ARC (1965) and MAFF (1975) recommend 640.87KJ/day/$W_{kg}^{0.734}$ and 737.00KJ/day/$W_{kg}^{0.734}$ respectively, when an animal is on similar intake and production. This simply indicates that in a tropical environment when a White Fulani cow should maintain its body temperature by dissipating energy and not using some of its energy to produce heat, it would require 83.14% and 72.29% of the ARC (1965) and MAFF (1975) recommendation respectively. The present investigation has revealed that the German Brown cows required 589.40KJ/day/$W_{kg}^{0.734}$ while ARC (1965) and MAFF (1975) recommend 704.50 and 810.18KJ/day/$W_{kg}^{0.734}$ respectively indicating that 83.66% (ARC, 1965) or 72.75% (MAFF, 1975) of the recommendations was needed by the German Brown cows. The Friesian cows required 610.30 KJ/day/$W_{kg}^{0.734}$ which is 84.45% of the 722.68KJ/day/$W_{kg}^{0.734}$ recommended by ARC (1965) or 73.43% of the 831.08KJ/day/$W_{kg}^{0.734}$ recommended by MAFF (1975). The values also obtained in the present study are lower than 920KJ/day/$W_{kg}^{0.734}$ obtained by NRC (1968), 746.43KJ/day/$W_{kg}^{0.734}$ by Neville and McCullough (1969) and 728.00KJ/day/$W_{kg}^{0.734}$ by Neville Jr. (1974). Apart from the environmental climate which has a pronounced effect on energy requirement, Neville and McCullough (1969) have also observed that actual energy requirements for maintenance and production were individualistic and subject to changes from time to time and place to place within cows.

The gross energetic efficiency of milk production of 10.23% calculated for the White Fulani cows (Table 4.29) compared well with 10.69% obtained by Ogunsiji (1974) but lower than 12.04% obtained by Olaloku (1972) for the same breed of cattle. The low percentage of gross energetic efficiency of milk production obtained for the exotic breeds in the present investigation were comparable to the values of 14.4% obtained by Brody (1945) with Jersey cows; 13.00% by Hohenboken, Hauser, Chapman and Cundiff (1972) with Hereford cows and 15.30% by Nevill Jr. (1974) also with Hereford cows. The net energetic efficiency for milk production obtained in the present study varied from 25.47% (WF), through 31.31% (GB) to 37.50% (F). The 25.47% obtained for the WF cows were higher but compared favourably with 20.31% obtained by Olaloku (1972) and 22.30% by Ogunsiji (1974). The values also obtained for the exotic breeds compared well with the 33.60% recorded by Neville Jr. (1974). Hooven, Miller and Plowman (1968) found that variations in feed efficiency depended more on milk yield than on feed consumed.

Requirements of digestible protein energy to digestible energy (DPE : DE) ratio estimated from the regression equation by plotting N-balance (g/day/$W_{kg}^{0.734}$) against DPE : DE ratio were 0.083 (WF), 0.112 (GB) and 0.103 (F). This indicates that 8.3% of the energy intake of the White Fulani cows, 11.2% of the German Brown and 10.3% of the Friesian cows were contributed by the protein fraction of the DM intake. The values obtained in the present study (with an overall mean value of 9.9% for all breeds) were slightly higher than 7.19% obtained for cows by Hegsted (1964) but much lower than 25% obtained by Akinsoyinu (1974) for goats. The variations in the results obtained in literature could be due to the observation of Hegsted (1964) that values often reported depended very much on a combined estimate of the needs of the tissues which varied from one animal to the other and the capacity of the diets to provide these needs.

In summary, the results obtained in these trials seemed to indicate that:

(1) With increase in the level of concentrate supplements in the ration, there was corresponding increase in milk yield, decrease in butterfat content of milk, increased percentage of milk protein, increase in the amount of total VFA's in the rumen liquor, a decrease in the ratio of acetic to propionic acid, increased level of ruminal NH_3-N and also a decrease in the ruminal pH values.

(2) The metabolic cages modified for use of the lactating cows without harnesses and collection bags are adequate for nitrogen and energy balance studies.

(3) The digestible crude protein (DCP) requirement values for maintenance ranged from 0.39 for the White Fulani through 0.47 for the German Brown to 0.52g/day/$W_{kg}^{0.734}$ for the Friesian breed.

(4) The digestible crude protein (DCP) requirement for milk production ranged from 6.69g/day/$W_{kg}^{0.734}$ for a White Fulani cow producing 3.35kg milk/day (3.25% protein) through 6.34g/day/$W_{kg}^{0.734}$ for a German Brown cow producing 6.17kg milk/day (3.03% protein) to 6.54g/day/$W_{kg}^{0.734}$ for a Friesian cow producing 7.08kg milk/day (3.10% protein).

(5) Metabolizable Energy (ME) requirement for maintenance ranged from 532.80 for the White Fulani breed through 589.40 for the German Brown breed to 610.30KJ/day/$W_{kg}^{0.734}$ for the Friesian breed.

(6) 8.3% of the energy intake of the White Fulani, 11.2% of the German Brown and 10.3% of the Friesian cows were contributed by the protein fraction of the DM intake.

GENERAL SUMMARY OF CONCLUSIONS

Investigations were carried out (a) to study suitable system of management for the newly imported exotic dairy cows (German Brown (GB) and Friesian (F)). (b) to estimate dry matter (DM) intake, liveweight changes, milk yield and composition of indigenous (White Fulani (WF)) and exotic lactating cows as affected by seasons and stages of lactation, and (c) to determine nutrient digestibilities, protein and energy utilization by the three breeds of cows as well as liveweight changes, milk yield and composition as affected by the rumen and blood metabolites particularly of the fistulated White Fulani cow.

The results indicated that grazed exotic cows consumed more DM and produced more milk than the stall-fed ones. The milk composition of the grazed cows including the butterfat, ash, solids-not-fat were higher, and protein lower, than those of the stall-fed ones ($P < 0.05$). Grazing cows gained weight while stall-fed ones lost weight. The water intake, body temperature and respiratory rate of the grazed cows were higher than the stall-fed ones.

The mean roughage DM intakes of the cows, when placed on a 28-week lactation study 5 days after parturition were 4.49 ± 0.16, 5.59 ± 0.16 and 5.92 ± 0.21kg/day for the WF, GB and F cows respectively. Peak milk production was attained between the 5th and 9th week of lactation and declined gradually thereafter for those first placed on high energy level and abruptly for the ones first placed on low energy level. Milk yield of the exotic cows were significantly higher than the indigenous ones ($P < 0.01$) although the latter produced milk of higher quality than the former. Though DM intake was higher during the dry season than the wet, yet milk yield was higher during the latter period than the former.

All cows lost weight immediately after calving until about the 8th to the 10th week of lactation and recovered gradually thereafter.

The trials on energy and protein utilization indicated that with increase in the level of concentrate supplements in the ration, there was corresponding increase in milk yield, decrease in butterfat content of milk, increased percentage of milk protein, increase in the amount of total VFA's in the rumen liquor, a decrease in the ratio of acetic to propionic acid, increased level of ruminal NH_3-N and a decrease in the ruminal pH values and increased blood urea-N. The digestible crude protein (DCP) requirement values for maintenance ranged from 0.39 for WF, through 0.47 for GR to 0.52g/day/$W_{kg}^{0.734}$ for the F breed. The DCP requirements for milk production ranged from 6.69g/day/$W_{kg}^{0.734}$ for a WF cow producing 3.35kg milk/day (3.25% protein) through 6.54g/day/$W_{kg}^{0.734}$ for a GB cow producing 6.17kg milk/day (3.03% protein) to 6.54g/day/$W_{kg}^{0.734}$ for a F cow producing 7.08kg milk/day (3.10% protein). The metabolizable energy (ME) requirements for maintenance ranged from 532.80 for the WF breed through 589.40 for the GB to 610.30KJ/day/$W_{kg}^{0.734}$ for the Friesian breed.

Finally, the trials also indicated that the protein fraction of the DM intake contributed 8.3% (WF), 11.2% (GB) and 10.3% (F) to the energy intake at the optimal level for production.

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APPENDIX

A2.1 Milk fat determination by Garber method.

A number of butyrometer tubes were placed in the stand, open end upwards, 10mls of the sulphuric acid (for milk analysis) were run into each, care being taken not to wet the inside of the next neck of the tube. 11mls of the mixed milk sample were allowed to run from the pipette down the sides of the butyrometer tubes and to float on the surface of the acid. The pipette was inserted in such a way that the milk did not wet the inside of the neck. One ml of amyl alcohol was then added. The stoppers were then firmly inserted and the butyrometers were shaken until the curb dissolved. The tubes werethen placed in the water bath at 65^{o}C for 5 minutes and the fat columns adjusted by means of the stoppers to coincide with the scale. The tubes were then rapidly transferred to the centrifuge where they were whirled at 1,100 r.p.m. for 4 minutes and then replaced in the water-bath at 65^{o}C for 5 minutes. The percentages of fat were quickly read off by holding the butyrometers up the light at eye-level where the fat coincide with one of the larger graduations of the scale; the reading was then taken from this point to the bottom of the upper meniscus of the fat column.

A2.2 Determination of lactose (Marier and Boulet)

1g of cow's milk was made up to 1 litre 10mls of this solution was pipetted into a 50ml size volumetric flask followed by 0.5ml of 80% w/v phenol reagent (20ml water + 80g phenol; the reagent is stable for at least 3 months at room temperature). 60mls of conc. H_2SO_4 were added slowly letting the acid run down the side of the tube. Then it was swirled to obtain good mixing, and let stand for 10 minutes at room temperature, it was cooled and made up to the mark with distilled water and read at 490mm. A blank determination was run. It contained the same quantity of reagent except milk and was made up to the mark with distilled water in a 50ml size volumetric flask.

Standard solution (0.1g lactose in 2 litres of water) was prepared. 2,4,6,8,10mls of this solution were pipetted separately into individual 50ml volumetric flask and reagents added as for the flask containing the sample; made up to the mark and read at 490mm. A graph of the optical density was plotted against the lactose concentration (mg). Sample concentrations were estimated by means of this standard curve.

APPENDIX B2.1

STATISTICAL ANALYSIS OF THE DATA OBTAINED ON THE GRAZED AND STALL-FED LACTATING COWS

(a) Milk yield (kg/week)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Diet	1	45.08	45.08	1.56	3.92	6.85	NS
Breed	1	44.70	44.70	1.55	3.92	6.85	NS
*Management (Man.)	1	1015.09	1015.09	35.19	3.92	6.85	**
Diet/Breed	1	2.85	2.85	0.10	3.92	6.85	NS
Diet/Man.	1	81.47	81.47	2.82	3.92	6.85	NS
Breed/Man.	1	52.33	52.33	1.81	3.92	6.85	NS
3-Way Interaction	1	16.00	16.00	0.55	3.92	6.85	NS
Between Blocks	15	891.94	59.46	2.06	1.61	1.79	**
Residual	105	3028.71	28.84				
Total	127	5178.16					

* Management: Systems of feeding (Grazing and Stall-feeding).
NS = Not Significant
** = Significant at 1% level ($P < 0.01$)

(b) Ash (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Diet	1	0.00011	0.00011	0.13	3.92	6.85	NS
Breed	1	0.01481	0.01481	17.79	3.92	6.85	**
Management	1	0.01199	0.01199	14.41	3.92	6.85	**
Diet/Breed	1	0.00675	0.00675	8.11	3.92	6.85	**
Diet/Man.	1	0.00123	0.00123	1.48	3.92	6.85	NS
Breed/Man.	1	0.04137	0.04137	49.70	3.92	6.85	**
3-Way Interaction	1	0.00176	0.00176	2.11	3.92	6.85	NS
Between Blocks	15	0.01215	0.00081	0.97	1.61	1.79	NS
Residual	105	0.08740	0.00083				
Total	127	0.17756					

NS = Not Significant
** = Significant at 1% level ($P < 0.01$)

(c) Protein (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Diet	1	0.33	0.33	3.33	3.92	6.85	NS
Breed	1	0.38	0.38	3.84	3.92	6.85	NS
Management	1	0.77	0.77	7.76	3.92	6.85	**
Diet/Breed	1	0.08	0.08	0.78	3.92	6.85	NS
Diet/Man.	1	0.89	0.89	9.03	3.92	6.85	**
Breed/Man.	1	1.33	1.33	13.50	3.92	6.85	**
3-Way Interaction	1	0.15	0.15	1.50	3.92	6.85	NS
Between Blocks	15	1.10	0.07	0.74	1.61	1.79	NS
Residual	105	10.38	0.10				
Total	127	15.41					

NS = Not Significant
** = Significant at 1% level ($P < 0.01$)

(d) Solids-not-fat (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Diet	1	0.00006	0.00006	0.00	3.92	6.85	NS
Breed	1	2.28178	2.28178	6.79	3.79	6.85	*
Management	1	1.91346	1.91346	5.69	3.92	6.85	*
Diet/Breed	1	0.13585	0.13585	0.40	3.92	6.85	NS
Diet/Man.	1	0.32906	0.32906	0.98	3.92	6.85	NS
Breed/Man.	1	1.65393	1.65393	4.92	3.92	6.85	*
3-Way Interaction	1	0.01926	0.01926	0.06	3.92	6.85	NS
Between Blocks	15	7.72958	0.51531	1.53	1.61	1.79	NS
Residual	105	35.28819	0.33608				
Total	127	49.35117					

NS = Not Significant
* = Significant at 5% level ($P < 0.05$)

(e) Total Solids (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Diet	1	1.39	1.39	7.99	3.92	6.85	**
Breed	1	4.87	4.87	28.05	3.92	6.85	**
Management	1	5.43	5.43	31.29	3.92	6.85	**
Diet/Breed	1	0.02	0.02	0.09	3.92	6.85	NS
Diet/Man.	1	0.17	0.17	0.99	3.92	6.85	NS
Breed/Man.	1	1.59	1.59	9.16	3.92	6.85	**
3-Way Interaction	1	0.09	0.09	0.51	3.92	6.85	NS
Between Blocks	15	4.76	0.32	1.83	1.61	1.79	**
Residual	105	18.23	0.17				
Total	127	36.55					

NS = Not Significant
** = Significant at 1% level ($P<0.01$)

(f) Fat (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Diet	1	1.52	1.52	6.10	3.92	6.85	*
Breed	1	0.69	0.69	2.76	3.92	6.85	NS
Management	1	1.69	1.69	6.80	3.92	6.85	*
Diet/Breed	1	0.18	0.18	0.74	3.92	6.85	NS
Diet/Man.	1	0.20	0.20	0.79	3.92	6.85	NS
Breed/Man.	1	0.15	0.15	0.61	3.92	6.85	NS
3-Way Interaction	1	0.0002	0.0002	0.00	3.92	6.85	NS
Between Blocks	15	11.80	0.79	3.16	1.61	1.79	**
Residual	105	26.14	0.25				
Total	127	42.37					

NS = Not Significant
** = Significant at 1% level ($P < 0.01$)
* = Significant at 5% level ($P < 0.05$)

(g) Dry Matter (DM) Intake (kg/day)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Diet	1	22.31	22.31	83.80	3.92	6.85	**
Breed	1	1.06	1.06	3.93	3.92	6.85	*
Management	1	1.75	1.75	6.58	3.92	6.85	*
Diet/Breed	1	0.03	0.03	0.11	3.92	6.85	NS
Diet/Man.	1	3.84	3.84	14.41	3.92	6.85	**
Breed/Man.	1	4.17	4.17	15.66	3.92	6.85	**
3-Way Interaction	1	0.89	0.89	3.35	3.92	6.85	NS
Between Blocks	15	1.49	0.10	0.37	1.61	1.79	NS
Residual	105	27.96	0.27				
Total	127	63.50					

NS = Not Significant
** = Significant at 1% level ($P < 0.01$)
* = Significant at 5% level ($P < 0.05$)

APPENDIX B3.1

Statistical analysis of the data obtained on the lactation studies with three breeds of cows fed on grass and low or high concentrate

(a) Milk yield (kg/week)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Breed	2	13025.28	6512.64	91.47	3.00	4.61	**
Lactation (Lact.)	2	37321.48	18660.74	262.10	3.00	4.61	**
Diet	1	86.27	86.27	1.21	3.84	6.63	NS
Breed/Lact.	4	2020.04	505.01	7.09	2.37	3.32	**
Breed/Diet	2	456.09	228.05	3.20	3.00	4.61	*
Lact./Diet	2	441.38	220.69	3.10	3.00	4.61	*
3-Way Interaction	4	2162.81	540.70	7.59	2.37	3.32	**
Between Blocks	17	1150.22	67.66	0.95	1.52	1.79	NS
Residual	289	20576.22	71.20				
Total	323	77239.79					

Seasons (wet and dry) effect on milk yield

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Groups	1	1095.80	1095.80	4.63	3.84	6.63	*
Error	322	76144.20	236.47				
Total	323	77240.00					

NS = Not Significant (P > 0.05)
** = Highly Significant (P < 0.01)
* = Significant (P < 0.05)

(b) Solids-corrected-Milk (kg/week)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	6246.36	3123.18	47.35	3.00	4.61	**
Lactation (Lact.)	2	33125.46	16562.73	251.10	3.00	4.61	**
Diet	1	70.20	70.20	1.06	3.84	6.63	NS
Breed/Lact.	4	1107.89	276.97	4.20	2.37	3.32	**
Breed/Diet	2	320.23	160.11	2.43	3.00	4.61	NS
Lact./Diet	2	397.08	198.54	3.01	3.00	4.61	*
3-Way Interaction	4	2345.76	586.44	8.89	2.37	3.32	**
Between Blocks	17	1170.14	68.83	1.04	1.52	1.79	NS
Residual	289	19062.63	65.96				
Total	323	63845.75					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	734.94	734.94	3.77	3.84	6.63	NS
Error	322	62758.96	194.90				
Total	323	63493.90					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(c) Fat (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	184.36	92.18	1418.40	3.00	4.61	**
Lactation (Lact.)	2	15.49	7.74	119.14	3.00	4.61	**
Diet	1	0.38	5.97	5.97	3.84	6.63	*
Breed/Lact.	4	2.08	0.52	7.99	2.37	3.32	**
Breed/Diet	2	0.51	0.25	3.90	3.00	4.61	*
Lact./Diet	2	0.13	0.07	1.02	3.00	4.61	NS
3-Way Interaction	4	0.13	0.03	0.51	2.37	3.32	NS
Between Blocks	17	2.61	0.15	2.36	1.52	1.79	**
Residual	189	18.78	0.65				
Total	323	224.48					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	3.18	3.18	4.63	3.84	6.63	*
Error	322	221.47	0.69				
Total	323	224.65					

NS = Not Significant (P>0.05)
** = Highly Significant (P<0.01)
* = Significant (P<0.05)

(d) Protein (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	4.26	2.13	65.37	3.00	4.61	**
Lactation (Lact.)	2	0.83	0.42	12.74	3.00	4.61	**
Diet	1	0.40	0.40	12.40	3.84	6.63	**
Breed/Lact.	4	0.32	0.08	2.48	2.37	3.32	*
Breed/Diet	2	0.64	0.32	9.77	3.00	4.61	**
Lact./Diet	2	0.19	0.09	2.88	3.00	4.61	NS
3-Way Interaction	4	0.38	0.10	2.93	2.37	3.32	*
Between Blocks	17	2.15	0.13	3.87	1.52	1.79	**
Residual	289	9.42	0.03				
Total	323	18.58					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	0.79	0.79	14.31	3.84	6.63	**
Error	322	17.88	0.06				
Total	323	18.67					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(e) **Lactose (g/100g milk)**

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Breed	2	2.80	1.40	26.16	3.00	4.61	**
Lactation (Lact.)	2	0.08	0.04	0.80	3.00	4.61	NS
Diet	1	0.08	0.08	1.51	3.84	6.63	NS
Breed/Lact.	4	0.39	0.10	1.80	2.37	3.32	NS
Breed/Diet	2	0.09	0.05	0.82	3.00	4.61	NS
Lact./Diet	2	0.68	0.34	6.36	3.00	4.61	**
3-Way Interaction	4	1.65	0.41	7.69	2.37	3.32	**
Between Blocks	17	1.66	0.10	1.83	1.52	1.79	**
Residual	289	15.48	0.05				
Total	323	22.91					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Groups	1	0.00	0.00	0.00	3.84	6.63	NS
Error	322	23.11	0.07				
Total	323	23.11					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(f) Total Solids (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Breed	2	48.26	24.13	143.27	3.00	4.61	**
Lactation (Lact.)	2	0.27	0.13	0.80	3.00	4.61	NS
Diet	1	2.30	2.30	13.68	3.84	6.63	**
Breed/Lact.	4	0.31	0.08	0.47	2.37	3.32	NS
Breed/Diet	2	1.50	0.75	4.45	3.00	4.61	*
Lact./Diet	2	2.76	1.38	8.19	3.00	4.61	**
3-Way Interaction	4	0.98	0.25	1.45	2.37	3.32	NS
Between Blocks	17	12.90	0.76	4.51	1.52	1.79	**
Residual	289	48.68	0.17				
Total	323	117.97					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Groups	1	5.77	5.77	16.50	3.84	6.63	**
Error	322	112.50	0.35				
Total	323	118.27					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(g) Solids-not-fat (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	62.85	31.42	96.50	3.00	4.61	**
Lactation (Lact.)	2	19.66	9.83	30.18	3.00	4.61	**
Diet	1	4.43	4.43	13.61	3.84	6.63	**
Breed/Lact.	4	3.55	0.89	2.72	2.37	3.32	*
Breed/Diet	2	1.72	0.86	2.64	3.00	4.61	NS
Lact./Diet	2	1.81	0.91	2.78	3.00	4.61	NS
3-Way Interaction	4	0.52	0.13	0.40	2.37	3.32	NS
Between Blocks	17	7.22	0.42	1.30	1.52	1.79	NS
Residual	289	94.11	0.33				
Total	323	195.87					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	0.43	0.43	0.71	3.84	6.63	NS
Error	322	195.56	0.61				
Total	323	195.99					

NS = Not Significant (P >0.05)
** = Highly Significant (P<0.01)
* = Significant (P< 0.05)

(h) Ash (g/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	0.0118	0.00592	43.54	3.00	4.61	**
Lactation (Lact.)	2	0.0039	0.00195	14.36	3.00	4.61	**
Diet	1	0.0011	0.00107	7.90	3.84	6.63	**
Breed/Lact.	4	0.0008	0.00019	1.43	2.37	3.32	NS
Breed/Diet	2	0.0006	0.00029	2.10	3.00	4.61	NS
Lact./Diet	2	0.0020	0.00098	7.22	3.00	4.61	**
3-Way Interaction	4	0.0087	0.00217	15.99	2.37	3.32	**
Between Blocks	17	0.0025	0.00015	1.09	1.52	1.79	NS
Residual	289	0.0393	0.00014				
Total	323	0.0706					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	0.00056	0.00056	2.56	3.84	6.63	NS
Error	322	0.07103	0.00022				
Total	323	0.07159					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(i) Energy (KJ/g freeze-dried milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	1.56	0.78	0.45	3.00	4.61	NS
Lactation (Lact.)	2	7.08	3.54	2.03	3.00	4.61	NS
Diet	1	49.40	49.40	28.37	3.84	6.63	**
Breed/Lact.	4	5.91	1.48	0.85	2.37	3.32	NS
Breed/Diet	2	1.19	0.60	0.34	3.00	4.61	NS
Lact./Diet	2	134.86	67.43	38.72	3.00	4.61	**
3-Way Interaction	4	284.79	71.20	40.88	2.37	3.32	**
Between Blocks	17	43.62	2.57	1.47	1.52	1.79	NS
Residual	289	503.27	1.74				
Total	323	1031.67					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	0.125	0.125	0.04	3.84	6.63	NS
Error	322	1031.80	3.204				
Total	323	1031.205					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(j) Calcium (mg/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	15020.64	7510.32	145.30	3.00	4.61	**
Lactation (Lact.)	2	1618.02	809.02	15.65	3.00	4.61	**
Diet	1	12.13	12.13	0.23	3.84	6.63	NS
Breed/Lact.	4	1009.93	252.48	4.88	2.37	3.32	**
Breed/Diet	2	340.39	170.19	3.29	3.00	4.61	*
Lact./Diet	2	2912.19	1456.10	28.17	3.00	4.61	**
3-Way Interaction	4	1455.13	363.78	7.04	2.37	3.32	**
Between Blocks	17	5197.06	305.71	5.91	1.52	1.79	**
Residual	289	14938.22	51.69				
Total	323	42503.75					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	35.00	35.00	0.27	3.84	6.63	NS
Error	322	42477.00	131.92				
Total	323	42512.00					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(k) Phosphorus (mg/100g milk)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Breed	2	25394.86	12697.43	99.09	3.00	4.61	**
Lactation (Lact.)	2	377.08	188.54	1.47	3.00	4.61	NS
Diet	1	7.02	7.02	0.05	3.84	6.63	NS
Breed/Lact.	4	179.01	44.75	0.35	2.37	3.32	NS
Breed/Diet	2	78.43	39.22	0.31	3.00	4.61	NS
Lact./Diet	2	343.02	171.51	1.34	3.00	4.61	NS
3-Way Interaction	4	383.34	95.83	0.75	2.37	3.32	NS
Between Blocks	17	932.73	54.87	0.43	1.52	1.79	NS
Residual	289	37033.65	128.14				
Total	323	64729.15					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Groups	1	332.00	332.00	1.66	3.84	6.63	NS
Error	322	64423.00	200.07				
Total	323	64755.00					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

(1) Forage Dry Matter Intake (kg/day)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Breed	2	127.82	63.91	85.08	3.00	4.61	**
Lactation (Lact.)	2	34.49	17.25	22.96	3.00	4.61	**
Diet	1	9.51	9.51	12.66	3.84	6.63	**
Breed/Lact.	4	15.88	3.97	5.29	2.37	3.32	**
Breed/Diet	2	11.50	5.75	7.65	3.00	4.61	**
Lact./Diet	2	15.44	7.72	10.27	3.00	4.61	**
3-Way Interaction	4	2.76	0.69	0.92	2.37	3.32	NS
Between Blocks	17	13.19	0.78	1.03	1.52	1.79	NS
Residual	289	217.08	0.75				
Total	323	447.68					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	F tabulated 0.01	
Groups	1	5.98	5.98	4.36	3.84	6.63	*
Error	322	441.84	1.37				
Total	323	447.82					

NS = Not Significant (P > 0.05)
** = Highly Significant (P < 0.01)
* = Significant (P < 0.05)

(m) Body weight changes (kg)

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Breed	2	23.56	11.78	7.01	3.00	4.61	**
Lactation (Lact.)	2	15.65	7.82	4.66	3.00	4.61	**
Diet	1	8.26	8.26	4.91	3.84	6.63	*
Breed/Lact.	4	43.59	10.90	6.49	2.37	3.32	**
Breed/Diet	2	26.44	13.22	7.87	3.00	4.61	**
Lact./Diet	2	9.52	4.76	2.83	3.00	4.61	NS
3-Way Interaction	4	45.84	11.46	6.82	2.37	3.32	**
Between Blocks	17	40.62	2.38	1.41	1.52	1.79	NS
Residual	289	485.65	1.68				
Total	323	699.13					

Effect of Seasons

Source of Variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Groups	1	8.55	8.55	3.98	3.84	6.63	*
Error	322	690.73	2.15				
Total	323	699.28					

NS = Not Significant ($P > 0.05$)
** = Highly Significant ($P < 0.01$)
* = Significant ($P < 0.05$)

APPENDIX B4.1

ANOVA: Comparison of the data of coefficients of apparent digestibilities between steers and lactating cows

DM : HC (WF)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	42.15					
Between means	1	4.53	4.53	0.48	7.71	21.2	NS
Within samples	4	37.62	9.41				

DM : LC (WF)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	34.35					
Between means	1	2.40	2.40	0.30	7.71	21.2	NS
Within samples	4	31.95	7.99				

DM : HC (GB)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	12.93					
Between means	1	2.88	2.88	1.15	7.71	21.2	NS
Within samples	4	10.05	2.51				

DM = Dry Matter
HC = High Concentrate
F = Friesian
WF = White Fulani
LC = Low Concentrate
NS = Not Significant
GB = German Brown

DM : LC (GB)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	9.59					
Between means	1	2.80	2.80	1.65	7.71	21.2	NS
Within samples	4	6.79	1.70				

DM : HC (F)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	2.13					
Between means	1	0.01	0.01	0.02	7.71	21.2	NS
Within samples	4	2.12	0.53				

DM : LC (F)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	8.39					
Between means	1	0.04	0.04	0.02	7.71	21.2	NS
Within samples	4	8.35	2.09				

DM = Dry Matter   WF = White Fulani   NS = Not Significant
HC = High Concentrate   LC = Low Concentrate   GB = German Brown
F = Friesian

CP : HC)WF)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05 0.01	
Total	5	23.29				
Between means	1	9.38	9.38	2.70	7.71 21.2	NS
Within samples	4	13.91	3.48			

CP : LC (WF)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05 0.01	
Total	5	23.68				
Between means	1	6.99	6.99	1.68	7.71 21.2	NS
Within samples	4	16.69	4.17			

CP : HC (GB)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05 0.01	
Total	5	10.86				
Between means	1	2.38	2.38	1.12	7.71 21.2	NS
Within samples	4	8.48	2.12			

DM = Dry Matter
HC = High Concentrate
F = Friesian
WF = White Fulani
LC = Low Concentrate
CP = Crude protein
NS = Not Significant
GB = German Brown

CP : LC (GB)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	11.92					
Between means	1	1.17	1.17	0.43	7.71	21.2	NS
Within samples	4	10.75	2.69				

EE : HC (F)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	75.81					
Between means	1	10.41	10.41	0.64	7.71	21.2	NS
Within samples	4	65.40	16.35				

EE : LC (F)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	26.73					
Between means	1	0.99	0.99	0.15	7.71	21.2	NS
Within samples	4	25.74	6.44				

DM = Dry Matter
HC = High Concentrate
F = Friesian
WF = White Fulani
LC = Low Concentrate
EE = Ether Extract
NS = Not Significant
GB = German Brown
CP = Crude Protein

CF : Forage (WF)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	23.37					
Between means	1	5.01	5.01	1.09	7.71	21.2	NS
Within samples	4	18.36	4.59				

Energy : Forage (GB)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	51.58					
Between means	1	0.08	0.08	0.006	7.71	21.2	NS
Within samples	4	51.50	12.87				

Energy : HC (WF)

Source of variation	d.f.	S.S.	M.S.	F calculated	F tabulated 0.05	0.01	
Total	5	6.25					
Between means	1	0.34	0.34	0.23	7.71	21.2	NS
Within samples	4	5.91	1.48				

DM = Dry Matter
HC = High Concentrate
F = Friesian
WF = White Fulani
LC = Low Concentrate
NS = Not Significant
GB = German Brown

EE. HC (WF)

Source of Variation	d.f.	S.S.	M.S.	$F_{cal.}$	$F_{0.05}$	$F_{0.01}$	
Total	5	99.52					
Between means	1	16.47	16.47	0.79	7.71	21.2	NS
Within samples	4	83.05	20.76				

EE. LC (WF)

Source of Variation	d.f.	S.S.	M.S.	$F_{cal.}$	$F_{0.05}$	$F_{0.01}$	
Total	5	28.93					
Between means	1	6.30	6.30	1.11	7.71	21.2	NS
Within sample	4	22.63	55.66				

Energy HC (GB)

Source of Variation	d.f.	S.S.	M.S.	$F_{cal.}$	$F_{0.05}$	$F_{0.01}$	
Total	5	8.62					
Between means	1	2.69	2.69	1.82	7.71	21.2	NS
Within samples	4	5.93	1.48				

Energy LC (GB)

Source of Variation	d.f.	S.S.	M.S.	$F_{cal.}$	$F_{0.05}$	$F_{0.01}$	
Total	5	9.61					
Betweem means	1	2.11	2.11	1.12	7.71	21.2	NS
Within samples	4	7.50	1.88				

DM = Dry Matter (%)
HC = High Concentrate.

Energy : LC (WF)

Source of variation	d.f.	S.S.	M.S.	F Calculated	F tabulated 0.05 0.01	
Total	5	87.47				
Between means	1	8.71	8.71	0.44	7.71 21.2	NS
Within samples	4	78.76	19.69			

APPENDIX B4.2

TWO-WAY ANALYSIS OF VARIANCE FOR COMPARISON OF THE DATA BETWEEN THE BREEDS AND TREATMENTS

ME Intake (MJ/day)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{0.05}$	$F_{0.01}$	
Treatment (T)	2	9768.98	4884.49	9.69	3.35	5.49	**
Breed (B)	2	4242.50	2121.25	4.21	3.34	5.49	*
Interaction (T X B)	4	1683.69	420.92	0.84	2.73	4.11	NS
Error	27	13604.09	503.86				
Total	35	29299.26					

ME Intake ($MJ/day/W_{kg}^{0.734}$)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{0.05}$	$F_{0.01}$	
Treatment (T)	2	1.124	0.62	155.00	3.35	5.49	**
Breed (B)	2	0.025	0.0125	3.125	3.35	5.49	NS
Interaction (T X B)	4	0.01	0.0025	0.625	2.73	4.11	NS
Error	27	0.11	0.0040				
Total	35	1.385					

ME = Metabolizable Energy
df = Degree of freedom
SS = Sum of Squares
MS = Mean Square
F_{cal} = F calculated
NS = Not Significant
** = Significant at 1% level
* = Significant at 5% level.

WF = White Fulani
GB = German Brown
Fr = Friesian
F = Forage ad lib
HC = ad lib forage + high concentrate ration
LC = ad lib forage + low concentrate ration.

Nitrogen Intake (g/day/$W_{kg}^{0.734}$)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{.05}$	$F_{.01}$	
Treatment (T)	2	3.90	1.95	11.61	3.35	5.49	**
Breed (B)	2	0.18	0.09	0.536	3.35	5.49	NS
Interaction (T X B)	4	0.06	0.015	0.089	2.73	4.11	NS
Error	27	4.54	0.168				
Total	35	8.68					

Nitrogen Intake (g/day)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{.05}$	$F_{.01}$	
Treatment (T)	2	27416.10	13708.05	10.22	3.35	5.49	**
Breed (B)	2	10783.00	5391.50	4.02	3.35	5.49	*
Interaction (T X B)	4	1018.11	254 .53	0.19	2.73	4.11	NS
Error	27	36211.62	1341.17				
Total	35	75428.83					

ME = Metabolizable Energy
df = Degree of freedom
SS = Sum of Squares
MS = Mean Square
F_{cal} = F calculated
NS = Not Significant
** = Significant at 1% level
* = Significant at 5% level.

WF = White Fulani
GB = German Brown
Fr = Friesian
F = Forage ad lib
HC = ad lib forage + high concentrate ration
LC = ad lib forage + low concentrate ration.

Faecal-Nitrogen ($g/day/W_{kg}^{0.734}$)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{.05}$	$F_{.01}$	
Treatment (T)	2	8.67	4.335	12.90	3.35	5.49	**
Breed (B)	2	5.15	2.725	8.11	3.35	5.49	**
Interaction (T X B)	4	0.50	0.125	0.372	2.72	4.11	NS
Error	27	9.07	0.336				
Total	35	23.69					

Urinary-Nitrogen ($g/day/W_{kg}^{0.734}$)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{.05}$	$F_{.01}$	
Treatment (T)	2	0.30	0.15	10.14	3.35	5.49	**
Breed (B)	2	0.01	0.005	0.34	3.35	5.49	NS
Interaction (T X B)	4	0.01	0.0025	0.17	2.73	4.11	NS
Error	27	0.40	0.0148				
Total	35	0.72					

ME = Metabolizable Energy
df = Degree of freedom
SS = Sum of Squares
MS = Mean Square
F_{cal} = F calculated
NS = Not Significant
** = Significant at 1% level
* = Significant at 5% level.

WF = White Fulani
GB = German Brown
Fr = Friesian
F = Forage ad lib
HC = ad lib forage + high concentrate ration
LC = ad lib forage + low concentrate ration.

Absorbed Nitrogen ($g/day/W_{kg}^{0.734}$)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{.05}$	$F_{.01}$	
Treatment (T)	2	1.53	0.765	173.86	3.35	5.49	**
Breed (B)	2	0.03	0.015	3.41	3.35	5.49	*
Interaction (T X B)	4	0.01	0.0025	0.57	2.73	4.11	NS
Error	27	0.12	0.0044				
Total	35	1.69					

Nitrogen Balance ($g/day/W_{kg}^{0.734}$)

Source of variation	d.f.	S.S.	M.S.	F_{cal}	$F_{.05}$	$F_{.01}$	
Treatment (T)	2	0.63	0.315	15.75	3.35	5.49	**
Breed (B)	2	0.04	0.02	1.00	3.35	5.49	NS
Interaction (T X B)	4	0.01	0.0025	0.125	2.73	4.11	NS
Error	27	0.61	0.02				
Total	35	1.29					

ME = Metabolizable Energy
df = Degree of freedom
SS = Sum of Squares
MS = Mean Square
F_{cal} = F calculated
NS = Not Significant
** = Significant at 1% level
* = Significant at 5% level.

WF = White Fulani
GB = German Brown
Fr = Friesian
F = Forage *ad lib*
HC = *ad lib* forage + high concentrate ration
LC = *ad lib* forage + low concentrate ration.

APPENDIX C2.1

(a) Total Dry Matter Intake (kg/day) of the grazed cows

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		65	-	88	-	42	-	90	-
		66	-	120	-	58	-	127	-
1	1	65	7.39(3.20)	88	7.52(2.40)	42	7.60(1.15)	90	9.12(1.80)
		66	7.57(3.10)	120	8.52(2.90)	58	7.79(1.40)	127	9.25(2.00)
	2	65	7.27(3.45)	88	7.51(2.40)	42	7.54(1.20)	90	9.18(1.54)
		66	7.54(3.50)	120	8.43(2.70)	58	7.65(1.40)	127	9.10(1.90)
	3	65	7.33(3.30)	88	7.88(2.90)	42	7.55(1.15)	90	9.29(1.60)
		66	7.67(3.50)	120	8.48(2.80)	58	7.56(1.20)	127	9.04(1.70)
	4	65	7.20(3.20)	88	7.27(2.20)	42	7.54(1.10)	90	9.28(1.65)
		66	7.64(3.00)	120	8.50(2.90)	58	7.95(1.60)	127	8.37(1.56)
2	1	42	6.42(1.90)	90	8.14(2.60)	65	8.56(1.95)	88	7.37(1.90)
		58	6.62(2.30)	127	8.30(1.45)	66	9.13(1.90)	120	8.00(2.01)
	2	42	6.22(1.80)	90	8.36(2.50)	65	8.45(2.00)	88	8.00(1.68)
		58	6.52(2.70)	127	8.35(1.70)	66	8.25(2.00)	120	8.11(1.86)
	3	42	6.15(1.70)	90	8.44(2.40)	65	8.62(1.90)	88	7.69(1.78)
		58	6.19(2.40)	127	8.50(1.82)	66	8.77(1.70)	120	8.17(1.86)
	4	42	6.57(1.10)	90	8.36(2.30)	65	8.36(2.05)	88	7.96(1.60)
		58	6.63(2.80)	127	8.32(1.60)	66	8.45(1.90)	120	8.35(1.86)

- Not determined

( ) Figures in parenthesis are the dry matter (DM) intake from concentrate ration.

(b) Total Dry Matter Intake (kg/day) of the Stall-fed cows

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		37	-	99	-	56	-	92	-
		67	-	121	-	64	-	123	-
1	1	37	7.64(2.14)	99	7.86(2.28)	56	8.26(2.00)	92	8.07(1.80)
		67	7.70(1.98)	121	8.52(3.00)	64	8.47(2.00)	123	8.32(2.00)
	2	37	7.49(2.16)	99	7.51(2.04)	56	8.00(1.90)	92	7.62(1.30)
		67	7.76(2.07)	121	8.82(3.20)	64	8.36(1.90)	123	8.30(2.00)
	3	37	6.89(1.89)	99	7.37(2.16)	56	7.96(2.00)	92	7.55(1.40)
		67	7.42(1.93)	121	8.41(3.06)	64	8.13(1.95)	123	8.89(1.95)
	4	37	7.00(2.06)	99	7.43(2.42)	56	9.31(1.80)	92	7.67(1.40)
		67	7.40(2.06)	121	7.47(3.04)	64	8.20(2.00)	123	8.15(1.90)
2	1	56	7.48(2.50)	92	7.23(1.91)	37	8.02(1.43)	99	7.54(1.60)
		64	7.35(3.00)	123	7.05(2.80)	67	7.81(1.43)	121	8.24(2.10)
	2	56	7.34(2.13)	92	7.03(2.12)	37	8.01(1.30)	99	8.76(1.50)
		64	7.90(2.53)	123	7.35(2.35)	67	7.80(1.40)	121	9.30(1.80)
	3	56	7.52(2.26)	92	7.01(2.00)	37	9.00(1.30)	99	7.67(1.50)
		64	7.97(2.56)	123	7.29(2.20)	67	6.66(1.30)	121	8.65(1.70)
	4	56	7.54(2.28)	92	7.16(2.20)	37	7.65(1.00)	99	8.45(1.35)
		64	7.51(2.07)	123	6.75(1.70)	67	8.57(1.20)	121	8.11(1.60)

- **Not determined**

( ) **Figures in parenthesis are the dry matter (DM) Intake from concentrate ration.**

APPENDIX C2.2

(a) <u>Milk yield (kg/week) of the grazing cows</u>

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		65	62.73	88	46.36	42	35.00	90	54.55
		66	60.91	120	55.91	58	43.18	127	62.73
1	1	65	67.73	88	48.18	42	36.82	90	48.64
		66	67.50	120	53.64	58	44.09	127	60.00
	2	65	65.00	88	56.38	42	35.91	90	50.00
		66	68.64	120	55.45	58	37.25	127	52.72
	3	65	62.73	88	62.73	42	34.55	90	51.36
		66	60.45	120	57.27	58	50.45	127	49.09
	4	65	60.45	88	62.27	42	37.72	90	51.30
		66	60.00	120	63.18	58	46.82	127	28.64
2	1	42	34.32	90	49.10	65	62.73	88	52.73
		58	51.82	127	32.72	66	80.45	120	58.63
	2	42	32.27	90	47.25	65	59.55	88	55.91
		58	45.90	127	35.90	66	53.64	120	58.63
	3	42	23.40	90	45.00	65	64.55	88	50.00
		58	55.45	127	31.82	66	58.15	120	58.60
	4	42	18.18	90	43.86	65	56.36	88	51.82
		58	54.09	127	43.86	66	58.64	120	64.56

(b) <u>Milk yield (kg/week) of the stall-fed cows</u>

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		37	42.28	99	45.00	56	61.37	92	56.82
		67	39.10	121	59.31	64	61.37	123	60.91
1	1	37	42.73	99	40.23	56	60.00	92	39.55
		67	40.91	121	63.40	64	58.64	123	58.64
	2	37	37.27	99	42.73	56	61.36	92	43.18
		67	38.18	121	60.45	64	60.00	123	61.36
	3	37	40.68	99	47.73	56	55.45	92	42.95
		67	40.68	121	60.00	64	60.45	123	60.00
	4	37	45.00	99	50.00	56	50.45	92	37.73
		67	45.00	121	65.91	64	59.54	123	55.00
2	1	56	42.04	92	41.59	37	39.55	99	41.82
		64	50.00	123	48.18	67	40.00	121	56.02
	2	56	44.55	92	38.64	37	40.23	99	45.45
		64	50.45	123	41.82	67	40.91	121	52.27
	3	56	45.00	92	42.73	37	34.55	99	40.00
		64	40.91	123	33.18	67	39.09	121	49.09
	4	56	42.73	92	42.05	37	36.37	99	35.91
		64	46.36	123	35.23	67	35.91	121	47.72

APPENDIX C2.3

(a) Solids-corrected milk (SCM) (kg/week) of the grazed cows

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		65	37.65	88	43.07	42	35.22	90	51.78
		66	59.72	120	48.48	58	43.31	127	53.67
1	1	65	61.13	88	43.96	42	36.94	90	46.59
		66	59.99	120	45.60	58	43.59	127	52.86
	2	65	58.16	88	53.00	42	36.10	90	47.65
		66	60.78	120	47.39	58	37.03	127	48.12
	3	65	56.60	88	55.72	42	35.25	90	49.03
		66	54.94	120	47.84	58	49.99	127	44.67
	4	65	54.34	88	57.74	42	37.97	90	49.71
		66	50.82	120	51.86	58	46.46	127	26.60
2	1	42	34.23	90	47.07	65	57.52	88	50.83
		58	51.38	127	29.95	66	70.33	120	50.88
	2	42	32.79	90	46.15	65	58.36	88	53.66
		58	44.79	127	33.56	66	50.14	120	51.93
	3	42	34.50	90	44.36	65	66.07	88	49.80
		58	54.53	127	30.37	66	58.19	120	55.66
	4	42	19.11	90	43.11	65	57.17	88	51.17
		58	54.64	127	41.58	66	60.09	120	57.41

(b) Solids-corrected Milk (SCM) (kg/week) of the stall-fed cows

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		37	39.95	99	41.96	56	58.09	92	53.68
		67	37.13	121	50.52	64	58.00	123	51.18
1	1	37	35.61	99	36.86	56	55.41	92	38.37
		67	38.64	121	52.23	64	54.30	123	47.41
	2	37	34.02	99	37.17	56	56.60	92	42.42
		67	35.45	121	47.21	64	54.88	123	50.52
	3	37	35.86	99	40.54	56	51.27	92	42.45
		67	36.66	121	47.26	64	53.26	123	50.24
	4	37	39.36	99	42.57	56	46.71	92	37.79
		67	39.97	121	48.65	64	51.84	123	46.16
2	1	56	37.94	92	41.33	37	35.81	99	35.30
		64	43.99	123	42.85	67	36.26	121	44.50
	2	56	40.10	92	38.47	37	37.61	99	41.43
		64	44.67	123	34.45	67	38.37	121	45.04
	3	56	41.15	92	42.43	37	34.86	99	37.13
		64	37.15	123	29.54	67	37.58	121	42.21
	4	56	37.03	92	41.83	37	38.47	99	34.47
		64	42.62	123	27.62	67	31.16	121	54.26

APPENDIX C2.3

(a) Liveweight (kg) of the grazed cows during the period of experiment

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		65	425.28	88	328.41	42	365.00	90	441.19
		66	402.56	120	356.22	58	302.67	127	426.56
1	1	65	424.11	88	324.12	42	368.42	90	443.56
		66	404.34	120	362.44	58	308.64	127	427.84
	2	65	426.56	88	305.26	42	366.24	90	442.84
		66	412.55	120	358.40	58	300.41	127	431.26
	3	65	434.85	88	312.00	42	363.48	90	446.56
		66	428.00	120	352.16	58	294.26	127	436.76
	4	65	440.84	88	322.62	42	365.25	90	448.71
		66	436.50	120	350.00	58	295.18	127	434.28
2	1	42	364.45	90	452.68	65	456.57	88	324.40
		58	298.42	127	436.00	66	432.41	120	351.62
	2	42	368.56	90	468.28	65	450.64	88	356.28
		58	296.25	127	434.40	66	436.85	120	358.80
	3	42	370.42	90	469.52	65	465.75	88	348.55
		58	300.24	127	441.26	66	438.55	120	362.20
	4	42	373.55	90	471.22	65	463.84	88	362.18
		58	300.00	127	439.25	66	441.62	120	361.22

(b) Liveweight (kg) of the stall-fed cows during the period of experiment

Period	Weeks	HIGH CONCENTRATE				HIGH FORAGE			
		No.	G. Brown	No.	Friesian	No.	G. Brown	No.	Friesian
Before Start of Experiment		37	412.25	99	418.25	56	395.80	92	385.44
		67	428.90	121	434.00	64	412.55	123	399.50
1	1	37	400.00	99	410.00	56	382.10	92	373.20
		67	427.00	121	420.00	64	408.12	123	381.40
	2	37	375.20	99	383.51	56	386.60	92	365.40
		67	412.00	121	401.50	64	400.21	123	375.45
	3	37	370.41	99	372.45	56	384.25	92	363.60
		67	400.45	121	398.64	64	398.25	123	368.50
	4	37	375.50	99	368.65	56	386.42	92	364.10
		67	398.28	121	390.52	64	400.80	123	365.45
2	1	56	390.50	92	368.25	37	380.00	99	361.00
		64	402.82	123	368.52	67	386.25	121	386.83
	2	56	392.40	92	375.45	37	390.18	99	369.21
		64	405.84	123	381.42	67	387.52	121	389.50
	3	56	394.21	92	372.27	37	385.46	99	364.65
		64	408.20	123	378.80	67	392.51	121	386.52
	4	56	398.56	92	374.75	37	391.12	99	364.10
		64	412.41	123	382.00	67	398.49	121	392.40

APPENDIX C3.

Animal No. ..Friesian No. 100........ Diet: High level ration + ad lib forage.....

Nutrient	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean
Milk yield (kg/wk)	38.64	50.45	66.36	64.55	67.73	68.64	65.00	60.91	59.36	57.27	45.90	30.45	32.73	32.27	52.88±14.28
SCM (kg/wk)	35.82	46.64	61.78	59.00	61.95	63.71	60.70	57.16	55.77	54.74	43.31	28.93	31.33	30.89	49.41±12.96
Forage Intake (kgDM/day)	5.87	6.57	7.44	7.44	7.77	7.02	7.44	6.70	6.36	5.84	5.24	5.57	5.72	5.64	6.48±0.23
Ration Intake (kgDM/day)	2.00	2.25	3.00	3.82	3.70	3.85	4.00	3.75	3.50	3.50	3.40	2.75	1.90	1.90	3.09±0.21
Total	7.87	8.82	10.54	11.26	11.47	10.87	11.44	10.45	9.86	9.34	8.64	8.32	7.62	7.54	9.57±0.39
Weight (kg)		421.50		398.64		390.15		381.82		371.52		365.00		370.28	385.56±7.48
Fat %	3.54	3.48	3.30	3.26	3.20	3.25	3.25	3.35	3.40	3.85	3.70	3.75	3.85	3.90	3.51±0.07
Protein %	2.95	2.98	2.95	2.93	2.98	2.97	3.00	3.05	3.03	3.11	3.07	3.08	3.05	3.03	3.01±0.02
Lactose %	4.80	4.81	4.82	4.80	4.82	4.85	4.80	4.80	4.80	4.80	4.75	4.78	4.77	4.85	4.80±0.01
Total Solids %	12.05	12.15	12.41	12.30	12.25	12.14	12.50	12.48	12.45	12.30	12.25	12.30	12.32	12.28	12.32±0.01
SNF %	8.60	8.67	9.11	9.04	9.05	9.16	9.25	9.13	9.05	8.45	8.55	8.55	8.47	8.38	8.82±0.06
Ash %	0.68	0.68	0.68	0.68	0.70	0.70	0.68	0.68	0.69	0.69	0.70	0.71	0.71	0.71	0.69±0.01
Calcium (mg/100g)	105.25	114.15	108.25	109.10	108.00	125.00	125.10	120.00	112.15	137.25	125.00	124.05	123.00	122.50	118.49±2.45
Phosphorus(mg/100g)	45.62	44.25	45.50	47.00	52.07	53.05	54.05	54.00	55.00	54.00	52.00	52.00	52.00	53.00	50.97±0.98
Energy (KJ/g)	19.16	19.00	20.50	18.41	17.57	18.83	19.71	19.62	19.46	19.66	19.96	20.21	20.54	20.88	19.54±0.24

APPENDIX C3.

Animal No. Friesian No. 100 (contd.) Diet: Low level ration + *ad lib* forage

Nutrient	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Mean	Grand* Total	Grand Mean
Milk yield	30.00	27.20	31.36	28.60	34.52	34.06	31.34	30.43	29.00	28.60	29.05	28.16	23.60	20.90	29.06±3.61	1147.16	40.97±15.86
SCM(kg/wk)	28.55	25.88	29.81	26.78	32.31	32.07	29.59	28.62	27.30	27.11	27.64	26.60	22.36	20.01	27.47±3.31	1076.32	38.44±14.52
Forage	4.26	4.79	4.23	4.91	4.96	4.67	4.76	4.95	5.42	5.44	4.71	4.95	4.34	4.34	4.77±0.10	1101.52	5.62±0.21
Ration	1.20	1.24	1.04	1.20	1.10	1.30	1.30	1.20	1.15	1.08	1.05	1.08	1.05	1.00	1.14±0.03	415.52	2.12±0.24
Total	5.46	6.03	5.27	6.11	6.06	5.97	6.06	6.15	6.57	6.52	5.76	6.03	5.39	3.54	5.91±0.11	1517.04	7.74±0.98
Weight(kg)		375.00		386.25		395.25		400.20		417.23		418.82		420.00	401.82±4.84	-	393.69±5.31
Fat %	3.90	3.95	3.85	3.80	3.85	4.00	4.05	3.95	4.00	4.05	4.05	4.00	4.10	4.30	3.99±0.03	43.02	3.75±0.06
Protein %	3.00	3.05	3.03	3.00	2.98	3.01	3.02	3.04	3.05	3.10	3.15	3.13	3.20	3.18	3.07±0.07	34.87	3.04±0.02
Lactose %	4.80	4.80	4.81	4.75	4.76	4.80	4.80	4.79	4.77	4.65	4.75	4.73	4.74	4.68	4.76±0.01	54.83	4.78±0.01
TS %	12.20	12.15	12.22	12.05	12.00	11.95	11.95	11.98	11.95	12.00	12.05	12.00	11.95	11.98	12.03±0.02	139.61	12.17±0.03
SNF %	8.30	8.20	8.37	8.25	8.15	7.95	7.90	8.03	7.95	7.95	8.00	8.00	7.85	8.00	8.06±0.04	96.82	8.44±0.04
Ash %	0.70	0.70	0.71	0.71	0.70	0.70	0.70	0.69	0.69	0.69	0.69	0.69	0.70	0.71	0.70±0.01	8.03	0.70±0.01
Calcium	110.00	109.00	108.00	109.00	115.15	114.00	116.00	120.00	122.00	125.00	125.00	126.00	124.00	125.10	117.73±1.91	1.35	118.11±2.96
Phosphorus	45.00	46.00	48.00	50.45	55.45	56.00	60.00	62.00	60.50	59.50	58.50	59.50	60.00	62.00	55.93±2.02	0.61	53.44±1.51
Energy	19.25	19.45	17.07	17.03	17.05	18.83	18.16	18.05	18.50	18.70	18.75	18.65	19.70	19.70	18.35±0.19	2.17x107	18.93±0.20

* Values given per 28 weeks.

APPENDIX C3.

Animal No. White Fulani No. 462. Diet: High level ration + ad lib forage

Nutrient	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean
Milk yield (kg/wk)	23.61	35.42	40.43	35.44	38.84	47.20	46.18	47.30	45.21	35.30	34.20	34.00	33.86	33.21	37.87±6.76
SCM (kg/wk)	24.50	37.07	42.27	36.41	41.92	51.34	48.36	50.38	48.20	37.58	36.25	35.93	35.48	35.25	40.07±7.46
Forage Intake (kgDM/day)	4.62	6.21	6.75	6.79	7.00	7.02	6.55	5.67	6.85	6.41	6.16	5.30	5.11	5.18	6.12±0.21
Ration Intake (kgDM/day)	1.50	1.34	2.10	2.40	2.10	2.30	2.80	2.70	2.65	2.65	2.00	2.00	2.00	2.00	2.18±0.12
Total	6.12	7.55	8.85	9.19	9.10	9.32	9.35	8.37	9.50	9.06	8.16	7.30	7.11	7.18	8.30±0.27
Weight (kg)		302.10		298.64		294.52		289.09		281.20		279.09		282.10	289.53±3.45
Fat %	4.61	4.72	4.73	4.68	4.71	4.70	4.63	4.92	4.88	4.86	4.76	4.80	4.86	4.92	4.77±0.03
Protein %	3.26	3.24	3.34	3.30	3.35	3.31	3.30	3.24	3.26	3.28	3.28	3.27	3.30	3.32	3.29±0.01
Lactose %	5.20	5.18	5.18	5.18	5.19	5.20	5.20	5.16	5.16	5.17	5.10	5.08	5.12	5.12	5.16±0.01
Total Solids %	12.88	12.91	12.89	12.66	13.42	13.56	13.00	13.02	13.07	13.06	13.08	13.00	12.81	12.96	13.02±0.06
SNF %	8.27	8.19	8.16	7.98	8.71	8.86	8.37	8.10	8.19	8.20	8.32	8.20	7.95	8.04	8.25±0.07
Ash %	0.72	0.73	0.73	0.74	0.72	0.73	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.71±0.01
Calcium (mg/100g)	120.80	124.82	124.26	125.25	126.40	128.45	121.25	117.46	128.46	127.52	128.00	126.65	126.80	126.25	125.17±0.71
Phosphorus(mg/100g)	65.25	65.50	65.50	65.50	65.26	67.20	68.25	66.21	64.22	65.25	64.00	65.20	63.26	63.00	65.20±0.83
Energy (KJ/g)	22.56	22.48	22.30	22.52	22.60	22.52	22.44	22.48	22.14	22.44	22.39	22.10	22.40	22.48	22.42±0.05

APPENDIX C3.

Animal No. White Fulani No. 462 (contd.) .... Diet: Low level ration + ad lib forage ....

Nutrient	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Mean	Grand* Total	Grand Mean
Milk yield	30.70	28.72	28.31	29.21	27.95	17.42	17.26	16.21	15.24	15.31	14.26	14.80	13.21	13.24	20.13±6.97	812.00	29.00±11.27
SCM(kg/wk)	32.31	29.93	29.87	30.92	29.64	18.14	18.20	17.14	16.46	16.35	15.12	15.82	13.88	14.23	21.29±7.29	859.04	30.68±11.99
Forage	5.25	5.00	5.00	4.25	4.28	3.82	4.18	4.85	3.85	4.00	4.16	3.25	3.47	3.82	4.23±0.16	1013.32	5.17±0.22
Ration	1.20	1.10	1.00	1.05	1.00	1.00	1.00	0.95	0.90	0.90	0.85	0.80	0.75	0.70	0.94±0.14	305.76	1.56±0.13
Total	6.45	6.10	6.00	5.30	5.28	4.82	5.18	5.79	4.75	4.90	5.01	4.05	4.22	4.52	5.16±0.17	1319.08	6.73±0.38
Weight(kg)		290.21		289.00		290.00	283.41	283.41		285.00		288.60		292.56	288.40±1.20	-	288.97±1.76
Fat %	4.86	4.85	5.21	5.21	5.20	4.98	5.28	5.50	5.81	5.57	5.62	5.68	5.70	6.00	5.39±0.96	41.25	5.08±0.08
Protein %	3.28	3.28	3.29	3.31	3.23	3.24	3.36	3.27	3.27	3.26	3.30	3.31	3.31	3.30	3.29±0.01	25.09	3.09±0.01
Lactose %	5.21	4.98	5.22	5.23	5.22	5.21	5.24	5.28	5.16	5.29	5.30	5.29	5.25	5.28	5.23±0.02	42.14	5.19±0.01
TS %	12.88	12.76	12.61	12.66	12.70	12.60	12.54	12.38	12.46	12.48	12.40	12.40	12.11	12.22	12.51±0.06	103.69	12.77±0.06
SNF %	8.02	7.91	7.40	7.45	7.50	7.62	7.26	6.88	6.65	6.91	6.70	6.72	6.41	6.22	7.12±0.15	62.44	7.69±0.14
Ash %	0.70	0.70	0.70	0.70	0.69	0.70	0.71	0.71	0.71	0.71	0.71	0.72	0.71	0.71	0.71±0.01	5.85	0.71±0.01
Calcium	122.45	122.45	128.62	130.20	136.44	138.26	139.42	130.65	134.00	132.47	137.26	138.00	138.00	141.20	133.53±3.00	1.05	129.35±2.37
Phosphorus	62.14	60.15	60.24	60.00	60.25	58.65	59.23	58.15	55.27	56.00	58.18	58.20	58.00	58.25	60.92±1.54	0.50	61.99±1.73
Energy	22.60	22.51	22.68	22.64	22.76	22.72	23.06	22.89	22.85	22.93	22.95	23.10	23.06	23.00	22.84±0.09	1.84 x 107	22.63±0.07

* Values given per 28 weeks.

APPENDIX C3.

Animal No. German Brown No. 64 .... Diet: High level ration + ad lib forage ....

Nutrient	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean
Milk yield (kg/wk)	35.45	43.63	45.68	49.32	48.18	47.27	49.09	53.64	55.00	55.05	51.82	50.00	49.09	45.00	48.44±5.13
SCM (kg/wk)	35.39	43.66	45.19	48.89	46.74	46.11	48.07	52.54	53.91	54.34	51.47	49.64	49.40	45.39	47.91±4.89
Forage Intake (kgDM/day)	5.41	6.77	6.42	6.80	7.28	6.77	6.45	6.09	5.29	5.99	5.49	6.08	5.21	5.11	6.08±0.14
Ration Intake (kgDM/day)	2.00	1.85	2.25	2.30	2.55	2.50	2.25	2.55	2.70	2.90	2.90	2.40	2.35	2.00	2.39±0.09
Total	7.41	8.62	8.67	9.10	9.83	9.27	8.70	8.64	7.99	8.89	8.39	8.48	7.56	7.11	8.48±0.15
Weight (kg)		385.20		372.73		385.50		390.00		400.18		418.18		425.28	396.72±7.18
Fat %	4.02	4.00	3.92	3.90	3.42	3.50	3.52	3.58	3.55	3.68	3.72	3.70	3.92	3.99	3.74±0.06
Protein %	3.50	3.50	3.50	3.52	3.54	3.58	3.60	3.61	3.57	3.68	3.70	3.65	3.57	3.59	3.58±0.02
Lactose %	4.80	4.85	4.86	4.80	4.81	4.76	4.74	4.70	4.82	4.93	4.86	4.90	4.91	4.93	4.83±0.02
Total Solids %	12.80	12.85	12.75	12.80	12.90	12.91	12.95	12.80	12.94	12.93	12.99	13.00	13.01	12.98	12.90±0.02
SNF %	8.78	8.85	8.83	8.90	9.48	9.41	9.43	9.22	9.39	9.25	9.27	9.30	9.09	8.99	9.16±0.05
Ash %	0.72	0.72	0.72	0.72	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73±0.00
Calcium (mg/100g)	140.10	132.00	152.00	148.40	145.40	145.20	132.50	125.12	135.34	142.00	145.00	148.20	145.20	148.00	141.75±2.07
Phosphorus(mg/100g)	92.52	94.80	98.72	102.50	112.50	87.25	88.10	83.42	76.00	78.25	80.25	81.50	89.00	92.82	89.60±4.50
Energy (KJ/g)	20.71	20.59	20.50	20.54	20.67	20.71	21.46	21.67	21.92	21.42	21.35	21.10	21.50	21.72	21.13±0.13

APPENDIX C3.

Animal No. German Brown No. 64 (contd.) Diet: Low level ration + *ad lib* forage

Nutrient	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Mean	Grand* Total	Grand Mean
Milk yield	42.73	37.27	35.00	30.00	30.00	30.00	26.36	25.00	25.90	24.45	26.36	28.64	22.73	20.45	28.71±6.15	1083.04	38.68±11.35
SCM(kg/wk)	43.12	37.65	35.39	30.28	30.30	30.33	26.72	25.39	26.07	24.54	26.46	29.01	22.52	20.40	29.16±6.13	1078.84	38.53±10.99
Forage	4.32	4.62	5.77	5.25	5.79	6.03	4.51	5.70	5.50	6.22	6.71	5.18	4.43	4.81	5.35±0.24	1119.16	5.71±0.21
Ration	1.50	1.50	1.05	1.20	1.20	1.20	1.20	1.20	1.35	1.35	1.20	1.35	1.35	1.00	1.26±0.05	344.96	1.83±0.12
Total	5.82	6.12	6.82	6.45	6.79	7.23	5.71	6.90	6.85	7.57	7.91	6.53	5.78	5.81	6.59±0.09	1475.88	7.53±0.19
Weight(kg)		420.91		415.00		419.50		420.00		434.93		430.28		432.98	424.80±2.94	-	410.76±5.39
Fat %	4.00	4.05	4.08	4.07	4.06	4.10	4.12	4.15	4.07	4.04	4.08	4.12	4.15	4.20	4.09±0.01	42.46*	3.92±0.06
Protein %	3.60	3.58	3.55	3.53	3.54	3.56	3.50	3.49	3.50	3.48	3.51	3.48	3.51	3.50	3.52±0.01	38.45*	3.55±0.02
Lactose %	4.80	4.86	4.90	4.87	4.86	4.62	4.70	4.68	4.67	4.65	4.52	4.58	4.59	4.57	4.71±0.03	51.66*	4.77±0.02
TS %	12.98	12.95	12.94	12.92	12.94	12.92	12.94	12.92	12.88	12.86	12.83	12.93	12.57	12.63	12.87±0.02	139.60*	12.89±0.01
SNF %	8.98	8.90	8.86	8.85	8.88	8.82	8.82	8.80	8.81	8.82	8.75	8.81	8.42	8.43	8.78±0.05	97.15*	8.97±0.08
Ash %	0.73	0.73	0.72	0.72	0.72	0.72	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72±0.01	7.80*	0.72±0.01
Calcium	148.82	145.70	148.00	152.50	150.25	158.20	162.00	167.00	158.30	160.00	162.00	157.00	146.00	150.00	154.66±3.80	1.60*	148.20±3.71
Phosphorus	85.28	88.20	85.11	88.40	90.00	82.42	80.40	80.25	80.00	82.45	95.00	88.10	90.20	90.50	86.17±2.61	10.95*	87.83±2.08
Energy	21.76	21.25	21.35	21.00	20.85	20.72	20.25	20.10	19.11	20.66	20.75	20.08	20.16	20.29	20.65±0.15	2.25×10^{7}	20.89±0.11

* Values given per 28 weeks.

APPENDIX C4.

Lactating Cows

Total Digestible Nutrient (TDN) (kg/100g feed) of the grass and concentrate

Breed	No.	DCP			DCF			DEE			DNFE			TDN (kg/100 kg feed)		
		a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
White Fulani	467	5.86	13.89	13.13	18.38	6.19	6.09	0.53	3.35	3.25	24.46	37.67	37.58	49.23(7.45)	61.10(9.24)	60.05(9.08)
	481	6.06	12.40	12.28	18.06	5.89	5.73	0.60	3.22	3.16	26.30	38.16	36.81	51.02(7.72)	59.67(9.03)	59.78(8.77)
	242	5.87	12.45	12.40	17.53	5.92	5.55	0.57	3.22	3.21	27.93	38.53	37.75	51.90(7.85)	60.12(9.09)	58.91(8.91)
	167	6.06	13.50	12.80	16.71	5.81	5.64	0.65	3.25	3.18	27.14	39.56	37.42	50.56(7.65)	62.12(9.40)	59.04(8.93)
	Mean	5.96	13.06	12.65	17.67	5.95	5.75	0.39	3.26	3.20	26.46	38.48	37.39	50.68(7.67)	60.75(9.19)	58.99(8.92)
German Brown	69	6.33	13.49	12.52	17.91	4.13	5.46	0.62	3.48	3.27	27.63	43.17	40.21	52.49(7.94)	64.27(9.72)	61.46(9.30)
	42	6.51	14.83	13.57	17.64	5.30	5.36	0.73	3.26	2.60	27.35	47.94	42.08	52.23(7.90)	71.33(10.79)	63.61(9.62)
	66	6.06	13.32	12.98	15.44	4.65	4.56	0.76	3.25	3.21	27.97	41.99	39.72	50.23(7.60)	63.21(9.56)	60.47(9.15)
	57	6.34	12.78	12.76	17.78	5.28	4.92	0.75	3.31	3.30	27.51	40.33	37.54	52.38(7.92)	61.70(9.33)	58.52(8.85)
	Mean	6.31	13.61	12.96	17.19	4.84	5.08	0.72	3.33	3.10	27.62	43.36	39.89	51.83(7.84)	65.14(9.85)	61.03(9.23)
Friesian	92	6.18	14.09	12.60	17.94	5.37	5.48	0.69	3.29	3.21	26.99	39.49	39.70	51.80(7.84)	62.24(9.42)	60.99(9.23)
	117	6.22	12.43	12.28	12.52	6.18	5.70	0.67	3.26	3.12	27.83	40.82	39.12	47.24(7.15)	62.69(9.48)	60.22(9.11)
	90	6.36	12.45	12.29	15.07	5.69	5.45	0.64	3.53	3.27	27.87	43.08	38.65	49.94(7.55)	64.75(9.79)	59.66(9.02)
	127	6.26	13.28	12.32	17.21	4.46	4.58	0.69	3.20	3.10	29.38	44.87	42.15	52.54(7.95)	65.81(9.96)	62.15(9.40)
	Mean	6.31	13.06	12.37	15.68	5.43	5.30	0.67	3.32	3.18	27.77	42.09	39.91	49.95(7.56)	63.79(9.65)	60.76(9.19)

( ) Values in parenthesis are expressed in MJME/kg feed.

Appendix C4.

STEERS

Total Digestible Nutrient (kg/100kg feed) of the grass and concentrate

Breed	No.	Digestible Crude Protein (DCP)			Digestible Crude Fibre (DCF)			Digestible Ether Extract (DEE)			Digestible Nitrogen Free Extractives (DNFE)			Total Digestible Nutrient TDN (kg/100 kg feed)		
		a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
White Fulani	245	5.93	12.60	12.54	17.11	5.88	5.58	0.74	3.20	3.15	26.80	38.88	38.54	50.58(7.65)	60.56(9.16)	59.81(9.05)
	85	6.03	13.18	13.39	17.09	5.93	5.61	0.76	3.32	3.23	27.12	38.22	36.57	51.00(7.71)	60.65(9.17)	58.80(8.89)
	Mean	5.98	12.89	12.97	17.10	5.91	5.60	0.75	3.26	3.19	26.96	38.55	37.56	50.79(7.68)	60.61(9.17)	59.32(8.97)
German Brown	64	6.23	13.68	13.56	16.39	5.60	4.85	0.76	3.41	3.21	27.31	41.15	38.39	50.69(7.67)	63.84(9.66)	60.01(9.08)
	65	6.34	13.65	13.37	16.65	5.33	5.46	0.71	3.35	3.30	26.84	40.61	37.83	50.54(7.65)	62.94(9.52)	59.96(9.07)
	Mean	6.29	13.66	13.47	16.52	5.47	5.16	0.74	3.38	3.26	27.07	40.87	38.11	50.62(7.66)	63.39(9.59)	59.99(9.07)
Friesian	132	6.36	13.54	13.50	15.65	5.36	5.25	0.69	3.28	3.14	27.86	43.26	40.99	50.56(7.65)	62.71(9.94)	62.88(9.51)
	358	6.15	13.27	12.40	16.06	5.21	5.11	0.66	3.23	3.11	27.18	39.55	38.71	50.05(7.57)	61.26(9.27)	60.33(9.13)
	Mean	6.26	13.41	12.95	15.86	5.29	5.18	0.68	3.26	3.13	27.52	41.41	40.35	50.32(7.61)	61.99(9.61)	61.61(9.32)

a = Forage
b = High Concentrate
c = Low Concentrate.

( ) Metabolizable energy (MJ/kg/kg feed) converted to ME by using Jagusch and Coop's (1971) Formula.

Appendix C4.5 **Energy intake and utilisation (MJ/day) in the three breeds of lactating cows in the declining phase of lactation maintained on grass and low or high concentrate supplements**

Breed	No.	Treatment*	Gross Energy Intake (MJ/day)	Losses (MJ/day)			ME (MJ/day)	Energy** Secreted in milk	GEE*** %	[1]wt kg/day	Weight of animal (kg)
				Faeces	Urine	Methane					
WHITE FULANI	467	F	76.266	33.798	17.799	1.552	23.117	3.52	15.227	-0.75	358.25
		HC	111.604	40.200	21.995	1.552	47.857	2.49	5.203	+0.20	366.85
		LC	104.885	41.166	8.368	1.552	53.799	2.79	5.186	+0.45	377.74
	481	F	64.187	30.301	17.259	1.552	15.075	4.79	31.774	-0.58	368.05
		HC	95.730	41.296	18.171	1.552	34.711	4.13	11.898	-0.12	351.93
		LC	99.291	30.296	8.468	1.552	58.975	4.59	7.783	+0.41	357.62
	242	F	69.956	29.811	16.121	1.552	22.472	5.41	24.074	-0.42	341.25
		HC	115.930	39.848	20.744	1.552	53.786	5.66	10.523	+0.34	350.75
		LC	106.023	33.229	13.573	1.552	57.669	5.83	10.109	+0.62	370.13
	167	F	72.471	30.376	11.888	1.552	28.655	5.31	18.531	-0.70	388.25
		HC	120.520	39.865	19.882	1.552	59.221	5.28	8.916	+0.15	350.75
		LC	123.972	33.669	18.577	1.552	70.174	3.99	5.686	+0.65	397.79
	Mean		96.74±6.06	35.32±1.37	16.07±1.31	1.552±0.0	43.793±5.22	4.48±0.32	10.23±2.38	+0.25	364.95±8.51
GERMAN BROWN	69	F	119.976	42.175	32.916	1.552	43.333	8.52	19.662	-0.52	451.92
		HC	151.528	59.421	25.476	1.556	65.075	6.48	9.958	+0.64	464.52
		LC	119.570	47.334	26.468	1.552	44.216	5.83	13.185	+0.51	474.21
	42	F	97.939	39.610	12.920	1.552	43.857	6.83	15.573	-0.98	420.92
		HC	135.189	37.338	42.388	1.556	53.907	7.21	13.275	+0.15	427.17
		LC	143.378	39.321	34.748	1.552	67.757	5.84	8.619	+0.84	439.76
	66	F	108.541	33.154	35.196	1.552	38.639	8.00	20.704	-0.65	386.50
		HC	136.997	34.543	31.606	1.556	69.292	5.45	7.865	-0.21	381.94
		LC	109.742	25.941	22.644	1.552	59.605	6.12	10.268	+0.55	398.09
	57	F	102.136	34.501	34.033	1.552	32.050	6.65	20.749	-1.10	472.50
		HC	134.043	46.363	34.037	1.556	52.087	6.57	12.614	-0.42	461.00
		LC	119.855	34.476	25.439	1.552	58.388	6.83	11.698	+0.24	466.68
	Mean		123.24±4.90	39.51±2.49	29.82±2.21	1.553±0.00	52.351±3.48	6.69±0.26	12.79±1.32	-0.65	437.10±6.82
FRIESIAN	92	F	101.085	39.313	35.426	1.552	24.734	9.48	38.235	-1.14	484.26
		HC	176.130	40.664	53.246	1.556	80.664	8.95	11.095	+0.02	484.77
		LC	122.533	47.187	11.050	1.552	62.744	7.25	11.985	-0.01	484.51
	117	F	80.801	34.485	31.108	1.552	13.656	7.86	57.557	-0.85	385.26
		HC	123.482	30.342	30.761	1.556	60.823	6.91	11.361	+0.41	393.05
		LC	115.211	34.899	14.481	1.552	64.279	6.97	10.843	+0.84	409.01
	90	F	73.638	34.982	18.836	1.552	18.268	7.87	43.081	-0.92	402.26
		HC	124.294	26.614	34.510	1.556	61.614	6.72	10.907	+0.15	406.01
		LC	154.080	47.212	14.481	1.552	90.835	5.94	6.539	+0.85	422.16
	127	F	b98.291	35.648	38.535	1.552	22.556	7.28	32.275	-1.01	421.54
		HC	153.699	41.091	42.844	1.556	68.208	6.31	9.251	+0.62	433.32
		LC	155.080	34.526	31.552	1.552	87.450	7.63	8.725	+0.80	449.28
	Mean		123.19±9.18	37.25±1.78	29.74±3.69	1.553±0.00	54.658±7.98	7.43±0.29	14.33±4.94	-0.24	431.29±10.52

*F = Forage alone
HC = High Concentrate (100% A.R.C. 1965 recommendation)
LC = Low Concentrate (75% " " ")

** Adjusted to MJ ME/day by using Neville Jr's formula (1974)
*** Gross Energetic Efficiency
1 Weight gain or loss (kg/day/cow).

APPENDIX C4.6

Comparison of ME intake (MJ/day) obtained from actual determination on the cow and that calculated from Total Digestible Nutrient (TDN)

Breed	No.	Treatment	[1]Actual Determination	[2]Calculated from TDN	Difference
White Fulani	467	F	23.12	26.82	-3.70
		HC	47.86	47.82	+0.04
		LC	53.80	43.04	+10.76
	481	F	15.08	28.33	-13.25
		HC	34.71	41.57	- 6.86
		LC	58.98	43.42	+15.56
	242	F	22.47	31.40	- 8.93
		HC	53.79	52.75	+ 1.04
		LC	57.67	48.32	+ 9.32
	167	F	28.66	36.95	- 8.29
		HC	59.22	54.49	+ 4.73
		LC	70.17	58.88	+11.29
		Mean	43.79±5.22	42.82±4.16	+ 0.97
German Brown	69	F	43.33	39.52	+ 3.81
		HC	65.08	62.72	+ 2.36
		LC	44.26	53.20	- 8.94
	42	F	43.88	46.29	- 2.41
		HC	53.91	74.18	-20.27
		LC	67.77	55.21	-13.56
	66	F	38.64	38.08	+ 0.56
		HC	69.29	50.20	+19.09
		LC	59.61	59.30	+ 0.31
	57	F	32.05	38.33	- 6.28
		HC	52.09	62.00	- 9.91
		LC	58.39	54.41	+ 3.98
		Mean	52.36±3.48	52.79±3.41	- 0.43
Friesian	92	F	24.79	45.24	-20.45
		HC	80.66	81.07	- 0.41
		LC	62.74	40.14	+22.60
	117	F	13.66	33.03	-19.37
		HC	60.82	54.72	+ 6.10
		LC	64.28	48.14	+15.87
	90	F	18.27	42.43	-24.16
		HC	61.61	70.02	- 8.41
		LC	90.84	71.65	+19.19
	127	F	22.56	37.21	-14.65
		HC	68.20	58.55	+ 9.65
		LC	87.45	75.58	+11.87
		Mean	54.66±7.98	54.82±5.17	- 0.61

1 = Figures taken from Table 4.26 2 = Figures calculated from Table 4.11 and Appendix C.56

F = Forage

HC = High Concentrate + forage LC = Low Concentrate + forage.