THE EFFECT OF DIFFERENT LEVELS OF CONCENTRATE AT DIFFERENT PHASES OF LACTATION ON MILK PRODUCTION OF LACTATING DAIRY COWS

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BY

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DECLARATION

This thesis is my original work and has not been presented for any degree in any university.

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DEDICATION

to

My Parents Rael and Abraham Serem,

My Brothers Ben, Isaac and Richard

My Sisters Dianah and Janeth

And to a special friend

Dr. Rael C. Mutai

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ABSTRACT

Eighteen lactating dairy cows were used to determine the effects of reallocation of a fixed amount of concentrates during the different phases of lactation on milk yield (both during period of feeding and total lactation yield) and live weight changes. The cows were randomly allocated to treatment groups as they calved. The design was randomised complete block design. There were two breeds {Friesians (405±21 kg) and Ayrshires (394±18 kg) each with nine cows} and three parities (2, 4 and 6) making six blocks. The cows were randomly assigned to the three treatments. The cows selected were to calve within two months.

Animals in treatment 1 received 2 kg /day of concentrate for 305 days while those on treatment 2 received 4kg/day of concentrate for first 150 days of lactation and those on treatment 3 received 8 kg/day of concentrate for first 75 days of lactation. For cows in treatment 2 concentrate feeding ceased after 150 days and those in treatment 3 after 75 days. This ensured that the same amount of concentrate was used for all treatments. The basal diet was based on pasture supplemented with Rhodes grass hay.

Throughout the lactation of 305 days, milk yields were recorded daily and 2-day composite samples were taken per week over 12 weeks of lactation for fat analysis. The liveweight and body condition scores of the cows were recorded once a week throughout the lactation. Blood samples were obtained from jugular

vein of all the cows for the first 12 weeks of lactation. The blood was analysed for blood urea nitrogen (BUN) and total plasma protein (TPP).

The mean total lactational yields (305 days) were similar for treatment 1 and treatment 2 (2543.6 kg and 2563.2 Kg respectively) but significantly higher ($P<0.05$) for treatment 3 (3155.0 Kg). This difference was attributed to significantly higher yield in earlier phase of lactation (12 weeks) for the treatment 3 group. No differences in yield were noted in later phases of lactation ($P<0.05$). There was no significant effect of level of concentrate on milk fat during the first 12 weeks of lactation.

Live weight changes varied between treatments. All the treatment groups experienced a period of weight loss in early lactation (to 6 weeks) before starting to gain steadily thereafter. In the first phase of lactation cows in treatment 1 and treatment 2 had a negative liveweight gain, -379 and -162 g/day, respectively while liveweight gain of cows in treatment 3 was 187 g/day which was significantly different ($P<0.05$) from the former groups. The mean body condition scores for the whole lactation were 3.00, 2.90 and 2.85 for treatments 3, 2 and 1 respectively. No significant differences ($P>0.05$) were observed in liveweight gain between treatments in the last 230 days of lactation. Treatment 3 had significantly higher ($P<0.05$) body condition score than the other groups in phases 2, 3 and 4. Blood urea nitrogen (BUN) and Total plasma protein (TPP) were not significantly affected by level of concentrate supplementation.

The important finding from this study was that concentrate reallocation to the first phase of lactation improved productivity of the dairy cows at no extra cost. It demonstrated that it is possible to extract 611 kg of extra milk during the cow's lactation by feeding the same amount of concentrate during early lactation at 8 kg/day during the first 11 weeks after calving. The study also showed that concentrate feeding can be withdrawn for the rest of lactation period without lowering milk production below that of cows that continue to be fed at a flat rate of 2 kg/day throughout their lactation.

CHAPTER 1: INTRODUCTION

Smallholder dairy farmers play an important role in the agricultural sector in Kenya. About 77% of the total cattle population is kept by these farmers and produce more than 75% of milk marketed in the country (Mbogoh, 1984; Brumby and Gryseel, 1985; Goldson and Ndeda, 1985; Kenya Government, 1986). More importantly, this sector employs many Kenyans and provides a regular source of income to the farmers (Brumby and Scholtens, 1986). Support targeted at improvement of these farmers would be expected to yield several economic and social benefits including satisfying increasing urban demand for milk, increased incomes to smallholder rural producers and increase in rural employment opportunities (Brumby and Scholtens, 1986).

Currently, almost all smallholder farmers practice mixed farming rather than specialising in dairy farming. Due to the divided attention, milk yields are low (Gitau *et al.*, 1994) estimated at 5 Kg/day (Omore *et al.*, 1996a). Feeding of dairy cattle is often based on crop residues and low quality hay and pasture. This, coupled with low DM intake, (Omore *et al.*, 1996b) exacerbates milk yields.

Since the basal feedstuffs are often low both in protein and energy, there is need for supplementary feeding to meet dairy cattle nutrient requirements. However, these farmers feed their cows concentrate throughout lactation, estimated at 2 Kg/day (Omore, 1996), without achieving peak milk yield and in addition, do not realise commensurate returns to their inputs.

It has been observed that in Kiambu district the lactation curve has a lower peak very early in lactation then collapses in a way that can be explained by a logarithmic function

$$Y_N = 9.93 - 2.12 \; InN$$

Where Y_N is the milk yield in the N^{th} month of lactation (Omore, 1996). Other studies in Kiambu showed the same trend (Staal *et al.*, 1997;Staal and Omore, 1998). They do not follow the conventional lactation curve described by a gamma function such as that of Wood (1969):

$$Y_n = an^b e^{-cn}$$

Where Y (n) is the milk yield in the n^{th} week; a, b, and c are positive parameters of which it peaks after period given by b/c (months).

The peak milk yield is generally held as the major determinant of total lactation yield (Muinga *et al.*, 1995). The relationship between peak yield and total lactation yield has been shown to be linear (Broster and Thomas, 1981). It has been shown that the variation in peak yield accounts for 83% of the total variance in the total yield, whereas variation in persistency accounts for only 12% (Broster and Thomas, 1981). Underfeeding in early lactation not only reduces milk yield at that time but also later in the lactation when the underfeeding has ceased (Broster, 1972; Broster and Strickland, 1977). Farmers in Kiambu do not seem to feed for maximum production (Omore, 1996). The long-term consequence of allowing lactation curve to decline is that it cannot be fully revived.

Smallholder dairy farmers have limited capital available for purchase of commercial concentrate, therefore, selective feeding of concentrates is widespread among these farmers (Kaitho and Kariuki, 1998). Reallocation of the available concentrate to coincide with the milk production requirements during early lactation period appears to be a sustainable option.

The main objective of this study was to investigate the effects of reallocating available concentrate at different stages of lactation on milk yield.

The specific objectives were to investigate the effects of the concentrate reallocation on:

a) Lactation curve
b) Total milk production, body condition score and bodyweight.
c) Blood metabolites (i.e. Blood urea nitrogen (BUN) and total plasma Protein (TPP) and milk composition.
d) Economic implication of this alternative feeding regime.

Null-Hypothesis:

Reallocation of available concentrates does not affect the lactation curve, total milk production, body condition, body weight and blood metabolites.

CHAPTER 2: LITERATURE REVIEW

2.1 Background:

2.1.1 Characteristics of smallholder dairying in Kenya

Smallholder dairying is concentrated in the high agricultural potential areas of Kenya in the Central, Rift Valley, parts of Western and Eastern (around Mt. Kenya) provinces. These areas correspond to the 1500-2500 metre altitude and 1200-2000 mm rainfall isohyet. The high agricultural potential in these areas has led to high human population density (Anindo, 1990) and about 80% of the dairy cattle population are kept here. Consequently, these areas are milk surplus regions (Staal *et al.*, 1997).

Most farmers in these areas keep their dairy cattle under either zero- or semi-zero grazing systems. Land sizes average one hectare per household where livestock keeping is integrated with crop production (Omore, 1996). The most common dairy breeds kept are Friesian, Ayrshire, Guernsey, Jersey and their crosses, though the Friesian constitutes the bulk of the dairy herd (MoALDM, 1995).

Apart from proceeds from cash crops and periodic sales of surplus subsistence crops, the dairy enterprise contributes a significant proportion of the household income through daily milk off-take, but more importantly in the provision of a cheap source of milk for household consumption. Milk offers an alternative source of dietary proteins to majority of Kenyans most of whose staple food is carbohydrate based (Sehmi, 1993). Milk produced from dairy cattle in smallholder farms is for household consumption and surplus milk is sold to neighbours, milk vendors or local dairy co-operatives (Staal *et al.*, 1997).

The proportion of farmers who consider dairying as the most important cash income earner in Kiambu ranged between 40% (Staal *et al.*, 1997) and 58% Methu (1998). This could be due to differences in the performances of different enterprises during different seasons of the year. The importance of dairying as source of income increases as one draws nearer to urban centres.

Constraints to smallholder dairying in Kenya

The Government of Kenya, through the Ministry of Agriculture, Livestock Development and Marketing (MoA), has identified several constraints that hamper the growth and development of the country's dairy sub-sector. These problems, although not entirely unique to smallholder dairying in the country, can be broadly classified into two categories (MoA, 1998) viz. Production and Marketing constraints.

Some of the production constraints to improvement of smallholder dairying in Kenya (MoA, 1998) include (i). Poor disease control and frequent occurrence of tick-borne diseases, which has led to as high mortality as 20% in suckling calves (Peeler and Omore, 1997) (ii). Inefficiency in breeding services (e.g. AI service) and lack of adequate quality breeding stock. Poor breeding programmes as characterised by low use of artificial insemination (AI), lack of alternative source of dietary proteins to majority of Kenyans most of whose staple food is carbohydrate based (Sehmi, 1993). Milk produced from dairy cattle in smallholder farms is for household consumption and surplus milk is sold to neighbours, milk vendors or local dairy co-operatives (Staal *et al.*, 1997).

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Other constraints include (i). Lack of suitable dairy credit system (ii). Diminishing land resource as a result of growth in human population, which means increased competition for land between food and fodder crop production (iii). Unfavourable input/output ratios of the dairy enterprise (iv). Poor management/husbandry practices for the dairy cattle (v). High cost of concentrate feeds (vi). Declining levels of soil fertility due to over-cropping and low application of fertiliser because of low incomes.

2.1.2 Nutritional factors influencing livestock production under smallholder dairying

One of the main factors characterising smallholder dairying in Kiambu is reliance on diverse sources of fodder (Irungu, 1999). Annual biomass distribution is highly variable, associated with erratic rainfall and their quality influenced by many factors. Fodder is cultivated, gathered or purchased from outside the farm.

Among the cultivated fodder is the high biomass yielding Napier grass (*Pennisetum purpureum*) and forage legumes such as *Desmodium spp, Lucaena* *spp and Calliandra spp*. In most cases, fodder (e.g. garden weeds and grass) is gathered on or off the farm, from road reserves and neighbours' farms, or purchased from either neighbours or established roadside fodder markets. Crop residues such as maize stover, wheat straw, bean haulms, sweet potato vine, banana residues and waste from horticultural products complement cultivated fodder.

Dry matter intake is the main limitation to animal production in central highlands of Kenya (Omore *et al*., 1994; Wandera *et al*., 1996) and are influenced by several factors.

First is the seasonal decline in biomass offered in the smallholder farms in dry periods. Animal production in the highlands is greatly influenced by seasonal distribution of annual rainfall and for some months of the year they experience a hot, or warm, dry climate which results in high potential evaporation. The rainfall is usually unreliable to allow continuous crop production. Usually the farm stocking rate is not planned commensurate to the amount of feed available during the dry periods and consequently seasonal consumption is limited by this factor (Preston and Leng, 1987).

Second factor limiting intake is forage digestibility and nutritive value. Digestibility values are associated with climate, mainly temperature, and to the species adapted to tropical conditions, and are difficult to manipulate by man. Other variable determinants of digestibility are forage age, species and varieties used. Tropical forage quality has been reviewed by Minson (1990) who reported average DM digestibilities of 54 and 57% for grasses and legumes and crude protein contents of 9 and 17%. The range of energy digestibility was 53% to 68% (Topps, 1984). Other crops and fibrous resources are complementary to pastures and their quality is highly variable.

A third group of factors influencing intake in current management systems in the smallholder dairying includes: herbage allowance per animal, which is not constant, spatial geographical distribution of feed resources and high amount of erratic feed resource mix. These limit consumption and quality of the feeds. With an appropriate management it is possible to improve intake within the limits of dry matter intake and availability (Leng, 1990).

Mostly tropical forages are limited by metabolisable energy and protein. This means that efficient supplements have to be highly digestible and less fibrous, and furthermore supplies rumen undegradable protein. In addition, it is important to achieve a highly efficient ruminal fermentation which enhances both energy and protein supply. This is mostly limited by nitrogen. It was reported that a positive relationship between ammonia nitrogen (N) concentration in the rumen and intake in forage diets, indicating that restrictions of N to rumen function might be present in this condition.

Protein is the most frequent limiting nutrient in low quality diets. Microbial protein synthesis per unit of fermentable energy is related to consumption (Chen *et al.*, 1992) and is an important factor in low quality fibrous diets, where high responses have been linked with the bypass protein supplementation in cows and growing animals (Leng, 1990).

An imbalance between the final products of digestion in relation to nutrients required by the animal can affect intake and productive response. Calculations by Orskov and Ryle (1990) indicate that glucose is not deficient in most diets at the levels of milk yield in tropical countries therefore the most limiting is nitrogen.

2.1.3 Nutritive value of grass

2.1.3.1 Contribution to energy requirements

Energy intake is closely related to DM intake (NRC, 1989). An increase in annual milk yield per cow can only be brought about by increasing the annual energy intake of the cow, and one of the limitations to increasing the contribution of grass and forage is that their energy density limits intake (Ketelaars and Tolkarp, 1992).

As animal performance and therefore energy requirements are closely related to intake it follows that grass will satisfy energy requirements, but the level of performance will be lower than if a more concentrated feed is fed as supplement (NRC, 1989).

In a lactating dairy cow, intake increases as the ME in the dry matter increases to the level of 11.5-12.0MJ/Kg DM. The relationship between the ME concentration of the diet and ME intake varies, however, for different qualities of forage fed in conjunction with concentrate supplements (Leaver, 1981).

A grazing animal has a range of factors that are likely to influence intake, and consequently the potential intake of the cow is rarely met. These factors are described by the equation:

Actual intake = Potential intake - Feed constraints - Environmental constraints.

Potential intake is determined by animal factors, feed constraints refer to herbage availability, quality, contamination and supplementary feeding and environmental constraints include weather and day length. The relationship between herbage intake and digestibility appears to be linear up to 80 per cent digestibility, but at equal digestibility there is a considerable variation in the intake of herbage.

ME concentrations of 12.0MJ/Kg are only achieved in the first few weeks of grazing season, followed by decline to 11.0-11.5MJ/Kg DM in mid season, and to 10.5-11.0MJ/Kg DM in late season. In addition the ME may fall to less than 10.0MJ/Kg DM during dry conditions (Leaver, 1980). As a consequence of this decline in quality, and to the increasing amount of herbage contamination by dung and soil, the shorter day lengths and the more inclement weather, intakes normally decline as season progresses (Le Du *et al.*, 1979)

A major factor affecting the intake of grazed herbage is its availability. In rotational grazing systems, intakes of herbage are reduced when the daily herbage allowance falls below 8-10cm (Le Du *et al.*, 1979). In set stocking systems, intakes are reduced when herbage heights are less than about 9 cm (Leaver, 1980).

The smaller bite size of the short-leafy material compared with the longer material in rotational grazing which is more easily prehended, means that the cow has to graze for longer periods and /or faster to obtain the same DM intake as under rotational grazing conditions. The cow will normally graze for only 8-9h/day where ample herbage is available (Leaver, 1981). The rate of intake with set stocking is likely to be less than the 30g DM/min observed for rotational systems, and as a consequence set stocking systems are unlikely on average to support more than maintenance plus 7 Kg/day of milk, whereas rotational systems will support maintenance plus 10 Kg/day where other constraints are not imposed.

The limitations imposed by grazing have meant that supplementary feeding is common practice. In the short term, responses to supplementary concentrates are not economical, averaging 0.3Kg milk /Kg concentrates (Leaver *et al.*, 1968). However, where herbage availability is restricting intake, and where the cows have a milk yield potential above that which the grazed herbage can satisfy, much higher responses to concentrates can be obtained (Journet and Demarquilly, 1979)

In unrestricted grazing or zero grazing conditions, therefore, total DM intakes are likely to be 25-30gDM/Kg live weight but, due to constraints intakes of herbage in practice may be only 20-25g DM/Kg live weight under unsupplemented grazing conditions for a high producing cow. If supplements are fed, intakes of herbage DM will be further reduced (Leaver, 1981).

2.1.3.2 Contribution to protein requirements

The crude protein content of grazed grass is generally high (15-25 percent in DM), although a proportion of this is in form of non-protein nitrogen (Leaver, 1981). Protein requirements of dairy cows on a rumen degradable protein basis (RDP) and undegradable protein (UDP) basis (ARC, 1980) confirms that the protein supply from grazed grass is generally adequate. In early lactation, however, when intakes are low, it is possible that the deficiencies in protein supply might occur in high yielding cows (Leaver, 1981). Since energy supply is also likely to be limiting, supplementary feeding is likely to be offered which could be used to offset any deficiencies in UDP supply. Feeding trials where protein supplements have been fed to dairy cows with no response in milk yield (Castle *et al.*, 1979) tend to confirm that grazed grass in general can contribute the entire protein requirements of dairy cows.

2.1.3.3 Contribution to mineral requirements.

The content of major minerals in grazed herbage varies according to soil type, soil pH, fertiliser and slurry applications. In Kenya little attention has been paid to soil analyses and any deficiencies of lime and minerals are not overcome, therefore deficiencies of major minerals in grazing dairy cattle occurs depending on the deficient minerals in the soils. The most likely deficiency to occur is magnesium.

2.2 Factors affecting milk production

The level of milk production of a cow is determined by an interplay of several factors including ovarian steroids and the anterior pituitary hormones. Genotype, previous lactational level of nutrition, stage of lactation and age are important factors influencing the physiological status of a cow and its ability to produce milk (Anindo, 1990). The prevailing level of nutrition and the type of diet influences the amount and the nature of the nutrients presented to the animal which, in turn, influences milk synthesis and secretion.

2.2.1 Plane of nutrition

High milk yields require ample nutrient intakes with appropriate distribution of feed over the lactation (Orskov and Dolberg, 1984). Nutritional limitations impose severe restrictions in milk production. Maximum voluntary intake, or appetite, is lower in early lactation than in mid lactation yet it is in early lactation that milk yield reaches its peak (Balch, 1984). This is because the rumen capacity is low in early lactation. Consequently, the shortage of nutrients for cattle, for some periods of the year can hinder the realisation of the potential milk production particularly if it happens early in lactation. The high yielding cow can, however achieve high yields in early lactation even when feed supply is sub-optimal, by mobilising body reserves (Anindo, 1990). In general, nutrient requirement for the lactating cows must be met every day if the potential yields are to be achieved. Any prolonged drop in milk yield resulting from undernutrition cannot be subsequently fully compensated for when nutritional level is improved (Broster and Strickland, 1977). Since milk yield reaches its peak in early lactation, the ability of the cow to augment the inadequate voluntary feed intake, characteristic of early lactation, by mobilising body reserves may well determine whether the cow qualifies as a good cow of high production ability (Balch, 1984).

2.2.1.1 Milk production from pasture.

Studies by Mukisira and Khasiani (1978) showed an increase in milk production from 9.06 to 11.63 kg by supplementing Friesian cows on Rhode grass with a legume (*Stylosanthes guianesis*). In a study covering the whole lactation, Irungu and Mbugua (1978) fed Friesian cows concentrates at the rate of 0, 1.20, 2.49 and 5.12 kg and reported a milk production levels of 9.95, 12.85, 12.81, and 12.81 kg, respectively. The two studies cited indicate that it is possible to obtain about 9 kg of milk from pasture. In another study, Kariuki *et al.*, (1991) supplemented dairy cows with either 2.8 kg of commercial dairy meal or 3.8 kg of ground maize grain per day and obtained milk yields of 12.7 and 14.5 kg per cow per day, respectively. One kg of commercial concentrate was able to support production of 4.8 kg of milk while one kg of maize grain supported production of 3.9 kg of milk. The basal diet fed the study animals was a sward of Rhodes grass and clover (*Trifolium semipilosum*) that had a crude protein concentration of 144 g per kg dry matter. The response in milk yield per gram of protein supplementation was 29 and 51g for the commercial concentrate and maize grain, respectively. This implies that under this feeding program, energy was more limiting to milk production than protein. Mukisira *et al* (1985) fed Friesian cows an average of 3.3 kg of concentrates per day and obtained an average milk yield of 12.1 kg per cow per day. The protein content in the concentrates used in this study was 220 g per kg, which was higher than the concentration obtained in commercially produced dairy meal.

2.2.1.2 Supplementary feeding

2.2.1.2.1 Objectives of supplementation in smallholder dairying

Supplementation plays an important role to satisfy restrictions in the base diets used by smallholder dairy farmers in Kiambu and their objectives could be grouped in three, associated to the restrictions that they are intended to solve: (i). Complement biomass seasonal restrictions (ii). Supplement nutrient deficiencies in the base diet and (iii). Increase diet energy concentration.

2.2.1.2.2 Complement biomass seasonal restrictions

This is the main objective of supplementation in areas with periods of feed shortage. In occasions the complement constitutes the main component of the diet and is not considered a supplement. Nevertheless, it is a supplement during a limited period of time if nutrients are not supplied in enough quantity by the basal diet.

The objective is to increase animal consumption using different feed options for supplementation of energy and other nutrients during different seasons of the year. The feeds most frequently used are: (i) Complementary crops- forages (ii) Conserved forages- hays and (iii) Crop by-products- Maize stovers, Banana leaves etc.

2.2.1.2.3 Supplement nutrients to the base diet

Urea and other NPN sources, such as poultry litter, can supply the Nitrogen (N) element and are aimed to improve rumen function. The most frequent situation in smallholder conditions is N deficiency during the dry season, where water restrictions limit the regrowth of pastures and old tissues constitute a high proportion of feed available. N supplementation in these conditions has a very limited impact in animal response because of limited dry matter. Rumen function is improved and there is a small increase in digestibility, but the main effect of this supplementation is a large increase in intake that is limited by restrictions in biomass offer during the dry season (Preston and Leng,1987). Consequently, N supplementation has to be accompanied by the supply of a feed resource supplying organic matter.

Other nutrients that may be deficient in forage based diets are minerals. Frequently sodium and occasionally calcium and phosphorous and other elements are below requirements and must be given as supplements, but as was pointed out by Preston and Leng (1987), mineral deficiencies should not be primarily considered to improve and develop production strategies. Deficiencies in feeds and their utilisation must be first satisfied and some of the resources used in this supplementation may also supply minerals, restricting the use of expensive mineral mixtures to correct for deficiencies.

The factor limiting milk yield to the levels achieved with tropical forages is energy, especially in early lactation (Muinga, 1992). To increase the level of production the energy concentration in the diet should be improved using supplements. Concentrate supplements are generally associated to the use of starch rich sources and may decrease the consumption and utilisation of the forage. This type of supplement is also commonly used to fulfil biomass deficiencies and other nutrients in the diet especially energy, but it is an expensive way to solve this problem.

2.2.1.3 Concentrate feeding and Peak milk yield

The overall response in milk yield to the level of concentrate feeding given to dairy cows during early lactation is greatly affected by the extent to which residual effects on milk yield persists during later lactation. The level of nutrition during the first few weeks of lactation have a major effect on total lactation performance (Broster, *et al.*, 1975) and that peak yield is a dominant factor in the whole milk yield performance (Broster and Strickland, 1977; Muinga, 1992).

Peak yield accounts for 66-80% of variance in total lactation yield and persistency accounts for only 8-12% (Broster, 1974). Some evidence (Broster, 1972; Broster and Strickland, 1977) shows that underfeeding in early lactation not only reduces milk yield at that time but also later in lactation when the underfeeding has ceased.

Supplementation with concentrates in the early phase of lactation would therefore satisfy the nutrient requirements for milk production during this period and consequently attaining higher peak at this period and high total lactational yield.

2.2.1.4 Constant rate versus graded concentrate feeding

Several trials have not shown a beneficial effect on total lactation yield from the feeding of concentrates according to a high/low system instead of a uniform daily allowance (Rakes and Davenport, 1971; Strickland, 1975; Ostergaard, 1976; Gordon, 1978). Most experiments showed a positive residual effect but a few showed a negative effect, including notably some trials in which protein supply was varied in early lactation (Oldham *et al*., 1979). Further evidence suggests that a flat rate feeding of concentrates given to all cows will produce similar mean levels of performance to those obtained with feed to yield system (Ostergaard, 1979; Steen and Gordon, 1980a; Gordon, 1982). There is ample evidence that the milk yield of a cow responds to changes in energy supply (NRC, 1989). Provided there is no change in body weight, milk output will be linearly related to energy input, although the level of feeding effect can induce curvilinearity (NRC, 1989). However, in practice, the cow responses to changes in energy supply in terms of both milk output and body weight changes are such that an increase in the intake of energy produces a negatively curvilinear response in milk and a positively curvilinear response in body gain (Broster *et al*., 1978). This effect is not confined to concentrate energy consumption. Similar effects are noted when energy input is increased by means of increasing the digestibility of conserved forage given to the cows over weeks 4-18 of lactation (NRC, 1989).

Increasing levels of fixed amounts of concentrate daily in early lactation was reported to cause greater peak yield and delay in lactation period when this peaking occurs (Broster *et al*., 1969). In mid lactation the persistence of the yield were equal but at different mean yields. Similar results were reported by Broster *et al*., (1975) and over 36 weeks of lactation, by Broster *et al*., (1978).

Johnson (1977) fed 2 fixed daily amounts of concentrate over weeks 1-20 of lactation. The high level led to a clearly defined peak yield in early lactation while lower level showed a steady decline in yield from calving onwards at the same rate as that shown post peak by the more generously fed group. In this experiment, 2 further sequences were applied which weighted concentrate towards early lactation at the cost of reduced allowances in mid lactation in order to equate total dairy concentrate. Greater peak yield and more precipitate falls in mid lactation resulted from this. Johnson (1979) fed 2 rates of compound/unit milk produced to cows of high and low milk potential. The rates were in general higher for the latter, and induced a better persistency of yield. Cows fed according to current yield exhibited an enhanced peak yield and a reduced persistency (Strickland and Broster, 1981).

2.2.1.5 Phase feeding system

Phase feeding is a feeding program divided into periods based on milk production, milk fat percentage, feed intake and body weight. Based on the trend of the above parameters five distinct feeding phases of lactating cows can be identified.

2.2.1.5.1 Phase 1: Early lactation, 0 to 75 days postpartum

Milk production usually peaks between 4 and 8 weeks postpartum, yet maximum dry matter intake (DMI) usually occurs between 10 and 14 weeks postpartum (NRC, 1989). This rise in feed intake may not occur if the cow is fed a diet containing less-than-optimal degradability (Oldham, 1984). The lag of maximum DMI behind peak milk yield causes a negative energy balance in early lactation, the cow consequently mobilises body tissues, particularly fat deposits, to overcome the energy deficit which results in weight loss (NRC, 1989). During this phase, adjusting the cow to the milking ration is an important management practice.

Protein content is critical during early lactation (Oldham *et al.*, 1979). Meeting or exceeding the crude protein requirements during this period helps to stimulate feed intake and permits efficient use of mobilised body tissue for milk production. Rations may need to contain 19% or more crude protein to meet the requirements during this phase.

When early lactation nutrient needs are not met, low peak production and ketosis may result.

2.2.1.5.2 Phase 2: Peak dry matter intake, 75 to 150 days postpartum

During this phase, cows should be fed to maintain milk production as long as possible. Feed intake is near maximum and can supply nutrient needs (NRC, 1989). Cows should be maintaining weight or making slight gains. Potential problems during phase 2 include drop in milk production, low fat test, silent heat periods and ketosis.

2.2.1.5.3 Phase 3 and 4: Mid- to late-lactation, 150 to 305 days postpartum

This is the easiest phase to manage the cow. During this period, milk production is declining, the cow is pregnant, and nutrient intake will easily meet or exceed requirements. The level of grain feeding should be adequate to meet production requirements, and to begin to replace body weight lost during early lactation. Lactating cows require less feed to replace a kilogram of body tissue than dry cows: hence, it is more efficient to have cows gain body weight near the end of lactation than during the dry period (NRC, 1989).

2.2.1.5.4 Phase 5: Dry phase, 45 to 60 days before parturition

The dry phase is an important period in preparation of the cow's subsequent lactation performance. A good dry cow feeding program can minimise metabolic problems at or immediately following calving and increase milk yield during the subsequent lactation (Smith and Guthrie, 1995).

2.2.1.6 Phase feeding of lactating dairy cattle in Kenya

There are few studies carried out in Kenya on the effect of phase feeding on milk production carried out in Kenya. Njenga and van Oers (1974) fed a group of 8 cows six kilograms of commercial concentrates per day in the first 100 days of lactation and then three kilograms per day in the next 100 days. The control group (8 cows) received 3 kg of the concentrate per day in the first 200 days of lactation. Van Oers (1976) carried out a similar study involving 42 cows and covering the full lactation. The lactation was divided into five periods, each of 60 days. In the first of two feeding regimes, each cow received 6 kg of commercial concentrates per day in the first two periods followed by 5, 2, and 1 kg in periods 3, 4 and 5, respectively. In the second feeding regime, 4 kg of concentrate were offered per day in each period. Total concentrate consumption was 1,200 kg for each regime. The milk yield for the first regime was 4,728 kg while in the second regime it was 3,976 kg. In this study, phase feeding improved milk production by 19 %. The efficiency of concentrate utilisation was better in the phase-fed animals than in those animals receiving a uniform amount of concentrates throughout the lactation.

2.2.1.7 Carry over effects of feeding

Gordon (1978,1981a, b) showed that both immediate and residual effects (residual effect is the prolongation of the effects of differential feeding after this itself has ceased) varied with the basal plane of nutrition to which supplements are added. Residual effect were absent with *ad lib* feeding of pasture (Gordon, 1980a; Leaver, 1980). Le Du *et al.*, (1979) encompassed both limited and generous pasture allowances in one study and demonstrated residual effects with the latter but not the former regime.

Several experiments have shown negative residual effect (no prolongation of the effects of differential feeding after this itself has ceased) with moderately to high planes of nutrition (Steen and Gordon, 1980a; Laird *et al.*, 1981) many of which involved pasture feeding in the recovery period when concentrate feeding has ceased. These negative residual effects could be due to compensatory intake effects following the period of reduced intake. A negative residual effect could also develop from an effect of previous feeding on digestibility of herbage and efficiency of nutrient utilisation in the recovery period, following very generous dairy concentrate. Digestive and metabolic upsets that may arise from overfeeding could also be potentially involved in negative residual effects.

Trials by Gordon (1981 a, b) demonstrated curvilinear immediate and total responses/additional Kg of concentrate feed as the basal ration is increased that is. It demonstrates that as the amount of basal diet increases the responses to increase in concentrate level reduce. It follows that there is less prolongation of the effects of the increased levels of concentrate probably curvilinearily and Gordon (1981a, b) noted that residual effects become zero above 7Kg compound fed in addition to *ad lib* silage of 0.68 DM digestibility, a high quality diet of good intake characteristics.

2.2.2 Genotype

Milk production of a cow is governed by the inherited genetic characteristics of a cow. Different breeds of cows have been shown to produce different quantities of milk when they were compared under the same environment (McDonald *et al.*, 1989).

The wide range in milk yield in Kiambu (Staal *et al.*, 1997) can be attributable to differences in genotypes such as the indigenous (*Bos indicus*), the exotic (*Bos taurus*) and the crosses. In the absence of serious nutritional or environmental stress, the respective descending order of milk yield among cows under the same conditions is Friesian, Ayrshire, Guernsey and Jersey (Mupeta, 1998). The exotic breeds have a high milk potential as compared to indigenous ones (Norval *et al.*, 1992).

Studies with dairy cows have demonstrated that within a group of cows of the same breed the potential for milk production may vary and that the amount of milk produced by the cow depends on feed intake, milk secretion and body tissue anabolism (Broster *et al.*, 1975). The cow normally divides her nutrient intake into, maintenance requirements, live weight gain, milk production and reproduction (Broster, 1972). Thus when two cows of different milk production potential are offered the same amount of feed, different partitioning of nutrients may be observed. The cow of low dairy merit is likely to channel most of the ingested feed towards body tissue anabolism with substantial live weight gain and low milk yield while the cow with high dairy merit may mobilise her body reserves to supplement dietary nutrient intake to realise her milk potential (Broster *et al.*, 1975).

Studies conducted in Kiambu District showed that the individual exotic cows failed to produce to their genetic potential in the environment because of feed and management constraints facing the smallholder sector (Staal and Omore, 1998).

2.2.3 Age and body size

Milk yield increases (at a decreasing rate) until about the 8th year of age and then it either decreases at an increasing rate or maintained at a relatively constant level (Winters, 1997).

Mature cows produce about 25% more milk than 2-year-old heifers. Increased body weight accounts for about 20% of this increase. The remaining 80% results from increased udder development during recurring pregnancies (Winters, 1997).

Heifers should be bred to calve at 24 months of age or earlier if they are of sufficient size to permit delivery of the calf. Although heifers will produce more milk during the first lactation if breeding is delayed to the point where she calves after 30 months of age, total lifetime production will be reduced (Hanson *et al*, 1983).

Large cows generally produce more milk than small cows, but milk yield does not vary in direct proportion to body weight. Rather, it varies by the 0.7 power of body weight, which is an approximation of the surface area of the cow (metabolic body size). A cow, which is twice as large as another usually, produces only about 70% instead of 100% more milk (Winters, 1997)).

Clark and Touchberry (1962) stated that environmental conditions that are conducive to large size also contribute to high levels of production. Therefore, large cows may give more milk, not only because they are large, but also because they are maintained under better management conditions than small cows.

The response in milk to feeding is greater in higher than lower yielding cows. Some dissidence of this consensus exists (Broster *et al.*, 1981); the argument is that the response is equal for all yield capacities when change in intake is expressed as allowance of compound feed.

Some findings (Gordon, 1984;Moisey and Leaver, 1984) appear to conflict with the well established fact that the cows of high-yield potential give a greater response to a change in energy input than do cows of low potential (Broster, *et al.*, 1975). Also high potential cows have been shown to exploit their potential better when given high rather than low planes of nutrition (Johnson, 1979; Strickland, 1980). However those experiments were carried out with forage at a fixed level and therefore changes in concentrate input affected energy intake.

2.3 Effects of feeding on live weight change

Milk production usually peaks between 4 and 8 weeks postpartum, yet maximum DMI usually occurs between 10 and 14 weeks postpartum. This rise in feed intake may not occur if the cow is fed a diet containing less-than-optimal amounts of dietary protein of less-than-optimal degradability (Oldham, 1984). The lag of maximum DMI behind peak yield causes a negative energy balance in early lactation; the cow consequently mobilises body tissues, particularly fat deposits, to overcome the energy deficit, which results in weight loss.

The pattern of live weight change over the lactation period is well defined. A fall in live weight occurs in the first few weeks after calving followed by a period of gain (NRC, 1989).

In early lactation more generous feeding reduce body weight losses (Strickland and Broster, 1981). This occurs also in mid lactation for cows but not for heifers. Cows fed according to yield show accelerated body losses in mid lactation. Broster *et al.*, (1969,1975), Gleeson (1970) and Le Du *et al.*, (1979) showed that the more generous plane of nutrition in early lactation benefited live weight change at this time, either reducing losses or increasing gains. In mid lactation there was a reverse effect, the previously less generously fed animals gained more weight in mid lactation than did the previously better fed animals. This occurred with equal diets in mid lactation as well as restricted grazing. Grainger *et al.*, (1982) reported that improved feeding in weeks 1-5 of lactation conserved body tissues, but better body condition at calving was associated with greater body loss in this period. In weeks 6-20 on equal feeding, change in body score was inversely proportional to feeding level in weeks 1-5 and the cows in better body condition at calving continued to lose more body weight. Body gain in mid lactation following underfeeding in early lactation constitutes a change in partition of nutrients of the cow (Bryant and Trigg, 1979).

With constant amounts of feed/day the differences between the different allowances decline from weeks 1-9 to weeks10-18 (Broster *et al.*, 1969,1975). Johnson (1977), contrasting high and low fixed amounts of feeds, found broadly similar trends to these but later he reported relatively constant live weights over the experimental period of weeks 1-20 of lactation (Johnson, 1979). The small losses of live weight in the first 2-4 weeks post caving were not statistically significant. Thus, a residual effect occurred of the opposite trend to that shown by milk yield.

2.4 Body condition score: Its importance as an indicator of feeding

Body condition scoring (BCS) is a subjective method of assessing the amount of metabolisable energy stored in fat and muscle (body reserves) in a live animal (Grainger and McGowan, 1982; Lamont *et al.*, 1984; Wright and Russell, 1984). However, it can be related to objective measures of biological change such as fat deposition and its mobilisation (Richards *et al.*, 1986; Wildman, 1979). Cattle condition scores have been related to milk yield (Grainger and McGowan, 1982; Grainger *et al.*, 1982) and reproductive performance (Baishya *et al.*, 1982; Ducker *et al.*, 1984; Ducker *et al.*, 1985; Garnsworthy *et al.*, 1982; Grainger and McGowan, 1982; Macmillan and Bryant, 1980; Richards *et al.*, 1986). Body condition scoring therefore is a valuable tool in evaluating dairy rations and feeding. It may also be used to evaluate the impact of various management practices and changes on herd performance.

The change in condition score follows the pattern of live weight change in dairy cattle (Johnson, 1984), and live weight change is associated with changing condition score (Grainger and McGowan, 1982; Frood and Croxton, 1978). Surface profiles of cows around the loins and rump have been correlated with body condition score (Grainger and McGowan, 1982) and weight. Frame measurements have been correlated with body condition score (Wildman *et al.*, 1982).

In production systems based on high quality forages with adequate protein, the highest lactation yield is achieved from condition score at calving of 3.5-4.0 (Edmonson *et al.*, 1989) on scale of 0 to 5.

Cows in higher condition (4-4.25) are at greater risk of metabolic disorders such as ketosis because these cows have reduced intakes postpartum and are more reliant on mobilised tissue for milk production, an indication that cows should not be overconditioned (Lean *et al.*, 1993).

Routine postpartum losses of greater than 1.0-1.25 BCS units are cause of concern (Lean *et al.*, 1993). Large negative energy balances postpartum are associated with reduced fertility. Animals should be managed to ensure adequate energy intake for maintenance, growth and production. Where dry matter intake is depressed in early lactation, the energy density of the ration should be increased in an attempt to limit body condition loss (NRC, 1989).

Cows are expected to lose body condition in early lactation (less or equal to 1. 0 unit), be gaining by mid lactation, and should be returned to optimum body condition score by drying or calving. The most energetically efficient method of increasing body condition is to feed rations of higher energy density during late lactation (Grant and Keown, 1999).

A change of 1.0 BCS at calving was associated with a change of 182 Kg total yield in months 1-7 of lactation a change of 25 Kg live weight (Frood and Croxton, 1978).

Neilson *et al.*, (1983) observed that the fattest group of cows lost the most fat during early lactation and have lower dry matter intakes and the differences between the groups in fat losses diminished as the lactation progressed. Garnsworthy and Jones (1987) found that body condition score change correlated with cumulative negative energy balance and this has an effect on performance in dairy cows. Body condition change is reflective of change in carcass composition and also energy utilisation in dairy cows and thus can serve as a useful proxy in the field for assessing energy management.

Grainger *et al.*, (1982) demonstrated that linear improvement of BCS improved yields of milk, protein and fat in weeks 1-20 of lactation; fat concentration in the milk was improved in weeks 1-5 but not thereafter, with progressively greater improvement as BCS increased. Increased BCS at calving was associated with greater BCS reduction in weeks 1-20, an effect also superimposed on the effect of early lactation feeding level. The benefit from improved body condition at calving was less than that from additional feeding in late lactation. There is a broad additive effect of pre and post calving feeding (Grant and Keown, 1999).

The interpretation is that both BCS and live weight respond to additional pre calving feeding and are associated with greater milk yield subsequently, but pre-calving feeding may not affect subsequent performance (Cowan *et al.*, 1981)

2.5 Effect of feeding on milk fat content

There is a definite breed order in relation to milk fat which is the reverse of that of milk yield i.e. Holstein (3.75%) Friesian (3.8%) Ayrshire (3.9%) Guernsey (4.63%) and Jersey (5.18%) (McDonald *et al.*, 1989). Strain and individuality of cows have an important effect on milk composition. As the age of the cow increases, the milk fat concentration decreases. Fat content is relatively constant for the first four lactations, and then decreases gradually with age (McDonald, 1989).

Advancing lactation has a marked effect on milk fat, which is lowest during the period when the yield is highest (NRC, 1989). In the early lactation period milk fat content is low and then improves gradually until the last three months of the lactation when the improvement is more rapid (NRC, 1989).

Altering the forage to concentrate ratio can result in substantial changes in milk fat percent. Increasing the proportion of concentrate in the diet results in greater propionic acid production, which in turn leads to increased odd chain and branched chain fatty acids as well as enhanced gluconeogenesis. As the proportion of concentrate is increased milk fat, percent tends to decline with the effect being particularly pronounced as the level of concentrate exceeds 50 to 60% and a concentration of 15-20% ADF in the diet on a dry matter basis (Mcdonald *et al.*, 1989). The reduction in milk fat percent has been attributed to lower ruminal production of fat precursors (acetate and -OH-butyrate) as well as an inhibitory effect of methyl malonyl CoA (produced from propionic acid) on fatty acid synthesis in the mammary gland (Sutton *et al.*, 1986,1989). Broster and Thomas (1981) showed that milk fat content fell at each level of DE intake as the proportion of concentrate was increased from 60-90%. The consequence is that no single proportion of roughage or fibre content in the diet can be recommended for maintaining milk fat content, the higher the level of feed intake, the higher the fibre content necessary to maintain a given fat content. The feeding system and frequency of feeding influence the extent of milk fat depression associated with high levels of concentrate feeding. In general, the impact will be less where total mixed rations are fed and/or if feed is offered three or more times daily. Basal diet changes the composition of milk and as Oldham and Sutton (1979) indicated, milk fat is very responsive to changes in diet. The major effect of feeds on milk butterfat test is associated with the level of fibre and the physical form of the feed. Coarse or 'effective' fibre has a scratching effect on the wall of the rumen. This causes the cow to bring feed up from the rumen and chew her cud. This chewing action causes a large amount of saliva flow into the rumen. Saliva is a natural buffer and creates conditions in the rumen necessary for the production of butterfat.

A number of studies have demonstrated that forage chop length and particle size of the concentrate influence milk fat percent by altering the effective fibre in the ration. Effective fibre in the diet is important to ensure optimum rumen conditions for cellulolytic bacteria and to promote adequate rumen motility. As effective fibre declines below the optimum level, milk fat depression will occur (Sutton and Morant, 1989)

Feeding cows less frequently especially if the concentrate is fed separately from the forage results in reduced ruminal acetate: propionate ratio, which in turn can result in reduced milk fat percent (Sutton and Morant, 1989). The impact of feeding frequency on milk fat percent is influenced by level of concentrate, feed intake, stage of lactation and the overall milk fat percent in the herd.

Feeding management can influence animal behaviour and consequently meal size and feeding frequency (Sutton and Morant, 1989). Thus, if cows are fed to a non nutritious feed, they will tend to consume a larger meal, which could result in milk fat being depressed in a similar fashion to infrequent feeding of concentrate.

Starchy concentrates will tend to result in greater propionic acid production compared to fibrous concentrates (Sutton and Morant, 1989). Thus, including a fibrous concentrate to replace a starchy concentrate can result in increased milk fat percent (Sutton *et al.*, 1980), probably due to an increased acetate: propionate ratio. Increases in rumen propionic, less certainly, glucose from postruminal starch digestion probably stimulate insulin release that depresses milk fat synthesis indirectly by increasing adipose tissue lipogenesis (Annison, 1976)

2.6 Effect of feeding on Blood Urea Nitrogen (BUN)

When forage quality is low, a deficiency in protein (nitrogen) intake can limit dry matter utilisation and intake (Hongerholt *et al.*, 1998). However, providing supplemental protein to cattle consuming low quality forage (low protein and low energy content) may or may not increase forage dry matter intake depending on the energy to protein ratio of the forage (NRC, 1989). The optimum ratio of digestible organic matter: Crude protein is 7: 1 (Moore, Bowman and Kunkle, 1995). Under feeding system where supplementation causes substitution effect and therefore causing changes in nutrient composition, it is difficult to assess the DOM: CP ratio of the consumed feed (Moore, Bowman and Kunkle, 1995). Body weight and body condition score may indicate that over time nutrient intake has been deficient, but without knowledge of the feed composition and intake, the response to supplementation cannot be predicted with certainty. In this situation, a metabolic indicator of the protein and energy status could be helpful in making nutritional management decisions. An example of such an indicator is blood urea nitrogen.

Digestible protein in the diet of ruminants is either degraded in rumen or escapes to the abomasum and small intestine where it is degraded to amino acids and small peptides then absorbed into the portal system. Nitrogen from the protein that is degraded in the rumen is used for microbial protein synthesis either by incorporation of ammonia nitrogen that arises from deamination of amino acids. Non protein nitrogen (NPN) such as urea also can be made into ruminal microbial protein following enzymatic conversion or breakdown of the NPN to ammonia in the rumen. Yield of microbial protein produced in the rumen is maximised when the ratio of available energy (fermentable organic matter) to protein (nitrogen) is optimised (Hammond, 1983). When there is an excess of nitrogen relative to energy in the rumen, ruminal ammonia concentration increases. Unused ruminal ammonia enters the portal blood through the rumen wall and is transported to the liver where it is detoxified by conversion to urea. The liver also produces urea from deamination of amino acids arising from the post ruminal digestion and systemic turnover. Urea then circulates in the blood to kidneys and is excreted with urine or it can diffuse from the blood back into the rumen, into saliva and back into the rumen, or diffuse from the blood into milk in the case of lactating females. When there is a deficiency of dietary protein, ruminal ammonia concentrations are relatively low and the proportion of nitrogen recycled back to the rumen as urea is increased as a result of these metabolic transactions. Blood urea nitrogen (BUN) is highly correlated with ruminal ammonia (Thornton, 1970; Hammond, 1983;Hennesy and Nolan, 1988). Therefore, in healthy ruminants BUN concentrations are indicative of the protein to energy ratio in the diet (DOM: CP), the ratio of dietary CP to ruminally fermentable OM (Oltner *et al.*, 1983; Oltner *et al.*, 1985) and postruminal protein metabolism (Higginbothan *et al.*, 1989). BUN may serve as an indicator of ruminal protein degradability (Barbano *et al.*, 1991) and postruminal protein supply (Roseler *et al.*, 1993).

Towards calving, total plasma protein (TPP) decrease and the blood urea nitrogen (BUN) increases probably due to insufficient energy (Mulei, 1991). This could be due to an increase in amino acid deamination with subsequent increase in BUN concentrations (Prior *et al.*, 1979). Decrease in TPP concentration towards calving is a common phenomenon in dairy cows. This is mainly due to transfer of immunoglobulins from the plasma into colostrum (Mulei, 1991).

2.6.1 Dietary and nutritional factors affecting BUN in cattle under controlled feeding situations.

When energy intake is held constant, increasing dietary protein increases

BUN concentrations. For growing steers, BUN levels between 11 and 15 mg/dl were associated with maximum rates of gain (Byers and Moxon, 1980). With finishing steers, maximum performance was associated with BUN concentrations of 7-8mg/dL (Preston, *et al*, 1978). Balanced diets for lactating dairy cows were associated with average BUN concentrations of 15 mg/dl (Roseler *et al*., 1993).

Increased solubility or degradability of dietary protein can lead to increased ruminal ammonia concentrations resulting in increased BUN concentrations (Hammond, 1983). In lactating dairy cows, an imbalance of degradable and undegradable protein intake increased BUN (Roseler *et al*., 1993). Similarly an imbalance of ruminal undegradable protein increased BUN in lactating dairy cows, but this increase was not as great as increase in BUN caused by excess CP (Baker *et al*., 1995).

Increasing dietary energy intake while holding protein intake constant would be expected to decrease BUN (Chase *et al*., 1993). At the high level of energy intake, BUN averaged 5. 6 mg/dl and at the low level of energy intake BUN averaged 19.7 mg/dl. Increased frequency of feeding has been associated with lower BUN (Thomas and Kelly, 1976) probably due to more efficient use of nitrogen in the rumen.

2.6.2 Other Factors Affecting BUN

Addition of sulphur to diets of cattle deficient in sulphur resulted in decreased BUN concentrations associated with increased animal performance (Kennedy and Siebert, 1972). This is because sulphur improves nitrogen retention by animals and also improves its utilisation by rumen microbes for amino acid synthesis and therefore less goes into blood circulation as ammonia. This reduces urea in blood.

Other factors that may affect BUN concentrations other than diet include health of the animal, physiological state, use of growth promotants, and breed (Rodriguez *et al.*,1997, Eismann *et al.*, 1989). The magnitude of the differences caused by these factors, except for certain disease conditions, is generally less than the dietary factor but the differences can be significant. Severe nutritional depletion as a result of prolonged under nutrition (Ward *et al.*, 1982; Hayden, *et al.*, 1993) or disease (Julien *et al.*, 1977) can cause catabolism of tissue protein and result in high concentrations of BUN.

In dairy cows, BUN increased as cows progressed from the dry stage through early lactation and the lactating pregnant period, and BUN increased with increased age (Peterson and Waldern, 1981). In beef cattle, the use of growth promotants generally decreases concentrations of BUN (Eismann *et al.*, 1989; Galbraith, 1980;Preston, Byers and Stevens, 1978). Use of feed additives such as monensin to increase feed efficiency has resulted in no change (Steen *et al.*, 1978) or small increases in BUN (Raun *et al.*, 1976;Thompson and Riley, 1980).

Lower concentrations of BUN in Hereford cows compared to Senepol cows (Hammond *et al.*, 1992) and lower concentrations of BUN in Angus bulls compared to Senepol bulls (Chase *et al.*, 1993) were observed suggesting differences in protein utilisation between breeds. Similarly, others have observed lower concentrations of BUN in Hereford compared to Brahman cattle (Hunter and Siebert, 1985), lower BUN in Angus compared to Brahman (Olbrich, 1996), and lower BUN in Angus x Hereford cattle compared to Brahman crosses (Coleman and Frahn, 1987).

2.6.3 Approaches and applications of BUN

Concentration of BUN of dairy cows is an indicator of the nutritional status as a retrospective diagnostic tool to analyse biological responses to protein or energy supplementation, change in pasture or forage on offer, or change in pasture management (Hammond *et al*., 1992). Another possible approach to using BUN is to make time adjustments in feeding or grazing management (Hammond *et al*., 1994). Time and amount of feed is determined by results of BUN analysis.

2.6.4 Effect of BUN on Reproductive Efficiency

High dietary protein (nitrogen) intake resulting in BUN of greater than 19 - 20mg/dL has been associated with an altered uterine environment and decreased fertility (reduced conception rate) in lactating dairy cows and heifers (Erode and Butler, 1993; Elrod, van Amburgh and Butler, 1993; Ferguson *et al*., 1993; Butler *et al*., 1996). However, high protein intake and high BUN have not always been associated with reduced efficiency (Carroll *et al*., 1988).

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

The experiment was conducted at the University of Nairobi Veterinary Farm. The farm lies in $1^0 10'$S $36^0 50'$E and at an altitude of 1740 m above sea level in the agroecological zone classified as upper midland zone 3 (Jaetzold and Smith, 1983).

The area received annual mean 1450 mm of rain in the experimental year (1998). Long rains came between January and May, totalling 1182 mm and constituted 79% of the annual average rainfall. The other months received 268 mm. Temperature ranged between 10 and 25^0C with little fluctuation throughout the year. During the experimental period, the area experienced *el nino* rains resulting in increased grass production in the experimental plots. Soils are predominantly nitosols, commonly called the Kikuyu red loam (Ikombo *et al.*, 1996).

3.2 Experimental Animals

Eighteen cows were selected from a herd of 100 lactating dairy cows for the feeding trial. The cows were selected according to calving date, parity and breed. They were blocked by parity and breeds. There were two breeds and three parities making six blocks of 3 animals each. Before calving the animals grazed on pasture and were supplemented with concentrate one month before calving each animal receiving 2 kg daily. They were recruited into the experiment as they calved and confined in paddocks. The animals were assigned to the treatments before calving based on parity and breed.

After selection, all the cows were treated with fendbendazole to control endoparasites (Panacur®, Hoechst). They were taken to the paddocks immediately after calving down.

3.3 Diets

The animals were fed on Rhodes hay and natural pasture (predominantly Kikuyu grass (*Pennisetum clandestinum*)) in the paddocks. The hay was procured from same source (Nakuru) and was harvested in January 1998. To minimise variation in the basal diet the hay was purchased in bulk before the start of the experiment.

The concentrate used in the experiment was a commercially manufactured dairy concentrate. Water and mineral supplement were offered *ad libitum*.

3.4 Experimental Design

The design was randomised complete block design. There were two breeds {Friesians (405±21 kg) and Ayrshires (394±18 kg) each with nine cows} and three parities (2, 4 and 6) making six blocks. The cows were randomly assigned to the three treatments. The cows selected were to calve within two months.

There were three treatments depending on the amount of concentrate calving each animal receiving 2 kg daily. They were recruited into the experiment as they calved and confined in paddocks. The animals were assigned to the treatments before calving based on parity and breed.

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There were three treatments depending on the amount of concentrate offered. Cows in treatment 1 received 2 Kg for 305 days(which simulated farmer's practice in Kiambu District), treatment 2 received 4 kg for 150 days and treatment 3 received 8 kg for 75 days of concentrate per cow per day. The amounts were calculated such that each cow received the same amount of concentrate (approximately 610 kg) during the whole lactation.

3.5 Management of Experimental Animals

The experiment was carried out in three paddocks measuring 45 X 70m. Troughs for hay, mineral blocks and water were provided in each paddock. Each treatment group was assigned a paddock.

The basal diet was Rhodes hay and natural pasture (predominantly Kikuyu grass, *Pennisetum clandestinum*) in the paddocks from which the cows obtained their maintenance and production requirements.

During the experiment, the cows were fed on concentrate daily according to treatment. The concentrate was fed in individual feeding troughs during milking in the milking parlour. Since cows on treatment 3 took a longer time to clear their concentrate allocation, they were milked last. The concentrate was withdrawn gradually after 75 days for the treatment 3 group at the rate of 1 kg per day for ten days and 150 days for treatment 2 at the rate of 1 kg per two days for 5 days.

The animals underwent routine management (spraying twice a week and deworming after every three months) similar to the other animals in the herd. Piped water was freely accessible in the water troughs in the paddocks. The cows were sprayed twice weekly in a spray race to control ectoparasites with triatix (Triatix® (*Amitraz*) Cooper, Welcome).

The Rhodes hay was offered *ad libitum* in the feed troughs in the morning and afternoon soon after milking. The cows had access to hay and grazing when the concentrate was withdrawn.

The cows were machine milked twice daily (0600 and 1600 hours). Daily milk yield was recorded for each cow.

3.6 Weighing and body condition scoring

The cows were weighed once weekly on the same day and at approximately the same time. Condition scoring were carried out once weekly using method by Edmonson *et al*. (1989) on scale of 0 to 5.

The body condition scoring and weighing were done for the whole lactation period.

3.7 Sampling

3.7.1 Milk

Milk samples were taken weekly. Milk was thoroughly mixed before sampling by releasing pressure in the vacuum milk container. Milk samples were collected into two falcon tubes and kept in airtight containers to prevent loss of moisture and kept in a cool dark place to prevent toughening of the cream layer and lowering the fat content. Samples were carried in an iced insulated case to maintain sample temperature at 4 °C. They were either analysed immediately or frozen awaiting analysis.

3.7.2 Blood

Blood was sampled weekly from each cow from jugular vein into two 10-ml Vacutainers and analysed on the same day of sampling.

3.8 Analysis

3.8.1 Blood Urea Nitrogen (BUN) and Total Plasma Protein (TPP)

The serum samples were incubated at 37°C for 24 hours, clots removed and tubes centrifuged. Serum urea was determined by using Urease Berthelot's method and total plasma protein using Biuret method (Diagnostica worldwide, Human ™, 1998)

3.8.2 Milk Butterfat content

Butterfat analysis was carried out by Gerber Method (Levowitz, 1960) as follows:-10 ml of sulphuric acid (SP g 1.820-1.825 Molar) was pipetted into the butyrometer (Weber Scientific, Inc., 658 Etra Road, East Windsor, NJ 08520). The milk sample at (20^0 C) was thoroughly mixed and 11ml pipetted into the butyrometer. Great care was taken to ensure slow mixing of acid and milk by slowly letting the milk drip along the wall of the butyrometer. 1ml of amyl alcohol (SP g 0.814-0.816) was added. A rubber stopper was fixed tightly and butyrometer turned upside down several times while holding the stopper until all the protein was dissolved. The butyrometer was placed upside down in a water bath for 10 minutes until the fat separated, and centrifuged for 5 minutes at 1200 rpm. It was then placed back into the water bath for 5 minutes and readings taken.

3.8.3 Feed Analysis

The feed analysed were pasture, hay and concentrate. Dry matter was determined by drying samples at 105°C for 24 hours and ash by ashing at 550° C for 12 hours. Crude protein content was determined by the standard procedure (A.O.A.C., 1984), ADF and NDF by the method of Goering and Van Soest (1970) and Hemicellulose was calculated as NDF-ADF.

Ether extract was determined by hexane extraction (Iso-Standard 5986).

3.9 Statistical Analyses

Milk production, body condition scores and liveweight gain were subjected to analysis of variance and means were compared by least significant difference (LSD) using the general linear model procedure (GLM) available in SAS [1988].

The model for milk production was:

$$Y_{ijklm} = \mu + C_i + P_j + (CP_{ij}) + BL_k + \beta_l M_l + \beta_m B_m + e_{ijklm}$$

Where:

Y_{ijklm}	= measurement of milk yield i^{th} level of concentrate, j^{th} phase of lactation and previous lactation milk production
μ	= Overall mean
C_i	= Fixed effect of i^{th} concentrate level (1, 2 and 3)
P_j	= Fixed effect of j^{th} Phase of lactation (1, 2, 3 and 4)
BL_k	= Effect of breed and parity as blocking factors

CP_{ij} = Effect of interaction between Phase and level of concentrate

M_l =Effect of previous milk production (Covariate)

B_m =Effect of Body weight (covariate)

e_{ijkl} =Random error associated with the model

The statistical model used in the analysis included covariates for effects of previous lactation yield and liveweight as well as the effects of levels of concentrate supplementation, phase of lactation and concentrate*phase interaction. The concentrate effect was included to account for variation between level of concentrate used in this study, the phase effect was fit to account for variation due to phase of lactation, and a concentrate by phase interaction was fit to remove variation due to the interaction of concentrate level with phase of lactation.

Liveweight gain was calculated by regressing body weight (kg) of individual animals measured at weekly intervals on time (in weeks). The changes in the concentrations of the blood component for the period 12 weeks after calving were obtained from linear regression. The slopes were obtained by individually regressing each blood component on week.

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CHAPTER 4: RESULTS

4.1 Diet composition

The chemical composition of the feed offered to the experimental cows is shown in Table 1. Crude protein contents of Rhodes grass hay (*Chloris gayana*) and concentrate were 83 and 152 g kg^{-1}DM respectively. The natural pasture (predominantly *pennisetum clandestinum*) and hay had lower hemi-cellulose than dairy meal.

Table 1. Mean chemical composition (g kg^{-1}) of feed offered.

	Hay	Concentrate	Pasture
Dry matter	853± 1.7	892± 1.1	312± 6.0
Crude protein	83±1.8	152± 2.3	86±1.8
Ether extract	31±1.2	102± 1.1	32±1.3
ADF	428.2±20.5	123± 12.3	370±17.3
NDF	647.3±14.7	424± 19.6	626±20.5
Hemicellulose	219.1±11.9	301± 21.0	256±16.8
Ash	77±0.25	162± 13.6	97±6.5

NDF = Neutral Detergent Fibre
ADF = Acid Detergent Fibre

CHAPTER 4: RESULTS

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4.2 Feed intake

All the cows consumed the concentrate allocated although the cows fed on 8 Kg of concentrate took longer to finish their allocation. Cows in treatment 3, treatment 2 and treatment 1 consumed mean of 610, 605 and 612 kg of concentrate within the 75, 150 and 305 days respectively. The Dry Matter intakes of hay and pasture were *ad libitum*.

4.3 Live weight and condition score

4.3.1 Body weight

Table 2 shows the liveweight gain (g/day) at different phases of lactation. The body weights of the experimental cows at calving were not significantly different between treatments (P>0.05). This shows that the cows in the three treatments had similar bodyweights at calving. The average bodyweight at calving was 403±27.2 Kg. The trend of the mean live weights of the cows during the experiment is presented in Figure 1. All the treatment groups experienced a phase of body weight loss in the first six weeks before starting to gain steadily thereafter. During first phase of lactation (1-75 days), treatment 1 group lost more weight than the other two groups. Weight changes during this phase were –378.6 g/day, -161.5 g/day and 187.4 g/day for treatments 1, 2 and 3 respectively. Changes were less for Treatment 2 and Treatment 1.

During the 2nd phase of lactation the cows in all the treatments gained weight with those in treatment 2 gaining more weight than the cows in

Treatments 1 and 3 though not significant. The cows in treatment 1 gained the least weight. This trend was repeated in the 3rd Phase but the cows in treatment 1 gained very low weight. In 4th phase the trend was almost the reverse with cows in treatment 1 gaining more weight than cows on the other treatments.

Generally the increase in weight during the residual period of lactation was not significantly different for any of the treatments and the rates of liveweight gain did differ at various times throughout the lactation.

4.3.2 Body Condition score

Table 2 shows the body condition scores of the experimental cows at different phases of lactation. The body conditions of all anmals at calving were similar ($P>0.05$, Figure1). The average body condition score was approximately 2.86. The Treatment 1 and 2 groups lost conditions soon after calving, at a declining rate but started to gain condition steadily from the beginning of the second phase of lactation. The Treatment 3 group did not lose body condition after calving.

Mean separation of the condition scores showed that for the whole lactation period the three treatments were significantly different from each other ($P<0.05$) with Treatment 3 group having the highest score, then Treatment 2 and lastly Treatment 1. The rate of decrease in condition score in the first phase of lactation was higher in treatment 1 than in treatment 2 and cows in treatment 2 had higher body condition improvement in last part of first phase than Treatments1 and 3.

Table 2. Liveweight gain (g/day) and body condition scores at different phases of lactation.

	Phases				
	1	2	3	4	
Days	1-75	76-150	151-225	226-305	
Live weight gain (g/day)					Initial weight (Kg)
Treat 1	-378.6^{a}	173.7^{a}	18.4^{a}	223.4^{a}	405.3^{a}
Treat 2	-161.5^{a}	276.8^{a}	345.5^{a}	109.1^{a}	394.0^{a}
Treat 3	187.4^{b}	235.5^{a}	260.5^{a}	122.3^{a}	408.6^{a}
LSD	245.97	172.52	380.81	197.65	28.30
Body condition score					Initial score
Treat 1	2.72^{a}	2.89^{a}	2.94^{a}	2.98^{a}	2.86^{a}
Treat 2	2.81^{a}	2.90^{a}	2.98^{b}	3.02^{b}	2.85^{a}
Treat 3	2.93^{a}	3.03^{b}	3.06^{c}	3.14^{c}	2.86^{a}
LSD	0.062	0.041	0.027	0.022	0.020

$^{a\,b\,c}$ Column means with the same superscripts are not significantly different (P>0.05).

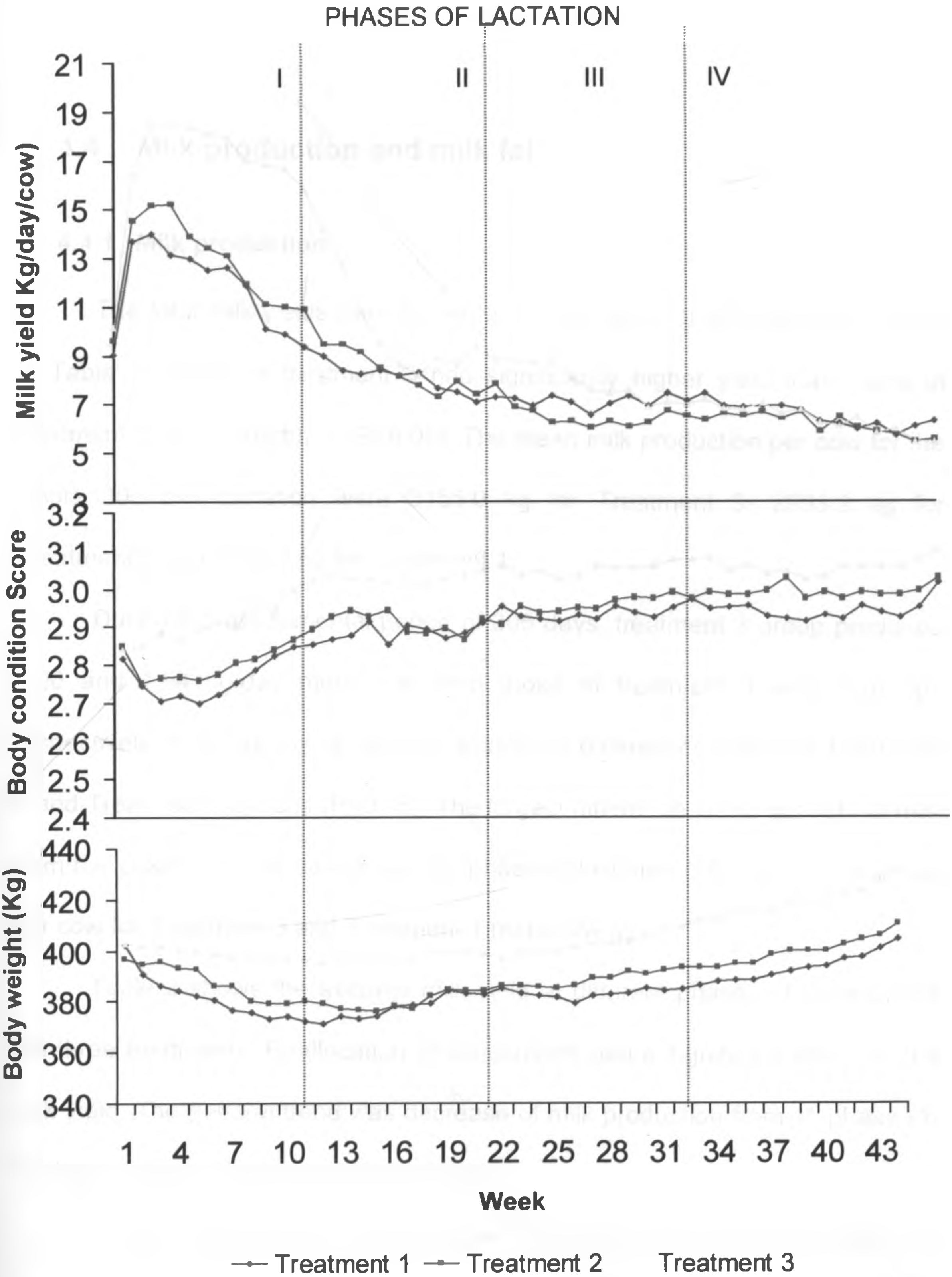

Figure 1 Lactation curves, trends of Mean body condition scores and body weights for cows supplemented with 2 (treatment 1), 4 (Treatment 2) and 8 kg (Treatment 3) of concentrate

4.4 Milk production and milk fat

4.4.1 Milk production

The total milk yields from the experimental cows for 305 days are shown in Table 3. Cows on treatment 3 had significantly higher yield than those in treatment 2 and treatment 1 ($P<0.05$). The mean milk production per cow for the whole 305 day lactation were 3155.0 kg for Treatment 3, 2563.2 kg for Treatment 2 and 2543.6 kg for Treatment 1.

During the experimental period of 305 days, treatment 3 group produced 2.00 and 1.94 kg/day more milk than those of treatment 1 and 2 groups respectively ($P<0.05$). There were no significant differences between Treatment 2 and Treatment 1 groups ($P<0.05$). The largest difference in the quantity of milk from the cows occurred during the first phase of lactation (15.9 vs. 9.57 per day per cow for Treatment 3 and Treatment 1 respectively).

Table 3 shows the average milk yield at different phases of lactation for the three treatments. Reallocation of concentrate had a significant effect on the milk yield. The general trend was decrease of milk production from 1st phase (1-75 days) through 4th phase (226-305 days).

In the residual period (Table 4) after initial adjustment to the new planes of nutrition, there was a remarkable similarity in the fall of milk yield for the treatments 1 and 2. Treatment 3 had a slope with higher gradient and the other treatments (11-22 weeks). After 22 weeks there was a similarity in the rate of fall of milk yield for the three treatments.

Milk productions from the cows in treatment 3 were significantly higher ($P<0.05$) than the treatments 1 and 2 in the first and second phase of lactation. In the subsequent phases (3 and 4) the milk productions were not significantly different ($P>0.05$). Though there were no significant differences in milk production in the three treatments in the third and fourth phases, the milk production from treatment 3 was higher than the other treatments because of significant differences in 1st and 2nd phases.

Table 3. Mean milk yield trends for the four phases of lactation for the three levels of concentrate supplementation (Milk yield in Kg).

	Phases					
	1	2	3	4		
Days	1-75	76-150	151-225	226-305	Total	Value (Kshs)
Treat 1	907.2^{bw}	610.6^{bx}	545.4^{by}	480.5^{bz}	2543.6^{b}	44,513.00*
Treat 2	987.1^{bw}	628.6^{bx}	489.3^{by}	458.2^{by}	2563.2^{b}	44,856.00
Treat 3	1314.3^{aw}	766.4^{ax}	572.3^{by}	502.4^{bz}	3155.0^{a}	55,212.50
LSD	174.4	130.1	91.1	120.9	422.2	
Concentrate (Kg / Phase)						Cost (Ksh)
Treat 1	154.5	152.5	152.5	152.5	612	6948.20
Treat 2	303	302	0	0	605	6868.70
Treat 3	610	0	0	0	610	6925.50

$^{a\,b}$ Column means with the same superscripts are not significantly different (P>0.05).

$^{w\,x}$ Row means with the same superscripts are not significantly different (P>0.05).

*Price of milk taken as Ksh. 17.50/Kg

Table 4. Mean peak yield (kg), persistency of yield of cows supplemented with 2 (Treatment 1), 4 (treatment 2) and 8 kg (Treatment 3) of concentrates

Treatment period	Treatment		
	Treatment 1	Treatment 2	Treatment 3
Peak yield	18.5	15.66	14.00
Persistency (%) Mean yield of weeks 18-22 as % of mean yield of weeks 9-11	76.9±11.54	71.4±5.46	58.0±13.03
Residual period ...			
Persistency (%) Mean yield of weeks 21-23 as % of mean yield of weeks 42-44	88.7±27.71	70.9±22.16	63.0±18.58
% Decline/week over 22 weeks	2.3	2.6	2.6
% Decline/week between weeks 11 and 22	1.6	1.8	2.7

The lactation curves for the average milk yields for the three treatments are shown in Figure 1. The Figure shows that an increase in amount of dairy concentrate fed during early lactation resulted in an increase in daily milk yield. There were peaking for the concentrate levels. The lowest amount of concentrate in treatment showed a steady decline in yield from the 3rd week post partum The Treatment 2 group had slightly higher milk yield than Treatment 1 group. The differences in milk yields declined as the lactation advanced. In treatment 3, the peak milk yield was 18.5 kg at the 4th week of lactation. The yield more or less stabilised to the 6th week then started declining gradually to the 11th. After the 12th week the decline in milk yield was more marked in this group (Table 4).

Milk production trend was different for Treatment 2 and Treatment 1 groups compared to treatment 3. The peak milk yields were 15.66 kg /day and 14.00 kg /day for Treatment 2 and Treatment 1 at 2 and 3 weeks post partum respectively. For these two groups the peak milk yields were attained earlier and were lower than those attained by the Treatment 3 group. From the week milk yield reached maximum to the end of lactation, persistency for the treatments 1 and 2 were more or less the same (Table 4).

During early lactation, there was large immediate response, but little residual milk yield to higher concentrate level offered. From 12th week to the end of the experimental phase the differences in the mean daily milk yields of the cows on the three levels of supplementation decreased. During the 305-day lactation period, the marginal efficiency of the concentrate (additional kg milk per additional kg dry matter of concentrate during early phase of lactation) was 0.04 between the treatments 1 and 2 and 0.37 between treatments 1 and 3.

The price of milk in Kiambu was assumed to be Ksh. 17.50 per litre and concentrate Ksh. 11.35 per Kg. The benefit from reallocating the concentrate to early phase of lactation was Ksh 10,699.50 for the whole lactation period as was calculated from Figures in Table 3.

4.4.2 Milk fat.

Butterfat (%) varied from 3.29 ± 0.15, 3.18 ± 0.25 to 3.19 ± 0.11 in treatments 1, 2 and 3 respectively. There was no significant effect of level of concentrate on milk fat during the 12 weeks of lactation. There was a tendency, however, for milk fat to be higher for cows on Treatment 1.

4.4.3 Factors affecting milk yields

The results of analysis of variance for some of the factors affecting milk yield are presented on Table 5. After adjustment by covariance on the previous lactation milk yield and the initial body weight, Treatment and Phase significantly affected milk yields from the cows ($P<0.001$) during the entire lactation. There was a significant ($P<0.001$) interaction between level of supplementation and phase of lactation because milk yield responses to concentrate feeding differ during different phases of lactation. Body weight at the beginning of the experiment and previous lactational milk yield significantly ($P<0.05$ and $P<0.001$ respectively) affected current milk production.

Table 5. Analysis of factors affecting milk yield

Source	DF	Mean Square	F Value	Pr > F
TRT	2	34.65	20.26	0.0001
BLOCK	5	12.22	7.14	0.0001
BWT	1	6.73	3.94	0.0133
MILK	1	295.61	172.85	0.0001
PHASE	3	89.20	52.16	0.0001
TRT*PHASE	6	6.28	3.67	0.0048
Error	44	1.71		
Corrected Total	62			
R-Square=0.91	C.V.=14.54			

DF= Degrees of Freedom; TRT=Treatment; MILK=Previous lactation milk yield; BWT=Body weight; PHASES=The four lactation phases of lactation; Pr=Probability; Block=Effect of breed and parity

4.4.4 Metabolic indicators Blood urea nitrogen and Total plasma protein

Mean BUN concentrations ($mgdl^{-1}$) over the first 12 weeks of lactation period were 19.3±0.84, 19.7± 0.82 and 21.2±1.1 while total plasma protein were 7.79, 7.89 and 7.87 (gdl^{-1}) in treatments 1, 2 and 3 respectively. The mean postpartum gradients of total plasma protein and BUN studied were 0.064 and 0.835 respectively. Increasing the level of concentrate supplementation from 2 kg to 8 kg did not significantly increase BUN concentration ($P>0.05$). However, BUN levels for treatment 3 were slightly higher than either treatment 1 or 2.

The trends of mean weekly BUN concentrations of the experimental cows during the 12 weeks of the experimental phase are presented in Figure 2. In all the three treatments, the BUN concentrations fell slightly in the 2 weeks following parturition before starting to rise gradually.

Increasing the levels of concentrate supplementation did not significantly affect TPP ($P>0.05$). The trends of mean weekly TPP concentrations of the experimental cows during the first 12 weeks of lactation are presented in Figure 3. In all the three treatments, the TPP concentrations stabilised for the 2 weeks following parturition after which they fell slightly into the third and fourth week before they started to rise gradually.

The Correlation coefficients among considered in this study are as shown in Table 6. The correlation between milk yield and levels of concentrate was low but significant. This shows that as the levels of concentrate was increased from 2 through 8 Kg milk significantly increased. The correlation between milk yield and week of lactation was negative (-0.68) as expected because milk yield usually decreases with time. Levels of concentrate also increased blood parameters TPP and BUN positively (0.003 and 0.139) though the former was close to Zero. There was a small negative correlation (-0.018) between level of concentrate and week of lactation which is expected because the magnitude of response to concentrate feeding decreases with week of lactation

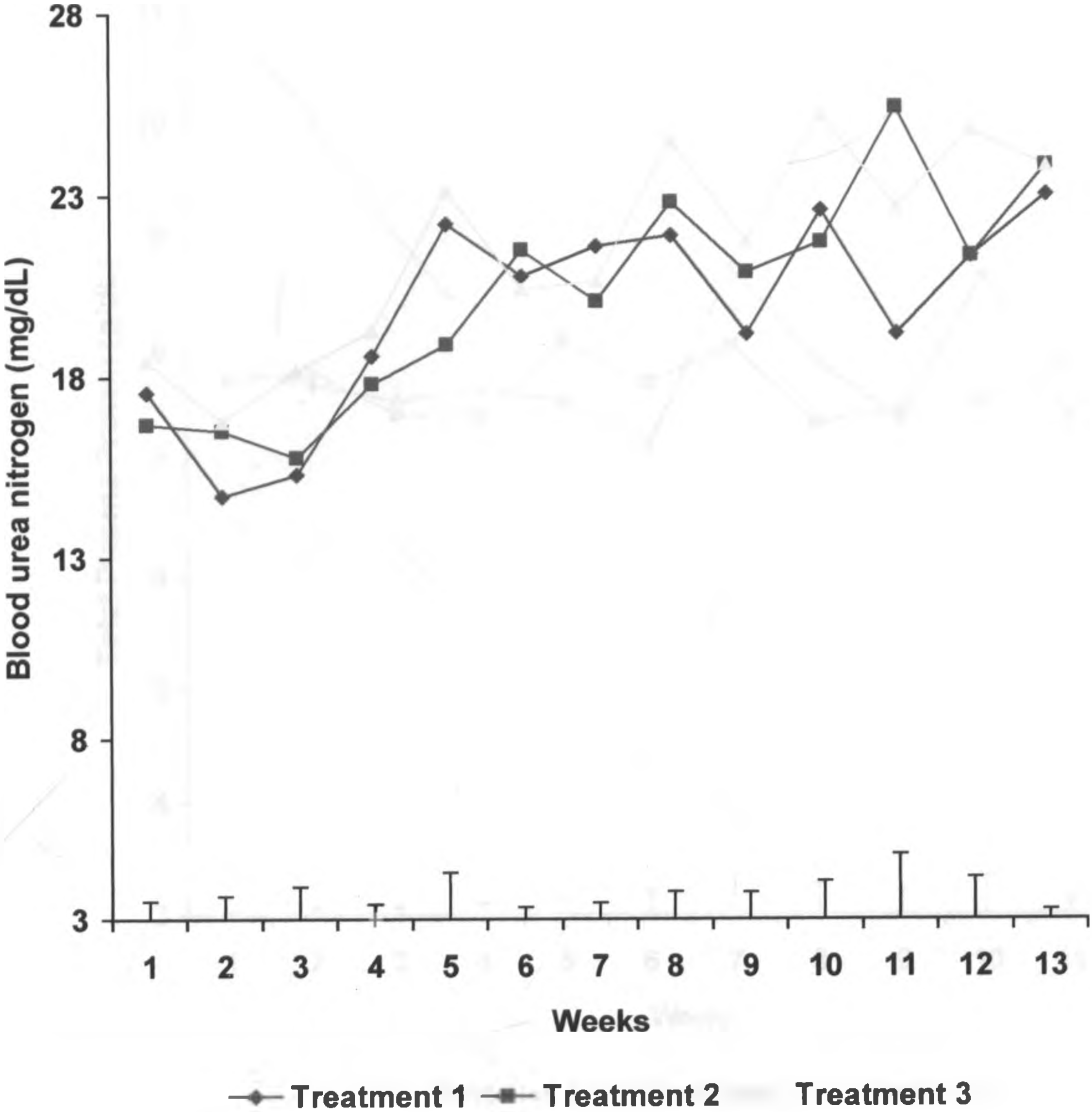

Figure 2: Trend of Blood Urea Nitrogen (+SE) over 12 weeks of the experimental period

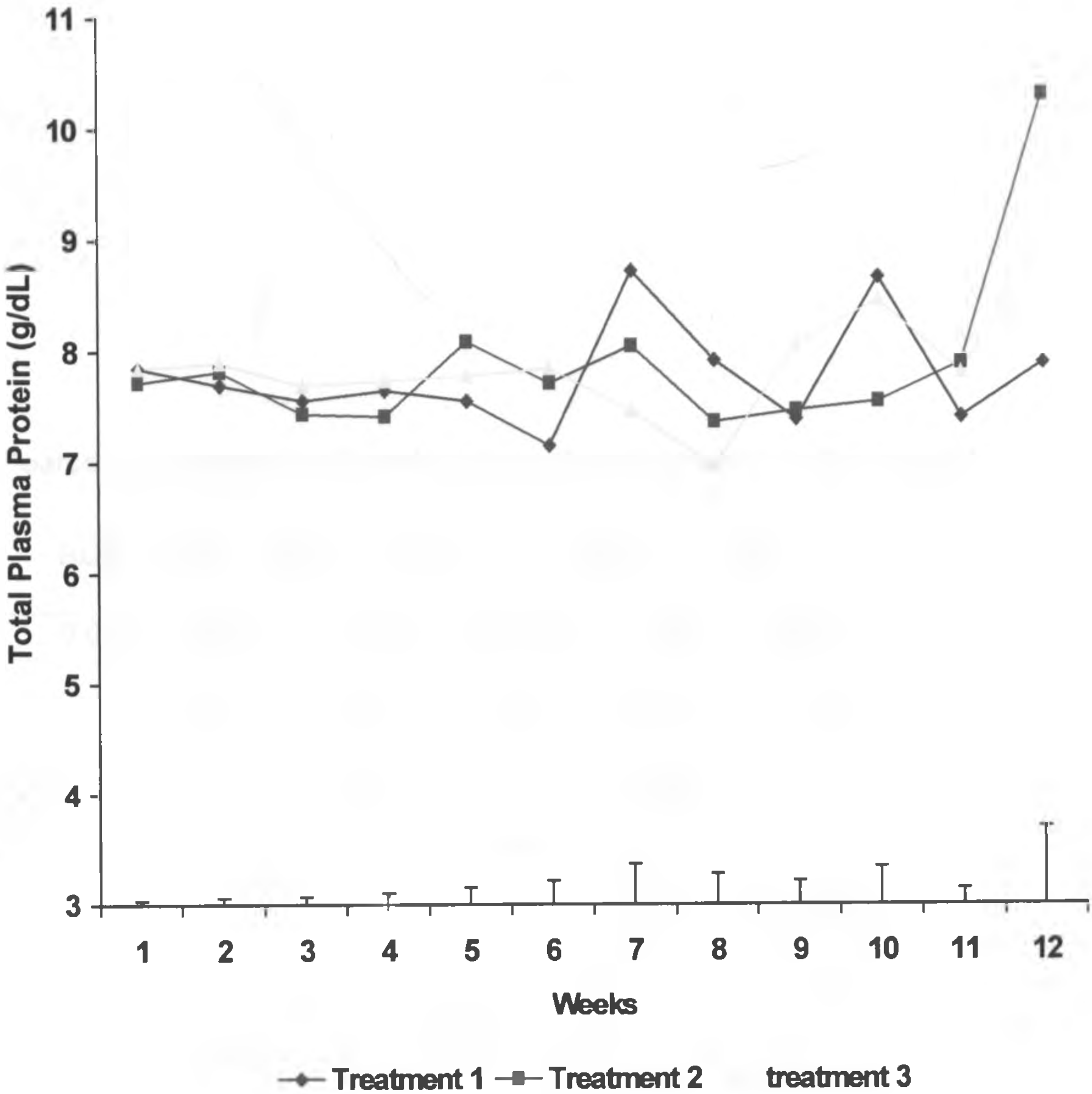

Figure 3: Trend of total Plasma protein (+SE) over 12 weeks of the experimental period

Table 6. Pearson correlation coefficients among the parameters in the present study.

	BUN	TPP	BWT	BCS	WEEK	TRT
MYIELD	0.012	-0.038	0.361***	-0.191**	-0.680***	0.202***
BUN		0.072**	0.003	0.280***	0.384**	0.139***
TPP			0.039	0.076**	0.084**	0.003**
BWT				0.291***	0.018	0.290***
BCS					0.437***	0.293***
WEEK						-0.018

MYIELD = Milk yield, BUN= Blood urea nitrogen, TPP= Total plasma protein, BWT= Body weight, BCS= Body condition Score, WEEK= Week of lactation.

CHAPTER 5: DISCUSSION

5.1 Feed composition

The observed mean CP content of hay was 83 g kg^{-1} DM. According to Leng (1990), low quality forages are considered as those having less than 80 g kg^{-1} DM. Hay in this study was above this threshold, and was therefore considered of fair quality. The CP content of hay is higher than 59 g kg^{-1} DM observed by Todd (1956a) at Muguga, 60 g kg^{-1} by Said (1981) at Kabete and 47 g kg^{-1} by Karue (1974) at Muguga. The CP content was comparable to those reported by Todd (1956a) with grass harvested at the height of 6-9 Inches in early-dry season.

The percentage dry matter content of Rhodes grass hay (85.3) was low compared to 88.7 g kg^{-1} DM reported by Todd (1956b) and 94.1 g kg^{-1} DM by Said (1981). The ash content is lower than those reported by Todd (1956b) and Said (1981).

In this study, the NDF contents were higher in the hay and pasture than those reported i.e. 647 g kg^{-1} DM and 626 g kg^{-1} DM respectively. Cell wall content is negatively correlated with intake (McDonald *et al*, 1989). High cell wall content increases rumination time and is associated with decreased efficiency of conversion of metabolisable energy to net energy (Van Soest, 1982). NDF and ADF levels generally met the minimum NRC (1989) dairy cow requirements that are 280 g kg^{-1} DM and 210 g kg^{-1} DM for NDF and ADF respectively. The high ADF and NDF could have been due to the stage of harvesting. The presence of long fibre in the hay conferred the cows a number of advantages. They provided a more continuous flow of fermentable carbohydrate to the ruminal microorganisms and thus improve the overall utilisation of the diet. Both slow and the fast fermenting carbohydrates therefore can act in a complimentary fashion to produce an optimal substrate for the ruminal microbes. Fibre is essential in ruminants for rumination, saliva flow, rumen buffering and health of the rumen wall (Mertens, 1987). The fibre cell wall consists of hemicellulose, cellulose and lignin, some of which may be digested by the rumen microbes (Van Soest, 1994).

Dry matter intake=0.03Xliveweigth(Kg)+0.1Xmilk yield (kg per day) gives about 14 kg dry matter per day. The feeds shown in Table 1 provide about 143.4 MJ/day of Metabolisable energy for treatment 3 for 75 days. For treatments 1 and 2 the metabolisable energy are 116.2MJ per day for 150 days and 105MJ per day for 305 days respectively. The feed provided 103 MJ/day for the rest of the lactation period after withdrawal of concentrate for treatments 2 and 3.

5.2 Live weight and body condition score

Body condition scoring is a subjective method of assessing the amount of ME stored in fat and muscle in a live cow (Edmonson, 1989). However, it can be related to objective measures of biological change such as fat deposition and its mobilisation. The body condition scores at parturition for the experimental cows were low (approximately 2.8). This was lower than 3.5-4.0 associated with high lactational production as reported by Edmonson (1989). The low body condition score at calving, therefore, may explain low milk yield obtained from cows on low concentrate level because they did not obtain enough energy from the feed to either increase or maintain milk yield. Most of the nutrients could have been diverted to improving the body condition of the cows (Figure 1). The lower body condition score at calving is generally associated with less body weight loss in first phase than cows which calf at a better body condition. Cows with lower body condition score partitioned a higher proportion of feed energy to improving body condition than those cows with higher body condition, at the expense of milk production.

Generally the body condition score trend (Figure 1) of the experimental cows followed the expected pattern. Cows lost body condition in early lactation gained weight by mid lactation, and returned to higher score by drying. In mid lactation there was a reverse effect; the cows previously fed on low concentrates gained more weight than did the cows previously fed on higher concentrate levels (treatments 2 and 3). Body gain in mid lactation following underfeeding in early lactation constitutes a change in partition of nutrients of the cow (Bryan and Trigg, 1979). Cows in treatment 1 lost their most condition from early lactation declining to 2.6.

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5.2.1 Milk yield and milk fat content

5.2.1.1 Immediate response (lactation weeks 1 to 11)

Immediate response in milk yield is the effect just after the introduction of the concentrate feeding in the early phase of lactation (Broster and Broster, 1984).

Milk production usually peaks between 4 and 8 weeks postpartum, yet maximum dry matter intake usually occurs between 10 and 14 weeks postpartum (NRC, 1989). The lag of maximum dry matter intake behind peak milk yield causes a negative energy balance in early lactation, the cow consequently mobilises body tissues, particularly fat deposits, to overcome the energy deficit which results in weight loss (NRC, 1989). If feeding is limited, the rate of decline is more rapid than normal leading to a somewhat downward slopping lactation curve as observed by Omore *et al.*, (1996). The appetite of the cow is rather low during the first months after calving, therefore, feeding of high quality roughage and a high level of supplementation with concentrates is needed. During this phase, lactating cows are usually heavily stressed because of increasing milk production nutrient demand. This was clearly demonstrated in this study.

In early lactation the increase in level of concentrate feeding gave a direct response of 0.53 and 0.90 kg of milk per Kg increase in concentrate intake of 2 kg and 6 kg respectively (i.e. when concentrate levels were increased in the treatments from Treatment 1 to Treatment 2 and from Treatment 1 to Treatment 3). The response obtained between low to medium and medium to high levels of concentrate feeding in this study were different from the dogma (Steen and Gordon, 1980) that the response to a change in feed level declines as the overall feeding level increase. However, Gordon (1984) showed that responses to additional concentrate vary considerably and the results obtained in this study are within range of those reported in a literature reviewed by Thomas (1980) where there was a response of 0.79 Kg of milk /Kg concentrate DM. Aston *et al* (1994) reported an increase of 0.49 to 0.89 Kg of milk /Kg of dairy concentrate. Higher milk yield responses to higher levels of concentrate have also been reported, 1.16 Kg of milk/Kg of concentrate by Taylor and Leaver (1986) and 1.6Kg of milk/Kg concentrate by Sutton *et al* (1994). A study by Mupeta (1998) in Zimbabwe showed a response for 1.33 kg of milk per Kilogram of concentrate. These results suggest that there is variability in milk production responses observed from concentrate supplementation in dairy cows. This could be due to differences in environments and management systems. The differences in this study were less than reported previously (Broster and Thomas, 1981) and may have been due to feed quality and low amount of hay consumed.

5.2.1.2 Residual (during lactation weeks 12 to 44) and total lactation yield

Residual effect is regarded as the prolongation of milk production due to the effects of differential feeding after this itself has ceased and the total effect is the summated effect over the total phase of lactation after application of differential feeding (Broster and Broster, 1984).

Increase in level of concentrate feeding produced a large direct response in milk production especially with Treatment 3. It has been suggested that large residual effects are to be expected only when there has been a large weight loss in early lactation that must be replenished during the residual phase (Broster, 1974; Broster and Strickland, 1977). This explains why the persistence in milk yields were higher comparatively for both Treatment 2 and Treatment 1 groups in later phases of lactation.

The possible reason for small differences in milk yields in later stages of lactation is withdrawal of concentrate in the Treatment 3 and Treatment 2 after 12th and 22nd weeks respectively. Substitution of concentrate with grass during post-concentrate feeding did not make up for the nutrient and probably dry matter requirement.

The potential cause of the shape of lactation curve shown in Fig 1 could be the crude protein (CP) and energy content shown in Table 1. Inadequate body tissue reserves at calving, as shown by the low body condition scores in Figure 1, may also cause non-conventional lactation responses. The nutrient intake goes into satisfying the body energy deficit first at an expense of milk production. For cows that may have had satisfactory adipose reserves, with limited dietary energy intake, homeorrhetic pathways that regulate high peak milk production are also likely to be disrupted by the inadequate CP supply from the forage to supplement the energy requirement from catabolised tissues (Licitra *et al.*, 1998).

The similarity in milk yields from the three treatment groups after withdrawal of concentrate feeding in Treatment 3 and Treatment 2 is in agreement with the results of other experiments in which cows were fed on different levels of concentrate and then turned out to pasture (Gordon, 1976). Low residual response in milk yield due to increasing in the level of concentrate supplementation in early lactation is also in agreement with other experiments in which cows were offered different levels of concentrate in addition to grass during early lactation. This response compare well with 0.42, 0.24 and 0.15 reported by Steen and Gordon (1980a).

5.2.1.3 Milk fat

The increase in of concentrate levels was expected to alter the forage to concentrate ratio resulting in changes in milk fat percent. The results show that increasing levels of concentrate from 4 kg to 8 kg did not affect milk fat. There was probably a small substitution effect of concentrate for forage and could not result in significant effect of milk fat. Low levels of concentrate had higher milk fat percentage though not significantly different from the other two treatments. Increased levels of concentrate substituted for forage and hence decreased the forage to concentrate ratios, which cause low ruminal production of fat precursors (acetate and –OH-Butyrate). This lowered the fat content though not significantly.

5.2.2 Blood Urea Nitrogen and total plasma protein

Cows have the ability to adapt their output and their biochemistry to the feed available. This applies in particular to situations where energy supply is inadequate. Cows can experience a severe energy constraint, adapt their output and end up a few weeks later much thinner with low milk yields, but BUN levels in blood within optimum ranges because energy balance has been re established (Whitaker *et al.*, 1999).

The mean values of BUN concentration (19.3, 19.7 and 21.2 for treatments 1, 2 and 3 respectively) were higher than average value associated with balanced diets i.e.15 mg/dl (Roseler *et al.*, 1993). This indicate an imbalance in the energy: protein ratio in the diets of the cows in the study since there were BUN concentrations outside the balance range (12 – 18mg/dl) obtained in various studies (Chase et. al., 1993). The higher concentrations of BUN indicate higher dietary protein (nitrogen) relative to digestible energy intake. Previously, Fergusson *et al* (1988,1993) reported a similar range of urea concentrations in cows and that value greater than 20mg/dL resulted in decreased conception rates.

The treatments differed in terms of the amount of dairy concentrate given but not in terms of protein/energy ratio in the diet. It was hypothesised that the higher amounts of concentrate given could cause substitution effect and subsequently the ratio of protein to energy could be affected consequently causing changes in BUN concentrations. The feed intake could not be established accurately because grazing complicated estimation of intake and therefore could not be related to BUN. BUN levels for Treatment 1 and Treatment 2 were not significantly different though the Treatment 3 was significantly different from the two. This could be due to the substitution effects which could have slightly affected protein /energy ratio. This agrees with previous studies discussed by Oltner *et al.*, (1985) that the total amount consumed had little influence on BUN but its concentrations were. These relatively high concentrations of BUN would be indicative of excessive dietary protein (nitrogen) relative to digestible energy intake so the positive response to energy supply was as expected. An imbalance of ruminally degradable and ruminally undegradable protein increased BUN in lactating dairy cows but this increase is not as great as an increase in BUN caused by excess CP (Baker, Fergusson and Chalupa, 1995).

The negative correlation between BUN concentration and live weight (Table 6) might be explained partly on the basis of a simple dilution. In a big cow the compartment for urea distribution is naturally larger than in small cow, and if the same amount of urea is formed in the liver, concentration in the blood will obviously be lower. With simple dilution, the effect of weight on blood urea concentration will also depend on absolute amount of urea to be distributed in the body. On diets producing much urea and consequently high blood urea concentration, the effect of live weight on blood urea will be greater on concentration basis. Pearson correlation coefficients show that BUN increased with time and increased with improvement of body condition. It has low positive correlation with treatment therefore increases at a slow rate with the levels of concentrate used in this study. Values of BUN concentrations usually decrease soon after calving due to insufficient energy intake (McDonald *et al*, 1989) initially and sufficient later because of the slow rate with which appetite of the cow returns to normal. This could have led to an increase in amino acid deamination with subsequent increase in BUN concentrations. Due to transfer of immunoglobulins from the plasma into colostrum, decrease in TPP concentrations toward calving is a common phenomenon in dairy cows (Mulei, 1991).

Grazing cows often have high BUN, indicating an excess ammonia formation in the gut. High concentrations of urea in body fluids of dairy cows reduce metabolic efficiency of milk yield (Kaufmann, 1982).

5.2.3 General Discussion

The main purpose of this study was to determine the effect of increasing levels of concentrate from 2 kg through 8 kg at different stages of lactation. This section endeavours to link up the effect of the same on parameters discussed above with respect to the objectives of the study and expound on the relevant physiological and biochemical concepts.

Lack of energy is the most common deficiency of dairy ration resulting in a decline in milk yields and loss in liveweight. Severe and prolonged energy deficiency also depresses reproductive performance. Cows in treatment 3 had significantly ($P<0.05$) higher positive body weight change and body condition score than cows in the other treatments. Reallocating concentrates to the first phase of lactation is an excellent method of reversing the general decline in body weight trend and long calving interval observed over time in this study (Broster and Thomas, 1981). Studies carried out in Kiambu district (Kenya highlands) showed that the exotic cows failed to produce to their genetic potential in the environment because of feed and management constraints facing the smallholder sector (Staal and Omore, 1998).

Most cows in the present study lost weight after calving, suggesting a negative energy balance. The cows receiving 2kg lost more weight than those receiving either 4 or 8kg of dairy concentrate. The cows on 8kg lost the least weight. This indicate that as the level of concentrate was increased the cow mobilised less body tissues, particularly fat deposits, to overcome the energy deficit which would have resulted in weight loss. Live weight and body condition score change can be related to milk production. The significant loss in weight was matched with reduced milk production since significant differences were reached in milk yield in early lactation. Most of the nutrients could have been diverted to improving or attempting to maintain the body condition of the cows receiving less concentrate. It has been shown that cows with lower body condition score partitioned a higher proportion of feed energy to improving cow condition than cows with higher body condition, at the expense of milk fat production (Garnsworthy and Jones, 1987).

There was no significant increase of milk yield as concentrate level was increased from 2 kg to 4 kg. This was probably due to a substitution effect of the concentrate on the intake of herbage dry matter by the 4 kg group, consequently, increase in energy intake was minimal. Whereas the concentrate supplement of additional 2kg was designed to supply additional nutrients for higher milk production, it did so only marginally.

Animals fed 2 kg of concentrate could not meet their requirements resulting in undernutrition which results in reduced milk yield with concomitant loss of body weight.

Treatment 3 ensured that more concentrate was given in weeks 1 to 12 and no concentrate in the later weeks. Consequently, higher ME intakes and milk yields were achieved for Treatment 3 in weeks 1 to 12 weeks and lower ME intakes and yields in the later phases. The decline of milk yield in treatment 3 group was more marked because of the withdrawal of concentrate supplementation, though gradual. This might be interpreted as the normal physiological change in the rate of milk synthesis associated with the progress of lactation together with the fact that concentrate supplementation was withdrawn. Milk production during the residual phase was similar for the three treatments. Steen and Gordon (1980) also reported similar milk yield trends during the residual phases.

The improvement in the milk yield when the ration was supplemented with concentrate in the early phase of lactation may be explained by the fact that quantity of CP was high in the rations. This was because of supplementation and subsequent maintenance of ammonia (NH_3) content in the rumen leading to an improved ruminant environment for microorganisms. Therefore, the digestibility and dry matter intake of hay and pasture was increased.

Live weight and body condition of dairy cows are related to milk production. The significant loss in live weight was related to milk production since significant differences were reached in milk yield. The lag of maximum dry matter intake behind peak milk yield causes a negative energy balance in early lactation (NRC, 1989). This results in negative energy balance that usually persists for 4-12 weeks of lactation (Butler, Everett and Coppock, 1981) and during which time, most dairy cows mobilise body reserves to support milk production adequately (Bauman and Currie, 1980). The condition (body reserves) of the cow at parturition is therefore acknowledged to be of paramount importance if high yield potentials are to be exploited (Johnson and Broster, 1980).

There are three possible reasons for the similarity in milk yield in the residual phase. First, withdrawal of the concentrate feeding greatly reduces residual response due to inadequacy in nutrients in basal diet being the only feed fed in the later phases of lactation. Secondly, the cows offered a lower level of concentrate feeding had a longer time of adapting to the feed for most part for the lactation and therefore more stable. Thirdly, the withdrawal of concentrate feeding depresses rumen microbial activity due to reduced availability of nitrogen for microbial functioning. Thus, withdrawal of concentrate feeding produced only a small residual effect. Deficiency in dietary nitrogen causes a very strong depression of the microbial activity in the rumen. This is followed by a decreased digestibility of the dietary energy leading subsequently to a secondary energy deficiency.

Results from this study indicate that the level of nutrition during the first few weeks of lactation have a major effect on total lactation performance. Cows supplemented with 8 kg concentrate (phase 1) significantly produced more milk than those supplemented either with 4 kg (phase 1 and 2) or 2 kg (Phase 1 to 4). Maximum voluntary intake, or appetite, is lower in early lactation than at mid lactation yet it is in early lactation that milk yield reaches its peak and the efficiency of milk production is high (Balch, 1984). This implies that feeding high nutrient density feed in phase 1 is necessary in order to meet the high nutrient demand. Although it costs more to feed cows in this phase in order to meet the nutrient demand, milk income is much higher and the net return above the cost of feed is increased. This is because feed and overhead costs for maintenance are practically the same, regardless of level of production.

Week is highly correlated with milk yield. This is usually expected since milk yields diminish with time because most the energy is increasingly diverted to body development. This is usually expected since body condition responds in a low rate to feeding because most of the energy is used for compensation of the body loss in the early lactation. The correlation between week and BUN was low i.e. 0.28. This could be an indicator that the deamination was increasing at a slow rate. Probably the cows were using nutrients more efficiently early in lactation than in later lactation because of low appetite in the former phase (NRC, 1989).

The influences of malnutrition in energy and protein on the urea content of blood were reflected in the results. The total plasma protein (TPP) results could not lead to a reliable conclusion as to whether the increased urea in blood was due to excess protein or on an energy restriction.

CHAPTER 6: CONCLUSIONS

1. Supplementation in the early phase of lactation enables the lactation curve to approximate the conventional one.
2. The study demonstrated that it is possible to extract 611 kg of extra milk per cow's lactation by feeding the same amount of concentrates up-front during early lactation at 8 kg/day during the first 12 weeks after calving.
3. After the reallocation of the concentrate to the first phase, the concentrate feeding can be withdrawn altogether for the rest of a lactation period without lowering milk production below that of cows that continue to be fed at a flat rate of 2 kg/day throughout their lactation.
4. The potential benefits from changing the shape of the lactation curve are higher total milk yields and hence higher profit. It is, therefore, economically sensible to reallocate dairy concentrate to the first phase of lactation phase.
5. Supplementary feeding in early phase of lactation decreases weight loss during this phase and increases weight gain during later phases.
6. High concentrate levels means high level of protein intake thus contributes to imbalance of energy to protein and therefore increases BUN levels.

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