

PERFORMANCE OF EXOTIC DAIRY CATTLE IN THE  
SOUTHERN HIGHLANDS OF TANZANIA AND PROSPECTS FOR GENETIC  
IMPROVEMENT



BY

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## ABSTRACT

This study was aimed at evaluating the performance of exotic dairy cattle in five large farms in Iringa and Mbeya regions. Main aspects studied included calf mortality rates, reproductive traits, milk yield, milk composition, and lifetime performance traits.

Rates of abortion ranged from 1.8 to 9.5% while rates of stillbirths varied between 3.4 and 9.8%. Death rates ranged from 9.3 to 25.5% for unweaned calves and from 13.2 to 29.6% for weaned calves. Diarrhoea/ scours, pneumonia and nutritional problems were the main causes of calf deaths.

Mean ages at first calving and calving intervals for the five farms ranged from 33 to 39 months and 375 to 489 days, respectively. Overall mean lactation milk yield, lactation length, dry period for individual farms ranged from 2197 to 2642 kg, 270 to 321 days and 86 to 165 days, respectively. The most important non-genetic factors affecting lactation performance traits were year of calving, parity and current calving interval. Milk production in most farms was declining, a trend attributed to deterioration in management. Weighted repeatability estimates were  $0.14 \pm 0.01$ ,  $0.21 \pm 0.02$  and  $0.37 \pm 0.01$  for calving interval, lactation length and lactation milk

yield, respectively.

Mean percentages of milk components on test-days did not differ much from those recorded for Friesians elsewhere in the tropics. Stage of lactation, calendar month, parity and year of recording highly influenced their variations. Milk yield on test-days had strong negative correlations with BF% (-0.47) and protein percent (-0.53). BF and protein percentages were positively correlated (0.59).

Day-to-day variation of milk yield was higher at Uyole than at Ihimbu and was associated with level of milk production and inaccurate recording. The most variable milk component was protein whose variation was ascribed mainly to errors of determination.

Part and cumulative milk records were highly influenced by parity, year and season of calving. Effect of calving interval was noticeable from the sixth month of lactation. Records in mid-lactation had the highest correlation with 305-day yield. Ratio and regression extension factors were derived based on findings from this study.

Performance in lifetime traits were similar to those reported elsewhere in the tropics. Age at first calving and first lactation yield had high association with lifetime

traits used in this study and were important estimators of lifetime milk production.

Several options of culling procedures were proposed and discussed. It was concluded that there is great opportunity for genetic improvement of dairy cattle in the southern highlands of Tanzania provided viability of calves is improved, the downward trend in performance is reversed, recording is improved and a culling procedure is adopted.

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DECLARATION

I, GEORGE CESILIUS KIFARO, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis has not been submitted for a higher degree award in any other university.

Signature:-----*GKif*-----

Date:-----*10-03-1995*-----

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## DEDICATION

"<sup>25</sup> And God made the beasts of the earth according to their kinds and the cattle according to their kinds,---. And God saw that it was good. <sup>26</sup> Then God said, 'Let us make man in our image, after our likeness and let them have dominion over the fish,--- and over the cattle and over all the earth,----'. <sup>31</sup> And God saw everything that he had made, and behold, it was very good."

Genesis 1: 25,26,31.

To my parents

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## LIST OF ABBREVIATIONS

ABA	Animal Breeding Abstracts
AI	Artificial insemination
AMY	Annualized milk yield
a.s.l.	Above sea level
BF	Butter-fat (milk fat)
°C	Degree Celsius
CAB	Commonwealth Agricultural Bureaux
CI	Calving interval
CP	Crude protein
DAFCO	Tanzania Dairy Farming Company
DP	Dry period
E	East
F <sub>1</sub>	First filial generation
FAO	Food and Agriculture Organization (of United Nations)
FCM	Fat Corrected Milk
ha	hectare/s
HPI	Heifer Project International
IDF	International Dairy Federation
ILCA	International Livestock Centre for Africa (Addis Ababa, Ethiopia)
kg	kilogramme(s)
km	kilometre(s)
LL	Lactation length

LMY	Lactation milk yield
LY	305-day milk yield
m	metre(s)
MALD	Ministry of Agriculture and Livestock Development (in Tanzania)
mm	millimetre(s)
NAFCO	National Food Company (in Tanzania)
No.	Number
S	South
SAS	Statistical Analysis System
SNF	Solids-not-fat
sp/spp	Species
TDL	Tanzania Dairies Limited
TISCO	Tanzania Industrial Studies and Consulting Organization
TS	Total solids
TSAP	Tanzania Society of Animal Production
TSZ	Tanzania shorthorn zebu
UAC	Uyole Agricultural Centre
UNDP	United Nations Development Programme
USA	United States of America
VFA	Volatile fatty acids

## LIST OF STATISTICAL NOTATIONS

ANOVA	Analysis of variance
b	regression coefficient
CV %	coefficient of variation in percent
d.f.	degrees of freedom
GLM	General Linear Models
LSM	Least squares mean(s)
MANOVA	Multivariate analysis of variance
MS	Mean square
n	number of observations in a sample
r	coefficient of correlation
R <sup>2</sup>	coefficient of determination
s.d.	standard deviation
s.e.	standard error
SS	Sum of squares

Significance levels: ns non significant (P > 0.05)

\* significant at 0.01 < P < 0.05

\*\* significant at 0.001 < P < 0.01

\*\*\* significant at P < 0.001

## CHAPTER 1

## INTRODUCTION

The first dairy development plan for Tanzania whose implementation formally started in 1975 was prompted by the increase in imports of dairy products from about Tsh.19 million in 1962 to 70 million in 1973 (Mwakatundu,1978). Furthermore, there was a rapidly increasing demand of milk in towns where dairy plants relied mainly on imported milk solids for reconstitution. The inception of the dairy development strategy was aimed at raising the country's number of exotic dairy animals and consequently be able to increase milk production.

The milk supply to Tanzanians in 1984, when the livestock census took place, was estimated to come mainly from the traditional subsector (220 million litres), followed by improved dairy cattle (73 million litres) and about 47 million litres were reconstituted by Tanzania Dairies Ltd. from imported milk solids (Kurwijila, 1988). ILCA (1991) reports estimated milk production from all cows (based on FAO reports) in 1987 to be 440 million litres and a per caput consumption of 22.0 litres per year. Tanzania's population growth rate during 1980-87 was 3.5% and the per caput annual growth rate in milk consumption for the period 1985-87 was negative (-1.8 %). This reflects the relatively small contribution of the exotic dairy cattle to the

country's total milk production.

As a strategy in implementing the dairy development plan, the Tanzania Dairy Farming Company (DAFCO) was formed in 1974 to be responsible, inter alia, for operating large scale dairy farms from which farmers could acquire surplus improved dairy cattle. In addition, the farms could increase the amount of pasteurized milk to urban consumers through dairy plants and play the role of establishing a national milk recording scheme (MALD,1986).

Three approaches have been attempted to increase the number of exotic dairy cattle in Tanzania. Firstly, through direct importation of live animals (cows/heifers and bulls). This started in the 1950s but was intensified in the late 1970s. Initially animals were imported from the neighbouring country Kenya but later importations were made from United States of America (USA), Europe, New Zealand, and lately from Zimbabwe. Some of these animals were sold directly to farmers but the majority were stocked in DAFCO and other government/parastatal farms. Secondly, artificial insemination (AI) services were developed to augment introduction of exotic germplasm into the national dairy herd. The third approach has been the establishment of livestock multiplication units in which pure exotic sires, mainly of Friesian, Ayrshire and Jersey breeds, are mated to zebu females (Boran or Tanzania shorthorn zebu-TSZ) to produce F<sub>1</sub> heifers for distribution to farmers.

The success of the exercise of increasing the number of dairy cattle largely depends on their survival rate and reproductive efficiency. Surplus animals can be used to expand the herds, stock other farms or sold to small-holder farmers. One of the reasons for poor herd growth rate is hypothesized to be low survival rate among calves. Losses could be due to abortions, still-births or deaths. Calf deaths result in loss of animals of high genetic value, fewer herd replacements and reduced selection differential.

For a country like Tanzania where the supply of milk is far below demand, milk yield from every lactating animal is of great importance. However, the level of milk production is determined by genotype of the cow, environmental sources of variation and the interaction between the two. Knowledge of important non-genetic factors influencing milk production is necessary for improving management of the animals and for implementing breeding programmes.

The importance of energy content in milk was recognized as early as 1920s (Gaines and Davidson, 1923 cited by CAB, 1980) when it was realized that a fair comparison of cows' milk producing abilities should be based on 4% fat-corrected milk (FCM). Of late, protein has received more attention from nutrition point of view and has been included not only in routine testing schemes but also in selection indices. No routine testing scheme for milk

composition has been attempted in Tanzania.

Dairy recording is at a very advanced stage in many developed countries. On the contrary, many developing countries have not regarded dairy recording at farm and national level as an integral component in dairy cattle management and improvement. Among large commercial dairy farms, some still practice hand milking while others are machine milking. Frequency of recording varies. Daily recording is still practised in many farms; few farms record twice or thrice per month. In developed countries investigations are being made on precision of milking devices (e.g. Smith and Plowman, 1968), but in developing countries quite few studies have been done on variation of daily records and errors of estimated lactation yields (e.g. Lindström, 1976a,b; Mchau et al, 1983). Less accurate daily records result in imprecise estimates of lactation yields. Frequent disturbances in daily routines such as variations in concentrate supply, poor handling of cows during milking including incomplete evacuation of udders, inadequate water available to cows and irregular intervals between milkings tend to increase day-to-day variation in milk yield and thus errors of lactation records.

In most progeny testing schemes, generation interval is minimised by using first lactation records and reduced still further by use of part records (Lamb and McGilliard, 1960). In order to increase number of daughters per sire,

incomplete records (terminated or in progress) are extended to full lactation records and included in sire evaluations. Extended records can also be used for ranking cows within herds in order to arrive at culling decisions. Level of influence of non-genetic factors on part records varies with stage of lactation (Fritz et al.,1960 and Auran, 1973). It is, therefore, necessary to establish which factors have to be adjusted for before records are extrapolated.

Herdlife or stayability is the duration a cow remains in the herd and obviously that is highly associated with number of calves she can leave behind, with the amount of milk she can produce in her lifetime and with the required annual herd recruitment rate. In dairying it is desirable that cows selected for high milk production stay in the herd for a long time, produce more milk during their high productive periods and leave calves of high genetic merit. Selection of cows is done early in life, after first or second lactation hence association between early life performance traits and herdlife is of interest. Furthermore, reasons for terminating herdlife are of interest for breeding, management and disease control purposes.

This study was undertaken with the following objectives:

1. To examine performance of exotic dairy cattle in the

southern highlands of Tanzania with respect to mortality, reproduction, milk composition, herd life and milk production traits.

2. To quantify non-genetic sources of variation affecting traits considered above (in 1).
3. To establish sound culling and breeding programmes which will optimize genetic progress for milk production.

## CHAPTER 2

## LITERATURE REVIEW

In this literature review, definitions and underlying concepts have been cited from all relevant sources but performance data have been restricted mainly to those reported in the tropics and/or sub-tropics. Only in occasions where studies from the tropics were not available, information from the temperate countries has been used. As much as possible literature based on Friesians, Ayrshires and Guernseys (breeds used in this study) was selected but occasionally other breeds or breed crosses available in Tanzania were cited.

## 2.1 Calf mortality

### 2.1.1 Introduction

In the tropics herd sizes grow slowly or remain stagnant due to high calf wastages. Besides economic losses due to costs already incurred on calf rearing, deaths also result in loss of animals of high genetic value, fewer herd replacements and reduced selection differential, which influences genetic gain (Vaccaro and Vaccaro, 1981). It is further pointed out by Asker and El-Itriby (1957) that calf

mortality rates of an introduced breed are closely associated with adaptability in a new environment and resistance to endemic diseases. The magnitude of death rate in a farm is a reflection of level of management but could also be indicative of herd health problems (Simensen, 1986) and may imply reduced annual income and increased veterinary expenses (Hollon and Braton, 1975).

#### 2.1.2 Abortions and Stillbirths

Abortions were defined by Simensen (1986) as deaths of foetuses before 270 days of gestation. Frequency of abortions is calculated as number of these incidences as percent of total number of pregnancies (Madsen and Vinther, 1975).

Rates of abortions have varied with country of study, herd and even between years within the same herd. Vaccaro (1974a) made a review on calf mortality rate in the tropics and reported rates of 2.5% from a Jersey herd in Latin America and 2.8% from a Friesian herd in Columbia. Red Danish cattle managed in Thailand had an abortion rate of 21.5% while their crosses with 67.5 to 93.75% Bos taurus blood had abortions ranging from 3.8 to 5.3% (Madsen and Vinther, 1975). Vaccaro and Vaccaro (1982) reported an overall abortion rate of 6.7% and a range from 2.5 to 11%

in various herds raising Friesian crosses in Venezuela. Records of Ayrshire cattle on one farm in Iringa region, Tanzania, showed incidence rate of abortion to be 4.1% (Kifaro and Temba, 1990). Comparatively low rates of 1.8% among purebred Friesians and 2.5% in their first crosses were observed by Asker and El-Itriby (1957). In Ghana, Canadian Holstein Friesians had an abortion rate of 6.7% (Kabuga, 1990).

In the article by Vaccaro and Vaccaro (1982) year differences in abortion rates were significant. There was an apparent increase in incidence rates as years went by. Effects of breed and season of calving were not important. In Brazil, Vaccaro (1974a) reported higher incidences among Friesians (11.1%) than in Jerseys (6.2%) or Guernseys (1.9%). Hollon and Braton (1975) found large variations between genetic groups with pure Friesians having higher frequencies of abortions compared to crossbred cows.

Stillbirths are perinatal deaths at over 270 days of gestation and during the first 24 hours of life (Auran, 1972). Rate of stillbirth is the proportion (in %) of number of such incidences to the total number of calves born (Igboeli, 1973a; Madsen and Vinther, 1975). Simensen (1986) notes that over 80% of all perinatal deaths are due to anoxia resulting from prolonged parturition, big calf

size and small pelvic opening of the dam but rarely septicaemia. Direct and maternal genetic effects contribute considerably towards difficult calvings and resulting stillbirths (Phillipson,1976).

Frequencies of stillbirths have been a subject of study by many workers. Igboeli (1973b) found that stillbirths accounted for 8.6% of all calvings in 15 Zambian state farms or privately owned dairy farms raising Friesians imported from South Africa and Europe. In a herd located in Maracay, Venezuela, Vaccaro (1974a) reported a rate of stillbirth of 6.9% while in Thailand, Madsen and Vinther (1975) obtained frequency of stillbirth of the order of 5.1% among Red Danish cows and ranging from 3.3 to 6.0% among their crosses with Indian milch cattle. Kabuga (1990) in Ghana recorded a rate of 8.6%. Rather low frequencies of stillbirths (2.5% to 3.3%) were noted by Vaccaro and Vaccaro (1981,1982) among Friesians and Brown Swiss first crosses in Venezuela and by Ragab and Asker (1959) (2.2%) among Dutch Friesians in India.

Analysis of frequencies of stillbirths by Vaccaro and Vaccaro (1981) indicated that differences between years and seasons were statistically significant with a tendency to increase with years; however, breed differences were not important.

### 2.1.3 Postnatal mortality rates

A number of ways are employed in calculating calf mortality rate. This variation is based on the chosen denominator. The numerator is always the number of calves that die while the denominator can be either total number of calves born (e.g. by Shoo et al., 1992) or the average number of calves in that population during the specified time period as described by Putt et al. (1987). It is imperative to specify the age limits of calves involved and time period considered, (e.g. annual mortality rate). The latter Putt et al. (1987) termed "crude death rate". "Proportional mortality rate" was defined as the number of deaths occurring from a specific cause in a specified time period divided by number of all dead calves during that period.

Differences in definition alone can cause variation in reported rates of deaths among herds. Death statistics from the tropics reviewed by Vaccaro (1974a) showed that most studies did not define ages. Most losses were observed to occur before 18 months of age and ranged from 16% to as high as 71% with most estimates being between 30 and 40%. Consistently it has been demonstrated that native and crossbred calves had superior survival rates compared to exotics. In Vaccaro's (1974a) review, Friesians managed in Venezuela, Fiji and Mozambique had death rates of 3.7, 19.7

and 33.3%, respectively. The Mozambique study had not specified age limits but the others had considered calves that were below 6 months of age. Asker and El-Itriby (1957) reported a death rate of 32.3% among Friesians in Egypt while Sharma et al. (1975) found an overall loss of 18.7% in Brown Swiss calves, Indian milch cattle and their crosses. Previous work in Tanzania by Mhaiki (1980), Msanga and Nduye (1991) and Shoo et al.(1992) have shown death rates from 5.8 to 12.1 for heifer calves below one year of age, 29.2% for calves below one year of age and a death rate of 23.0% (age not specified), respectively. These studies were carried out in the eastern and north-eastern zones of Tanzania and involved a wide spectrum of breeds and breed crosses.

Genetic and environmental factors influence rates of calf losses. Death rates have been shown to vary significantly with breed. Channel Island dairy breeds were observed to have higher calf deaths than Ayrshire which in turn had higher incidences than Shorthorns or Friesians (Roy, 1970). Similarly, crossbred calves experienced higher mortality (5.2%) compared to purebred Friesians (3.5%)(Peters, 1986) Effect of sex of calf on death rate has attracted a number of studies. The common phenomenon in all studies, irrespective of significance of the difference, has been higher survival rate in heifer calves than in bull calves.

One of the reasons advanced to explain this difference is the preferential treatment in terms of feeding and management given to heifer calves due to their higher economic value. In the herd studied by Msanga and Nduye (1991), for example, male calves were weaned at 12 weeks of age compared to 16 weeks for heifers. Survival rate of heifers was 75 while it was only 66.2% in males, the difference being significant ( $P < 0.05$ ). Ranatunga (1965), working with five government farms in Sri Lanka, found the post-natal mortality up to 6 months of age to be 6.4 and 5.2% in males and females, respectively. Corresponding death rates reported by Sharma et al., (1975) were 19.3 and 18.0%. It appears even when no preferential management is given to female calves, death rates are higher among males.

Another common feature in many studies on calf mortality rates ( e.g. Amble and Jain, 1967; Mchau et al., 1983; Miller and Gilmore, 1949; Sharma et al., 1975; Shoo et al., 1992) is that number of deaths declines as age of calves advances. Sharma et al. ( 1975) showed death rates of 9.3, 5.1 and 2.8% for calves below one month of age, 1 - 3 months and 3 to 12 months, respectively. Asker and El-Itriby (1957) noted that over 70% of all calf losses occurred before 6 months of age, thereafter losses decreased with age. Ragab and Asker (1959) found 79.3% of the deaths to occur before weaning; 29.6% in the first

month and 27% in the second month. As calves grow older they become better able to withstand adverse environmental conditions and infections. On the contrary, Msanga and Nduye (1991) reported higher post-weaning (4 to 12 months of age) mortality (21.8%) than pre-weaning mortality (8.4%) and attributed this to the failure of calves to withstand stressful out-door environment. In the report by Mchau et al. (1983) on Friesian calves, pre-weaning death rate was 12.8% whereas death rate from 3 to 12 months of age was 38.9%.

Year differences in death rates is a reflection of changes in management, weather and occurrence of epidemics. Often yearly variations are large. In the study by Sharma et al. (1975) which covered 20 years (1952 - 1971, inclusive), year effect was significant ( $P < 0.01$ ) and annual death rates ranged from 5.6 to 38.5%. In Ghana, Osei et al. (1991) studied influence of season of calving on calf deaths between zero and 12 months of age. They found that 9.6% of the deaths occurred in the dry season and 8.2% in the rainy season. No test for significance was made. However, Mhaiki (1980) found no significant influence of season on survival rate of calves in eastern Tanzania.

Calf management systems such as herd size, level of supervision, design of calf pens (pens on floor or on

elevated stalls, ventilation system) and liquid milk feeding programmes have been elucidated by Hartman et al.(1974) to contribute to calf deaths. Similarly, indoor or outdoor management system has been observed to affect survival of calves. Vaccaro (1974a) reported of a study done in the Philippines in which fully housed calves, calves housed at night only and those reared exclusively on pasture had death rates of 7, 17 and 43%, respectively.

#### 2.1.4 Causes of calf deaths

Roy (1980) and Simensen (1986) contemplate that enteric and respiratory disorders are the two major calf health hazards. Among the enteric disorders neonatal diarrhoea (that is, faeces of less than 120 g DM kg<sup>-1</sup>) occurs during the first 10 days of life. The most important pathogen responsible for this is Escherichia coli. At a later stage Salmonella spp. may play part (Roy, 1970; Simensen, 1986). Roy (1980) calls diarrhoea associated with E. coli as putrefactive diarrhoea. Nutritional diarrhoea arises from gastric dysfunction and may develop into infectious diarrhoea if enteropathogenic strains of E. coli become dominant. Both diarrhoeas cause damage to villi of duodenal mucosa, reduce enzyme activity such as of lactase and cause body weight loss of up to 25%. Respiratory disorders, on the other hand, frequently occur in 1 - 2 months old

calves. Causes are mainly bacteria, viruses and mycoplasmas (Simensen, 1986).

Amble and Jain (1967) were studying causes of deaths on military farms in India and observed that nearly two thirds of total deaths of female young stock was accounted for by pneumonia (22%), enteritis (21%) and rinderpest (19%). Among herd health traits studied by McDowell and McDaniel (1968) in heifers before calving were scours, pneumonia, diarrhoea, bronchitis, foot rot and sterility. Scours, pneumonia and sterility constituted 21% of the reasons for heifer disposals. In an earlier study on the Uyole dairy herd in Tanzania (Mchau *et al.*, 1983) involving calves of less than one year of age, greatest causes of death were pneumonia (18.1%) and nutritional deficiencies (20.8%). Recently a study was made on three dairy farms in the eastern zone of Tanzania (Shoo *et al.*, 1992). They had calculated 'cause specific mortality rates' of 322 dead calves of various dairy breeds without specifying age limits. Most common causes of death were diarrhoea (6%), pneumonia (5%) and what they termed weak calf syndrome (3%). In the latter ailment, calves were born weak, unable to stand and suckle but no significant lesions were observed on necropsy. They, however, admitted that aetiological agents responsible for pneumonia and diarrhoea were not determined. Tick-borne diseases, pneumonia and

enteritis were the most frequent diseases in the review of Vaccaro (1974a). Among the causes of losses reported later by Vaccaro and Vaccaro (1981), pneumonia, diarrhoea and joint infection caused by faulty housing accounted for 30.6, 27.1 and 19.4% of the deaths, respectively. Peters (1986) conducted a study on influence of management system on disease incidences and the resulting deaths among 1996 calves. Disease incidence rates for pneumonia, diarrhoea, pneumonia combined with diarrhoea, bloat and navel infection were 48.3, 14.1, 1.7, 0.6 and 0.6%, respectively. Corresponding case death rates (number of dead calves as percent of affected calves) were 2.3, 13.9, 40.0, 16.7 and 16.7%. The study illustrated that respiratory diseases followed by enteric diseases were the most common disease conditions encountered on a calf unit.

## 2.2 Reproductive traits

Due to un-developed artificial insemination services and recording systems, many important fertility traits have not been widely studied in the tropics. With the minimum amount of recording being practiced, at least calving dates are reported which permit calculation of ages at first calving and calving intervals. These are, therefore, the most commonly studied reproductive traits.

### 2.2.1 Age at first calving

Mean age at first calving in the tropics varies with location (Table 1). The means range from about 24 months to more than 48 months with the majority between 30 and 36 months. Information on Friesians appears widely studied compared to other breeds; with almost no information on Guernseys.

Rege (1991) conducted an analysis of variance on age at first calving of 8510 Friesian heifers in Kenya in which herd, year, and season of calving were included in the model. The three factors accounted for 7.0, 2.9 and 0.1% of the total variation, respectively and were significant. Year and season of calving were also included in the analysis made by Madsen and Vinther (1975). The two factors contributed 4.3 and 0.6% to the total variation of this trait, respectively. Again, both factors were significant (at 1 and 5% level of probability, respectively). Similar findings on effects of period and season were reported previously on the Uyole herd in Tanzania (Kifaro, 1984).

Table 1: Mean ages at first calving for Friesians,  
Ayrshires and Guernseys in the tropics

Breed	Country	Means(months)	Author/s
Friesian	Ghana	30.7	Gyawu <u>et al.</u> (1988)
,,	Ghana	34.1	Osei <u>et al.</u> (1991)
,,	Kenya	34	Kiwuwa (1974a)
,,	Kenya	35.1	Rege (1991)
,,	Malawi	41.7	Agyemang and Nkhonjera(1986)
,,	Malawi	37.7	,,
,,	Mozambique	>48	Vaccaro (1975)
,,	Nigeria	28.7	Knudsen and Sohael (1970)
,,	Uganda	27.5	Trail and Marples (1968)
,,	Zambia	30.7	Igboeli (1973b)
,,	Zambia	34.8	Mwenya and Shandomo (1986)
,,	Ecuador	31.2	Vaccaro (1974b)
,,	El-Salvador	32.2	Reaves <u>et al.</u> (1985)
,,	Peru	38	Vaccaro (1974b)
,,	Peru(Lima)	30	Vaccaro (1974b)
,,	Fiji	36.8	McIntyre (1971)
,,	Philipine	24.5	Vaccaro (1975)
,,	Sri Lanka	40	,,
Ayrshire	Kenya	36	Kimenye and Russell (1975)
Guernsey	EL-Salvador	32.4	Reaves <u>et al.</u> (1985)

### 2.2.2 Calving interval

Table 2 provides information on means of calving intervals for temperate dairy breeds in the tropics. The means range from 360 to as high as 537 days. Most reported means were above 400 days.

Igboeli (1973b) classified 870 calving intervals from six dairy farms in Zambia according to month of calving. The longest calving intervals occurred after calving in December whereas the shortest calving intervals (with most calvings) appeared in August and September. These findings demonstrate the association between seasonal availability and quality of forages, cows' energy balance level and reproduction efficiency. Kifaro (1984) found significant influence of season of previous calving on calving intervals in two dairy farms in Mbeya region, Tanzania. Season of calving contributed only 0.1% of total variation ( $P < 0.01$ ) in calving intervals of Kenya Friesians (Rege, 1991) and 0.2% (but not significant) in various dairy cattle crosses in Thailand (Madsen and Vinther, 1975).

Another important non-genetic factor investigated upon is parity. The influence of this factor on calving interval varies with farm (Kifaro, 1984). In some articles e.g. Sadana and Basu (1983) and Al-Ani *et al.* (1986), parity was not an important source of variation while in others (like

Table 2: Mean calving intervals for Friesians and Ayrshires in the tropics

Breed	Country	Mean or range of means (days)	Author/s
Friesian	Ghana	469 ± 9	Gyawu <i>et al.</i> (1988)
Friesian	Ghana	488 ± 67 <sup>a)</sup>	Osei <i>et al.</i> (1991)
Friesian	Kenya	425	Kiwuwa (1974a)
Friesian	Kenya	393 - 423	Collins-Lusweti (1990)
Friesian	Kenya	412	Rege (1991)
Friesian	Malawi	498	Agyemang & Nkhonjera (1986)
Friesian	Nigeria	367	Vaccaro (1973)
Friesian	S. Africa	383	Vaccaro (1973)
Friesian	Uganda	401	Trail and Marples (1968)
Friesian	Zambia	425 ± 3	Igboeli (1973b)
Friesian	Zambia	400 ± 2	Mwenya & Shandomo (1986)
Friesian	Zimbabwe	406	Vaccaro (1973)
Friesian	India	421 ± 15	Sadana and Basu (1983)
Friesian	India	443 ± 11	Mangurkar <i>et al.</i> (1987)
Friesian	Bolivia	417 - 470	Combellas <i>et al.</i> (1981)
Friesian	Ecuador	451	Vaccaro (1974b)
Friesian	Mexico	418 ± 61 <sup>a)</sup>	McDowell <i>et al.</i> (1975)
Friesian	Venezuela	432 ± 97 <sup>a)</sup>	Vaccaro and Vaccaro (1982)
Ayrshire	Kenya	458 - 460	Collins-Lusweti (1990)
Ayrshire	Tanzania	434 - 537	Bruhn and Mgheni (1977)
Ayrshire	Tanzania	425 - 485	Mhaiki (1980)

a) Standard deviations, the rest are standard errors

Madsen and Vinther, 1975) it was very important. In Rege's (1991) investigation age accounted for 1.7% ( $P < 0.01$ ) of total variation in calving intervals and was the second most important factor after effect of herd. Calving intervals after the second calving were found by Igboeli (1973b) and Al-Ani et al. (1986) to be longer than first or third calving intervals. On the contrary, analysis of one herd by Mchau et al. (1983) for the period 1971 - 1975 revealed that the first calving interval was longest (399 days) and that it decreased with age to fourth and above calvings (375 days).

Where natural service is practiced and bulls run with cows all the time, yearly variations in calving interval could be associated with variations among bulls used, feeding regime and nutritional status among cows. Calving interval has been shown by Madsen and Vinther (1975), Kifaro (1984) and Rege (1991) to be significantly influenced by year of calving.

## **2.3 Lactation performance traits**

### **2.3.1 Milk yield**

Many tropical countries have imported various temperate breeds in order to increase milk production. Reports on

performance of these cattle have been based on either total lactation yield or 305-day milk yield. Annualized milk production (an index which combines milk production and calving interval) has rarely been used (e.g. Agyemang and Nkhonjera, 1986; Rege, 1991). The term 305-day milk yield is the amount of milk produced in the first ten months of lactation which is considered the standard lactation length. Milk yield produced in less than 10 months is supposed to be considered a 305-day yield. Unfortunately such short lactations have often been omitted in data analyses.

There has been a tremendous amount of variation in performance, both between breeds and within breeds between locations (Table 3). Average milk yields have ranged from slightly above 1500 to above 4500 kg. This large variation in performance of the same breed between locations can be ascribed to large differences in nutrition and management practices. The Friesian herd reported by Martinez et al. (1982), for example, averaged 4291 kg, a production level which was thought to have been attained due to zero grazing management based on cut forages and high levels of concentrates.

The sources of variation influencing milk yields include month/season of calving, breed, year, parity or age and

Table 3: Reported mean milk yields for Friesian, Ayrshire and Guernsey breeds in the tropics and sub-tropics

Breed	Country	Record type <sup>1)</sup>	Mean/range of means (kg)	Author/s
Friesian	Ghana	305-D	4683 ± 149	Gyawu <i>et al.</i> (1988)
	Ghana	305-D	2499 ± 148	Osei <i>et al.</i> (1991)
	Kenya	LMY	2923	Kiwuwa (1974a)
	Kenya	305-D	2724 ± 14	Rege and Mosi (1989)
	Kenya	305-D	3577	Rege (1991)
	Kenya	AMY	2984	Rege (1991)
	Malawi	LMY	2366	Agyemang and Nkhonjera (1986)
	Malawi	AMY	2071	Agyemang and Nkhonjera (1986)
	Tanzania	LMY	2077-2846	Bruhn and Mgheni (1977)
	Tanzania	LMY	3789	Lauridsen (1979)
	Tanzania	LMY	1236-2376	Mhaiki (1980)
	Tanzania	LMY	2286 ± 35	Mchau <i>et al.</i> (1983)
	Uganda	305-D	2952	Trail and Marples (1968)
	Zambia	LMY	3400	Igboeli (1973a)
	Zambia	LMY	3863 ± 41	Mwenya and Shandomo (1986)
	Zimbabwe	LMY	4247	Collins-Lusweti (1990)
	India	305-D	2270-6406	Mangurkar <i>et al.</i> (1987)
	Brazil	LMY	3785-3959	Vaccaro (1974b)
	Ecuador	LMY	3888	Vaccaro (1974b)
	El-Salvador	LMY	3173	Reaves <i>et al.</i> (1985)
Honduras	LMY	3371 ± 37	Mejia <i>et al.</i> (1982)	
Mexico	LMY	4878 ± 1612	McDowell <i>et al.</i> (1975)	
Peru	LMY	1258 - 1757	Vaccaro (1974b)	
Venezuela	LMY	1582 - 4672	Combellas <i>et al.</i> (1981)	
Venezuela	305-D	4041 - 4564	Martinez <i>et al.</i> (1982)	

Table 3 contd.

Ayrshire	Kenya	LMY	1912 - 2463	Collins-Lusweti (1990)
	Kenya	305-D	2727	Kimenye and Russell (1975)
	Tanzania	LMY	1512 - 3646	Bruhn and Mgheni (1977)
	Tanzania	LMY	1739 - 2330	Mhaiki (1980)
Guernsey	El-Salvador	LMY	2737	Reaves <u>et al.</u> (1985)

<sup>1</sup> LMY= Lactation milk yield 305-D = 305-day milk yield

AMY = Annualized milk yield

herd differences. Variations among herds could be genetic or environmental but the latter contributes most. In a recent study in Kenya, Rege (1991) reported a significant herd effect on 305-day and annualized milk yields. In an earlier article (Rege and Mosi, 1989) herd accounted for almost 40% of total variation in 305-day milk yield.

Several authors have shown that milk yield increases with parity or age. Yield increases are associated with increase in body size of cows (more capacity to eat) and milk secretory cells in udders. Reports by Osei et al. (1991) and Rege and Mosi (1989) recorded increases of 48.0 and 38.2% between first lactation (1984 kg) and third lactation (2936 kg) and between first parity (2319 kg) and fifth parity

(3205 kg), respectively.

Kiwuwa (1974b) analysed records on Kenya Friesians for the period 1954-65 and found no marked yearly changes in milk yields. Reasons advanced for this finding was that there had been no selection, use of superior sires nor improvement in overall management. Phenotypic and environmental milk production trends evaluated by Rege and Mosi (1989) in Kenya indicated that 305-day milk yields went up between 1976 and 1984 and this was attributed to stabilized management including the setting up of more systematic breeding programmes. Martinez et al. (1982) revealed that year of calving significantly affected milk production in Venezuela. Between 1967 and 1971 milk yield increased but diminished thereafter.

Influence of season of calving on milk yield varies from location to location. Kiwuwa (1974b); Al-Ani et al.(1986) and Rege (1991) could not detect any significance of this factor on lactation milk yield but Martinez et al.(1982) did on 305-day milk yields and Rege (1991) on annualized milk production. It appears that the bigger the variation between the best and the worst season in terms of feeding levels, the larger the likelihood to detect real differences.

### 2.3.2 Lactation length

The duration of lactation is closely associated with milk production ( $r = 0.541$ ; Mwenya and Shandomo, 1986) and could partly be a measure of persistency. Ideally, a cow is supposed to calve annually, lactate for about 305-320 days and dry off for about 45-60 days. Lactation ceases because it is depressed by new pregnancy whose effect is noticeable from about 150 days after fertilization (depending on parity and stage of lactation; Auran, 1974) or because the cow is a poor milk producer. In view of that, lactation lengths vary with herd production level and length of calving interval. In a herd studied by Martinez *et al.* (1982), the herd average was 4371 kg, calving to conception interval was 5 months and lactation length was 325 days. Vaccaro (1974b) reported average lactation lengths of less than 290 days from a number of herds in Brazil and Ecuador. Mean lactation lengths among parities recorded by Lauridsen (1979) for imported cows of Kitulo herd, Tanzania ranged from 305 to 382 days in various parities. Two Friesian herds in Malawi had average lactation lengths of 321 and 290 days (Agyemang and Nkhonjera, 1986).

Kiwuwa (1974a,b) reported that lactation lengths were slightly shorter in younger than in older cows. The lengths

for the first three lactations were 274, 282 and 286 days, respectively. Quite the opposite was reported by Martinez et al. (1982) and Kifaro (1984). The latter author observed lactation lengths to decrease from 308 to 274 days between first and fourth lactation.

In Kenya lactation lengths after the two wet seasons were 9.8 and 11.8 days shorter than after calving in the dry season (Kiwuwa, 1974b). The explanation for this finding was that cows calving during the rainy months had their last phase of their lactation (7 - 9 months later) in the dry season. Shortage of feed during this period depressed milk production and the cows dried off earlier. The opposite was the case for dry season calving cows.

### 2.2.3 Dry period

If calving interval is kept constant, good milk producers will tend to lactate for a longer time and have short dry periods; the converse is also valid. Long dry periods allow cows to recoup and replenish body reserves ready for next lactation. McDowell et al. (1975); Sadana and Basu (1983); Al-Ani et al. (1986) and Mangurkar et al. (1987) reported mean dry periods of  $72 \pm 39$ ,  $85 \pm 13$ ,  $130 \pm 11$  and  $85 \pm 8$  days, respectively. Further, Bruhn and Mgheni (1977) recorded dry periods ranging from 32 to 209 among Friesians

and from 189 to 248 in Ayrshires at Morogoro, Tanzania. Agyemang and Nkhonjera (1986) reported mean dry periods from two Friesian herds in Malawi of 179 and 133 days.

Sadana and Basu (1983) analysed dry periods for effect of breed and lactation number. Only parity was a significant source of variation showing a clear trend of dry periods to decrease during the first three lactations ( 123, 106 and 61 days, respectively). Effects of farm, parity and calving season on dry periods were studied by Al-Ani *et al.* (1986). Each one accounted for less than 1.4% of total variation of this trait and none was significant.

#### 2.4 Repeatability estimates

Repeatability of a character is estimated as the proportion of the variance among observations which is caused by permanent differences among animals (Pirchner,1969). It indicates the proportion of the observed differences between individual records caused by differences in real producing ability. It is calculated as intra-class correlation:

$$r = v_b / (v_b + v_w) \quad (1)$$

where according to the genetic model (Falconer, 1981;

Becker, 1984)

$V_b$  = component of variance among individuals  
 = all genetic variances plus permanent  
 environmental variance peculiar to the  
 individual

$V_n$  = error component (within individuals)  
 = temporary environmental variance

Alternatively, it could be calculated as a product moment correlation between measurements of the same animal made at different times. Falconer (1981) further noted two assumptions implicit in the idea of repeatability: a) the variances of the different measurements are equal and have their components in the same proportions, and b) the different measurements reflect what is genetically the same trait.

There are several uses of repeatability:

1. It sets the upper limit of heritability ( $h^2$ ) of a trait. Where it is not possible to estimate  $h^2$ , repeatability provides an idea about the maximal possible size of  $h^2$  since  $h^2$  is never higher than repeatability (Pirchner, 1969; Falconer, 1981; Becker, 1984).
2. If a trait is highly repeatable, a single measurement will be accurate enough to predict future performance

and to estimate real producing ability of the individual from past records;

3.  $h^2$  is usually estimated from one record per individual. With  $n$  records per individual the temporary environmental variance is reduced by the reciprocal of  $n$ ; consequently  $h^2$  will be increased. The heritability of an average of  $n$  records is:

$$h_n^2 = h^2 \times n / [1 + (n - 1) r] \quad (2)$$

where  $h^2$  = heritability of a single record

$r$  = repeatability of the trait

Repeatability estimates for milk yield obtained by Mejia et al. (1982) on Friesian and Brown Swiss cattle in Honduras were  $0.61 \pm 0.05$  and  $0.48 \pm 0.01$ , respectively. In Mexico, McDowell et al. (1975) came up with an estimate of 0.45 for the same trait. Rege (1991) made estimates of repeatability for 305-day milk yield, annualized milk production and calving interval from a rather large body of data and obtained values of  $0.549 \pm 0.049$ ,  $0.433 \pm 0.045$  and  $0.253 \pm 0.059$ , respectively. The first two estimates were considered high enough to justify culling on basis of performance in early lactations. However, estimate for calving interval (0.253) was low suggesting that temporary environmental factors contributed appreciably to the

variation of this trait. Earlier on, Lindström and Solbu (1978) arrived at an estimate of repeatability for 305-day milk yield of 0.24 for Kenya Friesians and this was considered to be too low for efficient culling.

## 2.5 Milk Composition

### 2.5.1 Introduction

Milk is essentially an emulsion of fat in a watery solution of sugar and mineral salts with protein in colloidal suspension. The major solid constituents of milk are fat, protein and carbohydrates (O'Mahony and Peters, 1987). Milk fat is mixture of triglycerides containing saturated and un-saturated fatty acids (e.g. oleic, linoleic and linolenic) with several minor lipid components such as phospholipids, sterols, carotenoids and the fat soluble vitamins A,D,E and K ( O'Mahony and Peters, 1987; McDonald et al.,1988). About 80% of milk protein is casein and the remaining 20% is made up of whey proteins. Lactose is the major carbohydrate fraction in milk; a disaccharide which is found only in mammalian milk.

The contribution of milk fat in the total milk energy was recognized by Gaines and Davidson (1923; cited by

CAB,1980). They derived the formula:

$$\text{FCM} = \text{M} ( 0.4 + 0.15 \text{ F} ) \quad (3)$$

where FCM = milk yield in terms of "fat corrected milk," the unit being 1 kg of milk with 4% fat

M = milk yield (kg)

F = fat concentration in %

Milk is used for food as well as a raw material from which various other dairy products are manufactured. In many countries fat percent is tested when milk is passed from the producer to the dairy factory (Eckles et al., 1973) and has received major economic emphasis in pricing of milk (Laben, 1963; Leaver, 1983). From dairy cattle breeding point of view fat percent has been included in routine monthly tests and subsequently in selection indices. Recently protein content has been included. In Norway, for example, protein content has been used as criterion in progeny testing of AI bulls since 1974 (Skjervold, 1982) and the term "fat and protein corrected milk" has been used whereby protein has been given double the weighting of fat.

$$\text{FPCM} = 0.22 \text{ M} + 7.5 \text{ F} + 15 \text{ P} \quad (4)$$

where FPCM = fat and protein corrected milk

M = kg milk yield

F = kg fat

P = kg protein

Laben (1963) enumerated reasons for research on milk components: a) It helps to determine amount and causes of variation in the components, b) it helps to determine whether changes can be made, if desired, c) it enables to recommend procedures of management or breeding or both that can bring about desired changes most efficiently, d) studies on environmental influences provide data for accounting for their variations before attempting genetic studies, and finally e) it provides clues to possible useful feeding and management controls on milk composition.

Determination of various milk components is being done in a number of ways. Butter fat (BF) has in most studies been determined by Gerber butyrometers (Bayoumi and Khalifa, 1966; O'Donovan et al.1960; Waite et al.1956; Ryoba and Hansen, 1985) or the Babcock method (Gacula et al.1968; Johnson et al.1961). The gravimetric method (IOS, 1984) is known as the reference method. For protein, the conventional method has been the Kjeldahl procedure (IDF, 1986); but the conversion factors of nitrogen into crude protein has been 6.38 (IDF, 1986; Waite et al.1956) or 6.35 (Boekel and Ribadeau-Dumas, 1987) instead of 6.25. Other

methods of protein determination include the orange G dye (e.g. by Gacula et al.,1968) or the dye binding methods with buffalo black (Sargent, 1967) or with amido black.

Milk total solids has been determined by the lactometer method (Bayoumi and Khalifa,1966; Khalifa,1966; Sargent et al.1967; Ryoba and Hansen,1985). Ryoba and Hansen (1985) used the following formula to convert percent fat and lactometer reading into percent total solids (TS):

$$\% \text{ TS} = \% \text{ fat} \times 1.22 + \text{lactometer reading} \times 0.25 + 0.72$$

(5)

Alternatively, the gravimetric method can be used which is equivalent to dry matter (DM) determination (Johnson et al.,1961; O'Donovan et al.; 1960; Waite et al.1956). Solids-not-fat is calculated as difference between percent total solids and percent fat (e.g. O'Donovan et al. 1960).

#### 2.5.2 Sources of variation in milk components

Variations in milk composition are largely quantitative rather than qualitative in nature, that is, milk from every source regardless of breed or species will contain the same classes of constituents (Eckles et al.,1973). Within breed and location, variation in milk composition can be

associated with age of cow, stage of lactation, cow to cow variations, season of calving, year, types of feed fed and level of feeding. Table 4 illustrates differences in milk

Table 4: Milk constituents of Friesians from the tropics and sub-tropics

Milk component(%)	Reported value	Country	Author/s
BF	3.59	Zimbabwe	Collins-Lusweti (1990)
BF	3.81	Kenya	Collins-Lusweti (1990)
BF	3.68±0.47 <sup>†</sup>	Kenya	Rege (1991)
BF	4.20	Tanzania	Mhaiki (1980)
BF	3.80	Tanzania	Mhaiki (1980)
BF	4.09±0.88	Tanzania	Ryoba & Hansen(1985)
BF	3.28±1.10	Saudi Arabia	Sharaby (1988)
BF	3.22±0.01	Venezuela	Calles <i>et al.</i> 1987)
BF	3.13±0.01	Venezuela	Calles <i>et al.</i> (1987)
BF	3.80	Brazil	Vaccaro (1974b)
BF	3.47	Brazil	Vaccaro (1974b)
BF	3.34	Ecuador	Vaccaro (1974b)
BF	3.44	Ecuador	Vaccaro (1974b)
CP	3.13±0.01	Venezuela	Calles <i>et al.</i> (1987)
CP	3.73±0.83	Saudi Arabia	Sharaby (1988),
TS	12.68	Tanzania	Ryoba & Hansen (1985)
TS	12.31±1.25	Saudi Arabia	Sharaby (1988)
SNF	8.40±0.01	Venezuela	Calles <i>et al.</i> (1987)

\* Lactation average and standard deviation

composition from different places in the tropics. What transpires from Table 4 are two things: first, there is scanty information on milk components. Secondly, mainly BF is studied, rarely TS, protein or SNF and there is almost no information on ash content. In the study by Ryoba and Hansen (1985) BF percentages from single test-days ranged from 1.8 to 6.4%, while Rege (1991) reported a standard deviation of BF to be 0.47 implying that about 95% of the BF values lied between 2.74 and 4.62% ( $\pm$  two standard deviations). BF, protein and TS yields on test-days for Friesians reported by Sharaby (1988) averaged 0.215, 0.239 and 0.814 kg, respectively.

Most common text books on milk production ( e.g. Eckles et al. 1973; McDonald et al. 1988; Schmidt and Van Vleck, 1974) demonstrate that while milk production increases during early stages of lactation, concentration of milk components particularly fat and protein decreases. The converse is true towards the end of the lactation. Gilmore et al. (1961) studied the influence of stage of lactation on concentration of protein and SNF in milk. Percentages of these components declined rapidly to lowest values 45-75 days after calving and then increased to end of lactation. BF, protein and SNF% were observed by Von Krosigk et al. (1960) and Yadav et al. (1991) to be lowest during the second month of lactation and thereafter increased steadily until lactation terminated. Johnson et al. (1961) revealed

that 62 and 78% of the variations in BF% and SNF%, respectively were accounted for by stage of lactation (both  $P < 0.01$ ). BF% was highest in the first month (3.82%) and lowest (3.32%) in the third month of lactation, SNF% was least in second month (8.38%) and highest in the sixth month (8.98%) whereas TS% was highest in first month (12.38%) and least in third month (11.75%). On the contrary, Sharaby (1988) found no significant effect of stage of lactation on concentrations of milk components but a significant influence on yields of fat ( $P < 0.01$ ), protein and TS ( $P < 0.05$ ). Protein percent remained almost constant throughout lactation. Only Waite et al. (1956) studied variations in ash content. Ash content fell slightly during the first 45 days and thereafter remained virtually constant.

Waite et al. (1956) studied the influence of age on BF, SNF and protein concentrations. All these components decreased with parity. BF, SNF and protein were highest in first lactation (4.11, 9.01 and 3.36%, respectively) and least in fifth lactation (3.90, 8.72 and 3.26%). Similarly, Collins-Lusweti (1990) recorded highest BF% of 3.68 in the first lactation and lowest (3.38%) in fifth lactation of Friesian cows. Kiuwa et al. (1983) working in Ethiopia revealed no significant effect of parity on BF% though there was a slight decrease as cows became older. Sargent

et al.(1967) regressed BF and protein percent on age. Analysis for BF% showed that the linear term was significant ( $P < 0.01$ ) though it accounted for only 1.8% of the variance, whereas for protein both linear ( $P < 0.01$ ) and quadratic ( $P < 0.05$ ) terms were significant accounting for 4.9 and 0.4%, respectively of protein variation. The partial regression coefficients were negative indicating decrease in protein and BF% with increase in age. Johnson et al.(1961) and Calles et al.(1987), working with Friesians, found BF% to increase with parturition number while SNF% decreased. In the article of Calles et al.(1987) SNF% decreased from 8.63 in first parity to 8.44% in fourth parity. Protein percent increased significantly with age. Sharaby (1988) studied contents and yields of milk components as they were affected by parity. Effects of parity were not significant for BF and protein concentrations, moderately significant ( $P < 0.10$ ) for TS% and highly significant ( $P < 0.01$ ) for BF, TS and protein yields on test-days. No obvious trends could be discerned in his results.

Waite et al (1956); Laben (1963); Gacula et al (1968) and Gaunt (1973) have indicated that influence of season of calving on concentration and yields of milk components tend to vary from place to place depicting differences in types of feed fed, herd management systems and ambient

temperatures. Generally constituent percentages follow the opposite course of yields. Type of feed fed is associated with energy concentration in the diet and type of volatile fatty acids (VFA) produced (Laben, 1963). In temperate countries, for example, it has long been known that in fall and early winter cows produce more milk and higher fat yields than other seasons (Schmidt and Van Vleck, 1974). In winter farmers feed and take more care of their cattle. In summer, on the contrary, milk production is lower because of under-nutrition and high temperatures especially if pasture is the main feed. In Venezuela, Calles et al.(1987) analyzed BF and SNF% and found that both were significantly (  $P < 0.05$  and  $P < 0.01$ , respectively) affected by season of calving. BF and SNF% were highest in the dry season. Kiuwa et al.(1983) reported a non-significant effect of season of calving on BF% but Johnson et al.(1961) found that month of calving was significant and accounted for 27 and 11% of the variation of BF and SNF percentages, respectively. Seasonal influence on BF, TS and protein percentages and yields was also studied by Sharaby (1988) and revealed to be an important source of variation. Only Waite et al.(1956) studied effect of season on ash content of milk and found it to be of negligible importance.

Kiuwa et al.(1983) and Rege (1991) working in Ethiopia and Kenya , respectively revealed significant effect of year

of calving on BF%. Further, Calles et al.(1987) also found year to significantly influence variations of BF%, protein and SNF. Another study by Johnson et al.(1961) showed significant differences between years in BF and SNF content. Despite demonstrating that some years had low fat tests, there was a trend of increase in fat content between 1938 and 1954. This was attributed to selection done to increase fat content. SNF content was not a criterion for selection consequently year effect was erratic. In yet another study on effect of year on milk component yields and concentrations (Gacula et al.,1968), there were no significant differences between years in SNF yield and BF%. Yields of TS, BF and protein increased with years and this was thought to be due to improvements in genetic makeup, nutrition and management of animals. There was a downward trend for protein, TS and SNF percentages over the years. This was partly associated with increase in yield of milk. There was no apparent trend for BF%.

With the increasing importance of milk constituents, many studies have been undertaken to evaluate influences of energy level, type of feed and roughage:concentrate ratio on variation of milk components especially BF%, TS% and protein percent. Effects of rations on relative concentrations of various rumen volatile fatty acids as precursors of milk fat have been elucidated. There has been

a general consensus (Eckles et al.,1973; Schmidt and Van Vleck,1974; Gaunt, 1973) that nutrition has limited influence on BF, SNF and protein percentages. Further, if changes occur, they are temporary in nature and have no practical significance. Effects of feeding on milk composition can therefore be summarized as follows:

- a) Feeding cows with saturated fats such as linseed, cotton seed cake, tallow, tends to increase supply of long chain fatty acids and ultimately fat content of milk (Schmidt and Van Vleck,1974; Leaver,1983; Eckles et al., 1973). The opposite is true for unsaturated fat e.g. of fish meal;
- b) High concentrate, low roughage diets including grain, heat treated feeds, pelleted forages and general high level of feeding is associated with increase in milk and fat yield but reduces fat content. SNF% especially protein percent is said to be slightly increased by increased intensity of feeding (Gaunt, 1973; Laben, 1963; Jorgensen and Schultz, 1963; Johansson, 1961; Bishop et al.,1963). These rations are said to depress rumen acetic acid and  $\beta$ -hydroxybutyric acid used for milk fat synthesis and instead increase propionic acid.
- c) Level of feeding has marginal effect on contents of ash and lactose (Schmidt and Van Vleck, 1974; Leaver, 1983).

d) As discussed earlier, seasonal variations in milk yield and composition is a reflection of type of feed fed especially the fibre content (physical form of feed) and roughage:concentrate ratios (Johansson, 1961).

### 2.5.3 Association among milk components and with milk yield

It is important to know how milk components are inter-related and to what extent the correlations are genetic or environmental so that the right type of selection criteria are set. Most studies however, have concentrated on genetic correlations among milk components (e.g. Butcher et al., 1967; Gaunt, 1973; Von Krosigk et al., 1960) and tried to estimate correlated selection responses from their heritability and phenotypic standard deviations. Maijala and Hanna (1974) reviewed reliable phenotypic correlations among milk components and with milk yield. They calculated weighed means of reported correlations and found them to be: milk yield and BF yield=0.86; milk yield and protein yield=0.95; milk yield and BF%= -0.21; milk yield and protein %= -0.26. Correlation between BF and protein yield was high (0.93) and their percentages had a correlation of 0.49. Generally, associations between percentages and yields of these components were low ( -0.02 to 0.23).

In a more recent study by Chauhan and Heyes (1991) based on first lactation records of Friesian cows, they reported high phenotypic correlations among yield traits (above 0.73), negative correlations between milk yield and percentages of BF and protein (-0.31 and -0.39, respectively). Correlations among yields and percentages of milk constituents were low (-0.09 to 0.38). Correlation between BF% and protein % was 0.56. Calles et al. (1987) obtained a correlation of 0.26 between BF% and SNF%. Negative correlations between milk yield and BF%, protein percent and TS% reported by Sharaby (1988) were -0.15, -0.40 and -0.26, respectively. Correlations between percentages of TS and protein and BF were 0.51 and 0.81, respectively. Generally correlations between milk yield and yields of components were high, ranging from 0.73 to 0.97.

## 2.6 Day-to-day variation of milk yield and constituents

### 2.6.1 General overview

In many developing countries, including Tanzania, dairy recording is either poorly organized or has not been established at all. Some of the problems facing dairy recording is to justify expenditure on labour involved in recording vis a vis returns out of it. Amounts of calculations are quite substantial and resulting errors in

compiling records by using pocket calculators cannot be underrated.

Lindström (1976a) outlined problems of setting and running a milk recording scheme in developing countries to be:

- lack of well qualified extension workers and recorders;
- small average herd size;
- few incentives for farms to record their cows;
- poor communication;
- need for progeny testing and other breeding programmes not recognized;
- poor data collection and processing;

As a matter of routine, daily recording of milk yield of individual cows has been and is still being practiced in some farms. This is, of course, the most accurate method of estimating lactation milk yield (McDaniel, 1969). Of late, many dairy farms have adopted twice or thrice a month milk recording. Everett et al. (1968) and McDaniel (1969) have shown evidence that the accuracy of estimate of lactation yield was dependent upon length and number of test periods. Such estimates are based on individual test-day yields whose variation determines the reliability and accuracy of lactation records (Erb et al., 1952; Syrstad, 1977). McDaniel (1969) studied 60 research reports dealing

with estimation of lactation yields from samples taken at various intervals. Results from comparisons between estimated lactation yields from monthly tests for a 24-hour period with actual yields indicated that the average percentage error, ignoring sign, appeared to be 2.7% for milk yield. It was somewhat higher for fat yields (5.0%) and percentages (3.5%). Actual distribution of errors showed that at least 90% of milk yield estimates from a single day's yield once a month were within  $\pm 5\%$  of true production.

Syrstad (1977) noted that a large variation in production from day to day may bring doubt on validity of using test-day results as basis for calculating nutritional requirements of cows. When ordinary monthly tests are compared to surprise tests for verification, the random day-to-day variation has to be taken into account.

#### 2.6.2 Causes of day-to-day variations

Reasons for milk yield and its components to vary from day to day have been elucidated by a number of scientists (e.g. Erb et al., 1952; Everett et al., 1968; Eckles et al., 1973; Schmidt and Van Vleck 1974; Rook et al., 1992). According to Erb et al. (1952), it is known by most dairymen that a certain amount of daily variation in milk yield is there

but the magnitude of these variations depend on management procedures, normal physiological changes in the cow and anatomical defects and injuries of the udder. Daily variation in yield and composition is also related to completeness of evacuation of milk from the udder (Schmidt and Van Vleck, 1974; Johansson, 1961; Erb et al., 1952; Syrstad, 1977). When large amounts of residual milk (which has as high as 8 - 15% fat) is left in the udder, the evacuated milk will have sub-normal fat content and more milk and of higher fat content will be obtained at the next milking. Schmidt and Van Vleck (1974) listed other causes of daily variation to be diseases, underfeeding, being off-feed and oestrus or excitement.

Milking interval determines the amount of milk and concentration of milk components at the next milking. It is known that with a 12-hour milking interval, little variation is found although some cows may tend to have somewhat higher fat tests in the morning milk (Eckles et al., 1973). However, Syrstad (1977) recorded 0.6 and 0.1 percentage units lower fat and protein, respectively in the morning than in the afternoon milk. Gilbert et al. (1973) also recorded higher evening fat and protein tests (by 0.3 and 0.09%, respectively) than morning tests from a 12-hours milking interval study. However, evening milk yield was lower than morning milk yield by 0.65 kg. Johansson (1961)

further noted that the contents of protein and ash were practically unaffected by normal variations in udder evacuation and these components were more stable from milking to milking and day to day.

Everett et al.(1968) analysed variation of daily milk yields in four dairy breeds. Standard deviations for Friesian, Ayrshire, Jersey and Brown Swiss were 1.11, 0.84, 0.92 and 0.94, respectively, suggesting that Friesians were most variable and Ayrshires were least. Jerseys being low producers were expected to be least variable but this was not the case. Evidence from Everett et al.(1968) and Syrstad (1977) has shown that the higher the production level of the herd the higher the day-to-day variation. This appears to be in agreement with findings of Everett et al.(1968) in which mature cows (producing more milk) had a larger daily variation than two-year-old cows.

### 2.6.3 Estimation of daily variations and errors in lactation records

Several methods have been employed to estimate daily variations of milk yield and components. Everett et al.(1968) have insisted that in order to obtain an estimate of daily variation in milk production it is important to determine the variance of the random component of daily

production. In studies conducted by Everett et al.(1968), Smith and Plowman (1968) and later by Syrstad (1977) and Mchau et al.(1983), the standard deviations of daily milk records (in consecutive days) were taken as estimates of the random error of monthly records. The variance of estimated lactation record was then taken to be a function of variance of daily milk yield, average length of test period (in days) and total number of test periods. Thus by notation:

$$V( Y_{..k} ) = N_i M_{ij}^2 \delta_d^2 \quad (6)$$

where  $V(Y_{..k})$  = the variance of estimated lactation record of the  $k^{\text{th}}$  cow

$N_i$  = number of test periods

$M_{ij}$  = length of each test period

$\delta_d^2$  = variance of daily production of the same cow

It is often assumed that for a normal 305-day lactation period all test periods are of equal length of 30.5 days (10 test periods). The variance of lactation yield then becomes:

$$V (Y_{..k} ) = 10 ( 30.5 )^2 \delta_d^2 \quad (7)$$

and the standard error becomes:

$$S (Y_{..k}) = \sigma_d \times 30.5 \times \sqrt{10} \quad (8)$$

The 10 and 30.5 can be substituted by 5 and 61 respectively if testing is done bimonthly.

The standard error of lactation records ( $S_e$ ) was calculated by Syrstad (1977) and Mchau et al.(1983) to be:

$$S_e = \sigma_d \text{ kg} \times 305 / \sqrt{10} \quad (9)$$

The expected standard error of lactation fat percentage was estimated as:

$$S_e \text{ units} = \sigma_d / \sqrt{10} \quad (10)$$

The  $\sigma_d$  values for milk yield estimated by Everett et al.(1968), Syrstad (1977) and Mchau et al.(1983) were respectively 1.23, 1.566 and 1.5. Corresponding standard errors of 305-day lactation yields were calculated to be 119, 151 and 145 kg and they represented 2.0, 2.7 and 5.0% of their respective herd averages.

The second method reviewed by Syrstad (1977) was that variation within cows across days was estimated as:

$$S^2 = \sum d^2 / 2n \quad (11)$$

where  $S^2$  = variation between consecutive days  
d = difference between records of two  
consecutive days  
n = number of such differences

The standard deviations computed by this method were smaller compared to those calculated by the former formula.

Lee (1988) examined correlations between adjacent test days for fat percent, fat and milk yields. The objective was to look into day-to-day and test-day to test-day variations in these variables. Product moment correlations for milk yield and fat percent were computed and relevant results are summarized in Table 5. It can be concluded from Table 5 that: a) Correlations between original and retest (consecutive days) were higher than correlations between retest and next test or between original and next test (about one month apart). This was applicable to both variables. b) Correlations were higher for milk yield than for fat percent.

Table 5: Correlations between original test-day, next day retest and next regular test day fat percent and milk yield

Breed ( d.f.)		Milk yield		Fat percent	
		Retest	Next test	Retest	Next test
Friesian (15 591)	Original	0.96	0.84	0.71	0.52
	Retest		0.85		0.54
Ayrshire (3020)	Original	0.96	0.84	0.74	0.47
	Retest		0.85		0.51

Source: Lee (1988)

## 2.7 Part and cumulative lactation yields

### 2.7.1 Importance and use of part lactation records

Part (partial) or incomplete records are milk records made during the course of lactation. The "part" can be a single test-day or monthly total milk production. Successive parts of the lactation can be summed up to get cumulative part yields of various durations. Part records fall into two categories: a) those that are obtained from cows that have not yet completed their lactation (records still in progress) b) those that are terminated by either ceasing to record, death or sale of the cow and whose full

lactation record will never be known.

One of the possible bias in estimating breeding values of sires is the selective use of daughters' records. Ignoring records that have been terminated by death or sale in sire proofing will tend to overestimate sires' genetic potential (Lamb and McGilliard, 1960; Fritz et al., 1960) and decrease precision because few records are used. Extension of part or cumulative part records has been a subject of research since the 1950s and 1960s ( see reviews by Rønningen, 1967; Miller et al., 1972; Auran, 1976 and others). Lamb and McGilliard (1960) and Auran (1976) have summarized reasons for estimating 305-day yield from part lactations to be:

- a) Breeding values of all cows may be estimated at a certain date irrespective of calving date. This facilitates ranking of cows to be made without consideration of stage of lactation,
- b) i, Bias due to culling of poor milkers is avoided,  
ii, Precision is increased because more records are included in progeny groups,
- c) Projection of records in progress will reduce the time needed to prove sires by several months (Lamb and McGilliard, 1960) and thus reduce generation interval.

The extrapolation of part records is based on the

relationship between part-lactation or test-day record and total lactation yield. Different methods of utilizing these relationships have been suggested. Miller et al. (1972) and Auran (1976) have shown that the most precise method of estimating total production from part yield is by multiple regression method. Miller et al. (1972) compared mean absolute errors in projecting total lactation from part yield using ratio, simple regression and multiple regression methods. They found that the multiple regression method gave minimum errors. The second best method was the simple regression method which took into consideration the known milk production and the regression of the unknown part on the last test-day record. This was further elaborated by Auran (1976) who observed that the regression of the remaining part on the last test-day record gave nearly the same precision as multiple regression. For simplicity, the ratio of total lactation production to part lactation (multiplicative factors) has been used to be multiplied with actual production to estimate total production (Lamb and McGilliard, 1960, 1967; Rønningen, 1967). This method is by far the simplest and easiest to understand, derive and use. Alternatively, simple linear regression equations for total production on test-day or cumulative part record can be used for prediction (Fritz et al., 1960; Auran, 1976; Sharma et al., 1983). The relative merits of the two procedures (ratio versus simple

regression) were reviewed by Lamb and McGilliard (1960), Syrstad (1964), Rønningen (1967), and Miller et al. (1972) and summarized as follows:

- Multiplicative (ratio) factors may underestimate total production of low producing cows and overestimate total production of high producing cows since this method does not take into account the incomplete repeatability of the parts of lactation. The regression method, however, accounts for this incompleteness.
  
- The variation in total production estimated by ratio factors seem to be more nearly like the variation in actual total production whereas total production estimated by regression is less variable than actual production. Elaborating on this Lamb and McGilliard (1960) remarked that the ranking of cows and sires by the two methods will not change but the ratio method will merely spread out records while the regression method will group them more closely thus making selection decisions more difficult.
  
- The use of regression method will underestimate the differences between groups of animals differing for other reasons than sampling variance.

- The regression method gives the best agreement between estimated and actual production of individual animals.

Lamb and McGilliard (1960) and Rønningen (1967) have described the practicability of using part or cumulative records. The latter have been recommended for the reason that they utilize all available test-day information. It is difficult to store all monthly records but quite possible to store accumulated part yields. These authors have maintained that the use of part (test-day) records is mainly of theoretical interest though they could be used when cumulative production records are not available.

#### 2.7.2 Correlations of part and cumulative milk yields and 305-day yield

Phenotypic correlations of part and cumulative milk yields with 305-day yield have been calculated by quite a number of authors in an attempt to assess the reliability of using part records as selection criteria.

In those studies in which monthly or test-day milk yields were used (e.g. Rønningen, 1967; Lindström, 1976a; Sharma et al., 1983; Mchau and Syrstad, 1991) three fundamental results were evident: a) Correlations between milk yields in adjacent periods were higher than between those further

apart. b) Part records in mid-lactation showed the highest correlation with lactation yield. c) Genetic correlations are higher than phenotypic correlations.

Studies on association between cumulative part yields and total lactation have all (e.g. Sharma et al., 1983; Fritz et al., 1960; Auran, 1976) revealed that correlation coefficients become larger as the cumulative part increases.

## 2.8 Lifetime performance traits

### 2.8.1 Description and importance of lifetime performance

In dairying it is desirable that cows selected for high milk production stay in the herd for a long time to produce more milk during their productive periods and leave more calves of high genetic value (Gaalaas and Plowman, 1963). A long herd life is a commercial merit for the cow (Robertson and Barker, 1966) and it reduces annual herd replacement costs and allows for greater selection among their progeny ( Gill and Allaire, 1976a; Gaalaas and Plowman, 1963). In a study by Gill and Allaire (1976a) herd life accounted for 81.1 and 94.1% of variation in life profit and lifetime milk production, respectively. These increases were linear but milk per day of life and profit

per day of life increased curvilinearly.

Many terms have been used to describe longevity in dairy cattle. Variation in definitions per se has resulted in different findings. It is logical, therefore, that in studies involving longevity one has to define longevity (Hargrove et al.,1969). In progeny testing, for example, length of productive life is an inconvenient measurement as it takes many years for the last daughter of a bull to die. It is more appropriate to work with the proportion of cows that survive to various lactations. Furthermore, as pointed out by Sundaresan et al.(1954); Puri and Sharma (1965) and Syrstad (1979) a true measure of potential lifetime production in cows is seldom obtained for few cows are kept till their natural death.

Longevity and total lifespan have been used interchangeably to denote the duration from birth to date of disposal (Wilcox et al.,1966; Kabuga, 1990). Parker et al.(1960) further qualified the date of disposal to date of last calving prior to disposal. Herdlife, stayability and productive life have also been used synonymously to mean number of days (or months) from first calving to date of disposal (Strandberg,1992) or to end of last lactation (Kabuga,1990) or to last calving date (Gill and Allaire, 1976a). Other studies (Kabuga,1990; Gill and Allaire,

1976a; White and Nichols, 1965) have in addition used number of lactations completed as another lifetime trait.

Table 6 depicts some of the lifetime traits. Herdlife is reported to be as high as 2783 days (7.6 years; Igboeli, 1973a) and as low down as 1121 days (3.1 years; Vaccaro, 1974a). In reviewed articles average number of lifetime calvings or lactations completed did not exceed four. Amount of lifetime milk yields have been determined by the end point of the lifetime period. In the literature (Table 6) lifetime milk yield averages have not been lower than 13 000 kg.

#### 2.8.2 Association between early life and lifetime traits

In order to reduce generation interval in sire evaluation work, the first lactation is often used (White and Nichols, 1965; Gill and Allaire, 1976b). Hargrove et al. (1969) argued that selection for herdlife is automatic through retaining in the herd good cows longer who eventually leave more offsprings. Honnette et al. (1980) advocated identification of indicators of longevity in the first lactation. This is because it takes time to measure either herdlife or lifetime production. To be able to successfully use the first lactation record, it should have a high and positive relationship with later lactations and

Table 6: Mean lifetime performance traits from the literature

Trait	Breed	Country	Mean	sd <sup>1)</sup>	Author/s
<b>Herdlife (days)</b>					
	F	Ghana	1562	486	Kabuga (1990)
	F	Zambia	2783		Igboeli (1973a)
	F	Panama	1121		Vaccaro (1974a)
	F x S	India	2848	159	Singh <i>et al.</i> (1988)
<b>No. of calvings</b>					
	F	Ghana	3.9	1.3	Kabuga (1990)
	F	Venezuela	2.2		Vaccaro <i>et al.</i> (1983)
<b>No. of lactations</b>					
	F	Zambia	3.4		Igboeli (1973a)
<b>Total lifespan (days)</b>					
	F	Ghana	2680	654	Kabuga (1990)
<b>Lifetime milk (kg)</b>					
	F	Ghana	15 996	5402	Kabuga (1990)
	F x S	India	13 660		Sabota & Gill (1990)
	F x S	India	13 150		Sabota & Gill (1990)
	J x S	India	13 266		Singh <i>et al.</i> (1988)
<b>Milk/day of productive life (kg)</b>					
	J x S	India	6.0	0.4	Singh <i>et al.</i> (1988)

<sup>1)</sup> Standard deviation F = Friesian, J = Jersey and S= Sahiwal

length of herd life. Review by Honnette et al. (1980) indicated that phenotypic correlations between first lactation and measures of longevity (final age and length of herd life) ranged from 0.18 to 0.43. Some studies (e.g. Puri and Sharma, 1965; Gopal and Bhatnagar, 1972) have considered both age at first calving and first lactation yield in predicting lifetime milk production.

Associations between early life records such as age at first calving, first lactation yield, first inter-calving period and herd life production traits (e.g. number of lactations completed, lifetime milk yield and productive lifespan) have been investigated (Gaalaas and Plowman, 1963; Hargrove et al., 1969; Miller et al., 1967; White and Nichols, 1965; Singh et al., 1988 to mention a few). Frequently simple phenotypic correlations and regressions have been employed but sometimes multiple regressions (Sundaresan et al., 1954; Gopal and Bhatnagar, 1972; Puri and Sharma, 1965) have been used when two or more predictive traits were considered. Hargrove et al. (1969) recorded small and negative correlations between age at first calving and lifetime traits ( -0.09 with number of lactations completed, -0.07 with productive life and -0.05 with lifetime milk production). In another study involving Sahiwal cows, Gopal and Bhatnagar (1972) observed highly significant correlations between age at first calving and

milk yields up to 6, 8 and 10 years of age of -0.62, -0.54 and -0.51, respectively. Even milk yield per day of life was noted by Lamb (1963) to have a negative association with age at first calving (-0.34). Sundaresan et al. (1954) and Puri and Sharma (1965) used production up to 10 years of age as a lifetime trait to correlate with age at first calving. They recorded higher and significant negative correlations ranging between -0.662 and -0.733. The former authors, however, used quite scanty information (a sample of less than 30). It is conclusive from these studies that lifetime performances become poorer as first calving is delayed.

A scan through previous work has indicated that the correlation between first lactation yield and number of lactations completed, length of productive life and lifetime milk production has always been positive and significant (e.g. Gopal and Bhatnagar, 1972; Hargrove et al., 1969; Puri and Sharma, 1965; Gaalaas and Plowman, 1963; Parker et al., 1960). In most cases phenotypic correlation coefficients have been above 0.38 with some reports recording lower values. For example, Gaalaas and Plowman (1963) found a significant correlation coefficient of 0.173 between first lactation yield and total lifespan. White and Nichols (1965) observed a value of 0.216 between first lactation mature equivalent milk and number of lactations

completed. Miller et al.(1967) studied the association between herd life and first calving interval. They found the association between the two variables to be insignificant and virtually zero (-0.01 to 0.01). As can be expected, association among lifetime traits such as number of lactations completed, productive life and lifetime milk production, are always high. Correlation coefficients above 0.95 were recorded by Hargrove et al. (1969) between number of lactations completed, length of productive life and lifetime milk production.

Simple and/or multiple regression analyses have been employed to test the predictive ability of early life records on lifetime traits. Singh et al.(1988) used a third degree polynomial regression of lifetime traits (namely herd life up to 5 lactations, lifetime milk in all lactations and average milk yield/day of life) on what they termed productive variables (i.e. first lactation yield, first two lactation yields and average milk yield per day of first calving interval) and found that they did not have any significant bearing on any of the dependant variables. They, however, concluded that the first two lactations explained more of lifetime production and should be given emphasis in prediction.

The intention of using more than one predictive variable

is to increase accuracy of estimation of the dependent trait. Gopal and Bhatnagar (1972) considered age at first calving in addition to first lactation yield and found that the accuracy of predicting (R) lifetime milk production up to 6, 8 and 10 years increased by 29, 21 and 24%, respectively. On the contrary, Hargrove et al.(1969) had shown that first lactation milk yield accounted for 23.1% of variation in lifetime milk ( $P < 0.01$ ) but the inclusion of age at first calving (linear, quadratic and cubic terms) in the model increased it to 23.4% only, suggesting little could be gained by including age. Gandhi and Gurnani (1988) attempted to predict 5-year milk production of Sahiwal cows from early life records. Age at first calving, first 305-day milk yield, first lactation length and inter-calving period explained 42.1, 23.8, 7.0 and 3.7% of the variation in milk yield up to 5 years, respectively. However, the optimal equation for predicting 5-year lifetime production included first lactation length and calving interval. The accuracy of prediction was 74.1%.

### 2.8.3 Cow death and culling rates

There is dearth of information on cow mortality rates in dairy farms in the tropics for no apparent reason. Mahadevan (1966) cited by Mhaiki (1980) made a review of cow death rates among various grades of Friesian cattle.

Annual death rates ranged from 2 to 12%. Mwakatundu and Masanje (1984) recorded death rates ranging from 1.2 to 13.9% in three dairy farms in the southern highlands of Tanzania.

The purpose of culling cows is to remove the least profitable animals from the herd and profitability is closely related to reproduction and production (Syrstad, 1972). Culling signifies choice by man or nature hence there are voluntary (e.g. sales for dairy purposes or for beef due to low production, type faults, teat problems) and involuntary removals (e.g. deaths, calving problems, udder/teat injury, failure to conceive, leg problems). Culling rate is the proportion of cows that are removed from the herd to the average number of cows in the prescribed period. If the herd size is kept constant, culling rate is the inverse of herd life. Rates of culling have not been studied widely in the tropics. In Zambia, Igboeli (1973a) came up with an average annual culling rate of 13.62% and this was considered too low if it was intended to attain maximum genetic improvement. Friesian cattle managed in Uganda were reported by Trail and Marples (1968) to be culled at a rate of 20%. Studying culling rate in two farms in Iringa region, Tanzania, Kifaro and Temba (1990) revealed overall culling rates of 15.0 and 23.6%. Both farms raised Ayrshire cattle.

#### 2.8.4 Reasons for cows to exit from herds

Reasons for the disposal of dairy cows vary with time, herd and geographical area since they are a function of health status of dairy herds, beef prices, demand for breeding stock, change in culling policies and other factors (Asdell, 1951). A review on culling rates in the tropics done by Vaccaro (1974a) showed that in most studies no culling criteria were discussed other than causes of death. Diseases and sterility were the most important reasons rather than low production. In the study conducted in Zambia (Igboelli, 1973a) on reasons for disposals in 15 dairy farms, death accounted for 53.9% of disposals. Major reasons for culling were old age (47.9%), infertility (19.4%), calving problems (7.5%), accidents (9.4%), tick-borne diseases (5.0%), mastitis (2.3%) and other diseases (4.3%). In one Friesian herd in Panama (Vaccaro, 1974a) chief causes of disposal were udder infection (36%), infertility (26%) and foot rot (20%). Parker *et al.* (1960) studied longevity in two herds, one raising Friesians and the other Jerseys. Similar to other studies on longevity, their work was done retrospectively and results showed important reasons for disposals were non-breeders (those who failed to conceive before completing 305-day lactation), tuberculosis and Bang's reactors, udder troubles (e.g. blind teats, udder abscessation) and various other infections. In Venezuela 252 American Holsteins and 150 Dutch Friesians were imported (Vaccaro *et al.*, 1983). About 68% of the original female stock did not survive until their third calving. Principal causes of wastage were reproductive problems (50%), deaths (16.3%) and poor physical conditions (12.0%).

## CHAPTER 3

## MATERIALS AND METHODS

## 3.1 The study area

The southern highlands of Tanzania comprises Iringa, Mbeya, Rukwa and Ruvuma regions located on the south western corner of the country. This zone has an area of 247 081 km<sup>2</sup> or 26% of Tanzania's total land area and a human population of over 2.5 million. The 1984 national livestock count indicated that of the approximately 144 000 dairy cattle in Tanzania, the southern highlands regions had about 15 300 head of dairy cattle forming about 10.7% of the national herd. Although the area has good weather conditions with climate varying from tropical to temperate, the zone has low dairy cattle population. That places the southern highlands in a good position of making substantial expansions in the dairy industry.

## 3.2 Description of farms, source and management of animals

The data was collected from five farms: Ihimbu and Kitulo in Iringa region; Iwambi, Mbarali and Uyole Agricultural Centre (here-in-after to be called Uyole) in Mbeya region.

### 3.2.1 Ihimbu

Ihimbu dairy farm belonging to Tanzania Dairy Farming Company (DAFCO) is located 30 km south-east of Iringa town, on latitude  $8^{\circ}$  S and longitude  $36^{\circ} 10'$  E, at an altitude of 1743 m above sea level.

The average rainfall for 14 years (1976 - 89 ) was 753 mm. Mean rainfall days were 77.5. Maximum temperatures ranged from 23.9 to  $26.7^{\circ}\text{C}$  while minimum temperatures ranged from 12.8 to  $15.6^{\circ}\text{C}$ . The coolest months are June to August.

Ihimbu dairy farm has a size of 266 ha out of which 150 ha are under established pastures. Introduced pasture species are mainly Kikuyu grass (Pennisetum clandestinum), Rhodes grass (Chloris gayana) and Nandi setaria (Setaria sphacelata). Legumes include greenleaf desmodium (Desmodium intortum), silverleaf desmodium (D. uncinatum) and Glycine spp. A pure stand of lucerne (Medicago sativa) has been established on a small plot for feeding cows and calves. Themeda sp. is the main natural grass found at the farm.

In 1983, the farm received 50 Ayrshire cows plus several bulls from New Zealand. Other animals were imported from Zimbabwe in 1987. The farm has specialized in raising Ayrshire cattle.

Calves were fed colostrum in the first 3 - 5 days while staying with their dams. They were then separated and kept indoors in individual calf pens. They were fed 4 litres of whole milk per day in two equal meals. When available, milk replacers were used to minimize feeding costs. After six weeks, calves were taken outdoors and given a supplement of 250 g of concentrates per day especially during the June - December dry period. Weaning was done at about four months of age. Heifers were mated at about 24 months of age depending on the physical appearance of the heifer. Bulls ran with the breeding heifers all the time.

Cows were hand milked and milk recorded every day at 0430 and 1630 hours. Concentrates, mainly comprising of maize bran, cotton seed cake or sunflower cake and salt was offered at a flat rate of 4 kg per day. Cows producing over 10 kg during the dry season (June - December) were given 2 kg extra of concentrates and lucerne in their night paddock. The dry herd depended exclusively on pastures though occasionally mineral blocks were placed in their feed troughs. In the last 3 weeks before calving, pregnant cows were given 2 kg of maize bran per day. Due to shortage of liquid nitrogen and semen, bulls were used for mating by herding them together with cows.

All animals were dipped twice per week. Calves were

dewormed after every six months. Vaccinations performed at the farm included those against foot and mouth disease three times per year (but depending on availability of the vaccine), black quarter, lumpy skin disease, rinderpest and haemorrhagic septicaemia once per year. Heifers below one year of age were vaccinated against brucellosis using S<sub>19</sub> vaccine. Occasionally tests for brucellosis were conducted and positive reactors slaughtered. Most cows disposed were due to old age or accidents.

### 3.2.2 Iwambi

Iwambi is situated 10 km west of Mbeya town. The farm stands at an elevation of 1500 m above sea level. The Tanzania government bought the farm (then 296 ha) from a European farmer in September, 1966 and expanded it to 606 ha. The farm was handed over to DAFCO in 1976 with 64 milking animals.

The farm receives a unimodal rainfall starting from November and ending in May, averaging 875 mm (1975 - 89). No other weather variables were recorded at the farm.

Iwambi farm has an area of 606 ha out of which 400 ha had been planted with Rhodes grass (Chloris gayana). The rest is undeveloped land with natural pastures comprising

mainly of Themeda sp. and Hyperrrhenia sp.

Iwambi obtained its foundation stock from New Zealand in 1975 and 1978 during which 50 and 200 heifers were received, respectively. Friesians, Friesian x Jersey crosses and a few Jerseys were the main breeds of cattle. In 1984/85 Iwambi received 1000 head of Friesian cattle imported from Zimbabwe, many of these were on transit to other DAFCO farms.

Calves were left to suck their dams for 4 - 5 days in order to get colostrum. After that period calves were separated from their dams and fed 4 litres of whole milk in two equal morning and afternoon meals. For one month they were kept indoor in individual pens after which they were taken outdoors. Up to 1987 weaning was done at three months of age but after that it was decided to wean at about four months depending on the condition of the calf. About one month prior to weaning calves were provided with concentrates comprising essentially of maize bran fortified with mineral premixes. Heifers were bred by natural service at about 18 months of age.

Cows obtained their feed mainly from grazing. However, depending on availability, grass silage and hay were offered in the dry season. Concentrates were offered at the

rate of 2 to 4 kg per day during milking sessions. Amounts varied depending on availability of concentrates and season. Higher rates were given in the dry season. Maize bran and cotton seed cake were the main feed ingredients. Milk recording was done daily up to end of 1983. Monthly total yields for each cow were transferred into cows' individual record cards. Since 1984 milk recording was done twice per month (around the 15<sup>th</sup> and 30<sup>th</sup> day of the month). The average of the two was multiplied by number of days in a month to get a monthly record. The farm practiced natural mating all year round. Bulls were acquired either within the farm or from other DAFCO farms particularly Kitulo.

Heifers were vaccinated against brucellosis. All cattle were vaccinated against foot and mouth disease, anthrax, black quarter, haemorrhagic septicaemia, lumpy skin disease and rinderpest. Deworming was regularly done, especially against liverflukes. Dipping was routinely done twice per week.

Cows were not often disposed except in cases of emergency and when advised so by a veterinarian. The procedure of disposing animals was that the farm manager would first prepare a list of cows to be disposed of and reason/s thereof. Then the head office chief veterinarian would later be sent to the farm to verify the stated reasons.

Thereafter the farm manager would be instructed to dispose the animals and in the manner stipulated.

### 3.2.3 Kitulo

Kitulo plateau is an undulating hilly highland area on the tip of the Nyasa escarpment. It is 75 km south-east of Mbeya town and approximately 25 km north-west of Iwawa, the administrative centre of Makete district. Geographically, it lies within the coordination  $8^{\circ} 58'$  to  $9^{\circ} 10'$  S and  $33^{\circ} 46'$  to  $33^{\circ} 58'$  E. The geology of Kitulo is described to be of volcanic origin. The base of the plateau is a thick deposit of basalt. The top soil has high organic matter content. Elevation ranges from approximately 2630 to 2820 m, sloping gently from west to east (TISCO, 1983). United Nations Development Programme (UNDP) started research work on wheat and oats on the Kitulo plateau in 1965. Later the National Ranching Company (NARCO) with the assistance of UNDP initiated wool sheep raising. In 1976 UNDP handed over the farm to DAFCO together with wool sheep and a few beef animals. The latter secured a world bank loan for dairy development.

The average rainfall at Kitulo is 1457 mm (mean for 1979-89) which falls between October and May. TISCO (1983) reported other weather variables for the period 1965-82.

Maximum temperature averaged 16.5<sup>0</sup>C while the mean minimum temperature was 3.1<sup>0</sup>C. Sunshine hours averaged 5.1. Frosts frequently occur in the months of June to August. Due to high altitude Kitulo has generally cool temperatures all year round, low evapotranspiration rate, relatively few sunshine hours and brisk winds.

The natural vegetation of the Kitulo plateau is moorland type of grassland made up of Koeleria cristata, Festuca spp., Exothea abyssinica, Eragrostis spp. and Digitaria spp. Some of the common sedges and herbs found mostly in gullies are Helichrysum spp., Cyperus spp., Rhamnus prinoides (TISCO, 1983). Planted pastures at Kitulo include a mixture of Lolium perenne (perennial rye grass), Dactylis glomerata (cocksfoot) and Trifolium repens var ladino (ladino white clover), Phalaris tuberosa and Trifolium pratense (red clover). These pastures were established under a cover crop of oats (Avena sativa). Weeds in cultivated areas are the Oxalia, Senecio, Commelia and Conyza spp. (TISCO, 1983).

Dairy farming was introduced at Kitulo in 1974/75 when units 1 and 2 were established. During 1975-78, a total of 890 heifers were air-lifted from the United States of America (USA) with the help of Heifer Project International (HPI). Unit 3 was established in 1981/82 and 260 Friesian

heifers were imported from Zimbabwe in February, 1982. Units 4 and 5 were stocked with New Zealand Friesians and started working in 1984. Afterwards, in 1985/86, the same units received other Zimbabwe Friesians. Currently the farm has five working units (each unit being a farm; Fig.1) on a total area of 2650 ha. Kitulo is the largest dairy farm in Tanzania. During its establishment it had been planned to build 28 units on the plateau by year 1993, each with 120 milking cows at any one time. Essentially Kitulo has Friesians of USA, Zimbabwe and New Zealand origin.

Neonatal calves were allowed to suck their dams for 3-5 days and thereafter they were enclosed into individual pens and ear-tagged. They were fed 4 litres of whole milk per day in two equal meals. At one month of age, calves were taken out to pastures during the day and returned into calf pens in the evenings. Weaning was done at around 4 months of age depending on the physical condition of the calf. Heifers and bulls were separated soon after weaning. Heifers above 18 months of age always ran with bulls. Pregnancy diagnosis was done once every month and cows/heifers with about seven months pregnancy joined the

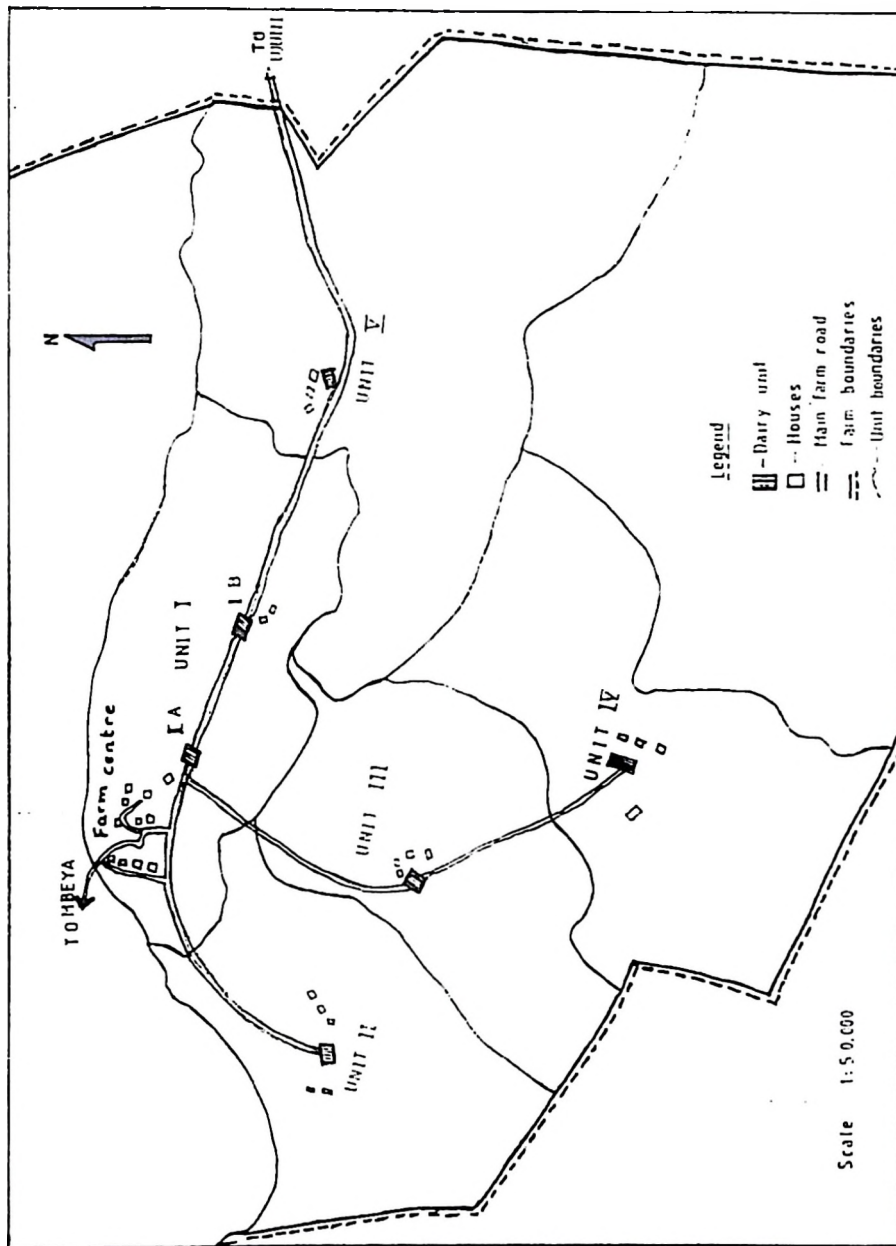


Figure 1. Kitulo dairy farm showing operating units

dry herd.

Cows were milked twice per day. Prior to 1984 milk recording was done daily. After that the 15<sup>th</sup> and the 30<sup>th</sup> day of the month were test-days, the average of which was multiplied by number of days to get monthly production. Cows depended mainly on pastures. The supply of concentrates was irregular because of the long distance from Mbeya town where all farm supplies were purchased. Concentrate supplementation ranged from zero to about 4 kg per day. In the early 1980s molasses was offered as additional source of energy. Concentrate ingredients commonly used were pyrethrum marc, rice polish, cotton seed cake, maize bran, common salt, wheat feed, dairy meal (special dairy cattle formulated feed), and mineral premixes. During the 1980s cows were also fed green oats, grass silage was being made for dry season feeding (July to November). Hay making is not practicable at Kitulo, thus deferred grazing system of conserving standing hay was adopted. To increase forage production phosphatic fertilizers (triple superphosphate) and nitrogen fertilizers were applied to pastures.

Artificial insemination stopped being used on the farm as early as 1978 due to difficulties in securing semen and liquid nitrogen. Since then natural service has been

practiced. Bulls were selected within the farm using rather dubious criteria.

Brucellosis tests were being conducted at irregular intervals and all positive reactors were being slaughtered. Weaner heifers were vaccinated against this disease. Lung worms (Dictyocaulus viviparus) were a problem at the farm thus a routine drenching programme was set. Young calves of 1-4 months of age were drenched once per month, those between 5 and 10 months were treated once in two months while adults were drenched twice a year. For the latter class this regime was chosen for economic reasons. Drenching against liver flukes was done after every three months. Vaccinations against foot and mouth disease were done using a quadrivalent vaccine (O,A,SAT 1 and SAT 2). Ticks of Kitulo plateau are said to be un-infective, nevertheless, dipping was done once per week or per two weeks during the warm months of October to January. Other routine vaccinations were done against anthrax, blackleg, rinderpest and lumpy skin disease.

Kitulo is known to be deficient in micronutrients copper (Cu), cobalt (Co), molybdenum (Mo) and selenium (Se). During the early 1980s when pasture management procedures were adhered to, 6 kg per ha per year of copper sulphate ( $\text{CuSO}_4$ ) was applied when establishing pastures and

thereafter 5 kg per ha was applied every fourth year. Similarly, 20 kg of elemental sulphur was sprayed annually. Cobalt was broadcasted at a rate of 280 g per ha in the first year and then 110 g per ha after every second year. Later it was decided to administer cobalt, molybdenum and selenium to animals as drenches.

#### 3.2.4 Mbarali

The farm is located on latitude  $8^{\circ} 38'$  S and longitude  $34^{\circ} 20'$  E (see Fig.1) and at an elevation of 1100 m above sea level. The farm belongs to Mbarali Rice Farms Ltd., a subsidiary of the National Food Company (NAFCO). The main preoccupation of the farm is rice growing. In an attempt to make use of rice milling by-products such as husks, broken rice and rice polish as livestock feed a dairy unit was established.

The farm lies in the Usangu plains where the temperatures are comparatively higher than the surrounding highland areas. Maximum temperatures (mean of 15 years, 1975-89) ranged from  $27.3^{\circ}\text{C}$  in June to  $31.5^{\circ}\text{C}$  in November. Mbarali receives a unimodal rainfall averaging 629 mm per year precipitating between November and April (Fig.2). The rest of the months form the long dry season.

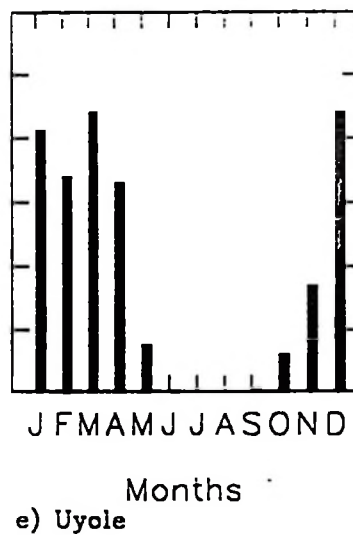
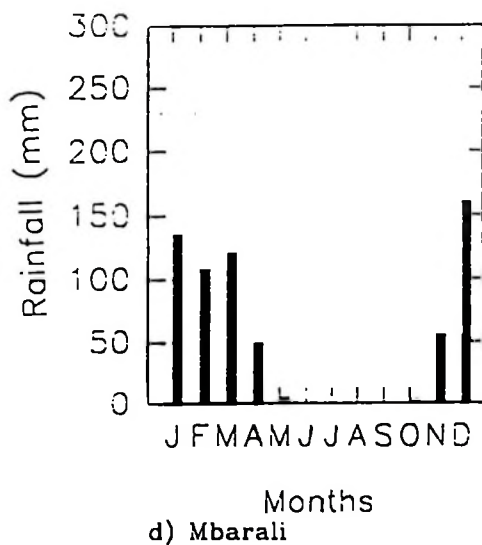
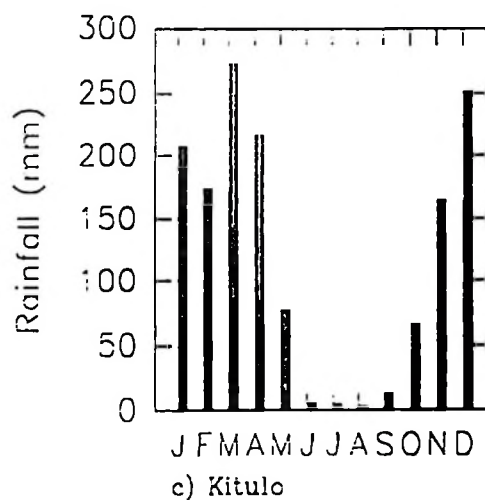
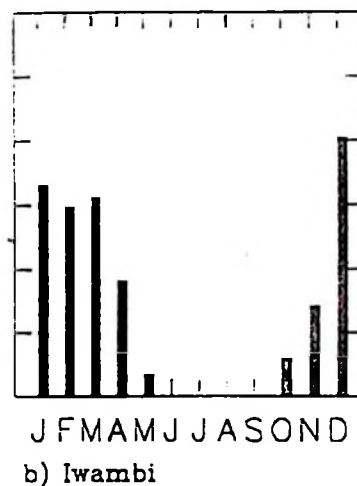
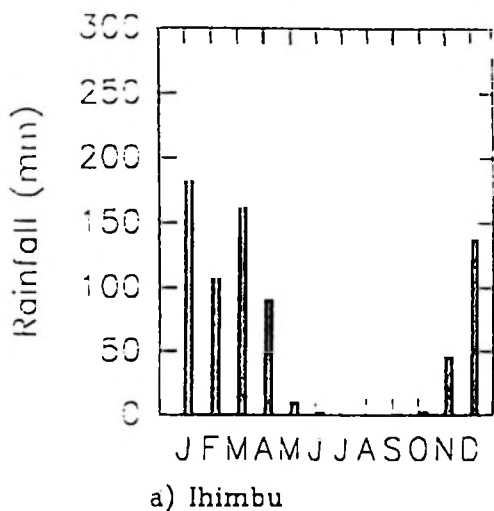


Figure 2. Average monthly rainfall during the study periods at Ihimbu, Iwambi, Kitulo, Mbarali and Uyole farms

Mbarali has specialized in raising Guernsey cattle which were thought to be able to withstand the rather harsh environment of Usangu plains. The herd was formed from collections within the country. Since Guernseys are not very common in Tanzania, of late the farm has had problems of getting replacement bulls and consequently Friesian bulls have been introduced. This study concentrated on the Guernseys only.

Calves suckled colostrum from their dams for 3-4 days after which they were kept in calf pens where they were fed 4 litres of whole milk per day in two meals. On the third month the amount was reduced to 3 litres per day. Small amounts of concentrates and water were provided. Calves were weaned at three months of age, after which they got cut grass, concentrates and grazed near the calf unit. At six months of age, male and female calves were separated. Heifers were mated by natural service after attaining 18 months of age.

Cows were hand milked twice per day and milk was weighed to the nearest half a kilogramme at each milking. Daily records were summed up to weekly, monthly and total lactation yields. Concentrates were fed according to production and ranged from 3 to 8 kg. Feed ingredients used included rice polish, cotton seed cake, white or yellow

maize, soya beans, bone meal, meat meal, sorghum, lime powder, beans and mineral premixes. The farm does not have established pastures thus cows grazed on natural pastures and paddy fields from 0700 to around 1430 hours.

The following prophylactic measures were done on the farm: young calves were sprayed and older classes were dipped twice per week. All animals above 6 months of age were vaccinated against black quarter and anthrax twice per year. After every three months animals were inoculated against foot and mouth disease. Annual vaccinations were done for lumpy skin disease and rinderpest. Dewormings were done after every 3 - 4 months. Occasionally, cows were treated against fascioliasis.

The farm policy was to maintain around 100 milking animals at any one time. Slaughters were done on rare occasions of dystocia, reactors to tuberculosis or brucellosis tests, accidents, old age and chronic cases of mastitis or any other disease. Culling of cows was based on udder problems and low production though for the latter no clarifications could be made.

### **3.2.5 Uyole Agricultural Centre**

Uyole dairy farm is one of the production and research

units of the Uyole Agricultural Centre (UAC), a government research and training institution located 12 km east of Mbeya town. It is on latitude 8<sup>0</sup> 55'S and longitude 35<sup>0</sup> 32'E at an altitude of 1860 m above sea level.

The mean temperature at Uyole was 17.1<sup>0</sup>C and the mean annual rainfall of 1141 mm (1978 - 89) which falls from December to May (Fig. 2).

The farm soils are classified as cambisols. These are deep, darkish to brown loamy with high silt content. The natural grasses in undeveloped paddocks are Hyperthysa spp. while planted pastures are mainly Rhodes grass mixed with silverleaf and greenleaf desmodiums (D. uncinatum and D. intortum, respectively). Few paddocks had setaria grass (Setaria splendida). Common weeds identified at Uyole (some of them causing poisoning to cattle) include Lantana camara, Senecio sp., Crotalaria brevis, C. polysperma and C. incana.

Uyole received its initial stock from Kenya in the late 1960s. Later, in October 1975 and in 1978, two batches of 199 and 20 heifers, respectively, some of which were incalf, arrived from New Zealand. They consisted of purebred Friesians and a few Friesian x Jersey crosses. Accompanying them were eight purebred Friesian bulls.

Between 1975 and 1978 natural mating was augmented by artificial insemination (AI) but since 1978 it was not possible to use AI on the herd due to irregularities in the supply of liquid nitrogen. At any one time there were more than one bull in the herd and hand mating was not possible. As in most other farms in Tanzania, pedigree recording was not practicable. To avoid inbreeding bulls were purchased from other dairy farms.

Newborn calves were identified by ear notches and separated from their dams just after calving. Four litres of colostrum was fed in the first four days and for the following 17 days four litres of whole milk continued to be fed in two equal feedings. Thereafter whole milk was reduced by one litre each week and substituted by two litres of skim-milk. Concentrates, mineral licks and good hay was offered ad libitum. After the 42<sup>nd</sup> day calves were given plastic ear-tags, taken out-doors and continued to be fed half a kilogramme of concentrates per day, grass hay, 6 litres of skim-milk per day plus grazing till the age of 105 days (3.5 months) when they were weaned. Henceforth, weaners depended mainly on pastures composed of Rhodes grass (Chloris gayana) mixed with both species of desmodium (D. uncinatum and D. intortum) and supplemented with 0.5 kg of concentrates per day when available. From about 180 kg liveweight heifers depended solely on

pastures, sometimes supplemented with little grass or maize silage in the July to November dry season. At about 275 kg live weight heifers joined the breeding herd which permanently ran with bulls.

Pregnancy diagnosis by rectal palpation was conducted after every two months. Heavy pregnant heifers and cows were "steamed up" from the seventh month of pregnancy by grazing them on good pastures in the rainy season and feeding maize or grass silage in the dry season. In addition about 3 kg of concentrates was offered each day in the milking parlour.

Upon calving, cows joined the milking herd and were machine milked twice a day at 0400 and 1500 hours. Lactating cows were always given the best pastures to graze. From July to November (dry season) cows were fed on maize (Zea mays) or grass or sometimes oats (Avena sativa) silage and hay. Due to late preservation, most of the silages and hay were of medium to poor quality. Sweet lupins (Lupinus spp.) as green chop was sometimes fed in July, August and early September. Prior to 1982 cows were fed concentrates according to daily milk yield, usually at a rate of 1 kg concentrate for every 2 kg of milk, not counting the first 3 kg. It was assumed that the nutrient requirements for maintenance and production of about 3 kg of milk per day

was met from pastures and/or conserved forages. Concentrate rates were slightly higher in the dry season than in the wet season. Ration ingredients were maize, rice polish, cotton seed cake, sunflower cake, salt, bone meal and vitamin-mineral premixes (Mchau et al. 1983; Kifaro, 1984). The standard concentrate ration was estimated to contain 12 - 14% crude protein.

All cows were vaccinated with "blanthrax", a combine vaccine against black leg and anthrax diseases once per year and against foot and mouth disease twice a year. Dipping was done weekly while tests for brucellosis and tubercullosis were occasionally done. Clinical cases of mastitis were carefully handled by veterinarians.

Before 1982 culling of cows was based essentially on milk production and reproduction. Slaughters were done on emergency cases e.g. dystocia, leg fractures. After that time number of cows to cull was largely determined by amount of revenue that was required to sustain the activities of the centre.

### **3.3. Data collection and analyses**

For data collection, forms were designed for transcribing records from farm books, reports and cow individual record

cards in a uniform manner. Separate forms were made to register calf births, deaths, herd strengths at the end of each month of study period, disposals and their reasons. On cows, information on birth date, calving dates, parity, drying off dates, monthly milk yields (total or test-day yields) and lactation totals were transcribed. Management aspects and disease prophylactic measures done in each farm were obtained from monthly reports (in which veterinary reports were included) and from interviews with recorders and farm managers. A long term study on milk composition and a short term study on day-to-day variation of milk components were conducted as described in sections 3.3.4 and 3.3.6, respectively.

### 3.3.1 Calf mortality

Incidences of abortions and stillbirths were compiled either from calf registers (Mbarali and Uyole) or from monthly farm reports (in case of Ihimbu, Iwambi and Kitulo). Summaries were made for each farm to obtain total number of pregnancies (confirmed by a calving), live births, abortions and stillbirths. Rate of abortion was computed as number of abortions as percent of all pregnancies while stillbirth rate was calculated as number of such incidences as a fraction of all calves born and expressed in percent. Calculations were done within years

and for the whole study period. Chi-square analysis (Snedecor and Cochran, 1989 and Putt et al.,1987) was performed to compare year (within farm) and farm differences in incidence rates.

At Mbarali and Uyole, all calves born on the farms during 1984-89 and 1980-89, respectively had been recorded in calf registers. Calves that died were deleted in the calf registers and death dates inscribed. That information was available for transcription. In DAFCO farms (Ihimbu, Iwambi and Kitulo), however, there were many missing books, more so for Kitulo. For these farms it was decided to use monthly reports. Monthly deaths by age group (calves, weaners, heifers of over 18 months of age and cows) and sex were reported. In addition, monthly herd strengths were available. All monthly deaths and herd strengths were summarized to get annual or study period totals and/or averages. In a similar way, births, deaths, total and average numbers of various classes of animals were calculated by sex, year and age.

Death rates were computed as number of calves that died as fraction of calves born (for pre-weaning mortality) or as proportion of calves weaned/at risk (for post-weaning mortality). This was done within sex, year and age subclasses. It is important to note further that in DAFCO

farms weaning was done around four months of age depending on health status of the calf. For Mbarali and Uyole age at death (in months) was calculated for each calf and categorized accordingly. Annual mortality rate for heifers of above 18 months of age was calculated as number of heifers that died as percent of average number of heifers. Again, chi-square tests were done to find out if differences in observations between subclasses were significant. To investigate the effect of season on mortality rate of pre-weaned calves, monthly death rates were calculated as number of calves that died during the month as percent of average number of calves for that particular month. Monthly death rates were thereafter averaged for the whole study period.

DAFCO farms and Uyole as a matter of routine write death certificates for each animal that dies on the farm. Besides indicating the most probable cause of death, clinical symptoms and post mortem findings, if any, are also shown. In case of Mbarali causes of deaths were reported in a book and in the dairy unit monthly report. All available causes of death for each dead animal were transcribed and later summarized. Proportional mortality rates were calculated as the total number of deaths occurring from a specific disease in the farm during the whole study period divided by the total number of deaths occurring during the time

period (Putt et al., 1987).

### 3.3.2 Reproductive traits

Reproduction traits available for study were age at first calving and calving interval.

Analyses of variance of age at first calving were done for each farm separately partly because of breed differences, and partly due to dissimilar study period lengths. Least squares analyses of variance (GLM procedure of SAS, 1988) was employed to analyse records with season of birth, period of birth and their interaction as fixed effects. In all analyses months of the year were classified into four seasons based on rainfall pattern and the accruing availability and quality of pastures and conserved forages to cattle:

Season 1: December - February is the early wet season when pastures are abundant and of relatively good quality;

Season 2: March - May is the late wet season. Cattle depend on either regrowth or the already coarse pastures;

Season 3: June - August are the early dry season months with cool weather and some farms experiencing sub-zero temperatures. Conserved forages are

used.

Season 4: September - November are late dry season months with very little or no supplemental forages being offered to animals. Feeding levels are often very poor.

Based on the distribution of records across years, periods of birth were classified differently for each farm. Table 7 presents classifications of years into periods of birth used in the analyses.

Table 7: Classifications of years into periods of birth used in the analyses of variance of age at first calving

Farm	Period of birth					
	1	2	3	4	5	6
Ihimbu	1971-74	1975-78	1979-82	1983-87	-	-
Iwambi	1975-77	1978-80	1981-83	-	-	-
Kitulo	1974-77	1978-81	1982-85	1986-89	-	-
Mbarali	1965-76	1977-80	1981-84	1985-88	-	-
Uyole	1968-70	1971-73	1974-76	1977-79	1980-82	1983-86

Subclass means from significant factors were compared by Newman-Keuls' test as modified by Kramer (1956) for unequal

numbers of observations in subclasses.

Calving intervals (CI) were analysed for each farm separately using a fixed effects model in which parity, year and season of calving were the factors. Parity subclasses were 1 to  $\geq 4$  for Kitulo and Uyole, 1 to  $\geq 5$  for Ihimbu and Mbarali and 1 to  $\geq 6$  for Iwambi. Study periods were 13 years (1976-88) for Iwambi, 16 years (1975-90) for Kitulo, 18 years (1973-90) for Ihimbu and 19 years (1971-89) for Mbarali. The study period for Uyole was 18 years (1971-88) but these were classified into 9 periods of 2 years each because 1971, 1981, 1982 and 1988 had very few records.

### 3.3.3 Lactation performance traits

Traits analysed were lactation milk yield (LMY), annualized milk yield (AMY), lactation length (LL) and dry period (DP). AMY was computed as LMY per day of calving interval and multiplied by 365.25. These traits were analysed for fixed effects of parity, year and season of calving. Current calving interval was included in the model as a covariate (except for AMY). Factors were described in a similar way as done for analysis of calving interval (section 3.3.2). Phenotypic time trends during the study periods were analysed by regressing annual least squares

means of lactation performance traits (assumed to be annual phenotypic levels) on year. Correlations among lactation performance traits (within cows) were computed from residual sum of squares and crossproducts obtained from multivariate analyses of variance (MANOVA option of GLM; SAS, 1988) in which parity, season, year and cow factors were included in the model.

#### 3.3.4 Repeatability estimates

Estimates of repeatability were made for CI, LMY, AMY, LL, and DP. Analyses described under section 3.3.2 and 3.3.3 for calving interval and lactation performance traits were repeated having included the "cow" factor in the model as a random effect.

$$Y_{ijklm} = \mu + P_i + S_j + Y_k + C_l + b_1 X_{ijklm} + e_{ijklm} \quad (12)$$

where  $Y_{ijklm}$  = a particular record of calving interval or lactation performance trait

$\mu$  = overall mean

$P_i$  = fixed effect of  $i^{\text{th}}$  parity

$S_j$  = fixed effect of  $j^{\text{th}}$  season of calving

$Y_k$  = fixed effect of  $k^{\text{th}}$  year of calving

$C_l$  = random effect of the  $l^{\text{th}}$  cow

$b_1$  = regression coefficient

$X_{ijklm}$  = calving interval

$e_{ijklm}$  = random residual component

The model for calving interval did not include the covariate (calving interval). The between cow and within cow variance components were used to calculate repeatability as an intra-cow correlation. Respective standard errors were estimated according to Becker (1984).

### 3.3.5 Milk composition

BF determination commenced at Uyole in January, 1986 as one component of a project "monitoring of performance of dairy cattle in large scale farms in the southern highlands of Tanzania". The prime objective was to try to establish a routine analysis of milk components. In December 1987 protein, TS and ash were included. Analyses stopped in May, 1990. This study was done on 186 cows of Friesian breed. At around the 15<sup>th</sup> day of each month both morning and afternoon milk was recorded and 35 ml samples taken. Samples were deep frozen before analysis. The composite daily sample was made by taking subsamples in proportion to the milk yield at each milking.

BF was determined by Gerber butyrometers method and protein by the conventional Kjeldahl method, using the factor 6.38

in converting nitrogen into crude protein (IDF, 1986). Total solids (TS) and ash were determined gravimetrically while solids-not-fat (SNF) was obtained by difference.

Some data were discarded during editing. Criteria for rejection were:

- milk yield was not recorded on sampling date or missed;
- calving date of cow could not be traced resulting in failure to trace stage of lactation, or parity was not known;
- BF value  $< 1.5$  and  $> 7.0$  % plus corresponding SNF values were considered grossly erroneous;
- Ash calculated to one decimal point was considered not good enough to detect differences between factors because of its low variability.

Yields of milk components on test-days were obtained by dividing the percent component by 100 and then multiplying by milk yield of the particular test-day.

Data was coded as follows: Parturition numbers were coded 1 to 5, code 5 included parturition number 5 and above. Years 1986 to 1990 were coded 1 to 5. Recording months January to December were coded 1 to 12. Lactation months were coded 1 to 10, records beyond the tenth month of

lactation were lumped into the tenth month sub-class.

The General Linear Models (GLM) procedure of SAS (1988) was employed to analyse milk yield and yields of milk components on test-days. Data were assumed to be described by the following model:

$$Y_{ijklm} = \mu + P_i + R_j + Y_k + L_l + e_{ijklm} \quad (13)$$

where  $Y_{ijklm}$  = milk or milk component yield on test-day

$\mu$  = overall mean

$P_i$  = fixed effect of  $i^{\text{th}}$  parity ( $i = 1, \dots, 5$ )

$R_j$  = fixed effect of  $j^{\text{th}}$  recording month  
( $j=1$ =January,  $\dots$ ,  $12$ =December)

$Y_k$  = fixed effect of  $k^{\text{th}}$  year of sampling ( $k=1, \dots, 5$ )

$L_l$  = fixed effect of  $l^{\text{th}}$  month of lactation  
( $l = 1, \dots, 10$ )

$e_{ijklm}$  = random error  $N(0, \sigma_e^2)$

In analysing percentages of milk components, milk yield on test-day was included in the model as a covariate. Phenotypic correlations among percentages, between percentages and yields and among yields of milk components on test-days were computed using Multivariate Analyses of Variance (MANOVA) option of GLM procedure (SAS, 1988).

### 3.3.6 Day-to-day variation of milk yield and components

#### Milk yield

Daily milk records for the month of October, 1982 for Uyole and May, 1989 for Ihimbu were the selected random months. At Uyole, out of the 116 milking cows during the selected month a sample of 45 were chosen while at Ihimbu 35 were chosen out of 46 milking cows. Selected cows fulfilled the following conditions:

- cows neither calved nor dried off during the month, that is, they were not at the beginning or end of lactation;
- there was no missing morning or afternoon milk yield record through out the month.
- there was no incidence of mastitis or any other sickness.

For the purpose of this study, records from day one to day 21 of the month (three weeks) were used. Uyole cows were Friesians and machine milked using bucket system at 0500 and 1600 hours. Milk was weighed on a spring scale to the nearest tenth of a kilogramme. Ihimbu had Ayrshire cows, hand milked at 0430 and 1630 hours. Milk was measured in the same way as at Uyole.

Since the data set was orthogonal, the standard factorial analysis of variance was employed. The main effects were milking time (morning vs afternoon), cow and day of milking. Milking time was considered as a fixed effect, whereas cow and day of milking were assumed to be random. Because of significant interaction between day x milking time, morning and afternoon milk yields were re-analysed separately for effects of day and cow. Since the number of cow sub-classes was large, the cow effect was absorbed in the analyses and consequently two-way interactions with cow effect could not be included in the model (SAS, 1988).

Records were assumed to be described by the following mixed effect model:

$$Y_{ijk} = \mu + D_i + C_j + T_k + DT_{ik} + e_{ijk} \quad (14)$$

where  $Y_{ijk}$  = milk yield record from the  $j^{\text{th}}$  cow milked on the  $i^{\text{th}}$  day and the  $k^{\text{th}}$  milking time;

$\mu$  = overall mean

$D_i$  = random effect of  $i^{\text{th}}$  day of milking  
( $i=1, \dots, 21$ )

$C_j$  = random effect of  $j^{\text{th}}$  cow ( $j=1, \dots, 45$  for Uyole and  $j=1, \dots, 35$  for Ihimbu)

$T_k$  = fixed effect of  $k^{\text{th}}$  milking time (1= morning, 2= afternoon)

$DT_{ik}$ , = two-way interaction as indicated by  
subscripts

$e_{ijk}$  = random error (N,  $\sigma_e^2$  )

### Milk components

This study was conducted for 14 days (between 21 April and 4 May, 1990) and involved 15 cows. Cows were separated from the main herd and milked first at around 0400 and 1500 hours. All cows had calved between February, 1989 and April, 1990 and at the start of sampling their milk yields ranged between 1.4 and 14.6 kg. Milk yields and components were handled as described previously (section 3.3.5). Due to shortage of reagents (especially sulphuric acid) and manpower, separate analyses for morning and afternoon samples was not possible. BF, protein, TS and ash were determined from daily composite samples. SNF was calculated by difference. Milk yield and percentages of milk contents were analysed for effects of cow and day as random effects.

Thus:

$$Y_{ij} = \mu + D_i + C_j + e_{ij} \quad (15)$$

where  $Y_{ij}$  = milk yield or percent of milk component

$D_i$  = random effect of  $i^{\text{th}}$  day of sampling

$C_j$  = random effect of  $j^{\text{th}}$  cow

$e_{ij}$  = random error N (0,  $\sigma_e^2$  )

Correlations between daily milk yields and percentages of milk components of consecutive days were calculated as intra-cow correlations.

### 3.3.7 Part and cumulative lactation records

In all farms, except Uyole, monthly total milk yields were transcribed from cows' individual record cards. Monthly total yields were obtained differently in the farms and in different periods. For Ihimbu and Mbarali, totals were a sum of daily milk yields recorded in the morning and evening. At Iwambi and Kitulo milk was recorded daily before 1984 but recording was reduced to two times per month since 1984. At Uyole, available records were monthly average yields based on three tests made around the 5<sup>th</sup>, 15<sup>th</sup> and 25<sup>th</sup> day of the month. For the purpose of this study, only the first ten records were considered. A cow that was dry after the fifth month of lactation was assigned a zero milk yield.

Because the first record had varied lengths, the number of days from calving date to the end of the month was calculated. Average milk yield for the first month of lactation was obtained by dividing the monthly yield by the calculated number of days in milk. Cumulative milk yields were calculated by summing the respective monthly average

yields. Data was coded to provide information on length of current calving interval, parity, year or period of calving, month or season of calving and farm. Records were analysed separately for each farm because of breed differences (Ihimbu and Mbarali) or had a unique recording system (Uyole). Iwambi and Kitulo had only Friesians with a similar recording system and hence their records were merged and analysed together.

Part and cumulative milk yields of Ihimbu, Mbarali and Uyole were analysed by GLM procedure of SAS (1988) for fixed effects of period, parity and season of calving. Interactions were ignored. Calving interval was included in the model in both linear and quadratic terms. The model employed was:

$$Y_{ijkl} = \mu + A_i + P_j + S_k + b_1X_1 + b_2X_2 + e_{ijkl} \quad (16)$$

where  $Y_{ijkl}$  = a particular record (monthly average yield or cumulative yield)

$\mu$  = overall mean/intercept

$A_i$  = fixed effect of  $i^{\text{th}}$  parity class in parturition number (  $i=1, \dots, \geq 5$  for Ihimbu and Mbarali and  $i=1, \dots, \geq 4$ , for Uyole)

$P_j$  = fixed effect of  $j^{\text{th}}$  period of calving (  $j=1$

- 4 for Ihimbu and Uyole and  $j=1 - 5$  for Mbarali)

$S_k$  = fixed effect of  $k^{\text{th}}$  season of calving ( $k=1 - 4$ )

$b_1$  = partial regression coefficient of part or cumulative yield on length of calving interval (linear)

$b_2$  = partial regression coefficient of part or cumulative yield on length of calving interval squared (quadratic)

$X_1$  = calving interval

$X_2$  = calving interval squared

$e_{ijkl}$  = random error associated with each observation

The following periods were assigned to the records of each farm:

Ihimbu 1 = 1977-79, 2 = 1980-82, 3 = 1983-85,  
4 = 1986-89;

Mbarali 1 = 1979-80, 2 = 1981-82, 3 = 1983-84,  
4 = 1985-86, 5 = 1987-88;

Uyole 1 = 1981-83, 2 = 1984-85, 3 = 1986-87,  
4 = 1988-89.

Iwambi and Kitulo records were merged. Separate analyses were made on records made prior to and after 1984 for reason stated above. Further, first and later lactation

records were analysed separately. To achieve this, records were organized to create the following data sets:

Data set 1. First lactations made between 1976 and 1983 (569 lactations),

Data set 2. Second and later lactations made between 1976 and 1983 (992 lactations),

Data set 3. First lactations made during 1984 - 90 (357 lactations; Iwambi had only 16 lactations which were deleted)

Data set 4. Second and later lactations made during 1984 - 90 (891 lactations; Iwambi had only 55 lactations which were excluded)

Data set 1 had Iwambi and Kitulo records and was analysed with the assumption that the following model described them:

$$Y_{ijkl} = \mu + F_i + M_j + P_k + FP_{ik} + b_1(X_{1ijkl} - X_{1mean}) + b_2(X_{2ijkl} - X_{2mean}) + e_{ijkl} \quad (17)$$

where  $Y_{ijkl}$  = a particular record (monthly average yield or cumulative yield)

$\mu$  = overall mean/intercept

$F_i$  = fixed effect of  $i^{th}$  farm ( $i = 1, 2$ )

$M_j$  = fixed effect of  $j^{th}$  month of calving ( $j = 1 \approx \text{January}, \dots, 12 = \text{December}$ )

$P_k$  = fixed effect of  $k^{\text{th}}$  year of calving ( 1 = 1976, ..., 8 = 1983)

$FP_{:y}$  = farm x year interaction

$X_1$  = calving interval

$X_{1\text{mean}}$  = mean calving interval

$X_2$  = calving interval squared

$X_{2\text{mean}}$  = mean calving interval squared

$b_1, b_2$  = partial linear and quadratic regression coefficients, respectively

$e_{ijkl}$  = error associated with each observation

Data set 2 was analysed by model 17 above, in addition fixed effect of parity ( 2, 3 and  $\geq 4$ ) was included. Data set 3 and 4 had Kitulo records only, so effects of farm and farm x year were removed from the model.

Phenotypic correlation coefficients among part and cumulative monthly yields and with 305-day lactation yield were calculated from residual sum of squares and cross-products using MANOVA option of GLM procedure ( SAS, 1988). Two types of extension factors were developed from pooled (all farms) records:

a) Ratio extension factors which made use of accumulated records and, in addition, predicted the remaining unknown part of lactation from the last test-day record (Auran, 1976). The prediction equation used

was:

$$Y_{305-D} = X_{p1-n} + (k \times X_{LTn}) \quad (18)$$

where  $Y_{305-D}$  = estimated 305-day milk yield

$X_{p1-n}$  = the accumulated yield of part  
lactation from the first to  $n^{th}$  month  
of lactation

$X_{LTn}$  = milk yield of the last test-day of month  $n$

$k$  = the ratio factor based on population  
average  $(Y - X_{p1-n}) / X_{LTn}$

$Y$  = population 305-day milk yield

b) Regression extension factors were developed for both  
monthly and cumulative records based on the simple  
linear regression model.

In both cases (a and b) separate factors were derived for  
first and later lactations commencing in the wet (December  
- May) and dry (June - November) season.

### 3.3.8 Life-time performance traits

A data set comprising of the following variables was  
assembled for each farm by matching data on milk,  
reproduction and disposals: cow number, date of birth,  
first calving date, second calving date, drying off date  
after the first lactation, first and second lactation milk

yields, number of life-time calvings, date of last calving before disposal, date of disposal, total milk yield from first calving date to date of disposal and life-time milk production in completed lactations only. The following variables were derived from the data set:

- age at first calving (in days);
- total life-span as interval (in days) from birth to date of disposal;
- length of productive life as interval (in days) from first calving to date of disposal;
- productive life in completed lactations as interval (in days) from first calving date to last calving date before disposal;
- calving interval and lactation length in first lactation
- annualized first lactation yield as first lactation milk yield divided by calving interval and multiplied by 365.25;
- milk yield per day of productive life as total life-time milk yield divided by length of productive life;
- milk yield per day of total life as total life-time milk yield divided by total life-span.

Means and standard deviations for each of the studied variables were computed. Simple correlation coefficients between traits were calculated. To test predictive ability

of early life records on life-time milk production a forward multiple regression analysis was performed to identify a combination of independent (early life) variables that would best explain the variation of life-time milk production and as a result be able to predict it. The model was:

$$Y = b_0 + \sum b_i X_i \quad (19)$$

where Y = expected life-time milk production

$b_0$  = intercept

$b_i$  = regression coefficient for each independent  
(early life record) variable;

$x_i$  = independent variable (early life record; age  
at first calving, first lactation milk yield,  
lactation length and calving interval)

Cow death rate was computed as number of cows that died in a particular year or whole study period as a fraction of the average number of cows during the year/s, while culling rate was obtained by dividing the number of cows that left the herd by death, sale and slaughter in a particular year (or all years) by the same denominator as above.

Reasons for cows leaving the herd were classified into three major categories; namely deaths, sales and

slaughters. Where applicable, reasons for cow exit within each major category were also classified. Frequencies (in percent) were thereafter calculated within and between major classes.

## CHAPTER 4

## RESULTS

## 4.1 Calf mortality

## 4.1.1 Abortions and stillbirths

The difference in abortion rates between farms was large (Chi-square=118.8;  $P < 0.001$ ). Yearly abortion rates ranged from zero to 20% while overall farm means ranged from 1.8 to 9.5%. The highest rate of abortions was recorded at Mbarali farm (9.5%). The rest of the farms had rates not exceeding 3% (Table 8). Differences between years in abortion rates were significant in all farms except Ihimbu.

Generally, rates of stillbirths were higher than abortion rates except for Mbarali farm. In three of the farms (Iwambi, Kitulo and Uyole), yearly variations in rates of stillbirth were remarkably large ( $P < 0.001$ ). Again, between farm difference was quite considerable (Chi-square=78.9;  $P < 0.001$ ). Overall rates ranged from 3.4% at Ihimbu to 9.8% at Iwambi.

Table 8: Rates of abortions and stillbirths in the five farms

Trait/aspect	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
Years covered	1981-89	1980-89	1979-90	1984-89	1980-89
<b>Abortions</b>					
Mean (%)	2.5	1.8	2.2	9.5	3.0
Range <sup>1)</sup>	0.9-7.2	0.0-6.9	0.0-4.3	3.8-20.0	0.0-7.0
Chi-square <sup>2)</sup>	10.8 ns	36.5 ***	53.0 ***	17.7 **	26.2 **
<b>Stillbirths</b>					
Mean (%)	3.4	9.8	9.6	3.8	5.0
Range <sup>1)</sup>	0.0-7.4	5.7-17.8	2.0-14.6	2.2-7.1	1.4-14.0
Chi-square <sup>2)</sup>	10.5 ns	30.7 ***	76.5 ***	4.7 ns	36.2 ***

<sup>1)</sup> Range of annual rates

<sup>2)</sup> Chi-square test for differences between years

#### 4.1.2 Calf mortality rates

Table 9 presents mortality rates of calves up to 18 months of age. Mortality rates of unweaned calves ranged from 9.3 at Iwambi to 25.5% at Kitulo. Between farm difference in death rates was significant (Chi-square=330.4;  $P < 0.001$ ). Differences between years, as expected, were significant ( $P < 0.01$  to  $0.001$ ) but no obvious trends were observed. Sex differences in death rates of unweaned calves were non-significant ( $P > 0.05$ ) in all farms except Iwambi where there was heavier (by 6.7%) heifer calf mortality.

Table 9. Mortality rates (%) among young stock of less than 18 months of age

Farm	Age class	No. of calves		Death rate	Between years		Between sexes		
		Born/at risk	Died		Range	Chi-square	M	F	Chi-square
Ihimbu	Un-weaned	734	73	9.9	0.0 - 43.5	112.3 <sup>***</sup>	11.1	8.9	0.8 <sup>***</sup>
	Weaned	661	112	16.9	4.8 - 56.4	56.4 <sup>***</sup>	13.7	19.8	3.9 <sup>†</sup>
	Birth-18 mon.	734	185	25.2	-	-	-	-	-
Iwambi	Un-weaned	1550	145	9.3	2.0 - 49.6	269.4 <sup>***</sup>	6.1	12.8	20.1 <sup>***</sup>
	Weaned	1405	416	29.6	5.7 - 100.0	565.8 <sup>***</sup>	11.6	49.6	242.6 <sup>***</sup>
	Birth-18 mon.	1550	561	36.2	-	-	-	-	-
Kitulo	Un-weaned	6096	1555	25.5	9.1 - 40.0	199.8 <sup>***</sup>	25.1	25.9	0.5 <sup>ns</sup>
	Weaned	4541	969	21.3	7.3 - 38.2	235.8 <sup>***</sup>	15.9	27.4	90.0 <sup>***</sup>
	Birth-18 mon.	6096	2524	41.4	-	-	-	-	-
Mbarali	Un-weaned	525	80	15.2	3.4 - 35.9	45.9 <sup>***</sup>	16.2	14.2	0.3 <sup>ns</sup>
	Weaned	445	59	13.2	0.0 - 25.0	42.1 <sup>***</sup>	10.4	16.1	3.1 <sup>ns</sup>
	Birth-18 mon.	525	139	26.4	-	-	-	-	-
Uyole	Un-weaned	1311	162	12.3	4.1 - 18.6	22.1 <sup>††</sup>	12.0	12.7	0.2 <sup>ns</sup>
	Weaned	1149	198	17.2	5.2 - 33.3	80.3 <sup>***</sup>	17.6	16.8	0.1 <sup>ns</sup>
	Birth-18 mon.	1311	360	27.4	-	-	-	-	-

After weaning, death rates ranged from 13.2% at Mbarali to 29.6% at Iwambi. Mean death rates at Kitulo, Ihimbu and Uyole were 21.3, 16.9 and 17.2%, respectively. There were real differences in death rates between farms (Chi-square =93.7;  $P < 0.001$ ). Again, differences between years were quite substantial ( $P < 0.001$ ) in all farms. Real sex differences in mortality rate among weaners was detected at Ihimbu ( $P < 0.05$ ), Iwambi ( $P < 0.001$ ) and at Kitulo ( $P < 0.001$ ).

Calculated total calf loss from birth to approximately 18 months of age was 25.2% at Ihimbu, 36.2% at Iwambi, 41.4% at Kitulo, 26.4% at Mbarali and 27.4% at Uyole.

Mortality rates among heifers of above 18 months of age were equally high, ranging from 7.1 at Ihimbu to 29.2% at Iwambi. Farm differences in death rates of heifers above 18 months of age were large (Chi-square=135.0;  $P < 0.001$ ). Yearly variations were notably high in all farms (Table 10). Overall loss of heifers from birth to first calving ranged between 32.1 and 68.8% indicating that one third to two thirds of all heifer calves born never reached the milking herd.

Distribution of monthly death rates of unweaned calves according to months of the year is shown in Appendix

Table 10: Mortality rates among heifers of over 18 months of age

Farm <sup>1)</sup>	Age class	No. of heifers		Death rate	Between years	
		At risk	Died		Range	Chi-square
Ihimbu	> 18 mon.	283	20	7.1	0.0-28.9	40.9 ***
	Birth-calving	-	-	32.1	-	-
Iwambi	> 18 mon.	746	218	29.2	4.4-100.0	375.2 ***
	Birth-calving	-	-	68.8	-	-
Kitulo	>18 mon.	2 064	257	12.4	2.5-26.5	98.2 ***
	Birth-calving	-	-	52.9	-	-
Uyole	>18 mon.	310	63	20.3	0.0-69.7	68.2 ***
	Birth-calving	-	-	42.1	-	-

<sup>1)</sup> Records for Mbarali did not permit making such calculations

Table 1. If the months are classified into seasons according to rainfall and temperature patterns in the farms, the late wet season months (March to May) and the early dry season months (June to August) contain the largest proportion of deaths. In three out of the four farms studied, the early rainy season (December to February) had the least death rates.

#### 4.1.3 Causes of calf deaths

Approximately 32 to 52% of all calf deaths in the studied farms were caused by three main disorders; namely pneumonia, scours and nutritional deficiencies (Tables 11a, and b). There were a few other farm specific major causes of death that need to be mentioned. At Ihimbu, tick-borne diseases (mainly anaplasmosis and east coast fever) were the cause of 10.5% of deaths of calves. Bloat (tyimpanites) was responsible for 9.6% of calf mortality at Ihimbu farm and was mainly associated with over-eating of

Table 11a: A summary of causes of deaths among young stock at Ihimbu, Iwambi, Mbarali and Uyole dairy farms

Cause of death	Percentage of total deaths			
	Farm			
	Ihimbu	Iwambi	Mbarali	Uyole
Total no. of deaths	209	776	139	305
1. Pneumonia	7.2	14.8	25.9	9.5
2. Diarrhoea/scours	18.7	11.1	9.4	9.8
3. Bloat	9.6	2.5	3.6	-
4. Nutritional deficiency	5.7	12.1	16.5	20.3
5. Born weak	2.4	2.9	-	3.6
6. Poisoning	4.3	25.8	18.7	3.9
7. Accident/drowned/trauma	5.3	3.6	2.9	3.6
8. Attacked by stray dogs	2.4	5.7	-	5.9
9. Fascioliasis	4.3	0.5	1.4	-
10. Lung worms	3.3	0.9	-	3.3
11. Tick-borne diseases	10.5	2.6	-	0.7
12. Other digestive system disorders	4.3	2.0	-	-
13. Liver failure (cirrhosis or abscessation)	-	2.5	-	4.3
14. Destroyed; general malaise	10.0	0.5	-	6.5
15. Scours and pneumonia	-	2.0	-	-
16. Lung abscesses	-	0.5	2.2	-
17. Foot and mouth disease	-	0.4	5.0	-
18. Lumpy skin disease	-	0.3	5.0	-
19. Lung tuberculosis	-	-	2.9	-
20. Navel infection	-	-	-	2.6
21. Other causes	12.0	9.3	6.5	25.9
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

Table 11b: Causes of death among young stock at Kitulo dairy farm

Cause of death	No. of deaths	Percent
1. Pneumonia	522	19.0
2. Diarrhoea/scours	314	11.4
3. Enteritis/gastroenteritis	308	11.2
4. Abscessions (general, lungs, liver)	166	6.1
5. Lung worms	159	5.8
6. Un-detected/un-known cases	157	5.7
7. Tympanites (bloat)	146	5.3
8. Drowning in water/mud	136	5.0
9. Nutritional deficiency/debility	117	4.3
10. Poisoning	110	4.0
11. Reproductive problems in heifers (including hydramnios/hydrallantois)	89	3.2
12. Multiple of causes	70	2.6
13. Liver failure/cirrhosis	61	2.2
14. High altitude (brisket) disease	53	1.9
15. Accidents/trauma	46	1.7
16. Helminthiasis (mainly tape worms)	42	1.5
17. Attack by stray dogs	30	1.1
18. Navel ill/joint ill	28	1.0
19. In-digestion	25	0.9
20. Born weak	22	0.8
21. Intestinal obstruction/strangulation	19	0.7
23. Cold stress	18	0.7
24. Fascioliasis	16	0.6
25. Tuberculosis	14	0.5
26. Destroyed due to ill health	8	0.3
27. Others	67	2.4
<b>Total</b>	<b>2743</b>	<b>100.0</b>

lucerne. Poisoning has featured highly at Iwambi due to the 1984 catastrophe whereby 157 weaners and heifers died when they were fed copper sulphate in concentrates as a remedy to copper deficiency. The rest of the poisonings were due to other causes such as snake venom, dip wash and molasses toxicity. Apparently poisoning also claimed lives of some calves at Mbarali ( 18.7% of deaths) and at Kitulo ( 4.0% of deaths). At Kitulo suspected poisons were copper sulphate, urea, acaricide and plant weeds.

Attack by stray dogs was responsible for 44 deaths (5.7%) at Iwambi and 18 deaths (5.9%) at Uyole. General abscessation and abscesses of lungs and liver (Table 11b) was the fourth major cause of calf death at Kitulo dairy farm. Also high on the list were incidences of lung worms (Dictyocaulus viviparus) and bloat. At Kitulo and Uyole there were a substantial number of un-detected/found dead cases in which even post mortem could not be performed. In the latter farm such cases were lumped into the "others" subclass.

## 4.2 Reproductive traits

### 4.2.1 Age at first calving

The average ages at first calving at Ihimbu (Ayrshires),

Iwambi (Friesians), Kitulo (Friesians), Mbarali (Guernseys) and Uyole (Friesians) were  $36.6 \pm 0.5$ ,  $38.9 \pm 0.8$ ,  $33.3 \pm 0.4$ ,  $34.5 \pm 0.8$  and  $34.4 \pm 0.3$  months, respectively. Analyses of variance performed for each farm (Table 12) indicates that season of birth was not an important source of variation ( $P > 0.05$ ) except at Uyole where it was significant ( $P < 0.01$ ). Estimated least squares means for age at first calving are presented in Table 13.

Table 12: Analyses of variance of age at first calving

Farm	Source of variation				Residual
		Season (S)	Period (P)	S x P	
Ihimbu	d.f.	3	3	9	130
	MS	41 ns	1 039 ***	54 ns	34
Iwambi	d.f.	3	2	6	90
	MS	114 ns	1 111 ns	57 ns	59
Kitulo	d.f.	3	3	9	229
	MS	36 ns	371 ***	63 ns	43
Mbarali	d.f.	3	3	9	94
	MS	25 ns	77 ns	43 ns	64
Uyole	d.f.	3	5	15	625
	MS	192 **	1 923 ***	145 ***	46

Variations due to period of birth were large and significant ( $P < 0.001$ ) at Ihimbu, Kitulo and Uyole. At

Table 13. Estimated least squares means for age at first calving in the dairy farms

	Farm, no. of animals and LSM <i>s.e.</i> (months)											
	Ihumbu		Iwambi		Kitulo		Mbarali		Uyole		n	LSM
	n	LSM	n	LSM	n	LSM	n	LSM	n	LSM		
Overall	146	36.6±0.5	102	38.9±0.8	245	33.3±0.4	110	34.5±0.8	649	34.4±0.3		
Season of birth												
Dec-Feb	30	39.0±1.8	32	38.6±1.7	56	32.8±1.0	27	33.8±1.8	169	35.4±0.5 <sup>1</sup>		
Mar-May	44	36.4±1.2	19	35.2±2.2	59	35.3±1.5	36	34.6±1.4	170	35.6±0.5 <sup>1</sup>		
Jun-Aug	34	36.1±1.1	23	36.3±1.8	53	33.8±1.0	33	33.4±1.4	162	36.4±0.6 <sup>2</sup>		
Sep-Nov	38	35.9±1.0	28	43.1±2.8	77	32.1±1.7	14	36.4±2.7	148	33.5±0.6 <sup>2</sup>		
Period of birth 1)												
1	20	27.0±1.4 <sup>2</sup>	28	36.0±1.6	56	30.6±1.4 <sup>b</sup>	23	36.5±1.9	95	35.5±0.7 <sup>2</sup>		
2	75	35.4±0.7 <sup>b</sup>	59	39.7±1.2	15	33.4±2.1 <sup>ab</sup>	39	33.1±1.3	77	35.0±0.8 <sup>2</sup>		
3	32	41.5±1.1 <sup>c</sup>	15	39.3±2.6	66	37.3±0.8 <sup>2</sup>	31	36.0±1.6	160	30.5±0.6 <sup>2</sup>		
4	19	45.6±1.8 <sup>c</sup>	-	-	108	32.6±0.7 <sup>b</sup>	17	32.7±2.5	138	30.7±0.6 <sup>2</sup>		
5	-	-	-	-	-	-	-	-	76	38.8±0.8 <sup>2</sup>		
6	-	-	-	-	-	-	-	-	103	40.9±0.7 <sup>2</sup>		

1) For description of periods see text (section 3.4.2)

2) In this and subsequent tables least squares means with different superscripts (no letter in common) in a column are significantly different ( $P < 0.05$ )

Uyole, the interaction between season and period of birth was also a significant ( $P < 0.001$ ) source of variation. Inspection on least squares means for period of birth show that age at first calving has been gradually increasing with time from 27 to about 46 months at Ihimbu and from 36 to 39 months at Iwambi. At Kitulo heifers freshened at around 31 months in 1974-77 then it went up to 37 months during 1982-85 but declined thereafter. Period effect on heifers at Mbarali was erratic. At Uyole age at first calving was lowest during 1974-79, afterwards it increased to about 41 months during 1983-86.

#### 4.2.2 Calving interval (CI)

Mean calving intervals (CI) were 432, 419, 489, 375 and 384 days, for Ihimbu, Iwambi, Kitulo, Mbarali and Uyole farms, respectively. Mbarali and Uyole had ideal CIs of less than 13 months while Kitulo had longest CIs averaging about 16 months. Analyses of variance of CIs presented in Table 14 show that the model accounted for less than 10% of total variation of calving intervals (except at Ihimbu). Parturition number was a significant source of variation in three of the farms though it accounted for only one percent or less of total variation of this trait. Table 15 shows the estimated least squares means for CI by parity and season of calving. CIs of first calvers were

longest at Ihimbu, Kitulo and Uyole but otherwise no specific trend could be discerned.

Season of calving was not an important source of variation for CI in any of the farms except Ihimbu where it accounted for 2% of total sum of squares. In this farm dry season (June to November) calvers had relatively longer CIs compared to those calving in the wet season.

Year differences accounted for 3 to 31% of total sum of squares and was a highly (  $P < 0.001$  ) significant source of variation in all farms except Mbarali. Year of calving was the most important factor influencing CIs in the farms.

Table 14: Proportions of total sum of squares accounted for by various factors in the analyses of variance of calving intervals

Proportions of sum of squares accounted for by:				
Farm	Model	Parity	Season	Year
Ihimbu	34	1 <sup>***</sup>	2 <sup>**</sup>	31 <sup>***</sup>
Iwambi	6	1 <sup>*</sup>	< 1 <sup>NS</sup>	3 <sup>***</sup>
Kitulo	4	< 1 <sup>NS</sup>	< 1 <sup>NS</sup>	4 <sup>***</sup>
Mbarali	4	< 1 <sup>NS</sup>	< 1 <sup>NS</sup>	3 <sup>NS</sup>
Uyole	5	< 1 <sup>*</sup>	< 1 <sup>NS</sup>	4 <sup>***</sup>

**Table 15: Least squares means for calving intervals (days) estimated for effects of parity and season of previous calving**

Factor	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
Overall	432 ± 5 (657) <sup>1)</sup>	419 ± 3 (1162)	489 ± 3 (2656)	375 ± 3 (936)	384 ± 2 (1482)
<b>Parity</b>					
1	467 ± 12 <sup>a</sup> (159)	443 ± 8 <sup>3b</sup> (278)	505 ± 6 (1032)	373 ± 7 (198)	389 ± 3 (557)
2	418 ± 13 <sup>b</sup> (134)	420 ± 9 <sup>b</sup> (244)	484 ± 7 (733)	369 ± 7 (173)	376 ± 4 (384)
3	395 ± 14 <sup>b</sup> (108)	428 ± 10 <sup>3b</sup> (212)	498 ± 8 (481)	380 ± 8 (138)	384 ± 5 (259)
4	409 ± 16 <sup>b</sup> (80)	422 ± 10 <sup>b</sup> (172)	498 ± 9 (410)	364 ± 9 (114)	378 ± 5 (282)
5	421 ± 12 <sup>b</sup> (176)	429 ± 11 <sup>2b</sup> (125)	— —	382 ± 6 (313)	— —
6	— —	464 ± 11 <sup>2</sup> (131)	— —	— —	— —
<b>Season of calving</b>					
Dec-Feb	402 ± 12 <sup>a</sup> (168)	428 ± 8 (244)	506 ± 7 (673)	377 ± 7 (231)	388 ± 4 (493)
Mar-May	412 ± 11 <sup>a</sup> (226)	441 ± 8 (244)	493 ± 7 (703)	371 ± 6 (278)	380 ± 4 (416)
Jun-Aug	415 ± 13 <sup>a</sup> (145)	434 ± 8 (269)	498 ± 7 (631)	374 ± 7 (216)	374 ± 5 (243)
Sep-Nov	459 ± 14 <sup>b</sup> (118)	433 ± 8 (405)	489 ± 7 (649)	372 ± 7 (211)	384 ± 4 (330)

<sup>1)</sup> In this and subsequent tables numbers in brackets are number of observations

### 4.3 Lactation performance traits

#### 4.3.1 Milk yield

Two traits were analysed; lactation milk yield (LMY) and annualized milk yield (AMY). Overall average LMYs were 2197, 2642, 2400, 2333 and 2585 kg at Ihimbu, Iwambi, Kitulo, Mbarali and Uyole, respectively. Coefficients of variation ranged from 27 to 42%. Corresponding mean AMYs were 1977, 2384, 1897, 2369 and 2516 kg and their respective coefficients of variation were 32, 33, 43, 43 and 29%. Analyses of variance for the two traits for each farm are presented in Table 16.

Parity was a significant ( $P < 0.01$  to  $P < 0.001$ ) source of variation on both milk yield traits in all farms, accounting for one to 10% of their total variation. Tables 17 and 18 show least squares means estimated for different parities and seasons. Looking at the parity effect, peak milk yield was attained in the third parturition at Kitulo and Uyole whereas in the rest of the farms, peak production was reached in the fourth parity. Peak LMY was about 18, 51, 12, 22 and 30% above first lactation yields at Ihimbu, Iwambi, Kitulo, Mbarali and Uyole farms, respectively. Corresponding increases for AMY were about 32, 49, 14, 26 and 31% of respective first lactation AMY.

Table 16: Proportions of total sum of squares accounted for by various factors used in the analyses of variance of lactation milk yield (LMY) and annualized milk yield (AMY)

Proportion of total sum of squares accounted for by:						
Variable	Farm	Model	Parity	Season	Year	CI
LMY						
	Ihimbu	14	2 <sup>**</sup>	< 1 <sup>NS</sup>	7 <sup>***</sup>	4 <sup>***</sup>
	Iwambi	35	6 <sup>***</sup>	1 <sup>***</sup>	11 <sup>***</sup>	12 <sup>***</sup>
	Kitulo	37	1 <sup>***</sup>	< 1 <sup>*</sup>	30 <sup>***</sup>	3 <sup>***</sup>
	Mbarali	20	2 <sup>***</sup>	< 1 <sup>NS</sup>	16 <sup>***</sup>	< 1 <sup>NS</sup>
	Uyole	24	10 <sup>***</sup>	1 <sup>**</sup>	11 <sup>***</sup>	3 <sup>***</sup>
AMY						
	Ihimbu	27	7 <sup>***</sup>	1 <sup>*</sup>	19 <sup>***</sup>	
	Iwambi	32	6 <sup>***</sup>	2 <sup>***</sup>	13 <sup>***</sup>	
	Kitulo	30	1 <sup>***</sup>	< 1 <sup>NS</sup>	28 <sup>***</sup>	
	Mbarali	22	2 <sup>***</sup>	1 <sup>NS</sup>	18 <sup>***</sup>	
	Uyole	20	10 <sup>***</sup>	< 1 <sup>NS</sup>	9 <sup>***</sup>	

Season of calving was the least important source of variation used in the model. It explained less than 2% of total variation of LMY and AMY in all farms. Variations due to seasonal differences were significant at Iwambi ( $P < 0.001$ ) for both milk yield traits, at Kitulo ( $P < 0.05$ ) for LMY, at Uyole  $P < 0.01$  for LMY and at Ihimbu  $P < 0.05$  for AMY. In the farms where seasonal variations were important (Iwambi and Uyole), the best season for cows to calve at Iwambi was the late dry season (September–November) followed by the early wet season (December–February). At Uyole the early wet season was the best season for calving.

Year of calving was the single most important source of variation influencing milk yield and it accounted for 7 to 30% of total variation. Regression on CI accounted for 3 to 12% of total sum of squares, and was significant,  $P < 0.001$  in all farms except Mbarali. Regression of LMY on CI was  $1.46 \pm 0.25$ ,  $3.78 \pm 0.27$ ,  $1.51 \pm 0.14$ ,  $0.54 \pm 0.36$  and  $1.77 \pm 0.26$  kg for Ihimbu, Iwambi, Kitulo, Mbarali and Uyole farms, respectively, indicating that CI had very high association with milk yield at Iwambi.

Table 17: Least squares means ( $\pm$  s.e.) for lactation milk yield (LMY) according to parity and season of calving

Factor	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
Overall	2197 $\pm$ 30 (641)	2642 $\pm$ 28 (1023)	2400 $\pm$ 22 (2169)	2333 $\pm$ 32 (859)	2585 $\pm$ 19 (1300)
Parity					
1	2106 $\pm$ 76 <sup>a</sup> (153)	1741 $\pm$ 76 <sup>d</sup> (257)	2466 $\pm$ 39 <sup>c</sup> (864)	2135 $\pm$ 75 <sup>a</sup> (181)	2056 $\pm$ 40 <sup>b</sup> (458)
2	2250 $\pm$ 80 <sup>abc</sup> (132)	2225 $\pm$ 85 <sup>c</sup> (220)	2760 $\pm$ 46 <sup>ab</sup> (601)	2310 $\pm$ 81 <sup>abc</sup> (155)	2556 $\pm$ 44 <sup>b</sup> (344)
3	2391 $\pm$ 87 <sup>ab</sup> (107)	2564 $\pm$ 87 <sup>ab</sup> (197)	2769 $\pm$ 56 <sup>a</sup> (387)	2485 $\pm$ 90 <sup>bc</sup> (122)	2667 $\pm$ 52 <sup>b</sup> (239)
4	2479 $\pm$ 101 <sup>a</sup> (75)	2622 $\pm$ 94 <sup>a</sup> (159)	2724 $\pm$ 63 <sup>abc</sup> (317)	2599 $\pm$ 95 <sup>c</sup> (107)	2588 $\pm$ 50 <sup>b</sup> (259)
5	2399 $\pm$ 76 <sup>ab</sup> (174)	2562 $\pm$ 106 <sup>ab</sup> (106)	-	2483 $\pm$ 62 <sup>bc</sup> (294)	-
6	-	2361 $\pm$ 111 <sup>abc</sup> (841)	-	-	-
Season of calving					
Dec-Feb	2404 $\pm$ 73 (162)	2390 $\pm$ 78 <sup>ab</sup> (209)	2759 $\pm$ 47 (557)	2532 $\pm$ 72 (211)	2580 $\pm$ 40 <sup>a</sup> (422)
Mar-May	2357 $\pm$ 69 (222)	2288 $\pm$ 77 <sup>ab</sup> (208)	2614 $\pm$ 48 (568)	2287 $\pm$ 64 (253)	2473 $\pm$ 43 <sup>ab</sup> (375)
Jun-Aug	2242 $\pm$ 80 (142)	2177 $\pm$ 77 <sup>b</sup> (232)	2608 $\pm$ 48 (524)	2371 $\pm$ 70 (199)	2402 $\pm$ 54 <sup>b</sup> (213)
Sep-Nov	2297 $\pm$ 85 (115)	2522 $\pm$ 70 <sup>a</sup> (374)	2737 $\pm$ 49 (520)	2420 $\pm$ 72 (196)	2412 $\pm$ 46 <sup>b</sup> (290)

Table 18: Least squares means ( $\pm$  s.e.) for annualized milk yield (AMY) according to parity and season of calving

Factor	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
Overall	1977 $\pm$ 24 (641)	2384 $\pm$ 24 (1023)	1897 $\pm$ 16 (2169)	2369 $\pm$ 34 (859)	2516 $\pm$ 20 (1300)
Parity					
1	1787 $\pm$ 64 <sup>a</sup> (153)	1591 $\pm$ 65 <sup>a</sup> (257)	1914 $\pm$ 31 <sup>a</sup> (864)	2158 $\pm$ 80 <sup>a</sup> (181)	1992 $\pm$ 42 <sup>a</sup> (458)
2	1991 $\pm$ 67 <sup>b</sup> (132)	2029 $\pm$ 73 <sup>b</sup> (220)	2188 $\pm$ 37 <sup>b</sup> (601)	2370 $\pm$ 85 <sup>bc</sup> (155)	2517 $\pm$ 47 <sup>b</sup> (344)
3	2243 $\pm$ 74 <sup>c</sup> (107)	2328 $\pm$ 76 <sup>c</sup> (197)	2142 $\pm$ 45 <sup>b</sup> (387)	2515 $\pm$ 95 <sup>cd</sup> (122)	2607 $\pm$ 54 <sup>b</sup> (239)
4	2359 $\pm$ 85 <sup>c</sup> (75)	2377 $\pm$ 82 <sup>c</sup> (159)	2135 $\pm$ 50 <sup>b</sup> (317)	2726 $\pm$ 101 <sup>d</sup> (107)	2545 $\pm$ 53 <sup>b</sup> (259)
5	2232 $\pm$ 64 <sup>c</sup> (174)	2374 $\pm$ 92 <sup>c</sup> (106)	-	2497 $\pm$ 65 <sup>bcd</sup> (294)	-
6	-	2122 $\pm$ 96 <sup>bc</sup> (84)	-	-	-
Season of calving					
Dec-Feb	2222 $\pm$ 61 (162)	2146 $\pm$ 67 <sup>ab</sup> (209)	2138 $\pm$ 37 (557)	2595 $\pm$ 77 (211)	2497 $\pm$ 42 (422)
Mar-May	2175 $\pm$ 58 (222)	2080 $\pm$ 67 <sup>a</sup> (208)	2059 $\pm$ 39 (568)	2348 $\pm$ 67 (253)	2426 $\pm$ 46 (375)
Jun-Aug	2098 $\pm$ 67 (142)	2001 $\pm$ 66 <sup>a</sup> (232)	2048 $\pm$ 39 (524)	2428 $\pm$ 74 (199)	2375 $\pm$ 56 (213)
Sep-Nov	1994 $\pm$ 72 (115)	2320 $\pm$ 61 <sup>b</sup> (374)	2134 $\pm$ 39 (520)	2441 $\pm$ 77 (196)	2363 $\pm$ 48 (290)

#### 4.3.2 Lactation length (LL)

Overall mean lactation lengths (LL) at Ihimbu, Iwambi, Kitulo, Mbarali and Uyole were 289, 316, 321, 270 and 294 days, respectively with Guernseys at Mbarali exhibiting the shortest lactating periods. Respective coefficients of variation were 23, 23, 30, 24 and 22%. Parity accounted for less than 5% of the variation in all farms and was not a significant source of variation ( $P > 0.05$ ) of LL at Iwambi and Uyole (Table 19).

The effect of season of calving was not of significance (except at Kitulo) and explained less than 1% of total variation in LL in all farms. The proportion of variation explained by year effect ranged from 3 to 8% and was significant ( $P < 0.01$  to  $P < 0.001$ ). It was the second most important source of variation after CI. LL highly ( $P < 0.001$ ) depended on length of CI as regression sum of squares of the latter constituted 6 to 40% of total sum of squares. Linear regressions of LL on CI for Ihimbu, Iwambi, Kitulo, Mbarali and Uyole were  $0.24 \pm 0.02$ ,  $0.60 \pm 0.02$ ,  $0.24 \pm 0.01$ ,  $0.18 \pm 0.02$  and  $0.57 \pm 0.05$  days, respectively.

Least squares means for LL according to parity and season of calving are displayed in Table 20. In three of the

farms (Iwambi, Kitulo and Uyole), LL increased with parturition number up to third or fourth calving, thereafter decreased. LL at Ihimbu and Mbarali decreased with advancement in age (in parity) of cows.

#### 4.3.3 Dry period (DP)

Mean dry periods (DP) were shortest at Uyole (86 days) and longest at Kitulo (165 days). At Ihimbu, Iwambi and Mbarali DPs averaged 134, 103 and 104 days, respectively. Coefficients of variation for this trait were high, ranging from 50 to 75%. Analyses of variance of DP (Table 19) indicated that parity was a significant factor at Ihimbu, Kitulo and Mbarali but not in the remaining two farms. Parity explained 2% or less of variation of DP. DPs had the opposite trend of LL as the two traits add up to CI (Table 21) and CI was used as a covariate.

Season of calving was not an important source of variation on DP in any farm, accounting for less than 1% of total variation of this trait (except Kitulo;  $P < 0.05$ ).

The proportion of variation of DP explained by effect of year of calving ranged from 1 to 4% and was significant in all farms. The largest portion of the variation in DP was accounted for by the regression on calving interval

Table 19: Proportions of total sum of squares accounted for by various factors used in the analyses of variance of lactation length (LL) and dry period (DP)

Proportion of total sum of squares accounted for by:						
Trait	Farm	Model	Parity	Season	Year	CI
LL	Ihimbu	33	5 <sup>***</sup>	< 1 <sup>NS</sup>	8 <sup>***</sup>	10 <sup>***</sup>
	Iwambi	46	< 1 <sup>NS</sup>	< 1 <sup>NS</sup>	3 <sup>***</sup>	40 <sup>***</sup>
	Kitulo	19	1 <sup>***</sup>	< 1 <sup>*</sup>	3 <sup>***</sup>	13 <sup>***</sup>
	Mbarali	15	2 <sup>**</sup>	< 1 <sup>NS</sup>	4 <sup>**</sup>	6 <sup>***</sup>
	Uyole	34	< 1 <sup>NS</sup>	< 1 <sup>NS</sup>	4 <sup>**</sup>	31 <sup>***</sup>
DP	Ihimbu	68	2 <sup>***</sup>	< 1 <sup>NS</sup>	4 <sup>***</sup>	49 <sup>***</sup>
	Iwambi	29	< 1 <sup>NS</sup>	< 1 <sup>NS</sup>	4 <sup>***</sup>	23 <sup>***</sup>
	Kitulo	63	< 1 <sup>***</sup>	< 1 <sup>*</sup>	1 <sup>***</sup>	60 <sup>***</sup>
	Mbarali	60	1 <sup>**</sup>	< 1 <sup>NS</sup>	2 <sup>**</sup>	55 <sup>***</sup>
	Uyole	27	1 <sup>NS</sup>	< 1 <sup>NS</sup>	4 <sup>**</sup>	20 <sup>***</sup>

forming 20 to 60% of total sum of squares. Regressions of DP on calving interval were  $0.76 \pm 0.02$ ,  $0.40 \pm 0.02$ ,  $0.76 \pm 0.01$ ,  $0.81 \pm 0.02$  and  $0.43 \pm 0.05$  days for Ihimbu, Iwambi, Kitulo, Mbarali and Uyole farms, respectively.

#### 4.3.4 Phenotypic time trends and correlations among traits

Regression coefficients for lactation performance traits and calving intervals on year are shown in Table 22. A desirable trend observed at Ihimbu was that, on average,

Table 20: Estimated least squares means for lactation length (days) in the five farms by parity and season of calving

Factor	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
Overall	289 ± 3 (618)	316 ± 2 (1148)	321 ± 2 (2352)	270 ± 2 (827)	294 ± 4 (267)
<b>Parity</b>					
1	318 ± 7 <sup>c</sup> (152)	317 ± 6 (276)	310 ± 4 <sup>a</sup> (925)	283 ± 5 <sup>a</sup> (166)	291 ± 7 (106)
2	295 ± 7 <sup>a</sup> (122)	321 ± 6 (241)	328 ± 4 <sup>b</sup> (652)	270 ± 6 <sup>ab</sup> (148)	301 ± 9 (69)
3	287 ± 8 <sup>ab</sup> (104)	321 ± 7 (212)	335 ± 5 <sup>bc</sup> (422)	266 ± 6 <sup>ab</sup> (119)	309 ± 10 (51)
4	277 ± 9 <sup>ab</sup> (72)	334 ± 7 (171)	346 ± 6 <sup>c</sup> (353)	272 ± 7 <sup>ab</sup> (104)	299 ± 11 (41)
5	263 ± 7 <sup>b</sup> (168)	321 ± 8 (121)	-	256 ± 4 <sup>b</sup> (290)	-
6	-	315 ± 8 (127)	-	-	-
<b>Season of calving</b>					
Dec-Feb	294 ± 6 (160)	322 ± 6 (238)	339 ± 4 <sup>a</sup> (595)	263 ± 5 (211)	299 ± 8 (84)
Mar-May	293 ± 6 (211)	321 ± 6 (242)	327 ± 4 <sup>ab</sup> (616)	276 ± 5 (240)	297 ± 10 (56)
Jun-Aug	287 ± 7 (135)	317 ± 6 (267)	331 ± 4 <sup>ab</sup> (557)	274 ± 5 (188)	305 ± 10 (49)
Sep-Nov	280 ± 8 (112)	326 ± 6 (401)	323 ± 4 <sup>b</sup> (584)	263 ± 5 (188)	299 ± 8 (78)

Table 21: Least squares means for dry period (days) estimated for effects of parity and season of calving

Factor	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
Overall	134 ± 3 (618)	103 ± 2 (1148)	165 ± 2 (2352)	104 ± 2 (827)	86 ± 4 (267)
<b>Parity</b>					
1	105 ± 7 <sup>a</sup> (152)	101 ± 6 (276)	176 ± 4 <sup>c</sup> (925)	91 ± 5 <sup>z</sup> (166)	89 ± 7 (106)
2	128 ± 7 <sup>ab</sup> (122)	97 ± 6 (241)	158 ± 4 <sup>a</sup> (652)	104 ± 6 <sup>2b</sup> (148)	79 ± 9 (69)
3	136 ± 8 <sup>abc</sup> (104)	97 ± 7 (212)	151 ± 5 <sup>2b</sup> (422)	108 ± 6 <sup>2b</sup> (119)	70 ± 10 (51)
4	145 ± 9 <sup>bc</sup> (72)	84 ± 7 (171)	140 ± 6 <sup>b</sup> (353)	103 ± 7 <sup>2b</sup> (104)	81 ± 11 (41)
5	160 ± 7 <sup>c</sup> (168)	97 ± 8 (121)	- -	118 ± 4 <sup>b</sup> (290)	-
6	-	103 ± 8 (127)	-	-	-
<b>Season of calving</b>					
Dec-Feb	130 ± 6 (160)	96 ± 6 (238)	147 ± 4 <sup>a</sup> (595)	111 ± 5 (211)	80 ± 8 (84)
Mar-May	131 ± 6 (211)	97 ± 6 (242)	159 ± 4 <sup>ab</sup> (616)	98 ± 5 (240)	83 ± 10 (56)
Jun-Aug	136 ± 7 (135)	101 ± 6 (267)	155 ± 4 <sup>ab</sup> (557)	100 ± 5 (188)	75 ± 10 (49)
Sep-Nov	143 ± 8 (112)	92 ± 6 (401)	164 ± 4 <sup>b</sup> (584)	11 ± 5 (188)	81 ± 8 (78)

lactation length increased by 3 days each year while the undesirable trend was the average increase of 8 days in CI per year. At Iwambi LMY and AMY decreased by 113 and 98 kg per year, respectively. There were highly significant annual decreases in LMY ( of 128 kg), AMY (of 90 kg) and LL (of 3 days) at Kitulo farm. However, CIs improved by 4 days per year. Trends for other traits (not pointed out) were not significantly different from zero.

In all farms there were high and positive within cow associations between LMY, AMY and LL, indicating that high milk production resulted into having long lactating periods and shorter DPs as exemplified by negative correlations between LMY and DP (  $r = -0.16$  to  $-0.36$ ; see Table 23). AMY was negatively correlated with CI and with DP. Long CIs were associated with long lactating periods ( $r = 0.24$  to  $0.64$ ) and long DPs (  $r = 0.54$  to  $0.83$ ). Since LL and DP add up to CI, their association was negative.

Table 22: Simple linear regressions of annual least squares means of LMY, AMY, LL and CI on year

Farm	Regression coefficients for:			
	LMY	AMY	LL	CI
	kg			days
Ihimbu	$-1 \pm 16^{ns}$	$-25 \pm 22^{ns}$	$3.42 \pm 0.84^{xxx}$	$8.59 \pm 3.61^x$
Iwambi	$-113 \pm 37^x$	$-98 \pm 32^x$	$0.32 \pm 2.03^{ns}$	$2.81 \pm 2.43^{ns}$
Kitulo	$-128 \pm 26^{xxx}$	$-90 \pm 20^{xxx}$	$-3.08 \pm 0.99^{xx}$	$-4.22 \pm 1.81^x$
Mbarali	$-33 \pm 20^{ns}$	$-31 \pm 21^{ns}$	$0.32 \pm 0.75^{ns}$	$-1.28 \pm 0.76^{ns}$
Uyole <sup>1)</sup>	$58 \pm 49^{ns}$	$64 \pm 46^{ns}$	-	$-2.85 \pm 2.42^{ns}$

<sup>1)</sup> Analysis for lactation length for Uyole was not performed because there were only 4 year subclasses

#### 4.4 Repeatability estimates

In the analyses of variance carried out to estimate variance components of lactation length and dry period, calving interval was included in the model. Consequently repeatability estimates for LL and DP were the same, hence reported for one of them only. Repeatabilities for CI were lowest ranging from 0.02 to 0.18 (see Table 24). Estimates for LMY and AMY ranged from 0.11 to 0.42 and from 0.10 to 0.46, respectively. Repeatability estimates for Mbarali farm were consistently lower than those for other farms. If estimates of Mbarali farm are ignored, overall weighted

Table 23: Within cow correlations (in %) among lactation performance traits

Traits being correlated	Farm					
	Ihimbu Iwambi		Kitulo	Mbarali	Uyole Uyole <sup>1)</sup>	
d.f.	430	728	1178	566	143	787
LMY and AMY	72	65	64	89	77	77
LMY and CI	18	42	27	4	11	12
LMY and LL	67	74	72	41	45	-
LMY and DP	-20	-29	-16	-23	-36	-
AMY and CI	-44	-35	-45	-35	-49	-50
AMY and LL	30	22	28	25	4	-
AMY and DP	-62	-67	-65	-49	-57	-
CI and LL	31	63	39	24	64	-
CI and DP	83	53	82	77	54	-
LL and DP	-27	-32	-20	-42	-30	-
Critical values for sign. at 5%	10	9	6	9	16	9

<sup>1)</sup> A second run of multivariate analysis of variance in which DP and LL were excluded in order to increase number of records

Table 24: Estimates of repeatability of milk yield and related traits

Farm	Variable			
	CI	LL	LMY	AMY
<b>Ihimbu</b>				
No. of cows	161	159	160	160
No. of records	657	618	641	641
Repeatability	0.02±0.03	0.22±0.04	0.29±0.04	0.31±0.04
<b>Iwambi</b>				
No. of cows	285	284	272	272
No. of records	1162	1148	1023	1023
Repeatability	0.18±0.04	0.17±0.03	0.42±0.03	0.46±0.03
<b>Kitulo</b>				
No. of cows	1039	975	937	937
No. of record	2656	2352	2169	2169
Repeatability	0.14±0.02	0.22±0.03	0.39±0.02	0.37±0.02
<b>Mbarali</b>				
No. of cows	211	211	210	210
No. of records	936	827	859	859
Repeatability	0.05±0.03	0.15±0.04	0.11±0.03	0.10±0.03
<b>Uyole</b>				
No. of cows	498	113	498	498
No. of records	1300	267	1300	1300
Repeatability	0.16±0.03	0.29±0.07	0.32±0.03	0.30±0.03
<b>Weighted<sup>1)</sup> means</b>	<b>0.14±0.01</b>	<b>0.21±0.02</b>	<b>0.37±0.01</b>	<b>0.36±0.01</b>

<sup>1)</sup> Weighted by number of records (Mbarali farm excluded)

means (weighted by number of records used in estimation) were calculated to be  $0.14 \pm 0.01$ ,  $0.21 \pm 0.02$ ,  $0.37 \pm 0.01$  and  $0.36 \pm 0.01$  for CI, LL, LMY and AMY, respectively.

#### 4.4 Milk composition

Average percentages of milk components and their standard deviations at Uyole farm are shown in Table 25. Butter-fat (BF), protein, total solids (TS), solids-not-fat (SNF) and ash average percentages were 3.89, 3.15, 12.10, 8.39 and 0.73, respectively. The column of coefficients of variation indicates that milk yield on test days was most variable (46.2%), followed by BF, protein, SNF, TS in that order and ash was least (8.2%). Mean yields of milk constituents on test days were 0.303, 0.237, 0.894, 0.631 and 0.047 kg for BF, protein, TS, SNF and ash, respectively. Coefficients of variation for yield traits were much larger (up to 5 times) compared with those of concentrations.

Analyses of variance for concentrations and yields of milk components performed by the least squares method are presented in Table 26. Among the factors included in the analyses, parity made the least contribution to the total variation of concentrations of milk components, accounting for only 2% or less of total sum of squares. It was not a significant ( $P > 0.05$ ) source of variation for SNF and ash

Table 25: Un-adjusted means and standard deviations of test-day milk yield (kg) and percentages and yields of milk components

Trait	n	Mean	std. dev.	CV%	Residual std. dev. <sup>1)</sup>
BF %	2423	3.89	0.97	24.93	0.78
Protein %	468	3.15	0.52	16.51	0.44
TS %	1448	12.10	1.21	10.00	1.13
SNF %	1400	8.39	1.25	14.90	1.07
Ash %	507	0.73	0.06	8.22	0.05
Milk yield					
(kg)	2466	8.03	3.71	46.20	2.76
BF (kg)	2423	0.303	0.15	49.50	0.12
Protein(kg)	468	0.237	0.11	46.41	0.08
TS (kg)	1448	0.894	0.39	43.62	0.30
SNF (kg)	1400	0.631	0.30	47.54	0.23
Ash (kg)	507	0.047	0.02	42.55	0.02

<sup>1)</sup> After accounting for effects of parity, year, month of lactation and recording month

percentages. With exception of ash yield, all yield traits were significantly ( $P < 0.01$ ) influenced by parturition number. BF percent was highest in second parity (4.0%) and protein in third parity (3.37%), thereafter concentrations decreased. On the other hand, percentages of TS and SNF were highest in first calvers (12.27 and 8.6%, respectively) and then declined with advancement in age. Lowest concentrations were obtained in the fifth and above lactations for TS and in the fourth lactation for SNF. All

yield traits increased with parturition number up to fourth parity, following the test day milk yield trend (Table 27 and Fig.3).

Effect of year of recording was not an important ( $P > 0.05$ ) source of variation on protein percent and yield, TS

Table 26: Analyses of variance showing the relative importance of parity, year, lactation month and recording month on milk constituents' percentages and yields

Variable	Percentage of total SS accounted for by:					Milk yield <sup>1)</sup>
	Model	Parity	Year	Rec.mon.	Lact.mon.	
BF %	36	1 <sup>***</sup>	17 <sup>***</sup>	8 <sup>***</sup>	2 <sup>***</sup>	2 <sup>***</sup>
Protein %	32	2 <sup>**</sup>	< 1 <sup>NS</sup>	9 <sup>***</sup>	3 <sup>†</sup>	3 <sup>***</sup>
TS %	15	1 <sup>**</sup>	7 <sup>***</sup>	7 <sup>***</sup>	3 <sup>***</sup>	< 1 <sup>NS</sup>
SNF %	27	< 1 <sup>NS</sup>	9 <sup>***</sup>	12 <sup>***</sup>	1 <sup>NS</sup>	1 <sup>***</sup>
Ash %	22	< 1 <sup>NS</sup>	1 <sup>†</sup>	12 <sup>***</sup>	6 <sup>***</sup>	1 <sup>†</sup>
Milk (kg)	45	2 <sup>***</sup>	4 <sup>***</sup>	7 <sup>***</sup>	24 <sup>***</sup>	—
BF (kg)	37	1 <sup>***</sup>	15 <sup>***</sup>	2 <sup>***</sup>	14 <sup>***</sup>	—
Protein	52	2 <sup>**</sup>	< 1 <sup>NS</sup>	9 <sup>***</sup>	22 <sup>***</sup>	—
TS (kg)	40	1 <sup>***</sup>	< 1 <sup>NS</sup>	10 <sup>***</sup>	25 <sup>***</sup>	—
SNF (kg)	44	1 <sup>***</sup>	1 <sup>***</sup>	12 <sup>***</sup>	24 <sup>***</sup>	—
Ash (kg)	50	1 <sup>NS</sup>	< 1 <sup>NS</sup>	9 <sup>***</sup>	36 <sup>***</sup>	—

1) Milk yield used as covariate in the analyses of percentages.

yield and ash yield on test days. Year effect accounted for less than 1% of total variation of these traits. However, yearly variations were quite substantial ( $P < 0.001$ ) on BF%, TS%, SNF%, test-day milk yield, BF yield and SNF yield accounting for 17, 7, 9, 4, 15 and 1%, respectively of their total sum of squares. Inspection of the least squares means for BF%, SNF% and yields of milk, BF, TS and SNF (Tables 29 and 30) show that these components decreased during the first three or four years of sampling. No trend could be discerned on TS% indicating year effect was erratic.

Stage of lactation significantly affected BF%, TS% and ash percent ( $P < 0.001$ ) and to a lower extent protein percent ( $P < 0.05$ ) but not SNF%. On yield traits, stage of lactation was the single most influential factor accounting for 14 to 36% of their variations (Table 26). BF% was lowest in the second month of lactation and then gradually increased to the tenth month. TS% had a similar pattern. No distinct pattern can be noted for protein and SNF percentages though their lowest percentages were recorded in the second month of lactation. All yield traits showed a uniform trend of values to decrease with advancement of lactation (Tables 27 and 28; Fig.4).

Table 27a: Least squares means (LSM  $\pm$  s.e.) of BF, protein and TS by parity and month of lactation

Factor	Milk component (%)					
	BF		Protein		TS	
	n	LSM	n	LSM	n	LSM
<b>Parity</b>						
1	724	3.98 $\pm$ 0.032	156	3.18 $\pm$ 0.047	475	12.27 $\pm$ 0.073
2	594	4.00 $\pm$ 0.034	97	3.17 $\pm$ 0.056	360	12.22 $\pm$ 0.082
3	467	3.98 $\pm$ 0.037	107	3.37 $\pm$ 0.051	255	12.15 $\pm$ 0.088
4	304	3.87 $\pm$ 0.045	47	3.25 $\pm$ 0.074	140	12.11 $\pm$ 0.011
$\geq 5$	334	3.72 $\pm$ 0.045	61	3.14 $\pm$ 0.064	218	11.89 $\pm$ 0.096
<b>Month of lactation</b>						
1	169	3.85 $\pm$ 0.065	18	3.37 $\pm$ 0.121	93	12.21 $\pm$ 0.138
2	264	3.77 $\pm$ 0.053	44	3.11 $\pm$ 0.076	146	11.86 $\pm$ 0.114
3	258	3.82 $\pm$ 0.051	48	3.16 $\pm$ 0.071	152	11.91 $\pm$ 0.106
4	243	3.79 $\pm$ 0.052	45	3.18 $\pm$ 0.073	141	11.90 $\pm$ 0.111
5	248	3.81 $\pm$ 0.051	38	3.31 $\pm$ 0.080	141	12.04 $\pm$ 0.110
6	236	3.86 $\pm$ 0.052	43	3.20 $\pm$ 0.075	133	12.01 $\pm$ 0.112
7	220	3.94 $\pm$ 0.055	38	3.12 $\pm$ 0.080	128	12.29 $\pm$ 0.115
8	206	4.02 $\pm$ 0.057	41	3.09 $\pm$ 0.076	130	12.24 $\pm$ 0.114
9	188	4.06 $\pm$ 0.059	45	3.30 $\pm$ 0.075	121	12.33 $\pm$ 0.120
10	391	4.20 $\pm$ 0.043	108	3.38 $\pm$ 0.059	263	12.50 $\pm$ 0.095

Table 27b: Least squares means (LSM±s.e.) of SNF and ash  
by parity and month of lactation

Factor	Milk component (%)			
	SNF		Ash	
	n	LSM	n	LSM
<b>Parity</b>				
1	457	8.60 ± 0.072	154	0.713 ± 0.007
2	344	8.45 ± 0.080	161	0.714 ± 0.006
3	252	8.45 ± 0.085	101	0.720 ± 0.007
4	135	8.40 ± 0.108	24	0.719 ± 0.012
≥ 5	121	8.51 ± 0.094	67	0.716 ± 0.008
<b>Month of lactation</b>				
1	90	8.64 ± 0.135	28	0.746 ± 0.013
2	143	8.29 ± 0.111	50	0.721 ± 0.010
3	145	8.40 ± 0.104	57	0.697 ± 0.009
4	134	8.36 ± 0.109	59	0.703 ± 0.009
5	138	8.47 ± 0.107	49	0.703 ± 0.009
6	129	8.48 ± 0.109	42	0.696 ± 0.010
7	123	8.57 ± 0.112	39	0.710 ± 0.010
8	123	8.59 ± 0.112	43	0.732 ± 0.010
9	117	8.46 ± 0.117	48	0.725 ± 0.010
10	258	8.55 ± 0.092	92	0.729 ± 0.008

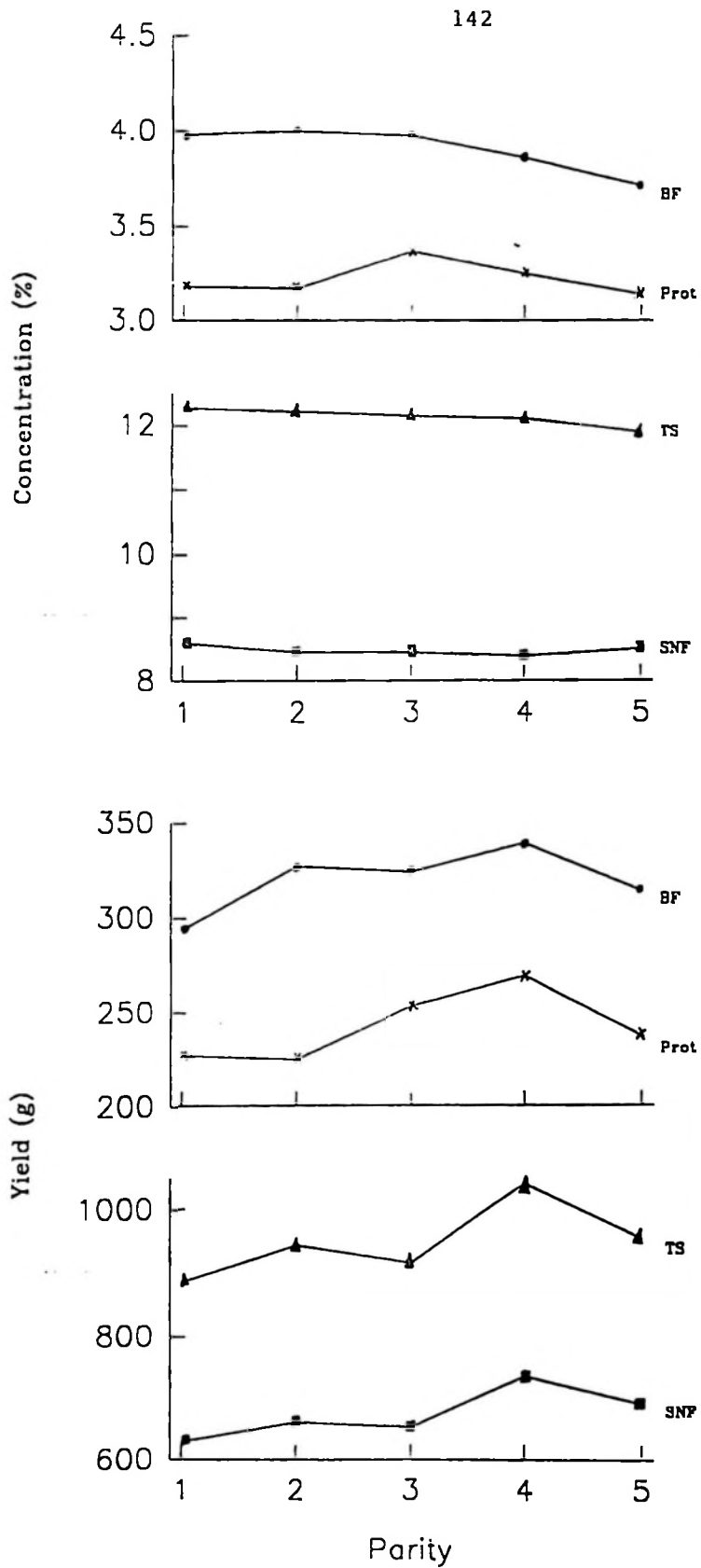


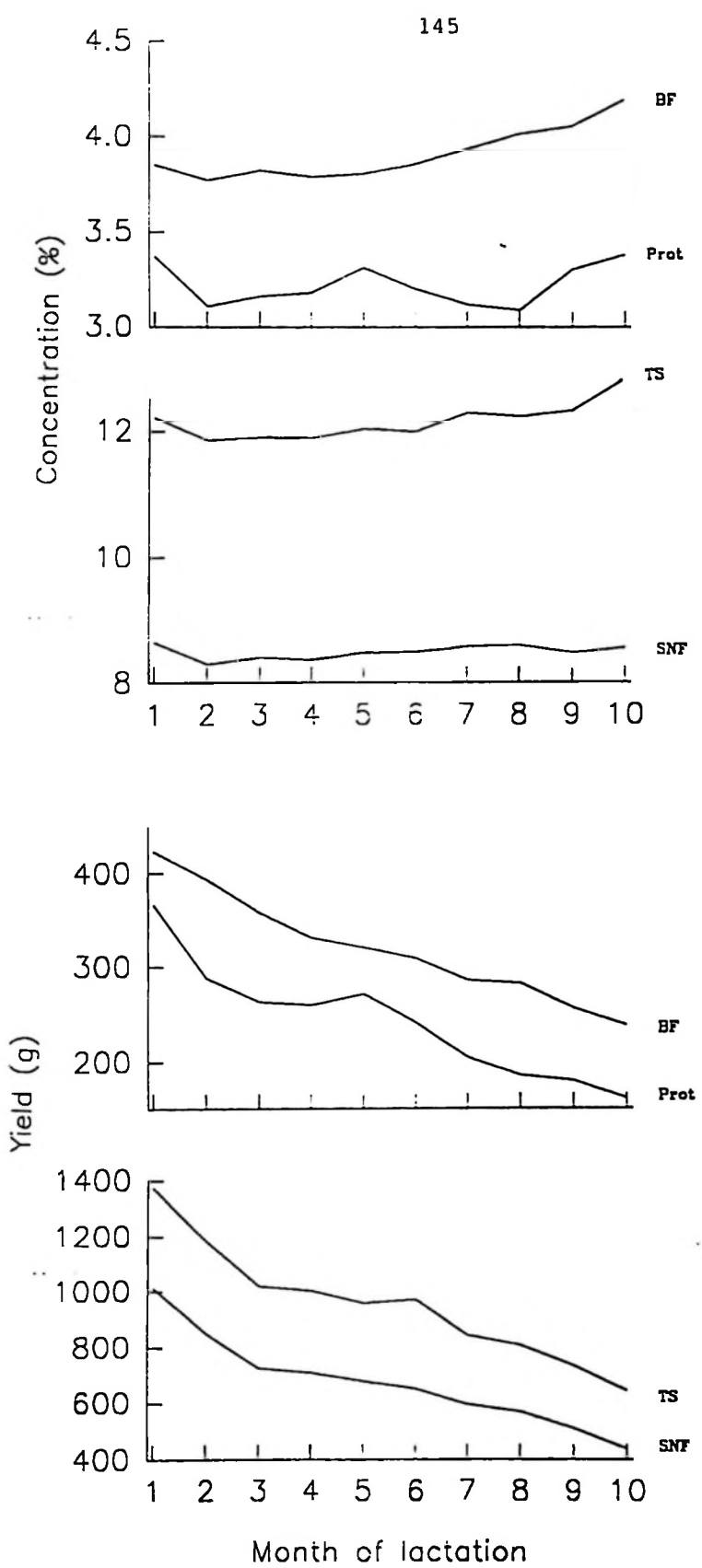
Figure 3. Effect of parity on concentrations and yields of milk components

Table 28a: Least squares means (LSM  $\pm$  s.e.) of test-day yields of milk, BF and protein by parity and month of lactation

Factor	Yield of :(kg)					
	Milk		BF		Protein	
	n	LSM	n	LSM	n	LSM
<b>Parity</b>						
1	738	7.48 $\pm$ 0.11	724	0.294 $\pm$ 0.005	156	0.227 $\pm$ 0.008
2	609	8.42 $\pm$ 0.12	594	0.327 $\pm$ 0.005	97	0.225 $\pm$ 0.010
3	470	8.39 $\pm$ 0.13	467	0.324 $\pm$ 0.006	107	0.253 $\pm$ 0.009
4	309	9.08 $\pm$ 0.16	304	0.339 $\pm$ 0.007	47	0.269 $\pm$ 0.013
$\geq 5$	340	8.86 $\pm$ 0.16	334	0.314 $\pm$ 0.007	61	0.237 $\pm$ 0.011
<b>Month of lactation</b>						
1	172	11.66 $\pm$ 0.22	169	0.423 $\pm$ 0.009	18	0.366 $\pm$ 0.020
2	267	10.99 $\pm$ 0.17	264	0.394 $\pm$ 0.007	44	0.288 $\pm$ 0.013
3	263	9.58 $\pm$ 0.18	258	0.263 $\pm$ 0.008	48	0.263 $\pm$ 0.012
4	249	9.03 $\pm$ 0.18	243	0.331 $\pm$ 0.008	45	0.260 $\pm$ 0.013
5	250	8.65 $\pm$ 0.18	248	0.320 $\pm$ 0.008	38	0.271 $\pm$ 0.014
6	239	8.17 $\pm$ 0.18	236	0.309 $\pm$ 0.008	43	0.241 $\pm$ 0.013
7	225	7.30 $\pm$ 0.19	220	0.285 $\pm$ 0.008	38	0.205 $\pm$ 0.014
8	213	7.06 $\pm$ 0.20	206	0.282 $\pm$ 0.008	41	0.186 $\pm$ 0.013
9	192	6.38 $\pm$ 0.20	188	0.256 $\pm$ 0.009	45	0.180 $\pm$ 0.013
10	396	5.64 $\pm$ 0.14	391	0.238 $\pm$ 0.006	108	0.161 $\pm$ 0.009

Table 28b: Least squares means (LSM  $\pm$ s.e) of test-day yields of TS, SNF and ash by parity and month of lactation

Factor	Yield of :(kg)					
	TS		SNF		Ash	
	n	LSM	n	LSM	n	LSM
<b>Parity</b>						
1	475	0.888 $\pm$ 0.020	457	0.630 $\pm$ 0.015	154	0.048 $\pm$ 0.002
2	360	0.945 $\pm$ 0.022	344	0.661 $\pm$ 0.017	161	0.051 $\pm$ 0.002
3	255	0.917 $\pm$ 0.024	252	0.653 $\pm$ 0.018	101	0.048 $\pm$ 0.002
4	140	1.039 $\pm$ 0.030	135	0.736 $\pm$ 0.023	24	0.055 $\pm$ 0.003
$\geq$ 5	218	0.953 $\pm$ 0.027	212	0.691 $\pm$ 0.020	67	0.050 $\pm$ 0.002
<b>Month of lactation</b>						
1	93	1.374 $\pm$ 0.035	90	1.013 $\pm$ 0.027	28	0.081 $\pm$ 0.003
2	146	1.183 $\pm$ 0.029	143	0.851 $\pm$ 0.023	50	0.067 $\pm$ 0.003
3	152	1.020 $\pm$ 0.028	145	0.726 $\pm$ 0.022	57	0.058 $\pm$ 0.003
4	141	1.001 $\pm$ 0.030	134	0.708 $\pm$ 0.023	59	0.053 $\pm$ 0.002
5	141	0.957 $\pm$ 0.029	138	0.679 $\pm$ 0.023	49	0.050 $\pm$ 0.003
6	133	0.917 $\pm$ 0.030	129	0.650 $\pm$ 0.023	42	0.043 $\pm$ 0.003
7	128	0.842 $\pm$ 0.031	123	0.596 $\pm$ 0.024	39	0.042 $\pm$ 0.003
8	130	0.808 $\pm$ 0.031	123	0.571 $\pm$ 0.024	43	0.043 $\pm$ 0.003
9	121	0.735 $\pm$ 0.032	117	0.511 $\pm$ 0.025	48	0.036 $\pm$ 0.003
10	262	0.645 $\pm$ 0.024	258	0.439 $\pm$ 0.019	92	0.030 $\pm$ 0.002



**Figure 4.** Changes in concentrations and yields of milk components with stage of lactation

Month of testing (recording) was observed to have a highly significant ( $P < 0.001$ ) influence on concentrations and yields of all milk components. It was the most important source of variation of concentrations of milk components, accounting for 2 to 12% of their respective total sum of squares, and the second most important factor (after stage of lactation) on yields of milk components (Table 26). Looking at the least squares means (Tables 29 and 30 and Fig. 5), it is evident that: a) Milk yield on test-days was highest in the rainy months (January to April) and lowest in the dry season months (July to October). b) Percentages of BF behaved oppositely. BF% values were high in July-October (4.24-4.33%) and low in December-April months (3.44-3.85). However, TS and SNF percentages followed the trend of test-day milk yield. c) Yields of all milk components followed the pattern of test-day milk yield, implying that their yields were highly dependant on the yield of milk.

### Correlations

Milk yield on test days had strong negative correlations with BF% ( -0.47) and protein percent ( -0.53) but had a positive correlation (0.42) with SNF%. Ash percent had a weak association with test-day milk yield and SNF% (Table 31). BF% and protein percent had a correlation of 0.59.

Table 29a: Least squares means (LSM  $\pm$ s.e.) of BF and TS by year and month of recording

Factor	Milk component (%)			
	BF		TS	
	n	LSM	n	LSM
<b>Year of recording</b>				
1986	352	4.52 $\pm$ 0.046	-	-
1987	630	4.02 $\pm$ 0.031	39	13.18 $\pm$ 0.219
1988	687	3.28 $\pm$ 0.031	629	11.97 $\pm$ 0.050
1989	584	4.07 $\pm$ 0.034	610	12.28 $\pm$ 0.051
1990	170	3.67 $\pm$ 0.067	170	11.09 $\pm$ 0.107
<b>Month of recording</b>				
Jan	202	3.49 $\pm$ 0.057	105	12.28 $\pm$ 0.132
Feb	273	3.67 $\pm$ 0.048	158	12.67 $\pm$ 0.110
Mar	164	3.85 $\pm$ 0.064	106	12.54 $\pm$ 0.129
Apr	239	3.71 $\pm$ 0.051	146	12.40 $\pm$ 0.110
May	202	3.95 $\pm$ 0.056	162	12.31 $\pm$ 0.106
Jun	173	4.08 $\pm$ 0.063	144	12.14 $\pm$ 0.115
Jul	177	4.33 $\pm$ 0.062	128	12.02 $\pm$ 0.119
Aug	117	4.28 $\pm$ 0.076	57	12.17 $\pm$ 0.168
Sep	235	4.25 $\pm$ 0.053	73	12.09 $\pm$ 0.150
Oct	225	4.24 $\pm$ 0.054	125	11.48 $\pm$ 0.120
Nov	234	3.66 $\pm$ 0.054	123	11.81 $\pm$ 0.122
Dec	182	3.44 $\pm$ 0.060	121	11.64 $\pm$ 0.111

**Table 29b: Least squares means (LSM  $\pm$ s.e.) of SNF and ash percentages by year and month of recording**

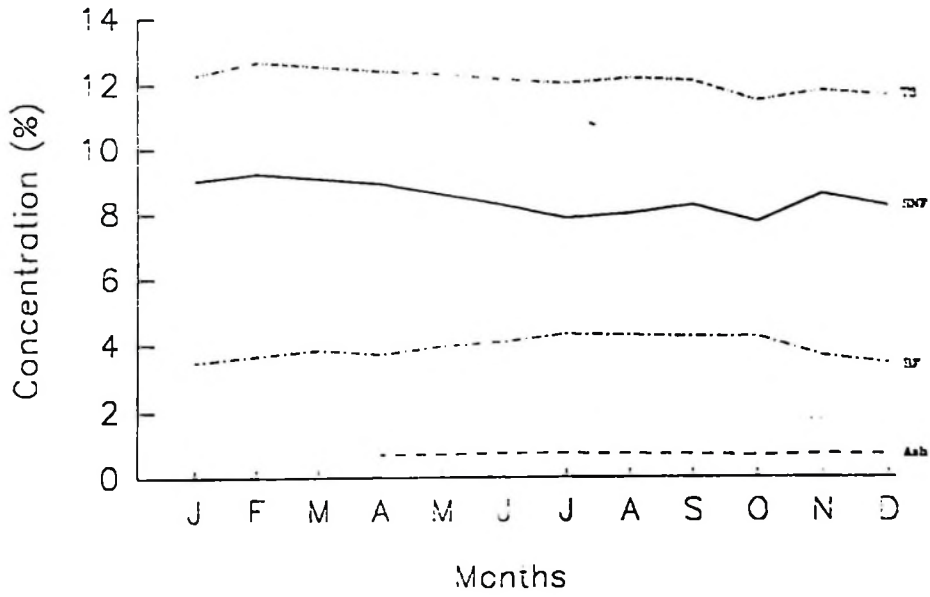
Factor	Milk component (%)			
	SNF		Ash	
	n	LSM	n	LSM
<b>Year of recording</b>				
1986	-	-	-	-
1987	35	9.67 $\pm$ 0.217	-	-
1988	621	8.63 $\pm$ 0.048	-	-
1989	574	8.19 $\pm$ 0.050	442	0.730 $\pm$ 0.004
1990	170	7.42 $\pm$ 0.102	65	0.703 $\pm$ 0.011
<b>Month of recording</b>				
Jan	99	9.02 $\pm$ 0.130	-	-
Feb	15	9.24 $\pm$ 0.106	-	-
Mar	106	9.08 $\pm$ 0.124	-	-
Apr	145	8.93 $\pm$ 0.106	33	0.702 $\pm$ 0.019
May	151	8.58 $\pm$ 0.105	86	0.703 $\pm$ 0.007
Jun	134	8.25 $\pm$ 0.113	69	0.741 $\pm$ 0.010
Jul	126	7.85 $\pm$ 0.115	58	0.739 $\pm$ 0.010
Aug	55	8.00 $\pm$ 0.163	53	0.734 $\pm$ 0.010
Sep	72	8.25 $\pm$ 0.145	59	0.716 $\pm$ 0.010
Oct	119	7.73 $\pm$ 0.117	58	0.672 $\pm$ 0.010
Nov	121	8.60 $\pm$ 0.118	58	0.735 $\pm$ 0.010
Dec	115	8.23 $\pm$ 0.108	33	0.703 $\pm$ 0.012

Table 30a: Least squares means (LSM  $\pm$  s.e.) of test-day yields of milk, BF and TS by year and month of recording

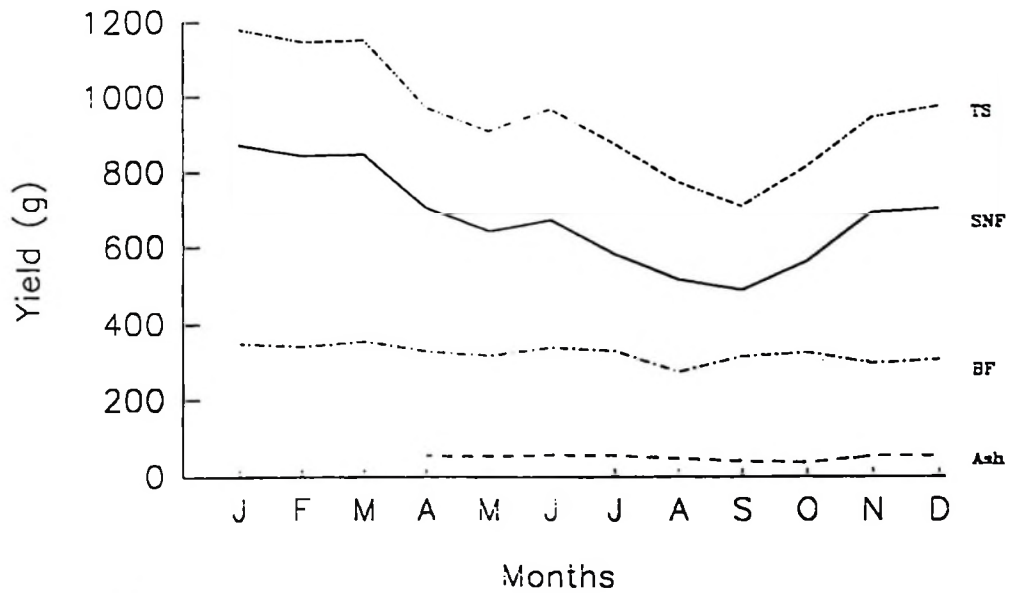
Factor	Yield of: (kg)					
	Milk		BF		TS	
	n	LSM	n	LSM	n	LSM
<b>Year of recording</b>						
1986	352	10.16 $\pm$ 0.16	352	0.435 $\pm$ 0.007	-	-
1987	633	8.56 $\pm$ 0.11	630	0.326 $\pm$ 0.005	39	1.011 $\pm$ 0.059
1988	694	7.76 $\pm$ 0.11	687	0.245 $\pm$ 0.005	629	0.930 $\pm$ 0.013
1989	617	7.59 $\pm$ 0.12	584	0.300 $\pm$ 0.005	610	0.921 $\pm$ 0.028
1990	170	8.17 $\pm$ 0.24	170	0.291 $\pm$ 0.010	170	0.932 $\pm$ 0.028
<b>Month of recording</b>						
Jan	208	10.39 $\pm$ 0.19	202	0.346 $\pm$ 0.008	105	1.182 $\pm$ 0.034
Feb	274	9.49 $\pm$ 0.17	273	0.340 $\pm$ 0.007	158	1.148 $\pm$ 0.029
Mar	164	9.60 $\pm$ 0.22	164	0.354 $\pm$ 0.010	106	1.151 $\pm$ 0.034
Apr	239	8.98 $\pm$ 0.18	239	0.326 $\pm$ 0.008	146	0.970 $\pm$ 0.030
May	211	8.31 $\pm$ 0.19	202	0.314 $\pm$ 0.009	162	0.906 $\pm$ 0.028
Jun	183	8.46 $\pm$ 0.22	173	0.334 $\pm$ 0.009	144	0.963 $\pm$ 0.031
Jul	179	7.67 $\pm$ 0.22	177	0.325 $\pm$ 0.009	128	0.872 $\pm$ 0.032
Aug	118	6.42 $\pm$ 0.27	117	0.270 $\pm$ 0.011	57	0.770 $\pm$ 0.045
Sep	236	7.20 $\pm$ 0.19	235	0.310 $\pm$ 0.008	73	0.703 $\pm$ 0.040
Oct	231	7.59 $\pm$ 0.19	225	0.321 $\pm$ 0.008	125	0.809 $\pm$ 0.032
Nov	236	8.35 $\pm$ 0.19	234	0.292 $\pm$ 0.008	123	0.939 $\pm$ 0.033
Dec	187	8.89 $\pm$ 0.21	182	0.302 $\pm$ 0.009	121	0.968 $\pm$ 0.030

Table 30b: Least squares means (LSM  $\pm$  s.e.) of test-day yields of SNF and ash by year and month of recording

Factor	Yield of: (kg)			
	SNF		Ash	
	n	LSM	n	LSM
<b>Year of recording</b>				
1986	-	-	-	-
1987	35	0.740 $\pm$ 0.047	-	-
1988	621	0.683 $\pm$ 0.010	-	-
1989	574	0.628 $\pm$ 0.011	442	0.051 $\pm$ 0.001
1990	170	0.647 $\pm$ 0.022	65	0.051 $\pm$ 0.003
<b>Month of recording</b>				
Jan	99	0.874 $\pm$ 0.027	-	-
Feb	157	0.845 $\pm$ 0.022	-	-
Mar	106	0.849 $\pm$ 0.026	-	-
Apr	145	0.703 $\pm$ 0.023	33	0.056 $\pm$ 0.003
May	151	0.639 $\pm$ 0.022	86	0.053 $\pm$ 0.003
Jun	134	0.668 $\pm$ 0.024	69	0.057 $\pm$ 0.003
Jul	126	0.577 $\pm$ 0.025	58	0.055 $\pm$ 0.003
Aug	55	0.512 $\pm$ 0.035	53	0.047 $\pm$ 0.003
Sep	72	0.484 $\pm$ 0.031	59	0.040 $\pm$ 0.003
Oct	119	0.557 $\pm$ 0.025	58	0.036 $\pm$ 0.003
Nov	121	0.687 $\pm$ 0.025	58	0.054 $\pm$ 0.003
Dec	115	0.697 $\pm$ 0.023	33	0.054 $\pm$ 0.003



a) Percentage of milk components



b) Yields of milk components

Figure 5. Influence of month of recording on concentrations and yields of milk components

Below the diagonal of Table 31, it is clearly observed that yield traits were positively and strongly correlated ( $r=0.76$  to  $0.98$ ) among themselves.

Three major observations can be made on Table 32, namely; a) concentrations of BF and protein were negatively correlated with yields of all milk components (except for BF% and BF yield which was  $-0.00$ ); b) TS and SNF percentages had, on the contrary, positive correlation with yield characters and c) ash percent had no significant correlation ( $r= -0.04$  to  $0.09$ ) with yields of milk constituents.

#### 4.6 Day-to-day variation of milk yield and composition

##### Milk yield

Analysis of both morning and afternoon milk yields in the two farms (Table 33) shows that variation due to day of milking was significant ( $P < 0.001$ ) at Ihimbu and at Uyole. Milking time was an important source of variation ( $P > 0.001$ ) at Uyole but not at Ihimbu. Interaction between milking day and time was significant ( $P < 0.001$ ) at both farms. This necessitated analysing morning and afternoon milk yields separately (Table 34). Both morning and afternoon milk yields were highly ( $P < 0.001$ ) influenced by effects of cow and day. Total daily yields

Table 31: Phenotypic correlations among milk components' percentages (above diagonal), yields (below diagonal) and with test-day milk yield (d.f.=140)

	Test-day					
	milk yield	BF	Protein	TS	SNF	Ash
Test-day						
milk yield	-	-0.47	-0.53	0.12	0.42	-0.07
BF	0.84	-	0.59	0.38	-0.24	0.16
Protein	0.90	0.87	-	0.23	-0.14	0.21
TS	0.95	0.86	0.88	-	0.81	0.19
SNF	0.93	0.76	0.83	0.98	-	0.10
Ash	0.98	0.83	0.88	0.94	0.92	-

Note: Critical values for significance are:  $P < 0.05 = 0.159$   
 $P < 0.01 = 0.208$

Table 32: Phenotypic correlation coefficients between milk components' yields and percentages (d.f.= 140)

	Percentage of:				
Yield of:	BF	Protein	TS	SNF	Ash
BF	-0.00	-0.30	0.35	0.36	0.01
Protein	-0.31	-0.23	0.22	0.42	-0.04
TS	-0.33	-0.45	0.37	0.60	-0.03
SNF	-0.42	-0.47	0.36	0.64	-0.04
Ash	-0.44	-0.52	0.12	0.40	0.09

Note: Critical values for significance are:  $P < 0.05 = 0.159$   
 $P < 0.01 = 0.208$

were also significantly influenced ( $P < 0.001$ ) by between cow and day variations.

Means and standard deviations of milk yields for both farms are shown in Table 35. At Uyole cows produced 440 g more milk in the morning than in the afternoon while at Ihimbu the difference was 50 g. Un-adjusted standard deviations for daily milk yields at Uyole and at Ihimbu were 3.03 and 2.35 kg, respectively while corresponding residual standard deviations (within cows) were 1.71 and 0.65 kg (Table 35). Day-to-day variation within cows was, therefore, much higher at Uyole than at Ihimbu.

Table 33: Analyses of variance for milk yield (morning and afternoon) at Uyole and Ihimbu farms

Source of variation <sup>1)</sup>	Uyole		Ihimbu	
	df	MS	df	MS
Cow	44	67.40 ***	34	54.82 ***
Day	20	4.53 ***	20	1.46 ***
Time (am vs pm)	1	92.05 ***	1	0.67 ns
Day x time	20	13.12 ***	20	0.68 ***
Residual	1804	1.43	1394	0.18

<sup>1)</sup> Effect of cow was absorbed in the analysis

Table 34: Analyses of variance of morning and afternoon milk yields (separately) and daily yields for both farms

Farm	Source of variation	df	MS		
			Morning	Afternoon	M o r n i n g + Afternoon
Uyole	Cow	44	37.64 ***	31.15 ***	134.87 ***
	Day	20	7.45 ***	10.20 ***	9.06 ***
	Residual	880	1.39	1.47	2.91
Ihimbu	Cow	34	26.80 ***	28.16 ***	109.64 ***
	Day	20	0.99 ***	1.15 ***	2.93 ***
	Residual	680	0.18	0.18	0.42

Table 35: Means and standard deviations (within cows across days) of morning and afternoon milk yield

Farm	Variable	Mean	std dev.	CV %
Uyole	Morning milk yield	5.32	1.18	22.18
	Afternoon milk yield	4.88	1.21	24.79
	(am + pm) milk yield	10.20	1.71	16.76
Ihimbu	Morning milk yield	3.94	0.43	10.91
	Afternoon milk yield	3.99	0.42	10.53
	(am + pm) milk yield	7.93	0.65	8.20

### Milk constituents

The average daily milk yield and percent composition of milk from the two weeks sampling study in Uyole is presented in Table 36. Table 37 shows the analyses of variance of the variables. Variation between cows was significant for all traits. Effect of day of milking was significant ( $P < 0.001$ ) for milk yield but not for milk components ( $P > 0.05$ ).

Within cow correlations between consecutive daily milk yields and components are shown in Table 36. It is important to note that protein content had the poorest repeatability ( $r=0.25$ ) whereas ash was almost constant from day to day. Intra-cow day-to-day variations in milk yields were higher in Uyole records ( $r=0.68$  and  $0.82$  for October 1982 and experimental days, respectively) but relatively stable ( $r=0.92$ ) in Ihimbu records. The within cow standard deviations for milk yield, BF, TS, SNF, protein and ash percentages were 1.51 kg, 0.11, 0.16, 0.14, 0.19 and 0.003 percent units, respectively (Table 37).

Table 36: Un-adjusted means, standard deviations, within cow standard deviations and intra-cow correlations of daily milk yield and milk components from the two weeks sampling study at Uyole

Variable	n	Mean	s.d.	s.d.within cows	intra-cow correlation
Milk yield	182	6.84	3.51	1.51	0.81
BF %	182	3.71	0.25	0.11	0.83
Protein %	182	3.16	0.19	0.16	0.25
TS %	182	12.50	1.15	0.14	0.98
SNF %	182	8.80	1.06	0.19	0.95
Ash %	182	0.75	0.06	0.003	1.00

Table 37: Mean squares from analyses of variance of milk yield and milk components from the two weeks sampling study

Variable	Mean square for:		
	Cow	Day	Residual
d.f.	14	13	182
Milk yield	141.099 <sup>***</sup>	14.450 <sup>***</sup>	2.2775
BF%	0.755 <sup>***</sup>	0.010 <sup>NS</sup>	0.0118
Protein %	0.142 <sup>***</sup>	0.047 <sup>NS</sup>	0.0293
TS%	19.558 <sup>***</sup>	0.012 <sup>NS</sup>	0.0186
SNF%	16.283 <sup>***</sup>	0.017 <sup>NS</sup>	0.0351
Ash%	0.053 <sup>***</sup>	0.000 <sup>NS</sup>	0.0000

## 4.7 Part and cumulative milk yields

### 4.7.1 Effects of non-genetic factors

Monthly average milk yields in all data sets followed the normal lactation curve with peak production in the second or third month of lactation and then gradually declining (Appendix Tables 2 and 3). Standard deviations of monthly milk yields decreased from the beginning of lactation to a minimum between the fifth and seventh month, varying with farm or data set, thereafter inclined to the end of lactation. Standard deviations for cumulative monthly yields increased with advancement of lactation.

Records for Ihimbu, Mbarali and Uyole were analysed for effects of parity, season and period of calving with current CI as a covariate (Tables 38-40). Effects of year, parity, calving month, farm, farm x year interaction and current CI were studied in Iwambi and Kitulo records (Tables 41-44). The proportion of total sum of squares accounted for by the model varied between farms or data sets, but there was a common feature that the model accounted for less and less of total variation as lactation advanced. In analyses of most part and cumulative yields the model accounted for over 20% of total sum of squares, with higher values obtained in

analyses of cumulative yields. Kitulo records made in and after 1984 (data sets 3 and 4) were surprisingly very poorly (often below 15%) explained by the prescribed model. Contrary to other data sets, data set 4 was more explained by the model as lactation advanced.

#### Effect of parity

Parity accounted for from less than 1 to 22% of total sum of squares of monthly milk records during the first 6 months of lactation at Ihimbu, Mbarali and Uyole. Importance of this factor decreased as lactation progressed, being an unimportant source of variation from the seventh month of lactation. On Iwambi and Kitulo data, parity explained less than 3% of total variation in monthly milk records and no trend could be discerned.

Analyses of variance on cumulative monthly yields revealed that parity had a highly significant influence on all cumulative yields accounting for 9-19%, 4-6% and 17-25% of total variation in Ihimbu, Mbarali and Uyole records, respectively. Its influence, however, declined from the seventh month of lactation onwards. Parity accounted for less than 3% of total variation of cumulative milk yields of Iwambi and Kitulo farms, but was significant. It appeared parity was a very important source of variation

when all lactation records were pooled (case of Ihimbu, Mbarali and Uyole) and has to be corrected for during the first six months of lactation for both monthly and cumulative yields.

#### Effect of period or year of calving

Period was the second most important factor on Ihimbu, Mbarali and Uyole records. Magnitudes of influence varied between farms and stages of lactation. On Ihimbu records, period accounted for 5-11% of total variation in the beginning and end of lactation but only 2-3% from the fourth to eighth month of lactation. Mbarali records revealed a decrease from 26% in the second month to 5% in the eighth to tenth month of lactation whereas Uyole records showed that period was important in the first 7 months during which it accounted for 5-15% of total sum of squares. Iwambi and Kitulo records were analysed for year effect and was observed to significantly influence monthly records except Kitulo first lactation records made during 1984-90 period (data set 3). In this data set, year accounted for less than 1 to 6% of total variation with a larger influence during late lactation.

A glance on analyses of variance of cumulative monthly yields shows a similar pattern as one described above on

Table 38: ANOVA of part and cumulative milk records of Ihimbu farm showing the proportions of total sum of squares accounted for by parity, season, period of calving and calving interval

		Month of Percentage of total SS accounted for by:					
Variable	lact.	Model	Parity	Season	Period	CI	CI <sup>2</sup>
Monthly	1	22	8 <sup>1</sup>	3 <sup>1</sup>	5 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
average	2	41	15 <sup>1</sup>	2 <sup>2</sup>	11 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
yield	3	35	16 <sup>1</sup>	1 <sup>3</sup>	6 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	30	14 <sup>1</sup>	3 <sup>1</sup>	2 <sup>2</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	22	12 <sup>1</sup>	2 <sup>2</sup>	3 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	8	5 <sup>1</sup>	< 1 <sup>4</sup>	2 <sup>3</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	7	3 <sup>2</sup>	< 1 <sup>4</sup>	2 <sup>2</sup>	1 <sup>2</sup>	1 <sup>2</sup>
	8	11	< 1 <sup>4</sup>	< 1 <sup>4</sup>	3 <sup>2</sup>	5 <sup>1</sup>	3 <sup>1</sup>
	9	20	1 <sup>4</sup>	< 1 <sup>4</sup>	5 <sup>1</sup>	6 <sup>1</sup>	5 <sup>1</sup>
	10	26	3 <sup>2</sup>	1 <sup>3</sup>	5 <sup>1</sup>	7 <sup>1</sup>	5 <sup>1</sup>
<hr/>							
Cumulative							
yield	2	36	14 <sup>1</sup>	3 <sup>1</sup>	7 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	40	17 <sup>1</sup>	3 <sup>1</sup>	7 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	41	18 <sup>1</sup>	3 <sup>1</sup>	6 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	41	19 <sup>1</sup>	3 <sup>1</sup>	6 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	37	19 <sup>1</sup>	2 <sup>1</sup>	8 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	32	17 <sup>1</sup>	1 <sup>3</sup>	4 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	26	16 <sup>1</sup>	1 <sup>4</sup>	3 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	20	12 <sup>1</sup>	1 <sup>4</sup>	2 <sup>2</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	10	15	9 <sup>1</sup>	1 <sup>4</sup>	2 <sup>2</sup>	1 <sup>3</sup>	1 <sup>3</sup>

**Superscripts:** 1 = P < 0.001

2 = P < 0.01

3 = P < 0.05

4 = not significant P > 0.05

Table 39: ANOVA of part and cumulative milk records of Mbarali farm showing proportions of total sum of squares accounted for by parity, season, period of calving and calving interval

Variable	Month of lact.	Percentage of total SS accounted for by:					
		Model	Parity	Season	Period	CI	CI <sup>2</sup>
Monthly milk yield	1	9	2 <sup>3</sup>	< 1 <sup>4</sup>	6 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	2	41	7 <sup>1</sup>	3 <sup>1</sup>	26 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	34	6 <sup>1</sup>	2 <sup>2</sup>	21 <sup>1</sup>	1 <sup>3</sup>	< 1 <sup>4</sup>
	4	27	5 <sup>1</sup>	2 <sup>3</sup>	17 <sup>1</sup>	1 <sup>3</sup>	1 <sup>3</sup>
	5	16	3 <sup>2</sup>	< 1 <sup>4</sup>	12 <sup>3</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	14	3 <sup>2</sup>	< 1 <sup>4</sup>	10 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	11	2 <sup>4</sup>	1 <sup>4</sup>	8 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	8	2 <sup>4</sup>	1 <sup>4</sup>	5 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	8	< 1 <sup>4</sup>	< 1 <sup>4</sup>	5 <sup>1</sup>	2 <sup>2</sup>	2 <sup>2</sup>
	10	10	< 1 <sup>4</sup>	< 1 <sup>4</sup>	5 <sup>1</sup>	3 <sup>1</sup>	3 <sup>1</sup>
<hr/>							
<b>Cumulative</b>							
yield	2	27	6 <sup>1</sup>	2 <sup>3</sup>	16 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	33	6 <sup>1</sup>	2 <sup>2</sup>	20 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	35	6 <sup>1</sup>	2 <sup>3</sup>	21 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	33	6 <sup>1</sup>	2 <sup>2</sup>	21 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	32	6 <sup>1</sup>	1 <sup>3</sup>	21 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	31	5 <sup>1</sup>	1 <sup>4</sup>	20 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	28	5 <sup>1</sup>	1 <sup>4</sup>	19 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	26	4 <sup>1</sup>	< 1 <sup>4</sup>	17 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	10	23	4 <sup>1</sup>	< 1 <sup>4</sup>	16 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>

**Superscripts:** 1 = P < 0.001

2 = P < 0.01

3 = P < 0.05

4 = not significant P > 0.05

Table 40: ANOVA of monthly and cumulative milk records of Uyole farm showing the proportions of total sum of squares accounted for parity, season, period of calving and calving interval

Variable	Month of lact.	Percentage of total SS accounted for by:					
		Model	Parity	Season	Period	CI	CI <sup>2</sup>
Monthly milk yield	1	37	22 <sup>1</sup>	1 <sup>4</sup>	5 <sup>1</sup>	1 <sup>4</sup>	1 <sup>4</sup>
	2	48	22 <sup>1</sup>	1 <sup>4</sup>	12 <sup>1</sup>	2 <sup>2</sup>	1 <sup>2</sup>
	3	42	18 <sup>1</sup>	1 <sup>4</sup>	12 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	45	19 <sup>1</sup>	1 <sup>4</sup>	14 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	42	15 <sup>1</sup>	1 <sup>4</sup>	15 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	32	10 <sup>1</sup>	3 <sup>2</sup>	10 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	20	4 <sup>2</sup>	5 <sup>1</sup>	7 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	7	2 <sup>4</sup>	2 <sup>4</sup>	1 <sup>4</sup>	1 <sup>4</sup>	1 <sup>4</sup>
	9	12	1 <sup>4</sup>	1 <sup>4</sup>	< 1 <sup>4</sup>	5 <sup>1</sup>	4 <sup>1</sup>
	10	31	< 1 <sup>4</sup>	1 <sup>4</sup>	1 <sup>4</sup>	13 <sup>1</sup>	9 <sup>1</sup>
<hr/>							
<b>Cumulative</b>							
yield	2	47	25 <sup>1</sup>	1 <sup>3</sup>	9 <sup>1</sup>	1 <sup>2</sup>	1 <sup>3</sup>
	3	49	25 <sup>1</sup>	1 <sup>4</sup>	11 <sup>1</sup>	1 <sup>3</sup>	1 <sup>3</sup>
	4	51	25 <sup>1</sup>	1 <sup>4</sup>	12 <sup>1</sup>	1 <sup>3</sup>	< 1 <sup>4</sup>
	5	52	25 <sup>1</sup>	< 1 <sup>4</sup>	14 <sup>1</sup>	1 <sup>4</sup>	< 1 <sup>4</sup>
	6	52	24 <sup>1</sup>	< 1 <sup>4</sup>	14 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	50	23 <sup>1</sup>	< 1 <sup>4</sup>	14 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	46	21 <sup>1</sup>	< 1 <sup>4</sup>	14 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	41	19 <sup>1</sup>	< 1 <sup>4</sup>	12 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	10	36	17 <sup>1</sup>	< 1 <sup>4</sup>	12 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>

**Superscripts:** 1 = P < 0.001

2 = P < 0.01

3 = P < 0.05

4 = not significant P > 0.05

Table 41: ANOVA of monthly and cumulative milk records of data set 1 (Iwambi/Kitulo, first lactation) showing the proportions of total sum of squares accounted for by various factors

Variable	Month of lact.	Percentage of total SS accounted for by:						
		Model	Year(Y)	Month	Farm(F)	FxY	CI	CI <sup>2</sup>
Monthly milk yield	1	37	8 <sup>1</sup>	1 <sup>4</sup>	21	3 <sup>2</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	2	56	17 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	56	14 <sup>1</sup>	3 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	41	12 <sup>1</sup>	4 <sup>1</sup>	3 <sup>1</sup>	2 <sup>2</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	40	10 <sup>1</sup>	8 <sup>1</sup>	3 <sup>1</sup>	3 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	31	8 <sup>1</sup>	8 <sup>1</sup>	1 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	27	7 <sup>1</sup>	6 <sup>1</sup>	< 1 <sup>4</sup>	4 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	27	6 <sup>1</sup>	5 <sup>1</sup>	< 1 <sup>4</sup>	5 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	26	9 <sup>1</sup>	3 <sup>2</sup>	< 1 <sup>4</sup>	3 <sup>1</sup>	1 <sup>3</sup>	< 1 <sup>4</sup>
	10	26	7 <sup>1</sup>	3 <sup>2</sup>	< 1 <sup>4</sup>	3 <sup>2</sup>	2 <sup>1</sup>	2 <sup>1</sup>
Cumulative yield	2	51	14 <sup>1</sup>	2 <sup>3</sup>	2 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	57	15 <sup>1</sup>	2 <sup>2</sup>	3 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	57	16 <sup>1</sup>	2 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	57	16 <sup>1</sup>	3 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	55	15 <sup>1</sup>	3 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	53	15 <sup>1</sup>	3 <sup>1</sup>	3 <sup>1</sup>	3 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	51	14 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>	3 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	49	14 <sup>1</sup>	3 <sup>2</sup>	2 <sup>1</sup>	3 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	10	47	14 <sup>1</sup>	2 <sup>2</sup>	2 <sup>1</sup>	3 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>

**Superscripts:** 1 = P < 0.001

2 = P < 0.01

3 = P < 0.05

4 = not significant P > 0.05

Table 42: ANOVA of monthly and cumulative milk records of data set 2 (Iwambi/Kitulo, second and later lactations) showing the proportions of total sum of squares accounted for by various factors

Variable	Month of lact.	Percentage of total SS accounted for by:							
		Model	Parity	Year (Y)	Month	Farm (F)	YxF	CI	CI <sup>2</sup>
Monthly milk yield	1	23	1 <sup>2</sup>	2 <sup>1</sup>	4 <sup>1</sup>	2 <sup>1</sup>	5 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	2	40	1 <sup>1</sup>	9 <sup>1</sup>	7 <sup>1</sup>	2 <sup>1</sup>	11 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	3	37	1 <sup>1</sup>	9 <sup>1</sup>	8 <sup>1</sup>	2 <sup>1</sup>	10 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	4	32	<1 <sup>3</sup>	9 <sup>1</sup>	10 <sup>1</sup>	2 <sup>1</sup>	8 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	5	27	1 <sup>1</sup>	7 <sup>1</sup>	7 <sup>1</sup>	2 <sup>1</sup>	6 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	6	22	<1 <sup>4</sup>	6 <sup>1</sup>	6 <sup>1</sup>	1 <sup>1</sup>	4 <sup>1</sup>	<1 <sup>3</sup>	<1 <sup>3</sup>
	7	17	<1 <sup>4</sup>	5 <sup>1</sup>	4 <sup>1</sup>	<1 <sup>3</sup>	3 <sup>1</sup>	2 <sup>1</sup>	1 <sup>1</sup>
	8	18	<1 <sup>4</sup>	4 <sup>1</sup>	3 <sup>2</sup>	<1 <sup>4</sup>	2 <sup>1</sup>	4 <sup>1</sup>	3 <sup>1</sup>
	9	16	<1 <sup>4</sup>	2 <sup>1</sup>	2 <sup>3</sup>	<1 <sup>4</sup>	2 <sup>2</sup>	6 <sup>1</sup>	4 <sup>1</sup>
	10	21	<1 <sup>4</sup>	2 <sup>2</sup>	1 <sup>3</sup>	<1 <sup>4</sup>	2 <sup>1</sup>	10 <sup>1</sup>	8 <sup>1</sup>
Cumulative yield	2	36	1 <sup>1</sup>	6 <sup>1</sup>	5 <sup>1</sup>	3 <sup>1</sup>	9 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	3	40	1 <sup>1</sup>	8 <sup>1</sup>	6 <sup>1</sup>	3 <sup>1</sup>	11 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	4	39	1 <sup>1</sup>	9 <sup>1</sup>	6 <sup>1</sup>	3 <sup>1</sup>	11 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	5	39	1 <sup>1</sup>	9 <sup>1</sup>	6 <sup>1</sup>	3 <sup>1</sup>	11 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	6	37	1 <sup>1</sup>	9 <sup>1</sup>	6 <sup>1</sup>	3 <sup>1</sup>	10 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	7	34	1 <sup>1</sup>	9 <sup>1</sup>	5 <sup>1</sup>	2 <sup>1</sup>	9 <sup>1</sup>	<1 <sup>4</sup>	<1 <sup>4</sup>
	8	32	1 <sup>2</sup>	9 <sup>1</sup>	4 <sup>1</sup>	2 <sup>1</sup>	9 <sup>1</sup>	<1 <sup>2</sup>	<1 <sup>2</sup>
	9	30	<1 <sup>2</sup>	9 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>	8 <sup>1</sup>	1 <sup>1</sup>	1 <sup>1</sup>
	10	29	<1 <sup>3</sup>	8 <sup>1</sup>	3 <sup>1</sup>	1 <sup>1</sup>	7 <sup>1</sup>	2 <sup>1</sup>	2 <sup>1</sup>

**Superscripts:** 1 = P < 0.001  
 2 = P < 0.01  
 3 = P < 0.05  
 4 = not significant P > 0.05

Table 43: ANOVA of monthly and cumulative milk records of data set 3 (Kitulo, first lactation) showing the proportions of total sum of squares explained by various factors

Variable	Month of lact.	Percentage of total SS explained by:				
		Model	Year	Month	CI	CI <sup>2</sup>
Monthly milk yield	1	5	1 <sup>4</sup>	2 <sup>4</sup>	1 <sup>3</sup>	1 <sup>3</sup>
	2	6	1 <sup>4</sup>	4 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	3	< 1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	4	< 1 <sup>4</sup>	3 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	4	< 1 <sup>4</sup>	3 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	3	1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	7	3 <sup>4</sup>	3 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	11	6 <sup>1</sup>	3 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	12	6 <sup>1</sup>	2 <sup>4</sup>	2 <sup>2</sup>	2 <sup>2</sup>
	10	11	3 <sup>4</sup>	2 <sup>4</sup>	5 <sup>1</sup>	4 <sup>1</sup>
Cumulative yield	2	6	1 <sup>4</sup>	3 <sup>4</sup>	1 <sup>3</sup>	< 1 <sup>4</sup>
	3	5	1 <sup>4</sup>	3 <sup>4</sup>	1 <sup>4</sup>	< 1 <sup>4</sup>
	4	4	< 1 <sup>4</sup>	2 <sup>4</sup>	1 <sup>4</sup>	< 1 <sup>4</sup>
	5	4	< 1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	3	< 1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	7	3	< 1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	8	3	1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	9	3	1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	10	4	1 <sup>4</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>

**Superscripts:** 1 = P < 0.001

2 = P < 0.01

3 = P < 0.05

4 = not significant P > 0.05

Table 44: ANOVA of monthly and cumulative milk records of data set 4 (Kitulo, second and later lactations) showing the proportions of total sum of squares explained by various factors

Variable	Month of lact	Percentage of total SS explained by:					
		Model	Parity	Year	Month	CI	CI <sup>2</sup>
Monthly milk yield	1	4	< 1 <sup>4</sup>	2 <sup>3</sup>	1 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	2	9	< 1 <sup>4</sup>	6 <sup>1</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	9	1 <sup>2</sup>	5 <sup>1</sup>	4 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	9	2 <sup>1</sup>	3 <sup>1</sup>	4 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	11	3 <sup>1</sup>	4 <sup>1</sup>	5 <sup>1</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	11	3 <sup>1</sup>	1 <sup>3</sup>	4 <sup>1</sup>	1 <sup>1</sup>	1 <sup>2</sup>
	7	11	2 <sup>1</sup>	2 <sup>2</sup>	4 <sup>1</sup>	2 <sup>1</sup>	2 <sup>1</sup>
	8	11	2 <sup>1</sup>	1 <sup>3</sup>	4 <sup>1</sup>	3 <sup>1</sup>	2 <sup>1</sup>
	9	14	< 1 <sup>4</sup>	1 <sup>3</sup>	2 <sup>3</sup>	7 <sup>1</sup>	5 <sup>1</sup>
	10	18	< 1 <sup>4</sup>	1 <sup>2</sup>	1 <sup>4</sup>	10 <sup>1</sup>	7 <sup>1</sup>
Cumulative yield	2	7	< 1 <sup>4</sup>	4 <sup>1</sup>	1 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	3	8	< 1 <sup>4</sup>	5 <sup>1</sup>	2 <sup>4</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	4	9	1 <sup>3</sup>	5 <sup>1</sup>	2 <sup>3</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	5	9	1 <sup>2</sup>	6 <sup>1</sup>	3 <sup>2</sup>	< 1 <sup>4</sup>	< 1 <sup>4</sup>
	6	9	2 <sup>1</sup>	5 <sup>1</sup>	3 <sup>2</sup>	< 1 <sup>3</sup>	< 1 <sup>3</sup>
	7	9	2 <sup>1</sup>	4 <sup>1</sup>	3 <sup>2</sup>	1 <sup>2</sup>	< 1 <sup>3</sup>
	8	10	2 <sup>1</sup>	4 <sup>1</sup>	3 <sup>2</sup>	1 <sup>1</sup>	1 <sup>2</sup>
	9	10	2 <sup>1</sup>	3 <sup>1</sup>	3 <sup>2</sup>	2 <sup>1</sup>	1 <sup>1</sup>
	10	10	2 <sup>1</sup>	3 <sup>1</sup>	2 <sup>3</sup>	3 <sup>1</sup>	2 <sup>1</sup>

**Superscripts:** 1 = P < 0.001

2 = P < 0.01

3 = P < 0.05

4 = not significant P > 0.05

Ihimbu and Mbarali data. No trend could be detected on Uyole and Iwambi/Kitulo records. Year was not an important source of variation (accounting for one or less than 1% of total variation) on Kitulo first lactation records made in the 1984-90 period (data set 3).

#### Effect of season or month of calving

Season of calving was the third most important factor influencing average monthly and cumulative yields. Season accounted for 1-3, 1-3 and 1-5% of sum of squares on Ihimbu, Iwambi and Uyole monthly records, respectively. It was a significant source of variation during the first 4-5 months of lactation in the first two farms. Effect of month of calving on monthly yields in data set 1 to 4 was accounting for 1-10% of their total variation.

Effect of season on cumulative monthly yields was important in the first 6 months of lactation of Ihimbu and Mbarali records. Cumulative monthly yields at Uyole were not affected by season of calving, accounting for one percent or less of total sum of squares. Month of calving was a significant source of variation on most cumulative yields in data set 1, 2 and 4 but not in data set 3 (Kitulo first lactation records of 1984-90 period).

### Calving interval (CI)

Influence of current calving interval on milk yield is due to the depressive effect of the new pregnancy. Consequently, its effect should be exhibited towards the end of lactation. Analyses of monthly and cumulative milk yields revealed that CI was important as from the sixth month of lactation but varying with farm. There was a sharp increase in effect towards the tenth month when it accounted for up to 18% of total variation (if linear and quadratic terms are summed up). It is worth to note that CI had almost no influence on cumulative yields of Ihimbu, Mbarali and partly Uyole farms. Cumulative records of the first 4 months of the latter farm were significantly affected by CI (Table 40), surprisingly.

### Effect of farm and farm x year interaction

Farm differences in part records of Iwambi and Kitulo (data set 1 and 2; Tables 41 and 42) accounted for <1-3% of total variation of monthly and cumulative records. It was a significant source of variation on monthly records of the first 6-7 months of lactation and on all cumulative records.

The interaction term was also significant accounting for

2-5% of total sum of squares of first lactation records (data set 1) and 2-11% in later lactations (data set 2: Table 42). In the latter, the importance decreased as lactation advanced.

#### 4.7.2 Correlations among monthly, among cumulative milk yields and between these and 305-day milk yield

Partial correlation coefficients between monthly yields and cumulative yields are shown in Tables 45 and Appendix Tables 4 to 10. Correlations between adjacent average monthly yields were higher than for those further apart. Milk yield in the first month of lactation was often very poorly associated with milk yield in the seventh to tenth month of lactation. With exception of Uyole data set in which records of the second to fifth month of lactation had highest correlation with 305-day milk yield, in all other data sets records of around mid lactation (fourth to eighth month) had highest correlation with 305-day milk yield. Comparison between records made during the daily recording period (data set 1 and 2) and those when two monthly tests were recorded (data set 3 and 4) indicates that there were almost no differences in correlation coefficients.

Correlations between cumulative monthly yields were higher

Table 45: A summary of correlation coefficients (x 100)  
between monthly and cumulative yield with 305-day  
milk yield

Month of lactation	Farm or data set <sup>1)</sup>						
	Ihimbu	Mbarali	Uyole	1	2	3	4
<b>Monthly yields</b>							
1	36	44	54	42	50	45	48
2	62	60	74	69	70	71	67
3	70	71	76	76	75	78	70
4	74	75	76	74	79	76	74
5	75	76	73	78	80	82	75
6	76	79	69	81	81	80	77
7	78	79	69	82	83	77	75
8	76	81	66	83	81	74	70
9	70	74	58	80	77	68	66
10	60	66	51	71	67	50	55
<b>Cumulative yield</b>							
2	56	62	71	61	69	65	66
3	68	72	79	73	78	77	76
4	76	78	84	80	82	84	83
5	83	83	80	85	87	89	88
6	88	88	91	90	91	93	92
7	92	93	94	95	94	95	95
8	96	97	97	97	97	98	98
9	99	99	99	99	99	99	99

<sup>1)</sup> Data set 1: First lactation Iwambi/Kitulo of 1976-83  
Data set 2: Second and later lactations of 1976-83  
Data set 3: Kitulo first lactation records of 1984-90  
Data set 4: Kitulo second and later lactations of 1984-90

than those between monthly yields. Further, correlations between cumulative yields and 305-day yield increased as the cumulative period increased.

#### 4.7.3 Extension factors

Based on the facts gathered in the analyses of variance of monthly and cumulative yields, the most important factors for correcting part yields were parity, year and season of calving. Further, parity and season were most important sources of variation during the first 6 months of lactation. Effect of farm can be avoided by extending records for each farm separately. Year effect is eliminated by making computations on annual basis or for two adjacent years. Calving interval is often not known when extending records hence can be ignored. It was justified to handle first and later lactations separately and reduce seasonal sub-classes to wet and dry season. Ratio and regression extension factors were derived for the four sub-classes and the results are shown in Tables 46 and 47.

Table 46: Ratio extension factors for estimating the remaining part of lactation from the last test-day yield for first and later lactations commencing in the wet and dry season

Month of lactation	First lactation		Later lactations	
	Wet season	Dry season	Wet season	Dry season
1	8.31	9.21	7.12	8.46
2	6.15	6.90	5.17	6.07
3	5.15	5.71	4.51	5.25
4	4.40	4.64	3.88	4.36
5	3.68	3.71	3.27	3.54
6	3.03	2.94	2.65	2.78
7	2.31	2.16	2.00	2.02
8	1.59	1.48	1.36	1.34
9	0.76	0.74	0.72	0.69
No. of lactat.	558	739	1531	1317

Table 47: Regression extension factors for first and subsequent lactations commencing in the wet and dry season

Month of lactation	First lactation				Subsequent lactations				
	Wet season		Dry season		Wet season		Dry season		
	a <sup>1</sup>	b <sup>2</sup>	a	b	a	b	a	b	
<b>Monthly yield</b>									
1	46.2	3.28	44.6	3.51	43.5	3.60	53.7	3.24	
2	21.1	5.59	22.0	5.89	20.9	5.18	24.7	5.53	
3	14.7	6.35	18.9	6.10	15.8	5.98	21.6	5.96	
4	18.4	6.14	17.4	6.21	14.9	6.56	18.7	6.40	
5	16.4	6.82	13.3	6.83	15.7	7.12	17.9	6.79	
6	20.9	6.88	18.0	6.70	21.6	7.25	23.0	6.66	
7	25.9	6.73	26.2	6.01	28.9	6.98	26.8	6.71	
8	31.0	6.66	32.6	5.77	39.8	6.42	38.4	6.04	
9	39.1	6.00	40.5	5.27	51.0	5.60	50.7	5.35	
10	50.0	5.07	48.9	4.76	60.2	4.96	62.0	4.76	
<b>Cumulative yield</b>									
2	26.0	2.74	27.3	2.82	21.3	2.76	25.0	3.01	
3	14.9	2.22	18.6	2.20	11.7	2.15	13.5	2.36	
4	8.1	1.86	12.2	1.82	6.3	1.77	6.7	1.94	
5	3.4	1.62	6.8	1.59	2.1	1.54	2.3	1.65	
6	0.5	1.44	2.0	1.44	-0.4	1.38	-0.9	1.45	
7	-1.3	1.30	-1.0	1.31	-2.3	1.25	-3.0	1.31	
8	-1.8	1.18	-2.2	1.19	-2.7	1.16	-3.6	1.18	
9	-1.6	1.08	-1.8	1.09	-2.0	1.07	-2.3	1.08	

<sup>1)</sup> a is the intercept

<sup>2)</sup> b is the regression coefficient

#### 4.8 Lifetime performance traits

##### 4.8.1 Association between early life and lifetime traits

Averages for herd life traits are shown in Table 48. Average total lifespan ranged from 2337 days (6.4 years) at Uyole to 3104 days (8.5 years) at Ihimbu. Length of productive life was longest at Mbarali (2071 days or 5.7 years) and shortest at Uyole (only 1154 days or 3.2 years). Total milk produced in the lifetime of the cow averaged 10 925, 12 522, 8132, 11 798 and 7350 kg for Ihimbu, Iwambi, Kitulo, Mbarali and Uyole farms, respectively. Number of lifetime calvings were highest at Mbarali (5.8 times) and least at Kitulo and Uyole where cows calved on average about 3.5 times. Average milk yield per day of total lifespan ranged between 2.9 and 3.5 kg while milk yield per day of productive life ranged from 4.8 to 6.1 kg.

Age at first calving was generally negatively associated with lifetime traits (Table 49). However in three of the farms (Kitulo, Mbarali and Uyole) most correlations were not significantly different from zero. First lactation milk yield was significantly and positively correlated with lifetime milk production traits but had varied association with duration (period) lifetime traits.

Table 48: Means and standard deviations of Lifetime Traits

Trait	Farm														
	Ihumbu			Lwambi			Kitulo			Mbarali			Hvoile		
	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n
Total lifespan (days)	3 104	1 112	(102)	2 764	960	(81)	2 797	1 008	(142)	2 877	1 211	(70)	2 337	586	(58)
Productive life (days)	2 003	1 141	(128)	1 957	953	(236)	1 816	982	(386)	2 071	1 340	(136)	1 154	560	(55)
Productive life to last calving (days)	1 526	1 065	(137)	1 552	914	(271)	1 255	816	(432)	1 827	1 328	(137)	975	533	(55)
Total milk prod. (kg)	10 925	6 545	(107)	12 522	5 808	(145)	8 132	4 449	(214)	11 798	8 730	(111)	7 350	4 418	(57)
Total milk in complete lact. (kg)	8 977	6 539	(106)	10 539	5 480	(145)	6 303	3 921	(214)	10 643	8 499	(119)	6 619	4 283	(57)
No. of lifetime calvings	4.6	2.7	(137)	4.7	2.2	(274)	3.5	1.6	(428)	5.8	3.4	(137)	3.5	1.7	(62)
Milk yield/day of total life (kg)	3.2	1.1	(79)	2.9	1.2	(32)	3.5	1.5	(62)	3.2	1.3	(59)	2.9	1.4	(53)
Milk yield/day of productive life (kg)	4.8	1.4	(101)	6.0	2.0	(126)	4.8	2.3	(208)	5.6	1.7	(110)	6.1	2.1	(53)

Annualized first lactation milk yield had similar associations with lifetime traits. The first inter-calving period was negatively correlated with length of productive life, productive life up to last calving date, total milk produced and milk produced to last calving date at Ihimbu ( $P < 0.001$ ) and at Iwambi ( $P < 0.05$ ). In the remaining farms, there were weak associations between the studied characters. Lactation length in the first lactation was poorly associated with lifetime traits.

In running forward multiple regression analyses the procedure of sequential introduction of independent variables resulted in many one-, two-, three- and four-independent factor prediction equations. The best prediction equations for lifetime milk production, judged by level of  $R^2$  and its significance, for each farm are reported in Table 50.

Three major observations were made on the results:

- a) Age at first calving was negatively related to lifetime milk production,
- b) First lactation milk yield was particularly useful in predicting lifetime milk production, either singly or with age at first calving and/or first calving interval,
- c) Almost all  $R^2$  values were below 50% suggesting that the independent variables used did not explain much of the total variation in lifetime milk yield.

Table 49a: Phenotypic correlations between early life and lifetime traits

Traits being correlated	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
AFC and TL	-0.29 <sup>2</sup>	-0.08 <sup>4</sup>	-0.02 <sup>4</sup>	0.19 <sup>4</sup>	-0.20 <sup>4</sup>
AFC and PL	-0.43 <sup>1</sup>	-0.32 <sup>2</sup>	-0.15 <sup>4</sup>	0.01 <sup>4</sup>	-0.07 <sup>4</sup>
AFC and PLLC	-0.47 <sup>1</sup>	-0.26 <sup>3</sup>	-0.11 <sup>4</sup>	-0.01 <sup>4</sup>	-0.20 <sup>4</sup>
AFC and TM	-0.48 <sup>1</sup>	-0.54 <sup>1</sup>	-0.36 <sup>2</sup>	-0.16 <sup>4</sup>	-0.10 <sup>4</sup>
AFC and TMLC	-0.49 <sup>1</sup>	-0.47 <sup>2</sup>	-0.30 <sup>3</sup>	-0.14 <sup>4</sup>	-0.19 <sup>4</sup>
FLMY and TL	0.05 <sup>4</sup>	0.11 <sup>4</sup>	0.09 <sup>4</sup>	0.13 <sup>4</sup>	0.29 <sup>3</sup>
FLMY and PL	0.06 <sup>4</sup>	0.35 <sup>1</sup>	0.13 <sup>3</sup>	0.34 <sup>1</sup>	0.27 <sup>3</sup>
FLMY and PLLC	0.10 <sup>4</sup>	0.30 <sup>1</sup>	-0.04 <sup>4</sup>	0.35 <sup>1</sup>	0.05 <sup>4</sup>
FLMY and TM	0.29 <sup>2</sup>	0.47 <sup>1</sup>	0.44 <sup>1</sup>	0.43 <sup>1</sup>	0.41 <sup>2</sup>
FLMY and TMLC	0.26 <sup>2</sup>	0.44 <sup>1</sup>	0.34 <sup>1</sup>	0.43 <sup>1</sup>	0.28 <sup>3</sup>
FAMY and TL	0.11 <sup>4</sup>	0.10 <sup>4</sup>	0.01 <sup>4</sup>	0.13 <sup>4</sup>	0.11 <sup>4</sup>
FAMY and PL	0.21 <sup>3</sup>	0.32 <sup>1</sup>	0.04 <sup>4</sup>	0.33 <sup>1</sup>	0.05 <sup>4</sup>
FAMY and PLLC	0.22 <sup>3</sup>	0.30 <sup>1</sup>	-0.05 <sup>4</sup>	0.35 <sup>1</sup>	-0.01 <sup>4</sup>
FAMY and TM	0.51 <sup>1</sup>	0.58 <sup>1</sup>	0.47 <sup>1</sup>	0.41 <sup>2</sup>	0.30 <sup>3</sup>
FAMY and TMLC	0.50 <sup>1</sup>	0.55 <sup>1</sup>	0.39 <sup>1</sup>	0.42 <sup>1</sup>	0.19 <sup>3</sup>

AFC = Age at first calving

FCI = First calving interval

TL = Total lifespan

FLL = First lactation length

PL = Productive life

PLLC = Productive life to last calving date

TM = Total milk produced

TMLC = Total milk produced to last calving date

FLMY = First lactation milk yield

FAMY = First annualized milk yield

Table 49b: Phenotypic correlations between early life and lifetime traits

Traits being correlated	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
FCI and TL	-0.21 <sup>2</sup>	0.18 <sup>4</sup>	0.00 <sup>4</sup>	0.16 <sup>4</sup>	0.04 <sup>4</sup>
FCI and PL	-0.37 <sup>1</sup>	-0.18 <sup>3</sup>	0.03 <sup>4</sup>	0.12 <sup>4</sup>	0.17 <sup>4</sup>
FCI and PLLC	-0.32 <sup>1</sup>	-0.17 <sup>3</sup>	0.00 <sup>4</sup>	0.12 <sup>4</sup>	0.21 <sup>4</sup>
FCI and TM	-0.41 <sup>1</sup>	-0.18 <sup>3</sup>	0.02 <sup>4</sup>	0.03 <sup>4</sup>	-0.04 <sup>4</sup>
FCI and TMLC	-0.42 <sup>1</sup>	-0.20 <sup>3</sup>	0.03 <sup>4</sup>	0.02 <sup>4</sup>	0.07 <sup>4</sup>
FLL and TL	-0.09 <sup>4</sup>	0.06 <sup>4</sup>	0.06 <sup>4</sup>	0.12 <sup>4</sup>	0.26 <sup>4</sup>
FLL and PL	-0.11 <sup>4</sup>	-0.01 <sup>4</sup>	0.13 <sup>3</sup>	0.13 <sup>4</sup>	0.29 <sup>3</sup>
FLL and PLLC	-0.07 <sup>4</sup>	0.02 <sup>4</sup>	0.03 <sup>4</sup>	0.12 <sup>4</sup>	0.13 <sup>4</sup>
FLL and TM	-0.19 <sup>4</sup>	0.06 <sup>4</sup>	0.20 <sup>2</sup>	0.06 <sup>4</sup>	0.21 <sup>4</sup>
FLL and TMLC	-0.16 <sup>4</sup>	0.07 <sup>4</sup>	0.23 <sup>1</sup>	0.07 <sup>4</sup>	0.41 <sup>2</sup>

Table 50: The best prediction equations for total lifetime milk production in each farm

Farm	n	Regression equation	R <sup>2</sup> %
Ihimbu	68	$Y_{TM} = 27561 - 8.0 X_1 + 3.9 X_2 - 21.7 X_3 - 23.4 X_4$	40
Iwambi	31	$Y_{TM} = 14869 - 13.2 X_1 + 1.8 X_2 + 9.8 X_3$	52
Kitulo	48	$Y_{TM} = 17954 - 8.3 X_1 + 1.2 X_2 - 9.2 X_3$	28
Mbarali	35	$Y_{TM} = 4492 + 3.0 X_2$	13
Uyole	43	$Y_{TM} = 9928 - 5.1 X_1 + 2.3 X_2$	17

where:  $Y_{TM}$  = total lifetime milk production (kg)  
 $X_1$  = age at first calving (days)  
 $X_2$  = first lactation milk yield (kg)  
 $X_3$  = first inter-calving period (days)  
 $X_4$  = lactation length in the first lactation (days)

#### 4.8.2 Cow culling rates

Average culling rates in the farms and ranges between years are presented in Table 51. Of the farms, Iwambi had least cullings due to sales and slaughters (4.3%) while Uyole had the highest (36.2%). Overall death rate among cows was lowest at Uyole (4.4%) but highest at Iwambi (13.4%). When the two types of disposals were combined, Uyole appeared to have disposed many cows (40.6%) compared to other farms where overall culling rates were below 20%.

Within farms, the relative magnitudes between sales/slaughters versus deaths varied from year to year. The relative importance between the two culling rates also differed between farms. At Ihimbu sales/slaughters were similar to death rate (5.9% each) whereas Iwambi and Kitulo farms had higher deaths (13.4 and 11.6%, respectively) than sales/slaughters (4.3 and 6.0%, respectively). Quite the opposite can be observed in the remaining two farms where sales/slaughters formed a larger component of the overall culling rate.

#### 4.8.3 Reasons for cows to exit from dairy herds

Reasons for cows to leave the herds were classified into three major subclasses of sales, slaughters or deaths. Since partition has been made between sales and

slaughters, it is worth to mention that compared to sales, slaughters were predominant at Iwambi, Kitulo and Mbarali. At Ihimbu and Uyole the opposite was true. No sales of cows were done at Mbarali farm (see Table 52 and Appendix Tables 11 to 15).

Within the subclass of sales, no reasons could be traced at Iwambi and Uyole. Sales were mostly done for slaughter or for dairy purposes.

Table 51: Sales and slaughters, deaths and overall culling rates (%) among cows

Farm	Years covered	Sales/slaught.		Death rates		All culling rates	
		Mean	Range <sup>1)</sup>	Mean	Range	Mean	Range
Ihimbu	1981-89	5.9	1.1-17.0	5.9	1.1-17.0	11.8	6.5-28.2
Iwambi	1980-89	4.3	0.0-15.7	13.4	6.2-30.3	17.7	7.5-41.2
Kitulo	1979-90	6.0	0.0-14.0	11.6	5.8-15.5	17.6	5.8-28.5
Mbarali	1984-89	13.9	4.8-28.4	4.9	2.4-10.1	18.8	8.4-38.5
Uyole	1980-87	36.2	24.3-69.6	4.4	2.0- 8.4	40.6	27.8-71.6

<sup>1)</sup> Range of annual culling rates

At Kitulo, a few cows were sold because they were off colour (not black and white) and at Ihimbu a few were disposed because of poor health (and probably for slaughter). Through verbal inquiry, it was revealed that most sales were due to poor milk production, reproduction problems or health problems though in none of the farms culling criteria were set. For DAFCO farms only the head office in Dar-es-Salaam had authority to grant permission for sale of cows and heifers.

Slaughters were the second (after deaths) major reason for cow disposals in all studied farms except Mbarali and Ihimbu. Again, in four of the farms failure to state reasons for slaughter in their reports was very common accounting for about 86, 54, 93 and 89% of all slaughters at Iwambi, Kitulo, Mbarali and Uyole, respectively. Cases of dystocia or prolapse of uterus/vagina and their associated secondary complications such as metritis, accounted for 10, 3.1, 7.2 and 4% of reasons for slaughtering cows at Ihimbu, Iwambi, Kitulo and Uyole farms, respectively. Accidents resulting into leg fractures or bone dislocations were responsible for 36.7% of reasons for slaughter at Ihimbu, 3.1% at Iwambi and 8% at Kitulo. Incidences of high altitude disease at Kitulo which necessitated some cows to be slaughtered was unique to that farm.

Table 52. A summary of reasons for disposals in each farm

Reason for disposal	Farm					
		Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
Sold	No.	39	36	63	0	319
	Percent	28.3	8.6	3.8	0.0	63.7
Slaughtered	No.	30	65	499	76	126
	Percent	21.7	15.6	30.4	73.8	25.1
Died	No.	69	316	1082	27	56
	Percent	50.0	75.8	65.8	26.2	11.2
Total disposals		138	417	1644	103	501
Years covered		1981-89	1980-89	1979-90	1984-89	1980-89

Disease incidences varied with farm. There were cases specific to certain farms. Ruminal tympany (bloat) was responsible for 8.9 and 7.4% of deaths of cows at Kitulo and Mbarali, respectively. Further, at Ihimbu and Iwambi about 32 and 10% of deaths, respectively were due to tick-borne diseases. Many cows (12.2% of deaths) at Kitulo drowned in water ponds or mud and got asphyxiated to death.

The most common cause of death occurring in all farms was poisoning (by snake venom, urea, molasses, dip wash, poisonous plants or copper) which was responsible for

14.5, 22.8, 10.1, 18.5 and 16.1% of all cow deaths at Ihimbu, Iwambi, Kitulo, Mbarali and Uyole, respectively. Deaths resulting from calving associated problems (dystocia, metritis, prolapse of reproductive organs) accounted for 14.5, 16.5, 9.7 and 16.1% of deaths at Ihimbu, Iwambi, Kitulo and Uyole, respectively. There was a large proportion of deaths that was not detected or reasons for death unknown. Fascioliasis and liver cirrhosis, both of them causing liver dysfunction were common causes of death in four of the farms (excluding Mbarali).

## CHAPTER 5

## DISCUSSION

## 5.1 Calf mortality

## Abortions and stillbirths

The average rates of abortion in four of the five farms studied (1.8 to 3.0%) do not differ from those reported in the literature for various exotic dairy breeds managed in the tropics (e.g. Vaccaro, 1974a; Kabuga, 1990). The abortion rate for Mbarali was, however, on the higher side. All farms, as a matter of routine, had vaccinated yearling heifers against brucellosis using a live attenuated vaccine S<sub>19</sub>. Moreover, occasionally farms have screened cows against brucellosis as evidenced by slaughters of positive reactors. Nevertheless, this does not exclude brucellosis as a possible cause of abortions. There could be other, non-infectious causes of abortion such as hormonal imbalances, physical stress, poisons as well as nutritional deficiencies. The significant differences between years in all farms (except Ihimbu) can be explained by the fact that incidence rates depend on specific causes of abortion. In that case rates are expected to fluctuate from year to year. Vaccaro and Vaccaro (1982) observed an increase in incidence rate as years went by but no reason was given

to explain the finding. Differences between farms could partly be ascribed to breed variations and partly to environmental differences. In the present case the two were confounded.

With exception of Mbarali farm, all farms had higher incidences of stillbirths than of abortions. In all farms natural mating was practiced, and length of gestation period was not known at the occurrence of abortion or stillbirth. Further, a veterinarian was not always around to assess the foetuses and a bias in registering could have happened. Otherwise the rates were consistent to those reported in Zambia (Igboeli 1973b), Ghana (Kabuga, 1990) and elsewhere in the tropics. On the other hand, these results are higher than incidence rates reported in the temperate countries ( e.g. Auran, 1972 of 2.6% and Roy, 1970 of 3.3%). Stillbirth rates of nearly 10% at Iwambi and Kitulo were higher than those reported in the other farms. Significant differences between farms and years could have the same reasons as those discussed above.

There is need to further investigate influencing factors such as season and age of dam at parturition. For example, Igboeli (1973b) found highest rates of stillbirths to occur after the hot dry period and Auran (1972) after the June-July pasture period. Both are stressful periods to the

cows. Moreover, it has been documented (Auran, 1972) that frequency of stillbirth is higher among heifers than among older cows.

#### Postnatal mortality rate

From the literature, calf mortality rates from the tropics have varied very much from as low as 4% to as high as 71% with most death rates below 30%. Calf death rates from the farms studied here are of similar magnitude. Direct comparison of results appears not quite valid because age limits are either not specified or are different. It may also mean comparing different breeds and/or management systems. Mwakatundu and Masanje (1984) indicated that in Tanzanian dairy farms, pre- and post-weaning mortality rates of 10% were considered tolerable rates. Based on this criterion, Ihimbu and Iwambi farms had acceptable pre-weaning mortality rates but all others should be considered as high. In this study pre- and post-weaning periods were of quite different durations (4 versus 14 months), it appears that in three of the farms the proportion of weaned calves that was lost was higher than proportion lost during pre-weaning period. This reflects the sub-standard management (especially feeding) given to calves after weaning as previously reported by Mchau *et al.* (1983) and Msanga and Nduye (1990) for similar farms in Tanzania.

Significant sex differences were obtained in three of the farms (Ihimbu, Iwambi and Kitulo) and in all cases mortality rate was higher in heifer than in bull calves. These farms belong to DAFCO and are commercial enterprises. Farm managers were given mandate to sell bull calves after they had received colostrum. Such occasional sales were difficult to be accounted for in calculating mortality rates hence a somewhat downward bias on males. The large variation in death rates between years was expected as annual death rates are a function of herd health, changes in management (e.g. personnel) and occurrence of disasters such as the 1984 copper poisoning at Iwambi. The tendency for pre-weaned calves to have higher deaths in late wet season and early dry season can be explained by the poor forages they have to depend on and the chilly weather to which they are exposed. The latter is supported by higher deaths due to pneumonia as will be discussed shortly. The overall death rates up to 18 months of age (excluding stillbirths) ranged from about 25 to 40%. These rates resemble those reviewed by Vaccaro (1974a) which ranged between 30 and 45%. They are, however, much higher compared to those experienced in the temperate countries (Peters, 1986; Simensen, 1986).

Heifers are the herd replacements. Death rates among heifers (birth to calving) found in this study are higher

than that of 25% among Friesian heifers reported by Vaccaro and Vaccaro (1981). On average one half of all heifers born did not reach the milking herd. This implies that almost no culling could be done among cows if herd size was to be maintained. It would have been interesting to derive replacement rates in the farms (number of first calvers as proportion of total number of calvings in a year) but the nature of the records (failure to trace first calvers in each year) could have given very un-realistic results. With such a high rate of heifer mortality, herds can only sustain herd numbers if calving rates are above 90%. Nevertheless, culling intensity for production is tantamount to be zero.

#### Causes of calf deaths

The major causes of death among calves, that is pneumonia and scours/diarrhoea have been widely reported (Roy, 1980; Simensen, 1986; Shoo et al., 1992; Amble and Jain, 1967). However, nutritional deficiency which was responsible for many deaths in all farms studied has rarely been reported elsewhere (e.g. Mchau et al., 1983). All three causes are management problems which can be controlled if seriously attended to. At Kitulo, digestive system disorders were rampant indicative of gross feeding and/or hygiene problems in the farm. Other conditions which can be curtailed through improved management include cases of drowning in

water/mud, poisoning, cold stress and undetected cases.

Dipping to control ticks was done in all farms, yet Ihimbu and Iwambi farms registered quite a number of deaths from tick-borne diseases. This can be explained by failure to counter-check or wrong reports on acaricide strength of dip washes or by allowing non-farm cattle to trespass their farms. Another speculation could be resistance of ticks to acaricides in use. High altitude disease was a farm specific cause of death among calves at Kitulo (altitude 2630-2820 m). It is a disease which affects cattle under one year of age and has also been reported in the Ethiopian highlands (Njau and Kasali, 1989). Although dewormings had been done in the five farms against various kinds of internal parasites, it appears fascioliasis, lungworms and other unidentified intestinal worms have claimed lives of many calves. This has probably been a result of irregular availability of drugs and increases in prices which led to sub-optimal deworming frequencies.

Finally, it is worth to mention (as also noted by Putt et al. 1987) that veterinarians vary in their diagnostic abilities, experience, dedication to work and in the use of the correct term for a disease or condition. This by itself may contribute to some extent, to the variation of frequencies reported.

## 5.2 Reproductive traits

### 5.2.1 Age at first calving

The average age at first calving achieved in the studied farms (of 33-39 months) are consistent with those reported in other parts of Africa (Kiwuwa, 1974a; Osei et al., 1991; Mhaiki, 1980; Mwenya and Shandomo, 1986) and elsewhere in the tropics (Vaccaro, 1974b, 1975). As indicated earlier, there hasn't been much documentation on Guernseys from the tropics thus rendering comparisons difficult.

Among the factors studied in the present material is season of birth which was a significant source of variation at Uyole. Although season of birth was not significant for the rest of the farms, Ihimbu and Iwambi farms showed large differences between the best and the worst seasons ( about 3 and 8 months, respectively) and such differences cannot be neglected. Generally, heifers born in late dry season or early wet season were youngest at calving, signifying that they were better seasons for calving or growth.

Period of birth was the most important source of variation on age at first calving in this study. Again, period effect was erratic at Iwambi, Mbarali and at Uyole but age tended to increase with years at Ihimbu and Kitulo. Since no planned improvement programme was at hand, the observed

changes are a reflection of fluctuations in management of heifers, especially feeding. Feeding determines growth rate which in turn influences time to attain physiological maturity for reproduction (McDonald et al.,1988). In the farms where age at first calving was increasing it suggests that management was deteriorating. Agyemang and Nkhonjera (1986) observed similar trends when they analysed data from two government farms in Malawi. The significant interaction between period and season at Uyole indicates that the goodness or badness of seasons varied between periods.

#### 5.2.2 Calving interval

The length of inter-calving period determines the annual calving rate and availability of replacements. Results from this study show that Mbarali and Uyole farms had quite acceptable calving intervals and below many reported calving intervals from the tropics. They were consistent with mean calving intervals reported by Vaccaro (1973) for South Africa and Nigeria. Kitulo farm had the longest calving intervals (489 days) resulting in an average calving rate of only about 73%. The low reproductive performance in the farm is possibly associated with phosphorus (P) deficiency (Laiser,P.; personal communication, 1992). Lauridsen (1978) analysed Kitulo pastures for magnesium (Mg), calcium (Ca) and P and results

indicated that cows could adequately be supplied with Mg and Ca from pastures but not P. He recommended supplementing cows with bone meal to improve P supply. P deficiency is associated with infertility in dairy cows when they graze on herbage deficient in the element (McDonald et al.; 1988).

The model used to analyse this variable explained less than 10% of total variation of the trait in the farms except Ihimbu (where it explained 34%). All what it implies is that this variable was more influenced by factors other than those included in the model. As a reproductive trait, temporary environmental factors play a bigger role in its variation (Rege, 1991). Since the variation in calving interval is largely determined by variation in days open (Auran, 1974;  $r = 0.88$ ), inclusion of month of calving (instead of season) and milk production level in early lactation could probably have increased  $R^2$ . El-Keraby and Aboul-Ela (1982) found a high positive association of calving to first oestrus interval and percent ovulatory anoestrus during the first month post-partum with level of daily milk yield. Furthermore, bulls contribute appreciably towards the overall reproductive efficiency in the herd.

Effect of parity was significant in three of the farms. This is in conformity with other studies (Madsen and

Vinther, 1975; Kifaro, 1984). However parity accounted for only a small proportion of the total variation of the trait (1 or < 1%) and that is similar to Rege's (1991) finding. In four of the farms the intercalving period after first parturition was longer than subsequent ones. The same was previously reported by Kiuwa (1974a) and Mchau et al. (1983) and could be ascribed to the physiological stress which first calvers experience in early lactation. During this period nutrients have to be partitioned between milk production, continuation of growth, and reproduction (McDonald et al., 1988). This may result in slightly longer calving to conception interval and/or more services per conception in primiparous cows compared to pluriparous cows as was reported by Bruhn and Mgheni (1977) and El-Keraby and Aboul-Ela (1982).

Seasonal variations in calving intervals in the present study were small and this conforms well with other reports (Sadana and Basu, 1983; Kifaro, 1984; Al-Ani et al., 1986). There was, nevertheless, a tendency for dry season calvers to have slightly longer subsequent calving intervals in three of the farms. Longer calving intervals after the dry season (also see Igboeli, 1973b) is known to occur because of the sub-maintenance feeding cows are subjected to during this period leading to weight loss and sub-fertility. Year was the most important source of variation on calving

interval. Yearly variations can mainly be attributed to differences in feeding regimes, bulls in use and other management practices specific to individual years.

### 5.3 Lactation performance traits

#### 5.3.1 Milk yield

Considering the fact that herd effect contributes most to the total variation of lactation yields (Rege, 1991), the average milk yields found in this study mainly reflect management levels. It is however impossible to dissociate genetic differences between herds from management differences in these data. Average herd milk production levels obtained in the present material are not at variance with many reports from the tropics. Mean annualized milk yields found here are largely in agreement with the finding of Agyemang and Nkhonjera (1986) in Malawi, but much lower than Rege's (1991) reported figure. The high production in the latter was due to high milk production level coupled with a relatively low average calving interval (411 days). The coefficients of variation for the two milk yield traits were similar to those reported by Rege (1991) in Kenya.

Year of calving was the most important factor influencing milk yield in all farms. Year to year fluctuations in

performance are attributable to weather variations which influence pasture growth, farm financial situation and consequently concentrate and mineral supply, availability of conserved forages, supervisory changes and other management aspects.

The second most important factor affecting milk yield was parturition number. The increase in milk yield with parity is a well known fact whose reasons were elucidated in the literature review (see section 2.3.2). Parity in which peak production occurs varies with farm suggesting it is a function of breed and management level. In some studies e.g. Kiuwa (1974a) and Rege (1991) actual age (in months) has been used instead of parity and demonstrated similar results. It appears justified to adjust all records for age or parity when evaluating cows. It has been recommended by Syrstad (1965) that within herds multiplicative age correction factors be used. From the least squares means presented in Table 17, multiplicative factors for adjusting lactation yield records for parity (age term commonly used in Tanzania) were derived using the following formula:

$$C_i = X_m / X_i \quad (20)$$

where  $C_i$  = the  $i^{\text{th}}$  correction factor

$X_m$  = mean yield at maturity

$X_i$  = mean milk yield of the  $i^{\text{th}}$  age group  
(in parturition number)

The results are shown in Table 53.

Table 53. Multiplicative age correction factors for lactation yields for each of the farms

Parity in which record is made	Farm				
	Ihimbu	Iwambi	Kitulo	Mbarali	Uyole
1	1.18	1.51	1.12	1.22	1.30
2	1.10	1.18	1.00	1.12	1.04
3	1.04	1.02	1.00	1.04	1.00
4	1.00	1.00	1.02	1.00	1.03
5	1.03	1.02	-	1.05	-
6	-	1.11	-	-	-

The factors obtained here are not very different from those previously estimated by Mchau *et al.* (1983) for Uyole farm from a rather small body of data.

The large increase from first lactation to peak production registered at Iwambi (51% for LMY and 46% for AMY) was partly due to considerably low first lactation milk yield (1741 and 1630 kg, respectively). Apparently there is no convincing reason to explain the low yields. It can however be speculated that although age at first calving in this

farm was the highest, probably cows had not attained their required physiological maturity.

Traditionally, the use of 305-day yield is assumed to get rid of most of calving interval effect and thus allow exclusion of calving interval in analyses. Kifaro (1984) included calving interval subclasses in analysing 305-day yields and detected significant effect of calving interval. It was concluded that even when lactation yield is truncated at 305-day, effect of calving interval would still be noticeable. Long lactations are often due to delayed pregnancy (Auran, 1974). The current study further gives evidence that calving interval is an important factor to be adjusted for before comparing records of different cows.

Many previous studies (e.g. Kiuwa 1974b; Kiuwa et al., 1983; Agyemang and Nkhonjera, 1986; Al-Ani et al. 1986; Rege and Mosi, 1989) have shown only trivial influence of season of calving on lactation yield. The best seasons of calving in the present study (in the farms where season was significant) were the late dry season and early wet seasons. The explanation behind this finding is that these cows attained their peak production during the rainy months when pastures were plenty. The persistency of lactation was improved. The converse was true for the remaining seasons.

The small seasonal differences often reported (also in two farms of this study) signifies the occurrence of a "wet season stimulus" (similar to the spring stimulus in the temperate countries described by Wood, 1969) during the later part of lactation. This boosts milk production thus ironing out seasonal differences. Mchau and Syrstad (1991) had shown this phenomenon in lactation curves of Mpwapwa cows calving in the dry and wet season.

#### 5.3.2 Lactation length

The mean lactation lengths in the present material do not differ much from those reported elsewhere in the tropics (Kiwuwa, 1974a,b; Vaccaro 1974b; Mwenya and Shandomo, 1986; Trail and Marples, 1968 and others). The mean lactation length of 270 days of Guernseys at Mbarali appears to be rather low in comparison to the other breeds. Jerseys, another Channel Island breed, had been reported to have similar lactation lengths in Kenya (Kiwuwa, 1974a) and eastern Tanzania (Bruhn and Mgheni, 1977) but altogether were much lower than the mean lactation length of 349 days reported from India (Mangurkar et al., 1987).

From the analyses of variance, it can be observed that calving interval had the largest influence on length of lactation. Since the persistency of lactation is partly

dependent on the depressive effect of new pregnancy (see literature review section 2.3.2), this result is according to expectation. Year differences were large and significant signifying fluctuations in feeding and management as discussed for milk yield. Parity was the third important factor affecting lactation length. Because of the positive association between lactation yield and length, and the fact that milk yield increases with parity, lactation length would increase as well. This was true for Kitulo, Iwambi and Uyole records but not Ihimbu and Mbarali. In the latter farms, as cows grew older they produced more milk in lactations of shorter duration, meaning more milk per day as age advanced.

### 5.3.3 Dry period

In normal dairy management procedures dry period lengths should vary between 45 and 60 days. Where lactations are short, dry periods can go up to 3 months and more, for example Kiuwa et al. (1983). Despite the fact that mean dry periods for Ihimbu and Kitulo were rather long, similar dry periods have been reported by Mhaiki (1980) and Agyemang and Nkhonjera (1986). Bruhn and Mgheni (1977) found even longer dry periods (over 170 days) among Friesians and Ayrshires at Morogoro, Tanzania but this was based on a small set of data. The coefficients of variation

for this trait were larger than for any other lactation trait indicating greater variability. In the literature similar findings have been documented (Kiwuwa et al., 1983; Agyemang and Nkhonjera, 1986).

The large influence of calving interval on this trait is according to expectation. With increase in calving interval there will be prolongations in both lactating and dry periods.

#### 5.3.4 Phenotypic time trends and correlations among traits

In all farms, except Uyole, and irrespective of significance, regression coefficients for both milk yield traits on year had negative signs implying that performance was declining over time. Iwambi and Kitulo had serious deteriorations in yields. When the animals were imported (some as donations through HPI and others purely on commercial transactions through World Bank loan; Lauridsen, 1979), a parallel farm improvement package was implemented. That included pasture establishment, farm structures, farm machinery, transport, expatriate advisors and manpower training. The average milk yield reported in 1979 for Kitulo was about 3790 kg (Lauridsen, 1979). Lauridsen proclaimed that the actual production potential of the

imported stock was close to 4500 kg if culling was exercised after allowing the cows to acclimatize to the southern highlands conditions. In this study, least squares means for milk yield at Kitulo for late 1970s ranged between 3600 and 4000 while at Iwambi means were about 3000 kg in early 1980s. With time pastures deteriorated and rarely re-establishment took place, farm inputs like fertilizers, drugs and concentrates have been difficult to obtain and forage conservation for dry season feeding has either not taken place or done at a minimum level. Furthermore, the prime objective of importing the animals was, first and foremost, to multiply them in order to get surplus stock for expanding the farms and to be sold to smallholder farmers. In other words, no selection had yet been applied to the cows. When heifers were imported, semen from USA was also obtained to augment introduction of foreign germplasm into the herds. Since 1978 AI has been non-functional, implying that no foreign genetic material was introduced into the herds. Exchange of bulls among herds has been practiced. Bearing in mind that rainfall is very reliable in this zone (that is, there has been no critical shortage of forages), the decline in performance found in this study is mainly attributed to deterioration in management.

At Ihimbu, there was a significant increase in lactation

length without a corresponding increase in milk yield (which showed random fluctuations). This increase can only be ascribed to the prolongation of calving interval in the farm (whose regression was also significant). Calving interval and lactation length were decreasing at Kitulo. It is difficult to single out cause-effect relationship among the traits but it could be stated that with reduction in milk yield (due to management problems) cows tended to lactate for shorter durations.

Correlations among traits were calculated after having removed effects of parity, season, year of calving and between cow variations. They are, therefore devoid of genetic and other permanent differences between cows. All correlations were according to expectation. High milk yield was positively associated with long lactation lengths and short dry periods. Annualized milk yield was negatively associated with calving interval because of their inverse relationship. Because calving interval and dry period were positively and highly associated, the relationship between annualized milk yield and dry period was supposed to be negative, and that was the case.

#### 5.4 Repeatability estimates

Estimated intra-cow correlations for milk yield traits (LMY and AMY) in the present material were lower than those estimated in Kenya (Rege 1991), Honduras (Mejia *et al.* 1982) and in Mexico (McDowell *et al.*, 1975). On the other hand they are larger than the repeatability reported by Lindström and Solbu (1978) for 305-day yield of Kenyan Friesians. With the assumption that it will take many more years before genetic parameters can be estimated from these farms, the present repeatability estimates can be used to compute "most probable producing abilities" of cows so as to arrive at culling decisions. They will also help to predict change in performance in a farm emanating from the culling process.

Repeatability estimates for calving interval were low and this compares fairly well with many studies. Being a reproductive trait, it is subject to many temporary influences such as nutritional status, reproductive disorders, bull in use and other management disturbances. The same reason applies to the consistently low repeatability estimates obtained for Mbarali farm.

### 5.5 Milk composition

Average percentages of milk components obtained in this study do not differ very much from those reviewed in the literature for Friesian cows from the tropics. The small disparities can be ascribed to differences in level of milk production resulting from different feeding levels and to measurement errors. The Uyole Friesians originated from New Zealand where selection is done for high milk yield from pastures. These cows would have higher fat content compared to American Friesians. Similarly, the standard deviations found in the present material are very similar to those reported elsewhere. The standard deviation of BF% reported by Rege (1991) of 0.47 (CV= 12.8%) was about half of what has been found in this study. His result was probably based on lactation averages.

Mean yields of milk components from individual test-days have rarely been reported. Sharaby (1988) reported on yields of TS, BF and protein which were slightly lower than those found here. The small discrepancy is attributed to the differences in milk yield (6.69 kg in his study versus 8.03 kg in the present one).

At constant milk yield on test-days, the most influential factor on all milk component percentages was the calendar

month. TS and SNF were high in the rainy months (December-May) but low in the dry season months (June-November). Besides associating the variations to personnel conducting determinations, a portion of the variation can probably be associated with feeding regime differences and type of feed. The plane of nutrition is higher during the wet season thus higher TS and SNF percentages during this period but BF% was higher in the dry season because by then all roughages were coarse. It is a well known fact that BF% shifts from low to high through the mechanism of decreased propionic to acetic acid ratio (Waite et al., 1956; Laben, 1963; Bishop et al., 1963). The latter forms a greater portion of rumen volatile fatty acids when the diet has high fibre content. The effect of calendar month on yields of milk components is mostly explained by variation in milk yield which was higher during the rainy season than in the dry season. Similar results were reported by Sargent et al. (1967) for months of the year which had depressive effect on milk yield.

Stage (month) of lactation was a more influential factor on yields of milk components than on their percentages. Decline in milk yield with advancement of lactation is the primary reason for the high effect of stage of lactation on yield traits. There was a linear decrease in test-day milk yield as lactation advanced, but most milk components

percentages were lowest in the second month of lactation. These results are in agreement with earlier findings (Waite *et al.*, 1956; Johnson *et al.*, 1961; Sharaby, 1988; Yadav *et al.*, 1991). The reason for low values at early lactation is the antagonistic relationship between milk yield and percentages of milk constituents. The gradual increase, especially of BF and protein percentages, towards the end of lactation is a result of decrease in milk yield on test-days (Johnson *et al.*, 1961; Laben, 1963).

Gacula *et al.* (1968) found that age accounted for 0-6% of total variation of BF and protein percentages but 4-23% for TS and SNF percentages in five dairy breeds. In the present study, age in parturition number accounted for much less than that. Concentrations of milk components, especially BF, tended to decrease with age. Decreases in percentages of milk constituents is attributed to increase in milk yield with parity. Gacula *et al.* (1968) used age in months and found that BF, TS, SNF and protein percentages declined with age. Johnson *et al.* (1961) reported similar results for BF and SNF percentages. On the contrary, Sharaby (1988) found no significant relationship between parity and concentrations of BF, TS and protein but yields were high in second parity and then declined with age. In this study, yields of milk constituents increased to fourth parity following the trend of milk yield.

Year of recording accounted for the largest proportion of total variation in BF yield and percentage. Least squares means for years indicate that 1986 had the highest values but 1988 and 1990 had below average tests. Reason for annual fluctuations could be changes in feeding and errors in determinations by laboratory technicians though the same method and equipments had consistently been used.

#### Correlations

Phenotypic correlations between milk yield and percentages of BF and protein were slightly higher than those found in the literature (e.g. Maijala and Hanna, 1974; Sharaby, 1988;). The correlation between milk yield and TS% was lower than those found elsewhere. The most surprising results in this study were the positive associations between milk yield and SNF% (0.42) and the negative correlation between BF and SNF percentages (-0.24). Most correlations reported in the literature, have opposite signs. The fact that SNF was calculated by difference could partly explain this. Otherwise it is difficult to speculate on the reason for such a disparity. The strong positive correlation between percentages of BF and protein conforms with previous studies (e.g. Butcher et al.,1967; Chauhan and Hayes,1991).

The very weak association between the percentage and yield

of BF was because BF yield was dependant on milk yield and the negative correlation between milk yield and BF%. It indicates that they are two different traits. It was appreciably lower than the correlation obtained by Butcher et al. (1967) of 0.32. The same authors reported lower associations between percentages and yields of milk components than those found here.

#### The milk components testing scheme

The scheme ran for four and a half years with some interruptions. The major setback was due to the failure to justify its existence in terms of offering immediate tangible results for use. Consequently, no funds could be allocated to the project. Researchers who initiated the project had left the research centre and only one person was ear-marked for the work. He had to sample Uyole, Iwambi and Kitulo (one unit) farms. Permission to go to the latter farms was only occasionally granted. Expansion of work did not go hand-in-hand with required increase in personnel, equipments and chemicals. Sulphuric acid for protein determination (by the tedious Kjeldahl method) was particularly limiting.

It may be pointed out that it was not necessary to determine TS and ash; BF and protein (or SNF) could have

sufficed. It was felt that at the initial stage it was justified to have an insight of variations of all these components before a more practical scheme is launched.

In spite of the small anomalies found in the results (correlations involving SNF and infrequent determinations of protein which resulted in some least squares means unestimable), the scheme has given acceptable results which did not deviate from those already known. If provided with a slightly faster equipment for protein and BF determination, reliable transport and trained personnel, a routine testing scheme for milk components can be launched in large farms in the southern highlands of Tanzania. At a later stage recorders in respective farms could do the sampling and submit the same to the laboratory.

#### 5.6 Day-to-day variation of milk yield and constituents

A significant effect of cow and day of milking on morning, afternoon and total daily milk yields was also reported by Gilbert et al. (1973) and Syrstad (1977). Of particular interest here was the effect of day of milking which has shown that milk yield varied greatly from one day to the other. The higher standard deviation for daily milk yields at Uyole than at Ihimbu is partly attributed to higher milk

yields in the former farm (10.20 versus 7.93 kg). While Erb et al. (1952) and Everett et al. (1968) demonstrated that with increasing milk production level daily variations increased, Lindström (1976a) attributed the large daily variation in milk yield observed under Kenyan conditions to absolute low level of milk yields. The present results further substantiate the former.

Assuming that the standard deviations of daily records are estimates of random errors of monthly records, then the estimated standard errors of 305-day lactation yield were (with 10 recordings; am + pm):

$$\text{Uyole: } 1.71 \text{ kg} \times 305 / \sqrt{10} = 165 \text{ kg}$$

$$\text{Ihimbu: } 0.65 \text{ kg} \times 305 / \sqrt{10} = 63 \text{ kg}$$

These errors were 6.4 and 2.9% of their respective herd averages. The error for Ihimbu was much smaller than those reported by Mchau et al. (1983) in Tanzania and by workers in the temperate countries (Everett et al., 1968; Syrstad, 1977). The reason for a small error is likely due to low milk yields coupled with fairly accurate recording of individual yields. Estimated error for Uyole was, on the contrary, very high. Detailed scrutiny of Uyole records revealed that almost all records had even decimal digits

(0.2, 0.4, 0.6, 0.8 ) and 64% had zero as their decimal digit. It was assumed that milk was being weighed to the nearest tenth of a kilogramme but apparently the recording was inaccurate and the recording error contributed to the day-to-day variation. On the other hand, although Ihimbu records had a similar bias, about 23% of records had odd decimal digits suggesting a less biased (more accurate) recording.

Besides milk yield, protein percent had high variation between days from the two weeks study. This is in contrast with findings of Gilbert et al.(1973), Syrstad (1977) and Rook et al. (1992) who found that BF% was more variable from day-to-day than protein percent. The expected standard errors of lactation percentages of BF, protein, TS, SNF and ash were estimated to be 0.03, 0.05, 0.04, 0.06 and 0.009 units, respectively, or 5.6, 0.8, 1.6, 0.3, 0.7 and 1.2% of herd averages. The estimated errors of percentages of milk components are much lower than those reviewed by McDaniel (1969) and those estimated by Syrstad (1977). The reasonable explanation for this low variability is the seriousness given to the sampling in terms of animal handling, accuracy of recording and determinations. This is further confirmed by the high repeatability estimates of percentages of all milk components except protein. The higher day-to-day variation of protein (hence low

repeatability of 0.25) can largely be ascribed to errors of determination. The intra-class correlation for milk yield was similar to Lee's (1988) correlations (Table 5) between test-day and re-test day yields but for BF% he found lower correlations. The higher correlation obtained in this work is likely due to the reason mentioned above.

#### 5.7 Part and cumulative milk yields

##### Effects of non-genetic factors

The decrease in standard deviations of monthly records with stage of lactation obtained in this study has also been observed by Erb et al. (1952), Kiwuwa (1973a) and Mchau and Syrstad (1991). The first month of lactation was observed by Erb et al. (1952) to be the most variable month and it was recommended not to use it for estimating lactation records. The decline in standard deviations was up to mid-lactation and then increased. The increase in variation towards the end of lactation was associated with having more cows drying off. Dry cows were assigned zero values.

The model used to analyse records explained less and less of total variation of part records as lactation progressed partly because effects of parity and period were more pronounced in early lactation than in late lactation. Similar evidences can be seen in the literature (e.g.

Kiwuwa, 1973b; Mchau and Syrstad, 1991). Second and later lactations of Kitulo farm (data set 4) were more explained by the model towards the end of lactation because calving interval was contributing substantially to total variation at that stage.

The proportion of total sum of squares accounted for by parity in this study is lower than the proportions reported by Auran (1973). The present findings, however, are similar to those reported by Mchau and Syrstad (1991) on Mowadwa cattle. The decreasing effect of parity with advancing lactation is a common observation reported in the literature (e.g. by Auran, 1973; Kiwuwa, 1973b; Al-Ani et al. 1986).

When first and subsequent parities are separated (data set 1 to 4 in this study) the effect of parity becomes of little importance. Mchau and Syrstad (1991) found in their study that least squares means differed mainly between first and later records. First calvers had low yields during early lactation but their lactation curve crossed that of pluriparous cows toward the end of lactation. The practical importance of this finding is that it justifies derivation of two sets of extension factors; one for first calvers and the other for pluriparous cows. In some studies actual age (in months) has been used instead of parity. Fritz et al. (1960) and Lamb and McGilliard (1967) have

conceded that there is an overlap of ages between first and second lactation which could be ignored. However, when first lactation is considered alone it is useful to consider actual age (e.g. by Sharma et al., 1983).

Effect of period or year of calving on part and cumulative yields has scarcely been studied mainly because many studies have been based on one to three years records. Nevertheless, such studies have involved quite a substantial amount of records. The amount of variation explained by this factor on both part and cumulative records in the present materials is in agreement with findings of Garcia et al. (1987) and Mchau and Syrstad (1991). When the use of part and cumulative records is limited within 1-2 adjacent years, year effect is of less practical concern.

Kiwuwa (1973b) investigated the effect of season on part and cumulative yields in six herds located in Tanzania and Kenya. Seasonal variations in part yields of less than 120 days were significant at Sengalo (Kenya) and Mpwapwa (Tanzania) but not in the other farms. In the same farms cumulative yields of up to 240 days were significantly influenced by season. Two conclusions were arrived at: a) Seasonal effects in Bos taurus cattle require separate correction factors for part and cumulative yields and b)

large seasonal differences occur in herds located in areas with unimodal rainfall patterns. The largest influence of season on part and cumulative records in this study occurred in early lactation contrary to observations made by Auran (1973) who found the largest effect to occur in the seventh and eighth test days. Mchau and Syrstad (1991) showed that effect of month of calving was significant on all monthly yields except the last month, and contributed 1-3% of their total variation. Considering the low contribution of season to total variation of part records in this study, it seems justified to reduce the season sub-classes to wet and dry season in order to have few but practically usable extension factors.

The marked increase in influence of calving interval from the sixth month of lactation was also reported by Auran (1974) and Mchau and Syrstad (1991). Auran (1974) found calving interval to account for nearly 30% of total sum of squares in the tenth test-day. He recommended adjusting for length of calving interval on records from seventh to tenth month using linear regression. In Tanzania, and probably in many other countries, AI is not working nor are mating records kept. Practically, adjusting part records for calving interval or days open is not feasible simply because calving interval is not known until after the following calving. By then full lactation record is known.

From the foregoing discussion it appears logical to adjust part records for parity and season of calving before part records are extrapolated or extension factors should be developed for each sub-class. In this work, the latter was adopted mainly for convenience purposes.

### Correlations

Phenotypic correlation coefficients between part and cumulative yields with total lactation yield were derived after having corrected records for non-genetic factors (period/year, parity, season/month of calving and calving interval) included in the respective models (section 3.3.7). With a number of data sets, as is the present case, small differences between sets are apt to occur. It is generally reported (Madden et al., 1959; Miller et al., 1972; Auran, 1976) that records in mid-lactation are highly correlated with total lactation yield. In the present materials this fact has been demonstrated but months of highest correlation have varied between farms and data sets.

Some of the reasons for high correlation between monthly yields in mid-lactation and total lactation yield are:

a) It is to some extent a part-to-whole relationship.

One expects therefore a higher correlation with months with the maximum production, which form the

largest part of the whole. Peak milk production during lactation is attained in different months in different farms, hence the difference in months with highest correlations.

- b) Yield at mid-lactation is less influenced by shape of the lactation curve than yield at either end of lactation.

The present findings give further evidence that a few records obtained around mid-lactation are accurate for predicting lactation records.

Comparison of correlations in first and later lactations (late months of data sets 1 and 2, all months of data sets 3 and 4) indicates that monthly yields of first calvers were more correlated to total yield than of older cows. Such observations were also made by Madden et al. (1959) and can probably be ascribed to higher persistency of first lactation compared to later lactations. The poor association for the first monthly yield with other monthly records and total lactation yield was due to varying interval from calving to recording coupled with the generally known (e.g. Miller et al., 1972) high variability of milk yield during the first month of lactation. Further, adjacent months were correlated more closely than non-adjacent months. This is due to the fact that adjacent months have more similar temporary environmental factors

influencing them than months further apart. Also different shapes of lactation curve have less effect for adjacent months. Lack of difference in correlations between data sets obtained from the period during which recording was done daily and when two tests were made per month testifies that there is no need for daily recording in Tanzanian dairy farms especially when records are used for culling and selection purposes.

The increase in correlation coefficients between cumulative and complete records with increase in the length of cumulative part has also been reported elsewhere (e.g. Fritz et al., 1960; Auran, 1976; Sharma et al., 1983; Mchau and Syrstad, 1991). The explanation is that correlations become larger as the cumulative part becomes an increasingly larger portion of the total production (part to whole relationship).

#### Extension factors

Numerous methods for extending part or cumulative records to full lactation records have been evaluated (Madden et al., 1959; Miller et al., 1972; Auran, 1976). The choice of method to use lies not only on its precision in predicting the complete record but also on its simplicity to be comprehended and used (see literature review section 2.7.1). Important non-genetic factors affecting part and

cumulative yields have already been discussed. From the foregoing results it was decided to use the ratio (equation 18 as suggested by Miller et al., 1972 and Auran, 1976) and the simple linear regression methods to derive extension factors. The former was based on earlier findings that the last test record was the best estimator of the unknown part of the lactation. Reason for opting for only two parity and season subclasses (besides those mentioned in section 4.7.3 and earlier part of this section) was to increase number of records in sub-classes in order to reduce sampling errors of extension factors and hence increase their reliability (especially the regression factors).

Errors in extrapolating part yields to 305-day yields by using the derived extension factors were not determined. The main reason was that it is not proper to make such a test on data from which the factors were derived. This might bias the errors downwards. Auran (1976) calculated average differences between estimated (by various methods) and actual yields from the same data set that was used to derive prediction equations and found the errors to be practically zero. It would be interesting to acquire another set of data which can be used to evaluate properties of the present extension factors.

Actual ratio extension factors similar to those in Table

46 have not been found in the literature in spite of the fact that the method has often been used to be compared with other methods. Here they have been presented for use and further evaluation. Regression extension factors for monthly yields in Table 47 resemble those obtained by Van Vleck and Henderson (1961). Their similarities are not only in the magnitudes of numerical values but also on the fact that regression coefficients of mid-lactation were larger than in either ends. Van Vleck and Henderson (1961) also found that the best months of lactation for predicting complete records were the fourth to sixth which individually accounted for about 72% of the variation of total records (based on correlation coefficient between predicted and actual value). The first, ninth and tenth month records were poor predictors.

Regression extension factors for cumulative yields gradually decreased approaching unity as lactation progressed. This concurs very well with previous findings (Madden et al., 1959; Fritz et al., 1960; Van Vleck and Henderson, 1961). Under Tanzanian situation extending cumulative records by simple linear regression is more practical (for simplicity reasons) compared to multiple regression though the latter has been reported to be slightly more accurate.

### 5.8 Lifetime performance traits

The mean lifetime performance traits observed in this study do not differ from those reported elsewhere in the tropics (refer to Table 6). Lifetime milk yields for Kitulo and Uyole were, however, on the low side. Lifetime milk productions found here are much lower than those reported for temperate countries (e.g. Hargrove et al., 1969; Honnette et al., 1980; Strandberg, 1992) with almost similar number of lifetime calvings and lengths of productive life. The disparities in lifetime performance traits among farms reflect differences in management of animals, disease incidence rates and farm policies on culling of cows. This is illustrated, for example, by the relatively more number of calvings at Mbarali (5.8) compared to only 3.5 at Kitulo and Uyole. Further, Kitulo had more deaths and slaughters while Uyole had more sales. The large standard deviations for most traits is an indication of large variability in these traits.

#### Correlations and prediction of lifetime milk production

Correlation coefficients between age at first calving and lifetime performance traits used in this study conformed with earlier findings (White and Nichols, 1965; Hargrove et al., 1969; Puri and Sharma, 1965). They indicate that a

delayed first parturition results in a short productive life. First lactation yield was positively correlated with lifetime milk production. Again, this association is partly automatic (part to whole relationship). It is expected that in farms where herd life is short, early life records should be able to explain more of the lifetime traits than otherwise. This is supported by Hargrove et al. (1969) who obtained a correlation of 0.42 between first lactation and lifetime milk yield for cows with two or more lactations but 0.77 for cows with less than two lactations. With a longer herd life, besides having a weaker part to whole relationship, there are more intervening environmental factors. The positive correlation between first lactation yield with most lifetime traits was also demonstrated by Van Vleck (1964) who observed that high producers in first lactation not only continued to outproduce their lower producing first lactation mates but also had a substantially longer herd life.

Prediction equations for lifetime milk production found here re-affirms earlier findings (Sundaresan et al., 1954; Gopal and Bhatnagar, 1972) on the importance of age at first calving and first lactation yield as predictors of lifetime milk production. When first calving interval is included, it adds prediction precision, but lactation length during first lactation seems to be of little value. It is

surprising that the best equation for predicting milk yield up to 5 years of age obtained by Gandhi and Gurnani (1988) was based on first lactation length and calving interval (with accuracy of prediction of 74.1%). The  $R^2$  values obtained in the present work were lower than those reported by Sundaresan *et al.* (1954); Gopal and Bhatnagar (1972) and Gandhi and Gurnani (1988). These results indicate that independent variables used in this study did not explain much of the variation of lifetime milk production.

#### Cow death and culling rates

Overall annual death rates among cows in the farms studied ranged from 4.4 to 13.4%, figures which do not deviate much from those obtained by Mhaiki (1980) and Mwakatundu and Masanje (1984) for similar farms in Tanzania. Culling rates were slightly higher at Uyole due to considerably more sales of cows, otherwise culling rates in the other farms resemble those found in similar environments (Trail and Marples, 1968; Igboeli, 1973a; Kifaro and Temba, 1990). It may be noted further that most of the cullings were involuntary with deaths, diseases and reproductive disorders necessitating slaughters being predominant reasons for disposals.

### Reasons for cow disposals

Reasons for cows to leave the herd would tend to differ between farms because of variation in the relative importance of reasons for culling (both voluntary and involuntary). Further, reasons for cows to leave the herd are expected to change as cows become older. In this report, deaths accounted for the largest proportion of disposals in the three farms which belong to DAFCO. The reason is partly that sales were restricted. The two other farms had higher sales and slaughters which reflects differences in farm policies regarding culling. Igboeli (1973a) and Vaccaro (1974a) have also shown that deaths were the major reasons for disposals in Zambia and in the tropics, respectively. Slaughters and sales were not done at random and for no apparent reason. In the farms studied, however, reasons for sales in particular and for slaughter to some extent were not recorded. This was a weakness in either recording efficiency or in justifying the action taken or both. Lack of culling policies is partly responsible for this.

Reasons for culling in temperate countries are related to economics of milk production and include causes like mastitis, sterility, low milk production, type and old age (O'Bleness and Van Vleck, 1962; Fosgate, 1965). On the

contrary, culling in the studied farms was not directly related to improvement in production (and mostly involuntary). In one farm in Tanzania studied by Kifaro and Temba (1990) culling of surplus cows for dairy purposes was indicated and was considered an exceptional case.

In four of the farms (except Mbarali) cases of dystocia, prolapses of reproductive organs and metritis resulted in quite a good number of slaughters and deaths. Similar incidence rates were reported by Vaccaro et al. (1983) from three farms in Venezuela. Tick-borne diseases are common in Africa south of the Sahara. They have been reported as cause of deaths among Friesian cows in Zambia (Igboeli, 1973a) and in Ghana (Kabuga, 1990). Despite weekly dipping at Ihimbu and Iwambi, a number of cows died of tick-borne diseases. Reasons discussed under calf mortality are valid here as well.

Poisoning was common in all farms used in this study. This has not been recorded in most literature though Kabuga (1990) reported only one incidence of plant poisoning. It appears most incidences of poisoning were management problems, for example molasses, urea and copper toxicities. Plant poisoning was a pasture management problem. A few cases were accidental such as dip wash and snake venom poisoning. Incidences cannot be eliminated but could

possibly be reduced. Fascioliasis could be reduced through effective deworming programmes. Hydramnios is said to be associated with inherited or acquired malformation of the foetus while hydrallantois is said to be due to inadequate placental drainage. Both result in abortion of foetuses but at Kitulo the excessive accumulation of fluid in foetal membranes has always resulted into deaths of pregnant heifers and cows. There is need to establish the cause and remedy for this condition.

#### 5.9 Prospects for genetic improvement through culling and selection

With some slight improvement in the farms' current production coefficients especially with respect to calf mortality, calving rates and disease control, surplus heifers can be raised thus allowing culling to be done. Table 54 presents prevailing mean production coefficients in the farms (derived by weighting herd averages) and anticipated improved values.

By the end of 1992, there were about 1700 breedable females in the five farms. By including other large dairy farms in the breeding programme, it is envisaged that a minimum of 2000 recorded cows can be involved.

Four options are evaluated based on the current situation and assuming slight improvements in management can be made.

Table 54: Production coefficients and other basic parameters for exotic dairy cattle in southern highlands of Tanzania

Trait	Current weighted average	Expected future performance
Age at first calving (months)	35	32
Age at first service for bulls (mo)	-	24
Calving interval (days)	434	410
No. of lifetime calvings	4.3	5.0 <sup>1</sup>
Length of productive life (years)	5.2	5.6 <sup>1</sup>
Heifer mortality rate to calving (%)	49	35
Annual herd replacement rate required (%)	19.2 <sup>1</sup>	-
Lactation milk yield (kg)	2450	-
Phenotypic standard deviation of milk yield (kg)	880	-
Repeatability of milk yield	0.37	-
Heritability of milk yield <sup>2</sup>	0.25	-

<sup>1</sup>) Inverse of length of productive life (equal to culling rate)

<sup>2</sup>) Assumed from the literature;

\* For cows surviving culling

Option 1: (Culling of cows only)

In this option it is assumed that voluntary culling is done on cows only. The upper limit of culling intensity in this case was given by Syrstad (1972) to be:

$$\{ n_p p + n_q ( 1 - p ) \} a = 1 \quad (21)$$

where  $p$  = fraction of cows culled

$n_p$  = average number of calvings for culls

$n_q$  = average number of calvings for non-culls

$a$  = probability that a calving results in a heifer calf which reaches first calving

If 50% of calves born are heifers and 35% of them do not reach the milking herd, then  $a = 0.5 \times 0.65 = 0.325$ . Assuming cows will be culled voluntarily after first lactation only, then  $n_p = 1$  while non-culls will be expected to have an average of 5.6 calvings (Table 54). The maximum fraction of cows to be culled shall be:

$$\{ p + 5 ( 1-p ) \} \times 0.325 = 1$$

$$p = 0.48$$

It means 48% of cows could be culled after first lactation and herd size can still be maintained by in-coming heifers. This is equivalent to a selection intensity ( $i$ ) of 0.766 (Falconer, 1981).

a) Effect of culling on production level in the herd:

For each heifer there would be  $0.52 \times 4 = 2.08$  "mature" cows (second and subsequent lactations) and the proportion of mature cows (survivors of culling) would be  $2.08 / (2.08 + 1) = 0.675$ . The effect on lactation yield would be:  $\hat{\sigma}_p \times r \times 0.766 \times 0.675$  where  $\hat{\sigma}_p$  is the phenotypic standard deviation and  $r$  is the repeatability of milk yield. Inserting values from Table 54, the increase in herd average will be about 168 kg.

b) Generally, prediction of genetic progress per year from selection was given by Rendel and Robertson (1950) to be:

$$\begin{aligned} \text{Genetic gain} &= (I_{SS} + I_{SD} + I_{DS} + I_{DD}) / (L_{SS} + L_{SD} + L_{DS} + L_{DD}) \\ &= \Sigma I / \Sigma L \end{aligned} \quad (22)$$

where  $I$  = estimated genetic superiority of animals from which progeny are raised

$L$  = generation interval

The subscripts SS, SD, DS and DD refer to paths from sires to sons, sires to daughters, dams to sons and dams to daughters, respectively. Generation intervals were estimated as follows: The generation interval from dams to their daughters ( $L_{DD}$ ) was taken to be equal to the average age of cows at calving i.e. the weighted average age at

first and subsequent consecutive calvings. Age at a particular calving was computed as the age at first calving plus the appropriate number of calving intervals. Average age at second and subsequent calvings was found to be 65.8 months (or 5.5 years) and the overall age at calving 54.5 months or 4.5 years.

The generation interval from sires to their offspring was calculated on the assumption that bulls were breeding at 24 months of age and used continuously for one year. The generation interval equals the average age at breeding plus the gestation length i.e. 30 + 9.2 months = 39.2 months or 3.3 years.

Genetic gain to be achieved when selection is done in one sex only is estimated as:

$$\text{Genetic gain} = (\sigma_p \times h^2 \times i \times 0.675) \frac{1}{2} \quad (23)$$

where  $h^2$  = heritability of milk yield

$\sigma_p$  = phenotypic standard deviation

$i$  = intensity of selection

Inserting relevant figures in the equation, genetic gain will be equal to 57 kg per generation of  $(4.5 + 3.3)/2 = 3.9$  years or 14.6 kg per year which is 0.6% of herd average.

Option 2: (Culling of cows plus bull-dam selection)

The second alternative is to combine culling performed in option 1 with selection of bull-dams. Assuming the best 10% of cows are selected to be bull-dams, selection intensity in this path will be 1.755. Genetic gain per generation will be  $(I_{DD} + I_{DS}) / 4$  and genetic gain per year will be  $(I_{DD} + I_{DS}) / (L_{DD} + L_{DS} + L_{SD} + L_{SS})$ .

$I_{DD}$  and  $L_{DD}$  will be as in option 1 and are equal to 114 kg and 4.5 years, respectively.

$$I_{DS} = 980 \text{ kg} \times 1.755 \times 0.25 = 386 \text{ kg.}$$

Genetic gain per generation will be:  $(114 + 386) \text{ kg} / 4 = 125 \text{ kg}$

On the assumption that bulls are selected from cows at second and subsequent calvings (because there is no information at first calving), the generation interval becomes:  $\{ 4.5 + 5.5 + (3.3 \times 2) \} / 4 = 4.2 \text{ years}$

Genetic gain per year will be  $125 / 4.2 = 29.8 \text{ kg.}$

There is more than twice as much gain in option 2 compared to option 1. The selection differential used here is over-estimated to some degree considering that cows would be

culled for other traits besides milk yield such as type, temperament and fertility. These will tend to reduce genetic progress in milk yield.

Option 3: (Option 2 plus progeny testing)

In this option culling of cows and selection of bull-dams will be complemented with progeny testing of bulls by natural service. AI is assumed not to be working as is the case at present. Paths from dams to daughters will be similar to option 2. Progeny testing by natural service will be conducted in the following way: Iwambi, Kitulo, Mbarali and Uyole farms will participate in the programme involving about 1400 cows. Ten percent of cows will be selected to become bull-dams. Based on growth and physical condition, bulls will be selected for test mating on all cows except bull-dams. Bulls will be rotated among farms after every two months in order to have progeny evenly distributed in all farms. While one set of bulls will be rotated monthly between the 5 units of Kitulo farm the other set will be rotated at Iwambi, Mbarali and Uyole (lowland farms). The two sets of bulls will be swapped after six months.

About 1100 calves will be born annually by cows not selected to become bull-dams and of these  $1100 \times 0.5 \times 0.65$  = about 360 heifers will reach first calving. According to

Robertson (1957), the number of test offsprings per sire which will maximise genetic response can be derived as:

$$n = 0.56 \sqrt{(N / s \times h^2)} \quad (24)$$

where  $n$  = number of offsprings per sire

$N$  = total number of offsprings for all progeny groups combined

$s$  = number of sires selected

$h^2$  = heritability of trait considered

Substituting figures in the formula ( $N = 360$ ,  $s = 2$ ,  $h^2 = 0.25$ )  $n$  comes to 15 daughters per test bull. This permits testing of 24 young bulls. Estimates of selection intensity ( $i$ ), accuracy of selection ( $r_{IG}$ ) and efficiency of selection ( $i \times r_{IG}$ ) for various progeny group sizes are entered in Table 55.

From Table 55 it appears that test mating of 20 young bulls each to have 18 daughters is the best alternative to be adopted. The two best bulls will be selected and used on bull-dams only (10% of cows). The selection intensity ( $i$ ) for bulls will be 1.638. Sires of daughters will have an average selection intensity of  $1.638 \times 0.1 = 0.1638$ . Robertson (1957) also gave a formula for estimating the accuracy of a progeny test:

Table 55: Selection intensities (i), accuracies of selection and efficiencies of selection for various progeny group sizes

Group size(n)	10	12	15	18	20	24
No of groups (N/n)	36	30	24	20	18	15
Selection intensity (i)	1.893	1.829	1.745	1.638	1.585	1.490
Accuracy of selection ( $r_{IG}$ )	0.63	0.67	0.71	0.74	0.75	0.78
Efficiency of selection ( $i \times r_{IG}$ )	1.192	1.225	1.239	1.212	1.189	1.162

N = 360,  $h^2 = 0.25$  and S = 2

$$r_{IG} = \sqrt{\left\{ \frac{n}{n + 4/h^2 - 1} \right\}} \quad (25)$$

where  $r_{IG}$  = correlation between the progeny average (I) and the breeding value of a sire (G)  
n and  $h^2$  as described above (formula 24)

In this case  $r_{IG} = 0.74$ . The genetic superiorities for each pathway would be:

$$I_{DD} = 114 \text{ kg}$$

$$I_{DS} = 386 \text{ kg}$$

$$\begin{aligned} I_{SS} &= i \times \sigma_p \times \sqrt{h^2} \times r_{IG} \\ &= 1.638 \times 880 \times \sqrt{0.25} \times 0.74 = 533 \text{ kg} \end{aligned}$$

$$I_{SD} = 0.1638 \times 880 \times \sqrt{0.25} \times 0.74 = 53 \text{ kg}$$

The generation interval from dams to daughters ( $L_{DD}$ ) will be as before (option 1; 4.5 years) but the interval from dams to sons will now be increased as cows can be used for planned mating only after completing one lactation and thus can produce bull calves for breeding from third calving onwards. Average age at third and subsequent calvings ( $L_{DS}$ ) has been computed to be 6 years (or 72.5 months).

Average age of bulls at progeny testing has been estimated as follows:

Age when all test heifers have been born	$36+9.2 = 45.2$
Time to reach calving age	$= 32.0$
Time to complete a lactation	<u><math>= 10</math></u>
Total	<u><math>87.2</math></u>

If it is assumed that the bulls are used for one year after progeny testing, the generation interval from sires to their sons ( $L_{SS}$ ) comes to  $(87.2 + 6 + 9.2) = 102.4$  months or 8.5 years.

The generation interval from sires to daughters ( $L_{SD}$ ) is the weighted average of that of progeny tested and tested bulls; weighted by their contribution to the calf crop. Thus  $(3.4 \text{ years} \times 0.9) + (8.5 \times 0.1) = 3.8 \text{ years}$ .

The generation interval for this option then sums up to  
 ( $L_{GD}=4.5$ ,  $L_{DS}=6.0$ ,  $L_{SS}=8.5$  and  $L_{SD}=3.8$ )  $22.8/4= 5.7$  years.

Genetic progress per year would then be about  $1086/22.8 = 48$  kg which is much higher than in options 1 and 2. The major contribution to genetic progress is obtained from progeny testing and from selection of bull-dams.

#### Option 4: (Suggested breeding plan)

It is assumed that all breedable females in large scale farms of southern highland regions are involved with a total of 2000 recorded cows. Other pre-requisites presumed include:

- ▣ establishment of a small AI centre for the zone,
- ▣ a limited importation of deep frozen semen from other countries of about 1000 doses per year
- ▣ standardized and improved recording scheme
- ▣ to restrict breeds in use to Friesian and Ayrshire only
- ▣ improved management of animals for better production coefficients

About 10% of the top best cows (200) are inseminated with imported semen. Mass selection based on contemporary comparison will be used. With a 90% calving rate about 90

bull calves will be born, 75 will be weaned. They will be tested for growth rate on pasture with minimum supplementation. Approximately 60% can be culled based on weight for age and estimated breeding values of sire and dam. Another 33% can be culled for physical defects and poor semen quality. Of the remaining cows, about 60% of cows will be mated to young bulls. The total number of heifers for progeny testing (N) will be  $1200 \times 0.9 \times 0.325 = 351$  heifers. If two sires will be selected for the AI centre, the number of offsprings per progeny group which will maximise genetic response (according to Robertson, 1957) will be:

$$\begin{aligned} n &= 0.56 \sqrt{N / (s \times h^2)} \\ &= 0.56 \sqrt{351 / (2 \times 0.25)} \\ &= 15 \text{ heifers} \end{aligned}$$

This will allow test mating of  $351/15 = 23$  young bulls annually. From Table 55 it is evident that test mating of 20 young bulls each to have about 18 daughters would be the best alternative to be adopted. The selected bulls will be mated to the remaining 30% of the cows. The rest of the bulls can be sold to livestock multiplication units (LMU) where  $F_1$  heifers are bred or to bull centres (BC) or sold directly to farmers. Ten percent or so of bulls from non-bull-dams can also be sold to LMU or BC or to farmers. The rest can be slaughtered.

In the cow population, about 30% will be culled annually and replaced by young heifers. Among the culled cows, 50% could be sold to smallholder farms. About 65% of the heifer calves born will join the milking herd annually as replacements (see Fig. 6).

In principle it is not possible to estimate genetic progress from the proposed plan because of the use of imported semen.

Overall genetic progress in the breeding plan will be derived from:

- Introduction of foreign germplasm through imported semen,
- Selection of bull-dams,
- Selection of best sires from the population through progeny testing,
- Culling of poor cows from the population.

It should be noted further that this plan does not claim to exploit the genetic optimum or the economic optimum with respect to proportions of cows bred with AI, young bulls or tested bulls, and on the use of available resources, respectively. More elaborate work on this is required if deemed necessary.

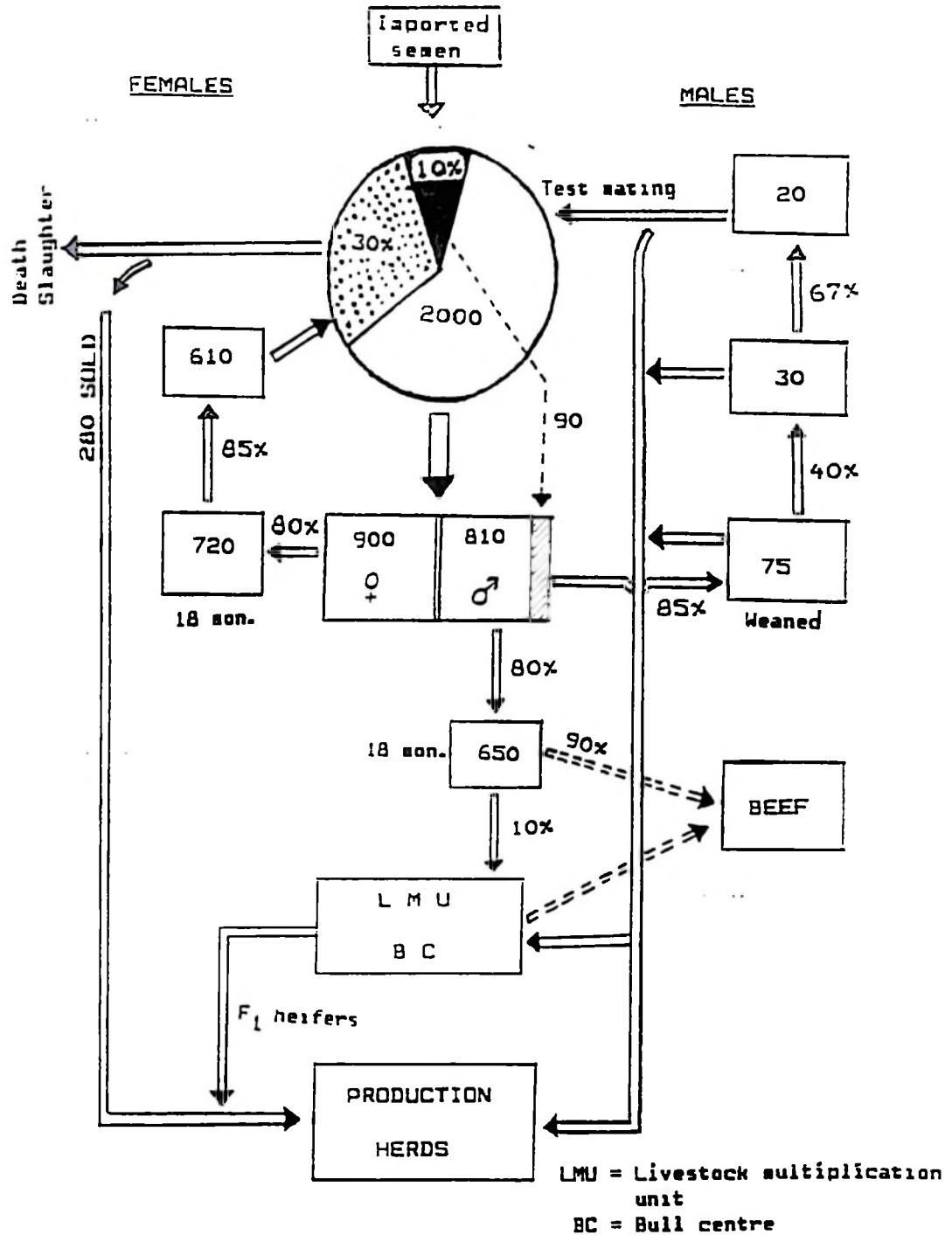


Figure 6. Proposed breeding plan for large scale dairy farms in southern highlands of Tanzania

## CHAPTER 6

## CONCLUSIONS AND RECOMMENDATIONS

## Calf mortality

- Abortion rates were similar to those reported elsewhere but rates of stillbirth showed a wide range among farms and were slightly higher than those reported in the temperate countries. Further research is warranted on causes and/or factors influencing their occurrence.
- ▣ Postnatal death rates were, in general, very high, especially among heifers, thus replacement rate will be low and consequently selection among cows will be minimal and no surpluses would be available for sale.
- Diarrhoea/scours, pneumonia and nutritional deficiencies were the main calf killers. Quite a number of diseases and other ailments could be controlled and mortality rates reduced through improved feeding and general husbandry practices.

## Reproduction

The observed mean ages at first calving and calving intervals were not very different from those reported from elsewhere in the tropics. Length of calving intervals was increasing at Ihimbu. Although there was an encouraging trend for calving intervals at Kitulo, the sub-optimal fertility in these two farms requires further

investigations.

#### Lactation performance traits

- Year, parity and calving interval were the most important non-genetic factors influencing milk yield traits. Correction of lactation records for parity and calving interval is essential before comparisons are made.
- Milk production was declining in most farms (more so in DAFCO farms) and was mainly associated with deterioration in management. Selection for improved production is meaningless without simultaneous improvement in management.

#### Milk composition

- The mean percentages and yields of milk components on test days did not differ from those recorded elsewhere on Friesians managed in the tropics. The most influential factors (in descending order) on percentages were calendar month, stage of lactation and year, while yields were highly influenced by stage of lactation, calendar month and parity.
- Phenotypic correlations among yields and percentages and between yields and percentages were according to expectation except for some correlations involving SNF.

- It was concluded that a routine testing scheme for protein and BF could be launched in the southern highlands of Tanzania provided faster equipment for determinations are installed, personnel are trained and transport is made available.

#### Day-to-day variations

- Milk yield was more variable from day-to-day at Uyole than at Ihimbu. The difference was attributed to higher milk yields and less accurate recording at Uyole. Acceptable precision of lactation records (errors of < 5%) can be achieved with monthly recording.
- In this study protein percent was the most variable milk component. It was speculated that the result was related mainly to errors in determination. Other milk components had very low day-to-day variations.

#### Part and cumulative milk yield

- The most important non-genetic factors influencing part and cumulative yields were year, parity and season of calving. Current calving interval was a significant source of variation from the sixth month of lactation.
- Part records of mid-lactation had the highest correlation with total lactation yield as reported in

the literature. Phenotypic correlations between cumulative and 305-day yield increased as lactation advanced signifying part to whole relationship.

- Based on findings from this study, ratio and regression extension factors were developed. However, it was recommended that:
  - a) Errors of prediction arising from the use of the present extension factors be evaluated.
  - b) Daily recording could be abandoned and less frequent (once or twice a month) recording be adopted. Further studies on less frequent recording be undertaken in order to determine the degree of accuracy.

#### Lifetime performance traits

- Means of lifetime traits found in this study were similar to those reported previously in the tropics. Lifetime milk production was lower than what is reported in temperate countries with almost similar number of lifetime calvings or lengths of herd life.
- Correlations between age at first calving and first lactation yield with lifetime traits were according to expectation. The two early life traits were important predictors of lifetime milk production.
- Overall culling rates were below 20% and conformed with culling rates reported in the literature.

However, the major part of the culling was involuntary through deaths and diseases necessitating slaughters. Reasons for sales and most slaughters were not reported. Causes for deaths and reasons for slaughter varied between farms.

#### Future breeding programme

Dairy cattle of southern highlands of Tanzania possess a broad genetic base which is one of the basic pre-requisites for a successful selection programme. The type of culling scheme to adopt entirely depends on resources and presence of a coordinating agent. Otherwise the opportunity for genetic progress is, indeed, quite considerable.

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## APPENDICES

Appendix Table 1: Average pre-weaning death rates (%) according to months of the year

Month of the year	Farm			
	Ihimbu	Iwambi	Kitulo	Uyole
January	1.1	1.2	5.8	3.2
February	1.2	2.8	4.4	2.5
March	2.2	2.9	8.5	1.5
April	3.2	3.1	8.1	3.7
May	1.9	1.8	6.9	3.0
June	3.1	2.2	5.6	2.3
July	3.5	2.5	5.4	5.1
August	1.4	2.6	6.2	4.8
September	1.7	2.9	5.2	0.8
October	1.0	3.2	5.2	1.8
November	1.0	1.5	5.4	4.4
December	0.5	2.5	3.7	5.3

Appendix Table 2: Monthly average and cumulative milk yields and their standard deviations (s.d.;kg) for Ihimbu, Mbarali and Uyole farms

Variable	Month of lactation	Farm and no. of lactations					
		Ihimbu (543)		Mbarali (459)		Uyole (304)	
		Mean	s.d.	Mean	s.d.	Mean	s.d.
Monthly milk yield	1	8.0	4.0	8.7	4.5	10.9	4.1
	2	9.8	3.3	9.3	3.8	11.1	4.1
	3	9.4	2.9	9.5	3.5	10.6	4.1
	4	8.9	2.8	9.2	3.0	9.8	3.5
	5	8.0	2.5	8.8	2.9	9.0	3.3
	6	7.2	2.4	8.0	3.0	8.3	3.2
	7	6.5	2.6	7.1	3.3	7.3	2.9
	8	5.5	3.0	5.9	3.6	5.8	3.1
	9	4.0	3.2	4.4	3.7	4.4	3.2
	10	2.6	3.0	2.7	3.5	2.7	3.1
Cumulative milk yield	2	17.8	6.3	17.9	6.9	21.9	7.7
	3	27.3	8.6	27.4	9.7	32.5	11.1
	4	36.0	10.7	36.6	12.1	42.3	14.1
	5	44.1	12.4	45.4	14.2	51.3	16.7
	6	51.3	13.8	53.4	16.2	59.6	19.0
	7	57.9	15.2	60.5	18.4	67.0	20.7
	8	63.3	16.6	66.5	20.8	72.8	22.0
	9	67.3	17.7	70.9	23.1	77.2	22.8
	10	69.9	18.7	73.6	25.0	79.9	23.5

Appendix Table 3: Monthly and cumulative monthly milk yields and their standard deviations (s.d.; kg) for Iwambi and Kitulo farms combined

		Data set <sup>1)</sup> and no. of lactations							
		1 (599)		2 (992)		3 (357)		4 (891)	
Variable	Month of lact.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Monthly milk yield	1	7.2	3.9	10.0	5.1	6.7	3.9	7.8	4.2
	2	8.8	3.5	12.7	4.4	7.6	3.2	8.5	3.6
	3	8.9	3.0	12.1	4.2	7.7	3.2	8.0	3.3
	4	8.9	3.0	11.6	3.8	7.6	3.3	7.6	3.3
	5	8.5	2.9	10.8	3.7	7.3	2.9	7.1	3.1
	6	7.9	2.8	10.1	3.9	6.6	3.0	6.3	3.0
	7	7.3	3.1	9.3	3.9	6.2	3.0	5.8	3.1
	8	6.7	3.2	8.1	4.3	5.2	2.9	5.0	3.0
	9	5.9	3.3	6.8	4.7	4.3	2.9	4.2	3.0
	10	4.8	3.4	5.1	4.7	3.0	2.7	3.1	2.9
<b>Cumulative</b>									
milk yield	2	16.0	6.8	22.7	8.4	14.3	6.2	16.2	6.7
	3	25.0	9.6	34.8	11.7	22.0	8.4	24.2	8.9
	4	33.8	12.0	46.5	14.8	29.6	10.7	31.8	11.1
	5	42.3	14.3	57.3	17.7	37.0	12.7	38.9	13.1
	6	50.2	16.4	67.4	20.5	43.6	14.8	45.2	15.1
	7	57.5	18.7	76.7	23.3	49.7	16.8	51.0	16.9
	8	64.2	21.1	84.8	26.2	55.0	18.5	56.0	18.7
	9	70.1	23.5	91.7	29.2	59.3	20.1	60.2	20.3
	10	74.8	25.8	96.8	32.1	62.3	21.3	63.3	21.7

<sup>1)</sup> 1 = Iwambi and Kitulo first lactation records of 1976 - 83  
 2 = Iwambi and Kitulo second and later records of 1976 - 83  
 3 = Kitulo first lactation records of 1984 - 90  
 4 = Kitulo second and later lactation records of 1984 - 90.

Appendix Table 4: Ihimbu: Partial correlation coefficients  
( x 100) mong monthly average milk yields above  
diagonal), cumulative yields (below diagonal) and  
with 305-day milk yield (LY) d.f.=529)<sup>†</sup>

Month of lacta tion	Month of lactation										
	1	2	3	4	5	6	7	8	9	10	LY
1	-	35	25	17	10	7	4	2	4	6	36
2	88	-	72	53	43	36	29	21	16	14	62
3	76	95	-	72	60	48	40	31	22	17	70
4	67	89	97	-	71	57	54	43	29	23	74
5	59	82	93	98	-	69	59	51	35	27	75
6	53	77	88	95	98	-	74	60	45	33	76
7	48	71	83	91	95	98	-	77	58	43	78
8	41	64	77	85	91	95	98	-	77	57	76
9	38	60	72	80	86	91	96	99	-	78	70
10	-	-	-	-	-	-	-	-	-	-	60
LY	36	56	68	76	83	88	92	96	99		

LY = 305-day milk yield

Critical values for significance are:  $P < 0.05 = 9$

$P < 0.01 = 11$

Appendix Table 5: Mbarali: Partial correlation coefficients

(x 100) among monthly milk yields (above diagonal),  
cumulative yields (below diagonal) and with 305-day  
milk yield (LY)(d.f.= 444)<sup>†</sup>

Month of lacta tion	Month of lactation										LY
	1	2	3	4	5	6	7	8	9	10	
1	-	32	31	27	21	24	18	14	8	9	44
2	89	-	73	58	44	35	28	29	23	16	60
3	77	95	-	79	62	47	35	37	29	27	71
4	70	90	98	-	74	60	42	43	37	31	75
5	64	84	94	98	-	71	54	51	41	38	76
6	60	80	90	95	99	-	71	64	51	41	79
7	56	76	86	91	95	98	-	79	65	51	79
8	52	71	81	86	91	95	99	-	81	60	81
9	47	66	76	82	87	91	96	99	-	76	74
10	-	-	-	-	-	-	-	-	-	-	66
LY	44	62	72	78	83	88	93	97	99		

\* Critical values for significance :  $P < 0.05 = 10$

$P < 0.01 = 13$

Appendix Table 6: Uyole: Partial correlation coefficients (x100) among monthly milk yields (above diagonal), cumulative yields (below diagonal) and with 305-day milk yield (LY)(d.f.=291)<sup>†</sup>

Month of lactation	Month of lactation										LY
	1	2	3	4	5	6	7	8	9	10	
1	-	59	45	35	27	21	20	14	14	6	54
2	90	-	73	59	52	41	33	28	20	19	74
3	81	95	-	71	58	47	38	28	21	21	76
4	75	91	98	-	70	51	41	33	24	27	76
5	69	87	95	98	-	63	45	33	23	27	73
6	65	83	92	96	98	-	65	39	22	22	69
7	62	80	89	93	96	99	-	60	38	29	69
8	59	77	85	90	93	96	99	-	65	41	66
9	57	74	82	87	90	93	96	99	-	22	58
10	-	-	-	-	-	-	-	-	-	-	51
LY	54	71	79	84	80	91	94	97	99		-

\* Critical values for significance:  $P < 0.05 = 11$

$P < 0.01 = 15$

Appendix Table 7: Data set 1: Partial correlation coefficients (x100) among monthly average milk yields (above diagonal), cumulative yields (below diagonal) and with 305-day milk yield (LY)(d.f.=569)<sup>†</sup>

Month of lactation	Month of lactation										LY
	1	2	3	4	5	6	7	8	9	10	
1	-	51	35	28	24	15	9	11	13	9	42
2	91	-	73	56	49	39	39	40	40	32	69
3	81	96	-	72	63	53	51	49	45	36	76
4	73	90	97	-	73	57	50	46	41	36	74
5	66	84	93	98	-	76	64	56	47	39	78
6	60	79	89	95	98	-	80	71	60	50	81
7	54	73	84	91	95	99	-	85	71	58	82
8	48	68	79	86	92	96	99	-	81	64	83
9	45	65	76	83	88	93	97	99	-	81	80
10	-	-	-	-	-	-	-	-	-	-	71
LY	42	61	73	80	85	90	95	97	99	-	-

\* Critical values for significance :  $P < 0.05 = 9$

$P < 0.01 = 11$

Appendix Table 8: Data set 2: Partial correlation coefficients (x100) among monthly milk yields (above diagonal), cumulative yields (below diagonal) and with 305-day milk yield (LY)(d.f. 960)<sup>‡</sup>

Month of lactation	Month of lactation										LY
	1	2	3	4	5	6	7	8	9	10	
1	-	42	36	36	32	29	26	23	19	15	50
2	88	-	74	65	55	48	44	40	33	28	70
3	78	96	-	75	63	58	51	45	39	30	75
4	71	91	98	-	75	63	59	50	43	34	79
5	67	87	95	98	-	74	65	55	49	40	80
6	63	83	92	96	99	-	78	62	53	43	81
7	59	80	88	93	97	99	-	76	64	53	83
8	56	76	85	90	94	97	99	-	78	62	81
9	53	72	81	87	91	94	97	99	-	77	77
10	-	-	-	-	-	-	-	-	-	-	67
LY	50	69	78	83	87	91	94	97	99	-	-

\* All correlations were highly significant  $P < 0.01$

Appendix Table 9: Data set 3: Partial correlation coefficients(x100) among monthly milk yields (above diagonal), among cumulative yields (below diagonal) and with 305-day milk yield (LY) (d.f.=336)<sup>‡</sup>

Month of lactation	Month of lactation										
	1	2	3	4	5	6	7	8	9	10	LY
1	-	51	36	23	17	14	11	8	13	14	45
2	90	-	69	53	53	44	39	32	26	15	71
3	79	95	-	76	65	55	48	37	32	15	78
4	69	88	97	-	73	60	54	44	31	13	76
5	62	82	93	98	-	77	64	55	45	25	82
6	56	77	89	95	99	-	78	61	46	28	80
7	52	73	85	92	96	99	-	70	52	35	77
8	48	69	82	89	94	97	99	-	75	51	74
9	46	67	79	86	92	95	97	99	-	73	68
10	-	-	-	-	-	-	-	-	-	-	50
LY	45	65	77	84	89	93	95	98	99	-	-

\* Critical values for significance:  $P < 0.05 = 11$

$P < 0.01 = 15$

Appendix Table 10: Data set 4: Partial correlation coefficients

among monthly milk yields (above diagonal), among cumulative yields (below diagonal) and with 305-day milk yield (LY)(d.f.=868)<sup>1</sup>

Month of lactation	Month of lactation										
	1	2	3	4	5	6	7	8	9	10	LY
1	-	47	30	26	22	19	14	9	9	9	48
2	88	-	63	51	42	36	32	23	24	19	67
3	78	95	-	63	54	46	36	28	25	17	70
4	70	89	97	-	66	56	42	36	32	25	74
5	64	84	93	98	-	68	56	44	35	26	75
6	60	79	89	95	99	-	70	59	44	34	77
7	56	75	85	92	96	99	-	72	57	44	75
8	52	71	81	88	93	97	99	-	71	51	70
9	50	68	78	85	90	94	97	99	-	70	66
10	-	-	-	-	-	-	-	-	-	-	55
LY	48	66	76	83	88	92	95	98	99	-	-

\* All correlations were highly significant  $P < 0.01$

Appendix Table 11: Reasons for cows to exit from Ihimbu dairy  
farm

Reason	Within subclass		Between subclass	
	No.	%	No	%
<b>1. Sold</b>				
Poor health	6	15.4		
Lameness	2	5.1		
No reason stated	25	64.1		
Others	5	15.5		
	<b>39</b>	<b>100.0</b>	<b>39</b>	<b>28.3</b>
<b>2. Slaughtered</b>				
Infertile	2	6.7		
Old age/low production	2	6.7		
No reason given	4	13.3		
Dystocia/uterine prolapse	3	10.0		
Leg fracture/dislocation	11	36.7		
Recumbent	3	10.0		
Others	5	16.7		
	<b>30</b>	<b>100.0</b>	<b>30</b>	<b>21.7</b>
<b>3. Died</b>				
Tick-borne diseases	22	31.9		
Poisoning	10	14.5		
Dystocia/metritis	10	14.5		
Accident/fell in ditch	6	8.7		
Helminthiasis/fascioliasis	5	7.2		
Sudden death	4	5.8		
Traumatic pericarditis	3	4.3		
Other diseases	9	13.0		
	<b>69</b>	<b>100.0</b>	<b>69</b>	<b>50.0</b>
<b>Grand total</b>			<b>138</b>	<b>100.0</b>

Appendix Table 12: Reasons for cow disposals at Iwambi dairy farm

Reason	Within subclass		Between subclasses	
	No	%	No	%
<b>1. Sold</b>				
No reason stated	36	100.0	36	8.6
<b>2. Slaughtered</b>				
No reason stated	56	86.1		
Loss of condition	5	7.7		
Prolapse of uterus	2	3.1		
Hip joint dislocation	2	3.1		
	65	100.0	65	15.6
<b>3. Died</b>				
Poisoning	72	22.8		
Dystocia/metritis/ prolapse of uterus	52	16.5		
Liver cirrhosis/ fascioliasis	40	12.6		
General malaise/old age	39	12.3		
Tick-borne diseases	31	9.8		
Unknown causes	23	7.3		
Reticuloperitonitis	10	3.2		
Haemorrhagic septicaemia	10	3.2		
Abscessation(liver, lungs)	9	2.8		
Acute mastitis	7	2.2		
Lumpy skin disease	5	1.6		
Bloat	4	1.3		
Other causes <sup>1)</sup>	14	4.4		
	316	100.0	316	75.8
<b>Grand total</b>			417	100.0

<sup>1)</sup> Included pneumonia, milk fever, lung worms and accidents

Appendix Table 13a: Reasons for cows to exit Kitulo dairy farm

Reason	Within subclass		Between subclass	
	No	%	No	%
1. Sold				
No reason stated	55	87.3		
Stolen from the farm	4	6.3		
Off colour	4	6.3		
	63	100.0	63	3.8
2. Slaughtered				
No reason shown	271	54.3		
Udder problems-mastitis				
blind teats	43	8.6		
Leg paralysis/dislocation/fracture	40	8.0		
Bloat	39	7.8		
Dystocia/metritis/vaginal prolapse	36	7.2		
Sick and weak	26	5.2		
Brucellosis/tuberculosis +ve	13	2.6		
Infertile	9	1.8		
Drowned/strangled	5	1.0		
High altitude disease	4	0.8		
Blind	4	0.8		
Others*	9	1.8		
	499	100.0	499	30.4

\* Included bad temperament and milk fever

Appendix Table 13b: Reasons for cows to exit Kitulo dairy farm

Reason	Within subclass		Between subclasses	
	No	%	No	%
3. Died				
Drowning in water/mud	132	12.2		
Poisoning	109	10.1		
Dystocia/prolapse of uterus	105	9.7		
Ruminal tympany (bloat)	96	8.9		
Unknown/undetected	86	7.9		
Abscessation (lungs/liver)	84	7.8		
Metritis	76	7.0		
Septicaemia	66	6.1		
Liver cirrhosis/failure	57	5.3		
General weakness/nutritional deficiency <sup>1)</sup>	47	4.3		
Pneumonia	37	3.4		
Lung worms	23	2.1		
Fascioliasis	22	2.0		
High altitude disease	22	2.0		
Hydrallantois/hydramnios	16	1.5		
Tuberculosis	15	1.4		
Enteritis	8	0.7		
Post parturient downer syndrome	8	0.7		
Strangled	7	0.6		
Peritonitis	7	0.6		
Other diseases/conditions <sup>2)</sup>	59	5.4		
	1082	100.0	1082	65.8
Grand total			1644	100.0

<sup>1)</sup> Suspected hypomagnesaemia, starvation, Cu and Co deficiency

<sup>2)</sup> Pleuritis, shock, gastritis, old age

Appendix Table 14. Reasons for cow disposals at Mbarali farm

Reason	Within subclass		Between subclasses	
	No	%	No	%
1. Sold				
No sales were made	0	0.0	0	0.0
2. Slaughtered				
Reasons not stated	71	93.4		
Tuberculosis positive	3	3.9		
Sick	2	2.6		
	76	100.0	76	73.8
3. Died				
Poisoning	5	18.5		
Foot and mouth disease	5	18.5		
Tuberculosis	3	11.1		
Septicaemia	2	7.4		
Lumpy skin disease	2	7.4		
Bloat	2	7.4		
Unknown cause	2	7.4		
Other causes†	6	22.2		
	27	100.0	27	26.2
Grand total			103	100.0

\* Included black quarter, babesiosis, liver cirrhosis and abscesses

Appendix Table 15: Reasons for cow disposals at Uyole farm

Reason	Within subclass		Between subclasses	
	No	%	No	%
1. Sold				
Reasons not specified	319	100.0	319	63.7
2. Slaughtered				
No reason given	112	88.9		
Dystocia/prolapse of uterus	5	4.0		
Sick	3	2.4		
Trauma	3	2.4		
Infertile	1	0.8		
Pendulous udder	1	0.8		
Blind	1	0.8		
	126	100.0	126	25.1
3. Died				
Unknown causes	18	32.1		
Dystocia/prolapse of uterus	9	16.1		
Poisoning	9	16.1		
Destroyed(prolonged sickness)	5	8.9		
Fascioliasis	3	5.4		
Trauma/accident	3	5.4		
Milk fever	2	3.6		
Liver cirrhosis	2	3.6		
Other causes <sup>1)</sup>	5	8.9		
	56	100.0	56	11.2
Grand total			501	100.0

<sup>1)</sup> included septicaemia, enteritis, abscesses, and traumatic pericarditis