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EVALUATION OF BREEDING STRATEGIES FOR GENETIC IMPROVEMENT OF DAIRY CATTLE IN KENYA

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A thesis submitted to the Graduate School in partial fulfilment for the requirements of the Master of Science Degree in Animal Production (Animal Breeding option) of Egerton University.

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JULY 2007



DECLARATION AND APPROVAL

1. DECLARATION

This thesis is my original work and has not, wholly or in part, been presented for an award of a degree or diploma in any other University.

Signed: _____

Okeno Tobias Otieno

Date: 15TH JULY 2007

2. APPROVAL

This thesis has been submitted for examination with our approval as the official University supervisors.

Signed: _____

Prof. Dr. A. K. Kahi

Date: 16th July 2007

Signed: _____

Dr. I. S. Kosgey

Date: 16th July, 2007

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DEDICATION

This work is dedicated to:

My parents Mr. Thomas Otieno and Mrs. Joyce Otieno for their endless efforts to support my education irrespective of their economic status, you are my hero dad and heroine mum;

My siblings Helena, Regina, Akumu, Omondi, Andoniko, Atieno and The late Nyangi for their great sacrifice, prayers and encouragement; and

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Nyasaye aduokoni erokamano kuom ngima kod chuny mane imiyo nera mondo omak bada eyor manyo rieko, Nyingi omiduong

ABSTRACT

Breeding of dairy cattle in Kenya involves utilization of local and imported genetic material. Imported genetic material has been used without adequate knowledge of their genetic and economic merits under local production conditions. The aim of this study was to genetically and economically evaluate four breeding strategies used for genetic improvement of dairy cattle in Kenya using a deterministic approach. The breeding strategies included those based on local selection programs, a closed progeny testing scheme (CPT) and a young bull system progeny of local bulls (PLB) and those involving imported semen, continuous semen importation (CSI) and a young bull system progeny of imported bulls (PIB). Imports were assumed to be from the USA. The breeding goal for the local selection program reflected a future scenario where payment for milk would be based on volume and fat while that for the USA represented the current marketing systems. The correlation between these breeding goals was high <0.97. The genetic response was calculated using gene-flow procedures and selection index methodology while cost-benefit analysis was used to assess the economic merit of the four breeding strategies using the NPV as the evaluation criterion. The effect of genetic correlation (r_g), initial differences in genetic merit, price of imported semen, discount and exchange rates between Kenya and the USA on genetic and economic ranking was examined. Genetically, CSI and PIB strategies ranked above CPT by, correspondingly, 37.1% and 22.5% when r_g between Kenya and the USA was assumed to be one. At a genetic correlation of less than 0.58, the estimated level of genotype-environment interaction between Kenya and the exporting countries, imports from countries that are 1.50SD above the local population were slightly better than CPT but were inferior to PLB. This means that if CSI strategy is to be used at a genetic correlation of 0.58, then only semen from countries which are 2.00SD above the Kenyan population should be imported. Economically, PLB was more profitable than CPT while CSI was not an economically viable alternative. The PIB was only viable if imports were from countries which are >2.00SD in genetic merit above the local dairy cattle population. Economic ranking of strategies was not sensitive to changes in genetic parameters but to economic parameters. The use of local semen from young bulls progeny of local proven bulls is recommended. Alternatively, PIB can be utilized but the semen will have to be imported from countries which are >2.00SD above the local dairy cattle population or the cost of imported semen should be ≤ US$40 per straw. Wholesale importation of semen as a means of achieving sustainable genetic progress in Kenya is a less optimal solution and there is the need for an effective local selection program.

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LIST OF ABBREVIATIONS

AFC	Age at first calving
AI	Artificial insemination
BLUP	Best Linear Unbiased Prediction
CAIS	Central Artificial Insemination Station
CDE	Cumulative discounted expressions
CI	Calving interval
CPT	Closed progeny testing
CSI	Continuous semen importation
EBVs	Estimated breeding values
FY	Fat yield
GDP	Gross domestic product
G x E	Genotype by environment interaction(s)
HF	Holstein-Friesian
KCC	Kenya Co-operative Creameries Limited
LL	Lactation length
MY	Milk yield
MACE	Multiple across-country evaluation
MOET	Multiple ovulation and embryo transfer
NPV	Net present value(s)
OBS	Old bull system
PIB	Young bulls system progeny of imported bulls
PLB	Young bulls system progeny of local bulls
PT	Progeny testing
PTS	Progeny testing scheme
PY	Protein yield
SEZ	East Africa Zebu
TPI	Total production index
USA	United States of America
YBS	Young bull system

CHAPTER ONE

GENERAL INTRODUCTION

1.1. Background information

The agricultural sector in Kenya contributes about 50% to the GDP. The sector is also the major source of livelihood for over 80% of the population. Dairy production is one of the major activities in the livestock sub-sector. It contributes 3.5% to the GDP and is the major source of livelihood for most small-scale farmers (KDDP, 2001). Currently, like in most other developing countries, Kenya is experiencing a high demand for animal products due to the rapid growth in human population, and increased urbanisation and income that have led to changes in consumer preference (Delgado et al., 1999; Omore et al., 1999). This growing demand has led to simultaneous growth in the production of animal products through increased animal populations rather than productivity (Nicholson et al., 2001). Despite the increased production of animal products, the consumption per capita still surpasses the nutritional optimum due to inefficiency in production (FAO, 1991; Delgado et al., 1999). Improving the production efficiency of dairy cattle to satisfy the demand for dairy products is the biggest challenge faced by developing countries (Bondoc et al., 1989). The market forces drive the need for improved performance, but this can only be achieved when there are changes in economic and institutional environments, that would give farmers full control over their resources (Peters, 1993).

Improved performance is possible through increased production per cow by use of appropriate breeding strategies. Breeding strategies for genetic improvement of dairy cattle in the developing countries have relied mainly on three alternatives: local selection programs, breed substitution and crossbreeding (Vaccaro, 1990). Selection of superior genotypes as parents of the future generations and migration of animals between populations are the major tools that have been utilised to improve productivity of dairy cattle by the industrialised countries. Local selection programs similar to those in the developed countries have been tried in the developing countries to improve productivity (Bondoc et al., 1989). The rates of genetic progress achieved through selection techniques such as PT, although slow, are cumulative, and therefore result in increased performance over time (Mpofu et al., 1993). In the developing countries, however, the success rates of such programs have generally been low due to major physical, social and economic constraints, low effective population sizes, poor performance and pedigree recording in the field, high costs of reproductive technologies and G x E (Cunningham, 1980; Bondoc et al., 1989; Ojango and Pollot, 2001; Kahi et al.,

2004). Therefore, given the costs involved in local selection programs, Smith (1988) recommended for developing countries the adoption of breeding strategies based on importation or on nucleus breeding schemes using MOET. Consequently, many developing countries turned to massive importation of high productive breeds/ germplasm from developed countries as an attempt to achieve faster genetic improvement in the local dairy cattle production (Smith, 1988; Mpofu et al., 1993).

The rate of genetic progress achieved from imported genes depends on the migration rate and the initial difference in genetic merit between the exporting and importing populations. Breeding strategies based on continuous importation of germplasm have higher genetic responses than the use of local gene pools (Mpofu et al., 1993). When genotypes are moved from an environment where their genetic values are known to a similar environment, the performance is likely to be the same. However, the performance may be greatly affected in a different environment. This confirms the low performance of the high yielding exotic dairy breeds in the tropics (Rege, 1991), which are characterised by environmental stresses due to poor nutrition, heat, and high parasite and disease incidences.

Dairy breeding in Kenya, as in other developing countries, relies on the use of germplasm sourced locally and internationally (Rege, 1991; Bebe et al., 2002; Ojango and Pollott, 2002). The local material is usually from progeny-tested bulls that are either sons of local or imported sires. However, these local selection programs are not efficient as a result of the decline in government funding, liberalisation of the dairy sector and lack of co-ordination among the institutions involved in the development and running of the dairy industry (Bebe et al., 2002). In some farms, breeding strategies involve total use of imported genetic material in the form of semen and embryos. These genetic materials are continuously imported to sustain these breeding strategies. Breeding strategies based on imported genetic material from temperate countries might not be the best because of significant G x E between Kenya and the exporting countries (Ojango and Pollott, 2002) and the breeding goals may not be similar. Rege (1991) reported that no substantial improvement had been achieved in the Kenyan HF population in twenty years of dairy cattle breeding.

The aim of using breeding strategies based on either local or imported genetic material is to improve dairy production. However, the choice of each of these strategies has often been done without due regard to their genetic and economic efficiency. The strategies have been studied in other countries but their evaluation under conditions in Kenya to quantify their efficiency in terms of genetic gain and profitability is rare. This means that these strategies are currently being utilised with the assumption that they can be as effective as in other countries

where they have been successfully adopted. This assumption might not be true because different countries have different production systems and operate under different environmental conditions. There is therefore need to evaluate and compare genetic and economic merits of breeding strategies based on the use of local and imported genetic material in relation to their adoption for genetic improvement of dairy cattle in Kenya.

1.2. Objectives

The overall objective of this study was to genetically and economically evaluate breeding strategies for genetic improvement of dairy cattle in Kenya. The specific objectives were:

1. To evaluate genetic progress in breeding strategies based on local selection programs when selection is on milk yield and fertility traits.
2. To evaluate genetic progress in breeding strategies based on continuous importation of genetic materials.
3. To determine the economic merits of the breeding strategies based on local selection programs and continuous importation of genetic materials.

1.3. Research questions

1. What is the genetic progress achieved when local selection programs are utilised to improve milk yield and fertility traits?
2. What is the genetic progress achieved when imported genetic materials are utilised to improve milk yield and fertility traits?
3. What are the economic merits of local selection programs and continuous importation of genetic materials in the genetic improvement of dairy cattle?

CHAPTER TWO

LITERATURE REVIEW

2.1. Dairy production in Kenya

The agricultural sector in Kenya contributes about 50% to the gross domestic product. The sector is also the major source of livelihood for over 80% of the population. The livestock sub-sector accounts for about 40% of the contribution of the agricultural sector to the economy (MLFD, 2004). Dairy production is one of the major activities in the livestock sub-sector. It contributes 3.5% of the GDP and is the major source of livelihood for most small-scale farmers (KDDP, 2001). The current dairy herd population is estimated at 3.3 million cows of which approximately 30% are purebred *Bos taurus* breeds while 70% are crossbreds (MLFD, 2004). The total annual milk production is estimated at 2.6 billion litres. This milk is primarily produced from cattle (84%), camel (12%) and dairy goats (4%). Out of the 84% of the total milk produced by cattle, the exotic dairy breeds and their crosses produce about 73% (Muriuki, 2001). Milk production is still far much below the demand since demand for dairy products is greatly increasing due to high human population growth rate (3% annually), increased urbanisation and income, and changes in consumer preferences (Bebe et al., 2002).

2.1.1. Dairy production systems

Dairy production is mainly concentrated in the highlands (Central Rift Valley, Central Province and parts of Eastern Province around Mount Kenya). The highlands comprise areas with an altitude of ≥1000 metres above sea level, annual mean temperatures of 15-24°C, a bimodal rainfall pattern (>800 mm annually), low risks of diseases, and fertile notisol soils with good potential for biomass production for forage-based dairy production (Jaetzold and Schmidt, 1983; Bebe et al., 2002). These areas also have better market opportunities for milk because of high human population densities with a tradition for milk consumption in their diet. Milk production is undertaken in specialised large-, medium- and small-scale dairy production systems (Ojango, 2000). In these systems, HF dairy cattle are the dominant breed due to their genetic potential for higher milk production, but the other breeds, namely, Ayrshire, Jersey, Guernsey and the Brown Swiss, and their crosses are also found. Some large-scale farms in the drier and sub-humid areas raise crosses of the Sahiwal and other *B. indicus* (Peeler and Omore, 1997).

Large-scale dairy production systems

Large-scale dairy production in Kenya was initiated in 1890's when the colonial white settlers introduced *B. taurus* dairy breeds from South Africa and Europe to upgrade the SEZ (Stotz, 1979). These farms are wholly commercial, raising over 50 animals and either owned by individuals, companies, state corporations and research or academic institutions (Ojango, 2000). They keep 24% of the total population of exotic dairy cattle. Their management vary from low input, low milk output to intensive zero-grazing based on irrigated pasture production (Peeler and Omore, 1997). They either produce their males and nearly all the females or produce their female replacements and purchase bulls, semen or embryos (Kahi and Nitter, 2004). The animals are fed on natural pastures, which are supplemented with fodder and concentrates, and are milked twice a day. Due to the intensive management practices, the production cost per kg of milk is highest but the productivity per cow and per unit of land is also high, i.e., the average milk production per cow per lactation for HF in large-scale farms is 5,056 kg while in small-scale farms the average production is 2,160 kg (Ojango, 2000). The production of the exotic dairy breeds, however, is significantly low compared to production in their countries of origin (Ojango and Pollott, 2002). The low performance can be due to the environmental stresses of poor quality feeds, heat and disease challenge in the tropics. Forages in the tropics have more cell wall constituents than forages in the temperate environments, which restrict their intake (Preston, 1995). In addition, differences in economic constraints and agricultural policies, and therefore herd management practices implemented, may also contribute to the low performances (Ojango and Pollott, 2002).

Medium-scale dairy production systems

These farms operate on land holdings of between 20-50 hectares and a herd size of 20-50 heads dominated by the HF breed. Ownership is mainly by individuals in the medium to high agricultural potential areas (Ojango, 2000). This production system is mainly characterised by mixed farming, as it involves both crop production and the raising of dairy cattle for milk production. The average milk production per cow per lactation (2,600 kg) is far much bellow that obtained in large-scale farms but higher than 2,160 kg recorded in small-scale farms (Wakhungu et al., 1996).

Small-scale dairy production systems

Small-scale dairy production in Kenya started pre-independence and was pioneered by those who provided labour in the colonial white settlers' farms (Conelly, 1998). In these systems, the maximum herd size is 5 and mixed farming is practised. The system is mostly practiced in agro-ecological zones 1 to 4 (Ojango, 2000). This system has been expanding since pre-independence when the Swynnerton Agricultural Reforms were implemented in 1954 (Jahnke, 1982). These reforms enabled farmers to acquire title deeds, which they could use as collateral to obtain credit. After independence in 1963, the Kenya Government developed policies that strongly supported the sub-division and selling of the white settlers' large-scale farms to smallholders at subsidised prices. This led to the rapid expansion of small-scale dairy production and reduction in the number of large-scale farms in the highlands (Bebe et al., 2002). Currently, the small-scale dairy farms own 80% of the dairy cattle herd in Kenya and account for 70% of the domestic milk production (Omore et al., 1999).

Dairy production in this system is labour intensive and HF is the common breed raised, contrary to the advice of the extension services that recommends the use of smaller breeds (i.e., Jersey and Guernsey) due to their low-input requirements in terms of feeds (Conelly, 1998). The mean lactation milk yield of HF breed in this system is 2,160 kg, far much lower than in large-scale farms (5,056 kg/lactation). The mean performance of the Jersey breed (2,609 kg/lactation) in large-scale farms is far much higher than that of HF in smallholder farms (Musani and Mayer, 1997; Ojango, 2000). The low performance of HF in the smallholder farms can be explained by the susceptibility of HF to stresses from the low-input resources in these farms.

2.1.2. Milk marketing structure

Milk marketing in Kenya consists of various marketing channels (ILRI, 2000) as presented in Figure 1. Before the liberalisation of the milk market, the major national milk marketing organisation was the KCC Ltd (MARD, 2000). It was operating on a contract and quota system until 1971 when the Government abolished the system to enable the smallholder dairy farmers to sell their milk to it. Liberalisation of the dairy sector started in 1992 following recommendations of the Dairy Master Plan (DANIDA, 1991). Its benefits include an increased diversity of market outlets, high prices for producers and low prices for consumers, and employment opportunities in small-scale milk trading (Owango et al., 1998).

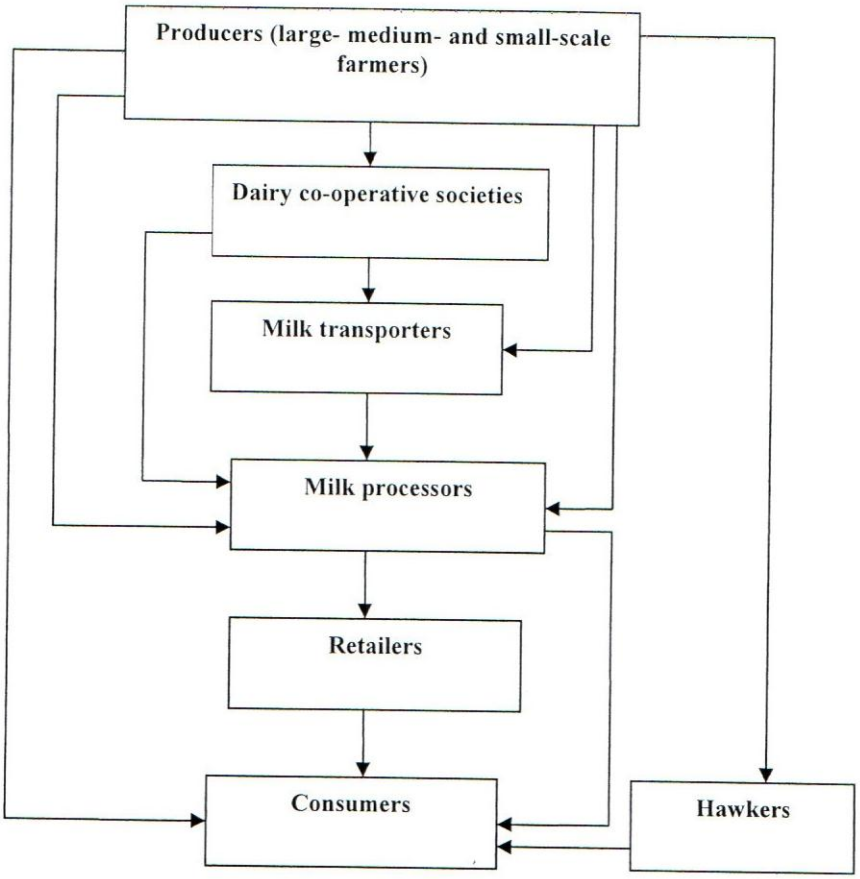


Figure 1. Milk marketing channels in Kenya

Liberalisation of the milk market led to the market becoming more competitive. This competition, and mismanagement of the KCC Ltd, led to inefficiency in operation of the KCC Ltd, and consequently its underperformance. Currently, it operates far much below its installed capacity (MLFD, 2004). Low intake capacities, low prices offered by the private processors and the inefficiency of the KCC Ltd resulted in raw milk marketing which now occupies about 80% of the total milk market (Bebe et al., 2002; MLFD, 2004). From the consumers' point of view, the shorter the chain the lower the prices. These explains why, since the liberalisation of the dairy industry, direct sales of raw milk from the producer to the consumer, and from the producer to the consumer but through milk hawkers (Figure 1), have been on the increase despite the public health risks associated with consumption of untreated milk and milk products. Raw fresh milk marketing has been increasing due to the traditional preferences for it, unwillingness by the consumers to pay the extra costs of pasteurisation and packaging, and difficulties of accessing distant urban markets because of poor road networks, and inadequate facilities for collection and cooling in some production areas, especially in

smallholder farms (de Leeuw et al., 1999). Despite the high transaction costs arising from economies of scale in raw milk marketing, it is expected to remain the major outlet, especially for smallholders, because substantial improvements in the roads and collection infrastructure are unlikely in the near future (Bebe et al., 2002).

2.1.3. Constraints to dairy production in Kenya

Some of the main constraints in dairy production in Kenya include prevalence of diseases and parasites, poor quality and quantity of feed resources, poor infrastructure, lack of well organised milk marketing channels, lack of breeding stock and credit facilities, especially to small-scale dairy producers who own 70% of the dairy cattle population (Bebe et al. 2003). The high demand for dairy products has led to the importation of exotic breeds that produce more milk but are less adapted to the tropical conditions. In the tropics, temperatures are relatively high. This causes heat stress to exotic cattle breeds, which in turn depresses feed intake, milk production and fertility, and also increases mortality rates (Ageeb and Hayes, 2000). Cattle diseases and parasites are common in the tropics and negatively affect production. In Kenya, for instance, ticks are common and they spread East Coast Fever, which causes great losses in the dairy sector. Before the liberalisation of the dairy industry in 1992, the Kenya government subsidised tick control, veterinary and AI services. However, the prices of these services were decontrolled and farmers were to pay for them at the market rates post-liberalisation (KDDP, 2001). This has had a negative impact on production as most animals succumb to parasite related diseases, and consequently low production and increased mortality rates. Some farmers have resorted to hand-spraying to control external parasites, which is even more expensive and ineffective compared to dipping.

Most dairy farmers have cited lack of quality feeds as a constraint to dairy production (Bebe et al., 2002). This is mostly common during the dry seasons as most plants are perennials. These forages have more cell wall constituents that restrict intake (Preston, 1995). The processed feeds, i.e., dairy meals are not only expensive but their quality is also questionable. Lack of feeds has been confounded by the continuous increase in human population in the agricultural potential areas, which has led to land fragmentation. This has reduced the space where pastures could be grown (Ojango and Pollott, 2001).

Lack of good infrastructure, i.e., roads and telecommunication in most of the rural areas where dairy production is practiced has affected the milk marketing system. This has been experienced in areas where farmers are far away from the market and therefore milk collection is not effective. Processors and hawkers offer farmers low prices for their milk as

they also face competition among themselves and from imported dairy products (KDDP, 2001). Because most dairy farmers, and especially the smallholders, operate individually, they cannot easily get access to credit facilities from banks to help them boost their production.

Since the liberalisation of the milk market, about 80% of dairy cattle breeding services in Kenya are in the hands of private individuals and AI schemes. The Government's AI services are only available on call and in certain areas. The charges of private AI schemes are expensive (Kenya shillings – KSh. 250 – 3,000) compared to the use of natural mating (KSh. 150 - 500), which has made most of the farmers to resort to the latter, and subsequently compromise the quality of their animals (Bebe et al., 2003). To curb this problem, it is essential to understand the various organizations that have been established before and after independence to handle genetic improvement of dairy cattle in Kenya.

2.1.4. Dairy cattle breeding and supportive organisations in Kenya

- Before the introduction of the European breeds, the local cattle population was dominated by the SEZ (Stotz, 1979). The upgrading of the SEZ cattle to combine adaptability to the local conditions and high milk yield through crossbreeding with European breeds started in the 1890's after the introduction of *B. taurus* breeds (HF, Jersey, Ayrshire, Guernsey, among others) from South Africa and Europe. The upgraded dairy cattle were used to initiate marketed dairy production on specialised large-scale farms (Bebe et al., 2002). Different input services and output market organisations were established to support marketed dairy production. The organisations established pre-independence included (Stotz, 1979).

- Veterinary Research Laboratories established in 1910 and mandated to carry out research on livestock diseases and parasites in the highlands and also to produce drugs and vaccines,
- KCC established in 1925 and was the organisation through which milk produced in all farming sectors was to be marketed,
- Animal Husbandry Station established in 1935 in Naivasha and mandated to carry out research on genetic improvement and nutrition,
- The CAIS established in 1946 with a mandate to acquire bulls or bull calves and produce good quality semen to be used in the commercial population for the county's breeding programs and
- Kenya Dairy Board (KDB) established in 1958 to regulate dairy marketing

After independence, the Kenya National Artificial Insemination Services (KNAIS) was established in 1966 to widen the distribution of AI semen to farmers (CAIS, 2000). Other institutions, which have played a role in the genetic improvement of dairy cattle in Kenya since independence include;

- Kenya Stud Book (KSB) whose obligation is to carry out ancestry registration and upgrading schemes of all animals,
- Kenya Milk Records (KMR), which was established to carry out milk recording, butter-fat testing and presenting records to CAIS for the Contract Mating Scheme (CMS) through which sires were acquired for national use. However, its collapse in 1990, affected the functions of CAIS as there were no good records to evaluate bulls. Genetic assessments, therefore, were pegged on the farmers' "know how", leading to erratic fluctuations in genetic progress (Rege, 1991b). Following the liberalisation of the dairy sector in 1992, the breed societies formed the Dairy Recording Service of Kenya (DRSK) in 1994 to perform the mandates of KMR. The DRSK is based in Nakuru and is a private and voluntary farmer's organisation under the patronage of the Agricultural Society of Kenya, and
- Livestock Recording Centre (LRC) is a section of the Department of Animal Production in the Ministry of Livestock and Fisheries Development. It is mandated to analyse data from the DRSK and make the results available for use in breeding programs (Ojango, 2000).

Figure 2 shows the interrelationship between the different organisations that are involved in dairy breeding in Kenya. The efficiency of the breeding programs in Kenya has been compromised by lack of proper co-ordination of these organisations, decline in government funding which has threatened their sustainability, and stiff competition from imported genetic materials and dairy products (Philipsson et al., 1988; Bebe et al., 2002). Following the liberalization of the dairy sector, there has been massive importation of genetic materials, especially semen from the USA, UK, Canada, Israel and The Netherlands (Ojango and Pollot, 2001). Currently, dairy breeding involves the use of both local and imported genetic material. The impact of germplasm importation on local milk production has been assessed in Kenya (Rege, 1991a; Ojango and Pollott, 2001). However, information on genetic and economic comparison between the use of local and imported genetic material under local production systems is lacking. Genetic and economic comparisons between strategies utilizing local and imported genetic material require knowledge of both productive and reproductive performances of different genotypes.

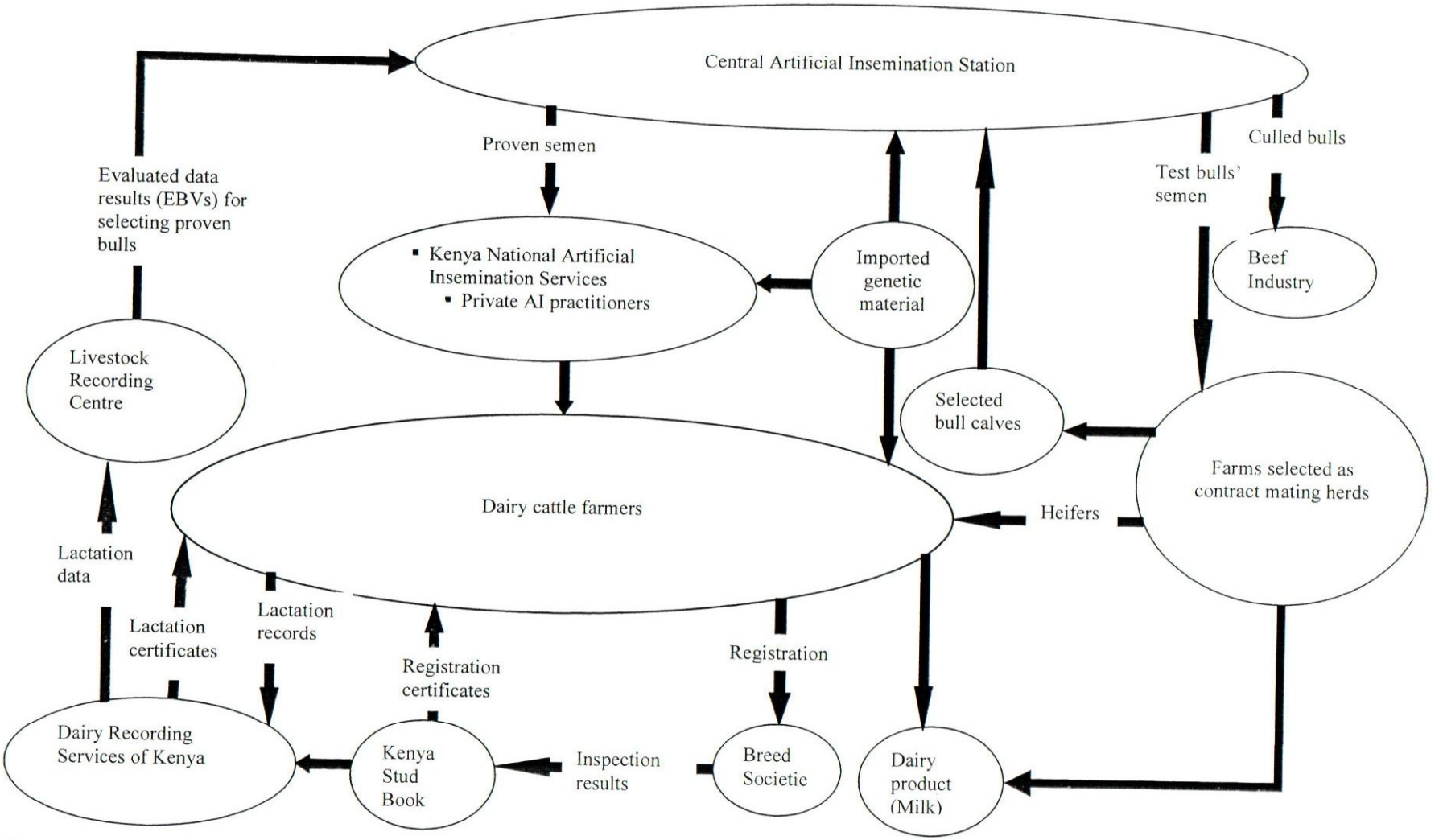


Figure 2. The inter-relationship between organisations involved in dairy cattle breeding in Kenya

2.2. Performance of some genotypes used for dairy production in the tropics

Most indigenous cattle genetic resources in the tropics are *B. indicus*. Through natural and artificial selection by indigenous communities keeping them over several generations, these animals are well adapted to the harsh environmental conditions prevailing in their localities (Syrstad and Ruane, 1998). These animals, however, have low potential for milk production, are late maturing, and do not let down milk easily unless stimulated by the suckling of the calf (Rege and Wakhungu, 1992; Syrstad and Ruane, 1998; Das et al., 2003). This has led to crossbreeding or to their replacement with high yielding exotic pure breeds. The performances of different exotic and indigenous genotypes and their crosses have been extensively studied in the tropics and the results are variable (Table 1).

2.2.1. Productive performances

Productive performances in dairy cattle are described by milk production traits such as 305-day milk yield, fat and protein yields and lactation length. Somatic cell count of milk has also been included in the selection criteria of many countries as a measure of susceptibility to mastitis (Schutz, 1994). There is variability in milk production traits (Table 1) as a result of the differences in genotypes, population sizes, levels of technology applied, conditions of production and selection. Comparisons between genotypes indicate that the *B. taurus* breeds produce more milk than the *B. indicus* and their crosses (Table 1). Among the *B. taurus* breeds, HF is the best producer. The HF is one of the breeds that have been highly selected for high milk yield over several generations (Ojango, 2000). Developing countries with large population sizes, high levels of technology application and conducive production conditions (e.g., Costa Rica) tend to achieve higher milk production compared to those with small populations sizes (Mpofu et al., 1993a; Ageeb and Hayes, 2000; Vargas, 2000; Ojango and Pollott, 2001). Strong negative genetic correlations have been reported between MY and its constituents (i.e., butterfat and protein content) (Maijala and Hanna, 1974; Pearson et al., 1990). In most countries in the tropics, however, protein and fat yields have not been considered in the breeding goal of dairy cattle as the market pays only for milk volume and not composition. Payment for volume instead of composition of milk may be due to low milk production that is not even able to satisfy the demand. Milk production from *B. taurus* breeds, especially HF, in Kenya has been increasing (Rege, 1991a; Ojango and Pollott, 2001) and compares well with those from other tropical countries (Table 1). This, to some extent, may be due to improved management and selection.

Table 1. Productive and reproductive performances of genotypes used for dairy production in the tropics

Genotype[b]	Traits[a]						Country	Source
	MY (kg)	PY (kg)	FY (kg)	LL (days)	AFC (days)	CI (days)		
HF	3,100				1,050	440	Kenya	Kiwuwa (1974)
,,	3,577		121		1,054	412	,,	Rege (1991b)
,,	5,056			300	837	406	,,	Ojango and Pollott (2001)
,,	5,117			363	756		The Sudan	Ageeb and Hayes (2000)
,,	4,791			294	961		Zimbabwe	Makuza and McDaniel (1996)
,,	5,830			300	720	372	,,	Mpofu et al. (1993a)
,,	4,000		117				Tunisia	Djemali and Berger (1992)
,,	6,855						Brazil	,,
,,	6,877		224				,,	Costa et al. (2000)
,,	6,000	158	202		837	390	Costa Rica	Vargas (2000)
,,	10,447						Israel	Weller (1989)
,,	7,204	226	253				South Africa	NDPT (1998)
,,	3,873						Egypt	Kassab (1995)
,,	2,808			271	1,147	455	Kenya	Kahi et al. (2004b)
A	2,573			253	1,147	471	,,	,,
G	2,189			269	1,080	486	,,	,,
J	1,872			242	1,026	430	,,	,,
,,	2,112				900	412	,,	Musani and Mayer (1997)
,,	4,000				837	390	Costa Rica	Vargas (2000)
S	1,868				1195	390	Kenya	Trail and Gregory (1981)
KS	2,519				1085	415	India	McDowell (1985)
BS	3,177			316		398	Kenya	Kahi (2000)
P	965			226			Bangladesh	Das et al. (2003)
HF x S	2,750			260			,,	,,
HF x P	2,069			228			,,	,,
S x P	1,546			250			,,	,,
S x BZ	1,482			254		454	,,	Sultan et al. (2001)

[a]MY = milk yield; LL = lactation length; AFC = age at first calving; CI = calving interval; PY = protein yield; FY = fat yield.
[b] HF = Holstein Friesian; A = Ayrshire; J = Jersey; G = Guernsey; S = Sahiwal; P = Pabna; BZ = Bangladesh Zebu; S*HF = Cross between S and HF; HF x P = Cross between HF and P; S x P = Cross between S and P; S x BZ = Cross between S and BZ; KS = Karan Swiss; BS = Brown Swiss.

Generally, MY in the tropics are lower than in the temperate countries. In the temperate countries there are large dairy cattle populations, utilisation of new technologies, and intensive and well-focused selection programs in the temperate countries (Pearson et al., 1990). Environmental stresses, i.e., poor quality feeds, heat, and disease and parasite challenges in the tropics are also contributing factors to low MY. As mentioned earlier, forages in the tropics have more cell wall constituents than forages in the temperate environments, which restricts intake (Preston, 1995). In addition, differences in economic constraints and agricultural policies influence herd management practices implemented, and consequently contribute to the low performances (Ojango and Pollott, 2002).

The total MY of about 2,808 and 2,573 kg for HF and Ayrshire, respectively, obtained by Kahi et al. (2004b) indicates that Ayrshire can also do well under good management and therefore further studies on this breed are necessary as it can offer an alternative to HF. Ojango (2000) compared the performances of HF, Ayrshire, Jersey and Guernsey in small-scale dairy production systems in Kenya and ranked them according to productive and reproductive performances. Jersey ranked first followed by Guernsey and Ayrshire, while HF ranked lowest. This indicates that small breeds like Jersey, Guernsey and their crosses are good for smallholder farms because they are hardy and their feed requirements are lower compared to the larger breeds (i.e., HF and Ayrshire).

2.2.2. Reproductive performances

Reproductive performances have greater impact on MY per lactation, overall lifetime production, number of calves born and, therefore, overall profitability of the farm (Boichard, 1990). Female reproductive traits include age at first breeding in heifers, AFC, CI, number of inseminations per conception and days open while those specific to males are sperm quality and quantity (Jansen, 1985; Ojango, 2000). Factors affecting the reproductive performances in dairy cattle have been extensively documented (Darwash et al., 1997).

Variation in the reproductive performances of dairy cattle breeds in the tropics is evident (Table 1). This can be explained by differences in management practices. In Kenya, the HF heifers have an AFC of 837 days (Ojango and Pollot, 2001). This AFC is shorter than the 1,054 days reported in earlier studies (Rege, 1991b), indicating improvement of production conditions because breeding practices of the producer mainly influence this trait. When compared with other herds in the tropics, the Kenyan HF heifers calved for the first time at an older age than their counterparts in Zimbabwe and the Sudan (Table 1). This could be due to the fact that HF heifers in Kenya were bred for the first time at the age of 540 days

compared to 450 and 486 days in Zimbabwe and the Sudan, respectively (Mpofu et al., 1993a; Ageeb and Hayes, 2000; Ojango and Pollott, 2001). Early breeding of heifers requires sound management practices such as oestrus detection and determination of time of insemination. However, very early breeding of heifers has negative consequences like calving difficulties, low milk production and poor general body condition and therefore should not be advocated. Compared to other dairy cattle breeds in Kenya, HF heifers have younger AFC compared to Ayrshire (1,147 days) and Jersey (900 days) (Musani and Mayer, 1997; Kahi et al., 2004b). This can be explained by the special attention given to HF cattle by Kenyan producers due to their genetic potential to produce more milk compared to other breeds.

The CI for most of the genotypes in the tropics is more than one year (Table 1). Calving interval is important in dairy production as it determines the availability of replacement stock. Prolonged CI is undesirable, especially in production systems with high demands for pregnant or lactating heifers, which is the situation in most developing countries. Prolonged CI could be as a result of the negative phenotypic correlation between MY and CI, or negative energy balance during early lactations which affects the onset of oestrus (Ojango and Pollott, 2001). Previous studies have indicated that high yielding animals are associated with longer days open and therefore longer CIs (Weller, 1989). In summary, both productive and reproductive performances are important in the development of breeding objectives.

2.3. Development of breeding objectives

Productive and reproductive performances are important when designing breeding objectives for genetic improvement as they determine the profitability of the herd (Ponzoni and Newman, 1989). The primary requirement of any genetic improvement program is the development of a well-defined breeding objective. The breeding objective is a weighted combination of traits to be genetically improved due to their economic importance to the producer. They should be comprehensive and incorporate all the needs and economic interests of the producers as well as ecological conditions (Sölkner et al., 1998). Development of a breeding objective requires information on performance levels, the production systems, available genetic resources, and other production and economic information such as prices and their changes (Ponzoni and Newman, 1989). Four main phases are involved in the development of a breeding objective: (i) specification of the breeding, production and marketing systems; (ii) identification of sources of income and expenses; (iii) determination of biological traits influencing revenues and costs; and (iv) derivation of economic values for each trait in the breeding objective (Ponzoni and Newman, 1989).

2.3.1. Specification of breeding, production and marketing systems

Specification of the breeding systems involves identification of the importance of the breed or breeds for which the breeding objective is being developed (Ponzoni and Newman, 1989). Dairy cattle breeds such as HF, Ayrshire, Jersey, Guernsey and their crosses are mainly used for milk production. However, culls and males not selected for breeding are sold for meat production. The choice of traits in the breeding objective is only feasible when the target groups are involved because this will reduce the risk of the breeding goal being ignored by the producers (Amer et al., 1998).

Specification of production and marketing systems includes the description of how animals are fed and managed, the age composition of the herd and the replacement policy (Ponzoni and Newman, 1989). The economic evaluation of breeding objectives is scarce in developing countries because it should account for inputs, i.e., feeds, husbandry and marketing costs as well as outputs, i.e., revenues from milk, surplus offspring and culled cows, which are difficult to quantify in production circumstances in these countries due to lack or poor recording at the farm level.

2.3.2. Identification of sources of income and expenses

The development of a profit function for a production system requires the identification of the actual sources of income and costs. The main sources of costs include variable and fixed costs. Variable costs are those costs that are influenced by the level of herd production and include feeding, health, labour, reproductive, marketing of milk and culled cows. Fixed costs are costs incurred by the producer (i.e., costs attributable to equipment, machines and farm structures) independent of the level of herd production (Ponzoni and Newman, 1989) except when the herd is expanded. Sources of income in a dairy production enterprise are revenues from sale of calves, milk, culled heifers and aged cows (Kahi et al., 2004a).

2.3.3. Determination of biological traits influencing revenues and costs

In the development of a breeding objective, the traits that influence revenues and costs need to be identified (Ponzoni and Newman, 1989). Breeding objectives for dairy cattle in Kenya have been defined (Kahi et al., 2004a). The breeding objectives include production (MY and FY), reproductive (AFC and CI), growth (live weight, pre-weaning daily gain, post-weaning daily gain and mature live weight), and longevity and survival traits (pre-weaning survival rate, post-weaning survival rate and productive lifetime). The inclusion of CI in the

breeding objective was important because in Kenya, prolonged CI has led to unavailability of replacement heifers and low annualised MY, especially in the smallholder dairy farms (Kahi, 2000). Pre-weaning survival rate coupled with post-weaning survival rate, contribute to higher net calf crop, leading to higher number of animals reaching the breeding age and consequently availability of replacement stock. This is important in the tropics where costs of production depend on the animal's ability to cope with the prevailing environmental conditions (Rege, 1998).

2.3.4. Derivation of economic values for each trait in the breeding objective

Development of a breeding objective involves estimation of economic values for all the traits that are of interest to the producer (James, 1982). The economic value for a trait can be defined as the improvement in profitability resulting from a unit of genetic improvement in a given trait, all other traits being held constant (Groen, 1990). The economic evaluation of breeding objectives is scarce for cattle in the developing countries of tropics because of greater environmental and managerial complexities involved (Franklin, 1986). This has often led to the definition of the breeding objectives in biological terms, which express costs and revenues in energy and/ or protein terms as opposed to monetary terms. Since all costs and revenues can not be expressed in energy and/ or protein terms, an economic definition becomes important (Groen, 1990). Generally bio-economic modelling (normative procedures) and analysis of field data (positive approaches) can be used to derive the economic values. The best method, however, depends on the traits of interest and production circumstances under consideration (Groen et al., 1997). The positive approach has a drawback of using historical prices yet breeding is future-oriented. Bio-economic models derive economic values by studying their reaction to changes in endogenous elements representing the genetic merits of the animal for a specific trait without changing other traits (Groen, 1990).

Partial budgeting and partial differentiation methods can be used to derive the economic values in bio-economic modelling. Partial budgeting involves the comparison of herd profitability before and after genetic improvement. In partial differentiation, economic values are obtained as the partial derivatives of profit per cow with respect to the trait of interest (Groen et al., 1997). The fixed costs can then be ignored because terms not involving the trait of interest disappear when obtaining the partial derivative of profit per cow in the herd (Smith, 1978). The economic values for traits in the breeding objectives in the two dairy production systems (i.e., smallholder and large-scale) that are characteristic for most systems in Kenya have been estimated (Kahi and Nitter, 2004).

2.4. Genetic and phenotypic parameters

Genetic and phenotypic parameters (heritability, repeatability and correlations) are ratios of (co)variance components. They are essential in the evaluation and selection of animals because they enable the breeders to predict responses to selection, select between various breeding strategies, choose appropriate traits to measure and predict breeding values of animals (Falconer and Mackay, 1996). Their accuracy is important when designing a breeding program for genetic improvement of dairy cattle (Kahi, 2000; Ojango, 2000). Many studies have reported variable genetic and phenotypic estimates for productive, reproductive and survival traits in cattle (Davis, 1993; Koots et al., 1994a and b; Lôbo et al., 2000). The estimates of genetic and phenotypic parameters for different traits in dairy cattle under tropical conditions are presented in Table 2. These estimates tend to vary from one population and environment to another depending on population history, genotypes and environmental effects, data size and structure, and method of analysis (Lôbo et al., 2000). It is therefore not recommended to apply estimates from one population to another. This is however difficult to achieve in practice, and therefore estimates are usually developed from search of the literature (Koots et al., 1994a and b).

2.4.1. Heritability

Heritability is the proportion of phenotypic variances that is due to heredity. The proportion of genetic improvement depends on the heritability of the trait and its relationship with other traits of economic importance. It plays a predictive role in genetics, by expressing the reliability of the phenotypic value as a guide to the breeding value (Schutz, 1994). Heritability can be classified as narrow or broad sense. Narrow sense heritability is the additive gene actions or average effects, which the individual genes posses in a population, while in addition to additive gene action, broad sense heritability also includes effects due to dominance and epistasis (Falconer and Mackay, 1996). Heritability values range from zero to one. Characters can be classified as having high (>0.5), medium (0.25-0.5), or low (<0.25) heritability. Traits with high heritability estimates (>0.5) have a greater genetic control and therefore can effectively be improved through selection.

able 2. Estimates of genetic and phenotypic parameters of productive and reproductive traits of dairy cattle genotypes in the tropics

enotype[a]	Traits 1[b]	Traits 2[b]	Model[c]	Parameters[d]				Country	Source
				h^2	r	$r_{g(1,2)}$	$r_{p(1,2)}$		
HF	MY	MY	SM	0.34	0.55			Kenya	Rege (1991a)
,,	,,	,,	RAM	0.29	0.34			,,	Ojango and Pollott (2001)
,,	,,	,,	,,	0.30	0.22			The Sudan	Ageeb and Hayes (2000)
,,	,,	,,	SM	0.35				Zimbabwe	Makuza and McDaniel (1996)
,,	,,	,,	RAM	0.30				Brazil	,,
,,	,,	,,	SM	0.38				Turkey	Sultan et al. (2001)
J	,,	,,	,,	0.21	0.24			Kenya	Musani and Mayer (1997)
S	,,	,,	,,	0.27	0.46			,,	Rege and Wakhungu (1992)
,,	,,	FY	SM			0.95	0.75	,,	Rege (1991a)
,,	,,	LL	RAM				0.72	The Sudan	Ageeb and Hayes (2000)
,,	,,	AFC	,,			0.54	-0.2	Kenya	Ojango and Pollott (2001)
,,	,,	CI	,,			-0.64	0.37	,,	,,
,,	,,	,,	SM			-0.32	0.11	,,	Rege (1991a)
,,	FY	FY	,,	0.23	0.50			,,	,,
S x HF	,,	,,		0.44	0.44			Bangladesh	Sultan et al. (2001)
,,	,,	AFC				0.05	-0.10	,,	,,
,,	,,	CI				0.08	0.08	,,	,,
,,	,,	,,	SM			-0.08	0.88	Kenya	Rege (1991a)
,,	LL	LL	,,	0.13				,,	,,
,,	,,	,,	RAM	0.09	0.11			,,	Ojango and Pollott (2001)
,,	,,	,,	,,	0.23	0.00			The Sudan	Ageeb and Hayes (2000)
,,	,,	CI				0.15	0.15	,,	,,
,,	AFC	AFC	RAM	0.38				Kenya	Ojango and Pollott (2001)
J	,,	,,	SM	0.13				,,	Musani and Mayer (1997)
HF	,,	CI	RAM			0.89	0.02	,,	Ojango and Pollott (2001)
,,	CI	,,	,,	0.05	0.06			,,	,,
J	,,	,,	SM	0.00	0.03			,,	Musani and Mayer (1997)

IF = Holstein-Friesian; J = Jersey; S = Sahiwal and S x HF = Cross between S and HF.
MY = milk yield; LL = lactation length; AFC = age at first calving; CI = calving interval; FY = fat yield.
M = sire model; RAM = repeatability animal model.
^{2} = heritability; r = repeatability; $r_{g(1,2)}$ = genetic correlation between trait 1 and 2; $r_{p(1,2)}$ = phenotypic correlation between trait 1 and 2.

Heritability estimates for productive and reproductive traits of dairy cattle in the tropics are variable (Table 2). As eluded earlier, this could be due to the differences in herd size, model of analysis, breed and environment under which the data is obtained (Falconer and Mackay, 1996). Breed variations can be explained by differences in genetic potential of different genotypes for traits of interest and the effects on additive genetic variation due to the level of selection. Variation due to model of analysis used is also evident (Table 2). Sire models have high estimates because they do not account for the females' contribution compared to animal models and therefore they tend to be biased (Meyer, 1987; Cassell, 1988).

Generally, the heritability estimates for the productive traits (MY and FY) are higher than for reproductive traits (CI and AFC) (Table 2). Whereas high heritability estimates for productive traits are due to the high genetic variances attributed to these traits, female reproductive traits are highly influenced by the environment (Koots et al., 1994a). Compared to estimates in temperate countries, the heritability estimates in the tropics are low (Cue et al., 1987; Dematawewa and Berger, 1998; Ojango and Pollott, 2001). This is because population sizes of dairy cattle in the tropics are too small to provide sufficient data for accurate estimation of genetic and phenotypic parameters.

High heritability estimates for AFC indicate a potential of improving this trait through selection while low estimates for CI imply that the environment rather than genes mainly influences this trait (Table 2). Therefore, CI can be improved through enhanced management practices. The heritability estimates for reproductive traits in the tropics compares well with those in the temperate regions (Dematawewa and Berger, 1998; Ojango and Pollott, 2001).

2.4.2. Repeatability

Repeatability is the within individual variance and computed as the correlation between the repeated measurements (Falconer and Mackay, 1996). It depends on the nature of the character, genetic properties of the population and the environmental conditions under which an individual is raised. It is an important measure of accuracy of gains expected from multiple measurements (Schutz, 1994). The variability in repeatability estimates for both productive and reproductive traits of dairy cattle in the tropics is mainly based on differences in genotypes and models of analysis (Table 2). Productive traits (MY, FY and LL) have higher estimates than reproductive traits (CI)

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(Table 2). It means that productive traits are under the influence of genes whereas reproductive traits are more under temporary environmental influences. Consequently, selection can play a major role in improving productive traits while manipulation of the production environment will improve reproduction traits (Ojango and Pollott, 2001).

2.4.3. Correlations

Correlated response is an automatic response in the unselected trait occurring simultaneously with the response in the trait under selection. Correlations can be classified as genetic or phenotypic. Phenotypic correlations among traits are the gross correlations that include both environmental and genetic portions of the co-variances while genetic correlations indicate how two traits are affected by the same genes (Kahi, 2000). Correlations are important because they directly affect the size of the selection differentials when several traits are used in the selection index, especially when the correlations are high (Kahi et al., 2004a). Genetic correlations are grouped into direct genetic correlations attributable to an individuals' gene set, and maternal genetic correlations attributed to maternal effects. Correlations generally range from -1 to +1 (Falconer and Mackay, 1996).

Genetic and phenotypic correlations between production traits (MY, FY and LL) are positive and approach unity (Table 2). This suggests that selection for high MY combined with improved management, leads to improvement in FY. Age at first calving and CI also have strong positive genetic correlations between them. The negative genetic correlations between productive traits (MY and FY) and CI (Table 2) imply that genes that positively affect MY and FY likely reduce CI. However, a positive phenotypic correlation between them indicates that animals that produce more milk have longer CI. This confirms that the antagonistic relationship between productive and reproductive traits in animals that have been selected for high milk yield is due to environmental factors rather than genetics (Rege, 1991b; Campos et al., 1994; Dematawewa and Berger, 1998; Ojango and Pollott, 2001). It therefore becomes necessary to consider relationships between traits when evaluating dairy cattle breeding strategies and structures.

2.5. Dairy cattle breeding strategies and structures

2.5.1. Breeding strategies

Breeding strategies are breeding components integrated into a structured system of genetic improvement with an aim of maximising the breeding goal (Bondoc et al., 1989). These strategies can be based on local selection programs or on imported genetic material (Smith, 1988).

Progeny testing scheme

Progeny testing is the process of selecting and ranking males on genetic merits based on the performance of their progeny (Dekkers and Shook, 2001). Its efficiency in genetic gain is influenced by the number of daughters that reach milking age, number of herds in which the daughters are milked, the distribution of the daughters across herds, number of bulls and the intensity of subsequent culling (Rege and Wakhungu, 1992; Dekkers and Shook, 2001). The use of this scheme for genetic improvement of dairy cattle in the developed countries has been successful due to large dairy cattle populations, widespread milk recording schemes and extensive use of AI. However, in the developing countries, the scheme has proved to be inefficient owing to various constraints, e.g., small herd size, lack of systematic identification of animals, poor performance and pedigree recording and lack of funds and expertise for efficient operation of improvement programs based on AI (McGuirk, 1989; Rege and Wakhungu, 1992; Mpofu et al., 1993a; Kahi et al., 2004a).

Young bull system (YBS)

This strategy involves utilization of untested young bulls selected on the basis of pedigree information as sires of daughters in both the nucleus and commercial populations. These bulls are slaughtered after semen has been collected and stored until the daughters' records are available to select the best semen for future mating (Niebel and Fewson, 1978). The use of the YBS for dairy cattle breeding was first raised by Owen (1975). That study concluded that YBS are more profitable than conventional OBS because low costs are involved. Recent studies in the tropics have also confirmed the profitability of YBS over OBS schemes (Mpofu et al., 1993a; Nitter, 1998; Kahi et al., 2004a). In Zimbabwe, Mpofu et al. (1993a) reported high NPV for YBS while Nitter (1998) reported that YBS are superior to OBS in profit but

are inferior in terms of genetic gains. Using deterministic simulation to examine a two-tier open nucleus breeding scheme using young bulls to evaluate genetic and economic efficiency of different breeding objectives for dairy cattle in Kenya, Kahi et al. (2004a) concluded that in a well organised two-tier open breeding program, use of young bulls is profitable and results in overall improvement of production in dairy cattle. This system might therefore be the best for developing countries where profit maximization rather than genetic gains is the major interest (Nitter, 1998).

Importation of genetic material

Programs exist in which genetic improvement of the local stock is based on imported genetic material (i.e., semen) and therefore no selection is done within the domestic population. These programs include strategies such as continuous importation of semen and establishment of domestic breeding nucleus of exotic stock by importing females and males of high genetic merits, and then breeding the nucleus continuously by high merit exotic semen (Smith, 1988). As indicated earlier, most developing countries have created nucleus dairy herds from exotic breeds but they still rely heavily on imported genetic materials to breed them (Bondoc et al., 1989). For instance, out of the 354 recorded grand-sires and sires used between 1986 and 1997 in both large-scale and smallholder farms in Kenya, 71% were imported (Ojango and Pollott, 2001). Studies also indicate that daughters of dairy cattle sired by foreign bulls are preferred to those sired by local bulls (Ojango et al., 2005). Consequently, daughters sired by local bulls are at higher risks of being voluntarily culled than those sired by foreign bulls.

Importation of semen of high genetic merit to improve milk production in the tropics continues to increase as restrictions on marketing across borders ease (Ojango and Pollott, 2002). The rate of genetic progress achieved from imported genes depends on migration rate and the initial difference in genetic mean between the exporting and importing populations. Breeding strategies based on unrestricted transfer of germplasm and genetic stock of moderate price but above average quality across boundaries has been found to have higher genetic responses than the use of local genes (Mpofu et al., 1993a). Smith (1988) recommended for developing countries with unimproved stock and scarce resources for testing and selection, the adoption of breeding strategies based on importation or on MOET. The use of MOET has been made possible through perfection of methods of recovering, storing and

implanting cattle embryos (Cunningham, 1999). It is now possible to superovulate cows and recover embryos non-surgically. Multiple ovulation and embryo transfer increases the reproductive rate of females, leading to reduced number of dams needed to be selected for the next generation and increased amounts of information available on sibs for estimation of breeding values of males and females for selection (McGuirk, 1989).

Importation of genetic material is only recommended when; the exotic stocks are genetically better than the domestic stock, the selection objectives of the importing and exporting countries are similar and when the G x E are not important. When genotypes are moved from an environment where their genetic values are known to a similar environment, the performance is likely to be the same. However, the performance may be greatly affected in a different environment. Previous studies have confirmed that the performances of high yielding dairy cattle breeds from temperate countries are often negatively affected in the tropics (Bondoc et al., 1989; Rege, 1991a; Ojango and Pollott, 2002). Therefore, G x E between populations is important in determining the rate of genetic progress when animals migrate to a different environment, and should be given the same consideration as the initial genetic difference between populations.

The use of continuous importation of genetic materials does not require local breeding programs as an insurance against future import uncertainties because there will be a large population of improved stock in the importing country (Smith, 1988). However, it may lead to loss of the native stocks. Therefore, conservation of the endangered stocks by storing semen or embryos and maintaining live breeding stocks to preserve their genetic variation as an insurance against uncertain future conditions and requirements is paramount (Bondoc et al., 1989).

2.5.2. Breeding structures for the dissemination of superior genes

The use of nucleus breeding schemes in developing countries has been recommended because they require few resources, as trait recording and genetic evaluations are done only in the nucleus (Smith, 1988). Depending on the complexity and requirement of the breeding program, a nucleus scheme, which is analogous to a pyramid structure, can have different number of tiers and migration policies (Roden, 1994). Generally, at the peak of the pyramid is the nucleus whose main purpose is selection of superior animals while below it are the multipliers and the commercial

populations that source the genetic materials (i.e., semen and embryos) from the nucleus (Bondoc and Smith, 1993). In the dairy industry, the multipliers are less important because AI enables direct gene flow from the nucleus to the commercial population (Garrick, 1993). The breeding nucleus can be classified as either open or closed.

Closed nucleus schemes

In a closed nucleus scheme, male replacement stock for the nucleus herds are selected only within the nucleus and no importation is done from the commercial population, resulting in a one-way flow of genes. This scheme is only possible when the necessary infrastructure are in place due to the required high level of organization and expertise, and use of reproductive technologies evident in industrialised countries (Cunningham, 1999). Closing the nucleus initially has the advantage of blocking unimproved genetic material from the commercial populations to compromise the genetic gain made in the nucleus. Genetic improvement in the lower tiers is through the use of genetically superior males and females not selected for replacement in the nucleus (James, 1977). The nucleus can be opened, by introducing above average bull-dams from the co-operating herds, after considerable genetic gains have been achieved in the commercial population. The basis of this is that some animals in the co-operating herds might be genetically superior to some nucleus animals due to Mendelian sampling (Garrick, 1993).

Open nucleus schemes

This is a scheme in which the female nucleus replacements are selected from the nucleus and the lower tiers (i.e., multiplier and commercial populations) but male replacements are only selected from the nucleus-born animals, leading to a two-way gene flow (Roden, 1994). The movement of animals from the lower tiers to the nucleus is recommended because, as alluded earlier, Mendelian sampling can generate superior offspring to the average of the parents in the commercial population (Garrick, 1993). This movement is also beneficial when selecting for lowly heritable traits, as lower response per generation would reduce the genetic lag between the nucleus and the commercial population (James, 1977). The establishment of two-tier open nucleus breeding systems to maximise genetic improvement, to reduce the rate of inbreeding and to reduce the total cost of recording in the commercial populations has been

recommended (Bondoc and Smith, 1993). The two-way flow of genes enables open nucleus schemes to be 10% superior in genetic gain to closed nucleus schemes of the same size. This is because of higher expected mean genetic value of nucleus replacements and integration of farmers' resources, resulting from the participation of more farmers and therefore reduced overhead costs (Bondoc and Smith, 1993; Roden, 1994). It is, however, important to evaluate alternative breeding strategies and structures in order to provide appropriate advice to dairy farmers on what to adopt.

2.6. Evaluation of breeding strategies and structures

2.6.1. Genetic evaluation of breeding strategies and structures

The use of conventional methods of quantitative genetics and animal breeding has played a crucial role in genetic evaluation of breeding strategies and structures (Dickerson and Wilham, 1983). However, in future, molecular biology and its related disciplines may provide new and powerful methods of genetic evaluation of breeding programs, schemes and strategies (Smith, 1988). The conventional methods of genetic evaluation depend on intensities and accuracies of selection, additive genetic standard deviations and generation intervals in the different pathways of selection (Rendel and Robertson, 1950).

Evaluation of animal breeding programs involves genetic, economic and environmental factors. These factors interact with each other in a complex manner, making it impossible for an individual to assess with confidence the consequences of alternative breeding programs. Simulation, however, can be used to analyse such complex interactions because it uses classical principles of quantitative genetics theory (Nitter et al., 1994). Simulations have been successfully used to evaluate breeding strategies and structures, examine the effects of the genetic changes on profit or production efficiency, and to derive economic values of traits in different production systems. Simulation is the process of data generation using a computer program to mimic reality. It involves the development of ideas and concepts about the operation and control of a system from data obtained during experimentation (France and Thornley, 1984). Simulation makes it possible to assess with confidence the consequences of alternative breeding and management strategies on the efficiency of production or long-term profitability of an enterprise. Computer simulation uses different models such as deterministic, stochastic and a hybrid of the two. A

deterministic simulation model involves the development and use of theories that utilize mathematical equations to predict results of interest with absolute certainty while stochastic simulation models involve generation and propagation of populations at the animal level (Kinghorn, 1993).

In the recent past, simulation models have been developed to analyse breeding programs for different animal species. Ruane and Thompson (1989) used Monte Carlo simulation procedures to estimate the efficiency of a closed adult MOET nucleus in dairy cattle with discrete generations Dekkers and Shook (1990) employed semi-stochastic simulation to economically evaluate alternative breeding programs for commercial AI firms in the USA. Mpofu et al. (1993a and b) used deterministic simulation models to genetically and economically evaluate different breeding strategies for improvement of dairy cattle in Zimbabwe. Vargas and van Arendonk (2004) also applied a deterministic simulation approach to compare breeding schemes based on imported semen and local breeding schemes for Costa Rican HF dairy cattle population. In Kenya, simulations have also been used to evaluate different breeding programs in the dairy industry. Kahi et al. (1998) and Kahi et al. (2004a) used deterministic simulation models to evaluate the influence of production circumstances and economic comparison of breeds and breed crosses, and alternative objectives and schemes using a two-tier open nucleus and the YBS, respectively. Kosgey et al. (2005) evaluated closed adult nucleus MOET and conventional PT breeding schemes for milk production in tropical crossbred cattle using deterministic simulation. In the current study, deterministic simulation was used to genetically and economically evaluate four breeding strategies for improvement of dairy cattle in Kenya. These strategies were compared based on their economic responses using gene flow procedures (Hill, 1974) and selection index methodology (Hazel, 1943).

2.6.2. Economic evaluation of breeding strategies and structures

Like any other development projects, breeding programs need to be evaluated in order to assess their future success or failure. Evaluation of projects is not only limited to the completed projects but on-going projects also require appraisal. The commonly used method of project evaluation is cost-benefit analysis (Perman et al., 1999). This method is used in circumstances where important components of the real costs and benefits of a project are not adequately represented by the market prices or would not be traded through the market at all (Randal, 1987), which is characteristic

of breeding programs in developing countries. The two types of cost-benefit analysis used in analysing agricultural projects include financial and economic analysis (Gittinger, 1982).

Financial analysis is the assessment of the project's viability from the individual's or agency's points of view. Project evaluation is mainly practiced in the developed countries where most of the industries are owned by individuals or agencies (Fewson, 1989; Dekkers and Shook, 1990). Economic analysis is where the viability of the project is assessed by considering the welfare of the whole nation. In developing countries, this type of cost-benefit analysis is more appropriate for project evaluation because most of the projects are government sponsored (Gittinger, 1982; Mpofu et al., 1993b). Both financial and economic types of cost-benefit analyses have several analytical criteria that can be used to select a project from several projects available for implementation. These criteria include NPV, benefit cost ratio (BC), internal rate of return (IRR) and net benefit investment ratio (NK) (Gittinger, 1982; Randal, 1987). Generally, there is not much to choose among these four criteria for the purposes of analysing and ranking projects (Randall, 1987). Although NK is the preferred method of ranking independent projects, it can only be used to rank mutually exclusive projects when the net benefit investment ratios of all the projects are known. In practice, this would be either impossible or analytically very complex and therefore NPV is commonly used.

Net present value has been used widely by animal breeders as a financial and an economic evaluation criterion to evaluate economic merits of breeding strategies and structures (Fewson, 1989; Dekkers and Shook, 1990; Mpofu et al., 1993b). The NPV is easy, straightforward and can be used to rank mutually exclusive projects, which is a characteristic of the breeding strategies and structures. Mpofu et al. (1993b) used NPV as an economic criterion to compare the economic benefits of breeding strategies utilizing local and imported genetic materials for improvement of MY in Zimbabwe. In that study, it was observed that local PT, PT utilising foreign bulls as sires of sons and continuous embryo importation were the only strategies with positive NPV. This means that these were the only strategies that could recover the investment costs when discounted at an opportunity cost of capital. In the same study, NPV was also used to rank the breeding strategies. The results obtained by Mpofu et al. (1993b) were, however, contradicting those obtained by Fewson (1989) and Dekkers and Shook (1990). The latter compared the economic merits of MOET and

PT schemes using NPV as financial analyses criteria. These studies showed that even though PT was more profitable than MOET schemes, the latter is also economically viable. Response to selection therefore becomes necessary to make decisions on breeding schemes to be utilized for genetic improvement.

2.7. Response to selection

Response to selection is the difference between the mean genetic value of the progeny of selected parents and that of progeny of all possible parents. It can be classified as direct (i.e., change on a trait due to selection directed at the same trait), correlated (i.e., change in a trait due to selection based on another trait), expected (estimated selection response based on genetic and phenotypic parameters) or realised (change in a trait from field evaluation) (Pirchner, 1983). Selection response is a function of selection intensity and accuracy, additive genetic standard deviation of the breeding goal and the generation interval (Rendel and Robertson, 1950). Generally, the estimation of selection response is done based on the four main selection pathways; sires to breed sons (SS), sires to breed daughters (SD), dams to breed sons (DS) and dams to breed daughters (DD). It is calculated as:

$$R = \frac{\sum i_j \times r_j \times \sigma_H}{\sum L_j} \qquad [1]$$

where R is the response to selection, i the selection intensity, σ_H the standard deviation of the breeding goal, j the selection pathways along which genetic material is transmitted from one generation to the next and L generation intervals.

The standard deviation of the breeding goal specifies the variability and the units of measurement of traits of interest and in most cases it is constant. Therefore, acceleration of genetic progress can be achieved through increased selection intensity, accuracy and reduced generation interval (Dekkers, 1993). The magnitude of selection response also depends on whether the generations are overlapping or not. An overlapping generation is where improvement in performance in successive years from one round of selection is variable (Hill, 1974). This is because genes from the selected parents may take many years to be possessed by the population. Selection responses can therefore be estimated using gene flow procedures that take into account generation differences (McClintock and Cunningham, 1974). To achieve good response, selection criteria must be chosen carefully.

2.7.1. Selection criteria

In the development of a breeding objective, all the traits of economic importance to the producer should be included in the breeding objective. Some of these traits, however, have low heritability, are expensive to measure or may not be expressed by the animal. Consequently, breeders have resorted to use of indicator traits on decisions pertaining to the improvement of traits of interest. These indicator traits are called selection criteria, and can be defined as measurable characters that can be used to predict the breeding values of traits in the breeding goal (Nitter et al., 1994). In dairy cattle, traits such as fertility in both males and females and mastitis in lactating cows cannot be measured directly as they are complex non-yielding traits (Thaller, 1998). Age at first breeding in heifers, CI, non-return rate, number of inseminations per conception and days open have been used as criteria traits for fertility in cows while semen quality and quantity, and scrotal circumference are used to measure male fertility (Jansen, 1985; Ojango, 2000). Currently, somatic cell count has been included in the selection criteria to measure mastitis in lactating dairy cows in the developed countries (Schutz, 1994). Mortality rates, tolerance to disease and parasites, and long productive lifetime can be used as indicators of survival traits. These indicators should be weighted and included in the selection index to maximize the correlation between the index and the breeding objective (Hazel, 1943). The accuracy of selection of the objective traits can be increased by adjusting the criteria traits for non-genetic effects and by increasing information sources and the number of selection criteria traits (Harris et al., 1984). This can be done using the selection index methodology.

2.7.2. Selection index methodology

The selection index method involves combining the measurements of two or more characters into a single value for each individual (Dickerson, 1969). Hazel (1943) developed a method of combining information from several sources to predict genetic merit of an animal. Selection index is a linear combination of various types of phenotypic information and appropriate weighting factors. Selection indices generally take the form of:

$$b = P^{-1}Gv \qquad [2]$$

where b is a vector of index weights, P the phenotypic variance-covariance matrix of the traits in the selection criteria, G the genetic variance-covariance matrix between the traits in the criteria and those in the breeding objective and v a vector of the economic values of traits in the breeding goal.

Genetic and economic indexes are the two major components of selection index methodology (Henderson, 1953). The genetic index ($P^{-1}G$) is a measure of the animal's ability to transmit genes to the next generation. It makes the best estimates of an animal's ability to transmit genes to the next generation by discounting the effects of its management regimes and other environmental factors, making it possible to compare animals in different herds managed under different systems (Hazel et al., 1994). The economic index (v) is the combination of weighting factors and genetic information (phenotypic data or genetic predictions) on more than one trait. Selection index weights can be computed for each trait as a function of genetic and phenotypic parameters, and economic values for traits. The accuracy of genetic and phenotypic parameters of traits of interest should be ascertained by testing the variance-covariance matrices created to check if they satisfy the permissibility criteria as described by Foulley and Ollivier (1986). The selection index methodology, however, is not commonly used in estimating breeding values in dairy cattle. This is because it cannot utilize all possible information sources available, and therefore result in biased results (Lin, 1978). This shortcoming of selection index methodology led to the development of BLUP procedures, which can utilize all the relationships in animals and therefore more accurate estimates (Henderson, 1975). Even though BLUP has been adopted as the method of choice in the evaluation of breeding values, selection index methodology still remains a useful tool for approximating the accuracy of BLUP selection and predicting selection responses. It was therefore used in the present study.

2.7.3. Best Linear Unbiased Prediction (BLUP)

Best linear unbiased prediction is a statistical procedure that combines selection index and linear model principles to estimate breeding values of animals when data is sourced from genetically diverse groups (Henderson, 1975). This procedure was described as early as selection index (1940's), but its widespread use became feasible in the 1980's due to advancement in computers and mathematical

algorithms. This methodology results in unbiased EBVs because it combines information on the individual and all relatives in a selection program, leading to increased accuracy of selection, especially for traits with low heritability estimates (van Vleck, 1993). Best linear unbiased prediction has been applied in dairy cattle breeding using models such as sire, sire maternal grandsire and animal models.

Sire models group the animals' records according to the sire's pedigree but does not account for the dams, maternal half-sibs and sons of sires (Cassel, 1988). The resulting parameter estimates are therefore biased as only half-sib relationships are considered (Henderson, 1986; Meyer, 1987). In addition to the sire model, the sire maternal grandsire model considers the effect of the dam through its maternal grandsire. This, however, does not directly account for the dam's contribution and therefore the results are biased. The use of animal models is currently common because they utilise performances of all the individuals with known pedigree relationships to estimate breeding values (Mrode and Swanson, 1994). The model accounts for all genetic relationships among animals whose EBVs are to be estimated, repeated records, multiple traits, and both random and fixed effects. Selection based on BLUP EBVs maximises response to selection. Long-term selection on BLUP, however, compromises genetic response due to inbreeding (Henderson, 1988; Mrode and Swanson, 1994).

CHAPTER THREE

GENETIC EVALUATION OF BREEDING STRATEGIES FOR IMPROVEMENT OF DAIRY CATTLE

3.1. Introduction

Like in other developing countries, breeding of dairy cattle in Kenya involves the utilization of breeding strategies that use both local and imported genetic material (Ojango, 2000; Bebe et al., 2002). The local genetic material is a product of local selection programs that involve PT of bulls that are either sons of local or imported sires. The genetic progress achieved through local selection programs, although low, are cumulative and therefore result in improvement over time. The genetic materials mostly imported for use in Kenya for dairy production include semen and embryos. Such importations have been stimulated by the low success rate of the local selection program due to major physical, social and economic constraints, low effective population size, and poor performance and pedigree field recording.

Breeding strategies based on imported genetic material from temperate countries might not be the best because the rate of genetic progress achieved through imported genes depends on the migration rate, the initial difference in genetic mean and the magnitude of G x E between the importing and exporting populations (Mpofu et al., 1993a; Vargas and van Arendonk, 2004). Significant effects of G x E between Kenya and the exporting countries have been reported (Ojango and Pollott, 2002). In light of this, it is important to evaluate breeding strategies for their potential to bring about genetic progress in dairy herds in the country. In Kenya, studies to evaluate breeding strategies for their genetic efficiency are scarce, the widespread use of imported germplasm notwithstanding. In this chapter, alternative breeding strategies for genetic improvement of dairy cattle in Kenya are genetically compared.

3.2. Materials and methods

3.2.1. Breeding goal and economic values

A breeding goal is a weighted combination of traits to be genetically improved due to their economic importance to the producer. In this study, the breeding goals for dairy cattle in Kenya and for HF in the exporting country were considered. The exporting country was the USA. Following the liberalization of the dairy sector in

Kenya, there has been massive importation of genetic materials, especially semen, from the USA (Ojango and Pollot, 2001). The breeding goal for dairy cattle in Kenya was previously defined for both large- and small-scale dairy production systems under different circumstances (Kahi and Nitter, 2004). In the current study, the breeding goal that reflected a future scenario where payment for milk would be based on volume and fat content was adopted to evaluate breeding strategies utilizing local genetic material. The breeding goal for the USA represented the current marketing systems where payment for milk is based on composition. Two production traits (MY and FY) and one functional trait (AFC) were considered based on the analysis performed by Kahi and Nitter (2004). Protein yield was also considered based on results published in Holstein USA (2006).

The economic values for traits in Kenya's breeding goal were calculated by Kahi and Nitter (2004) assuming a fixed herd size and payment of milk based on volume and fat content. Economic values for the USA were calculated using the current total production index (TPI) (Holstein USA, 2006). These economic values reflect the relative weights in the TPI; an economic index that is used for selection of HF cattle in the USA (Holstein USA, 2006). This index includes productive (FY and PY), health (productive lifetime and somatic cell count), type (udder, feet and leg conformation) and fertility (daughter pregnancy rate and calving ease) traits with relative weights of 7:2:4:1.

In calculating economic values for FY and PY in the breeding goal for the USA, it was assumed that the ratio of economic values for fat to protein in the USA is 2:5 (Costa et al., 2000). It was further assumed that the total ratio for productive traits (7) in the USA is equivalent to the sum of the economic values of productive traits in Kenya (0.27+0.00+1.32 US$). Therefore, the economic values for FY and PY in the USA were US$ 0.45 $(=\frac{2}{7}\times(0.27+0.00+1.32))$ and US$ 1.14 $(=\frac{5}{7}\times(0.27+0.00+1.32))$, respectively. The approach employed in this study was as used by Vargas and van Arendonk (2004) to assign economic values to production traits in the USA based on values estimated for Costa Rica. The economic values for MY and AFC in the USA, and for PY in Kenya were assumed to be zero. The use of different economic values for traits in the breeding goal does not affect the accuracy of estimating genetic gains of breeding programs operating under similar production

systems (Mulder and Bijma, 2006; Mulder et al., 2006). Table 3 shows the economic values for traits in the breeding goals in Kenya and the USA.

Table 3. Means, phenotypic standard deviations (σ_p), economic values (v), heritabilities (h^2) (along diagonal), genetic correlations (below diagonal) and phenotypic correlations (above diagonal) of traits in the breeding goal in Kenya and the USA

			v (US$/unit)		h^2 and correlations			
Traits[a]	Mean	σ_p	Kenya	USA	MY	FY	PY	AFC
MY (kg)	5,056.00	1,110.00	0.27	0.00	**0.30**	0.75	0.70	-0.20
FY (kg)	227.30	41.30	1.32	0.45	0.75	**0.34**	0.85	0.05
PY (kg)	289.20	39.50	0.00	1.14	0.70	0.85	**0.31**	0.05
AFC (d)	837.00	448.76	-0.05	0.00	0.54	-0.1	0.05	**0.38**

[a] MY = milk yield; FY = fat yield; PY = protein yield ; AFC = age at first calving.

Usually breeding strategies with different breeding goals cannot be directly comparable; one may not distinguish between the impact of the strategy and that of the different traits in the breeding goal. The impact of the differences in the traits in the breeding goals was assessed by estimating the correlations among breeding goals and selection index of sires in the two countries. These correlations were estimated as suggested by Gibson and van Arendonk (1998) and were high (<0.97), indicating that any differences in breeding strategies cannot be attributed to the difference in breeding goals between Kenya and the USA.

3.2.2. Cumulative discounted expressions

Cumulative discounted expressions of traits were calculated using the computer program Gflow (Brascamp, 1978). The CDE can be calculated based on the year or generation approach. In this study, the year approach was used because the generation approach usually overestimates CDE (Hill, 1974). In the program, CDE are estimated as follows:

$$CDE_{lT} = \sum_{t=0}^{T} hm_{lt} \left(\frac{1}{1+r} \right)^{t} \qquad [3]$$

where T is the time horizon, l the selection path, h the incidence vector that specifies frequencies of the contribution of each age-class to phenotypic expression of a trait, m_{lt} a vector which specifies the relative contribution of the initial set of genes in a particular selection pathway l to the genes of animals in this age-class at time t, and r the interest rate at the base year (t = 0). The numbers of rows of h and m vectors are

equal to the number of age-classes and sexes within the tiers considered in the gene flow. In this study, only one tier (nucleus) with six male and five female age-classes was evaluated within a projected period of 25 years.

The incidence vectors were defined based on production, reproduction and replacement times. In this study, they accounted only for the proportion of lactating cows in different age-classes. The incidence vector for productive (MY, FY and PY) and reproductive (AFC) traits was given as h = (0 0 0 0 0 0 | 0.15 0.14 0.09 0.07 0.05). Time adjustments to productive and reproductive traits were 0.5 and -1 years, respectively.

In calculating m_{lt}, an initial n_{lt} vector (vector with gene frequency in one of the defined age-classes by sex subclasses) was defined. In matrix algebra, the transmission of genes through n_{lt} and m_{lt} vectors can be described as follows (Brascamp, 1978):

$$n_{lt} = Q n_{l(t-1)} \qquad [4]$$

$$m_{lt} = R_l n_{l(t-1)} + (R+Q) m_{l(t-1)} \qquad [5]$$

$$R = \sum_{l=1}^{l} R_l \qquad [6]$$

where R describes the processes of gene transmission by reproduction while Q is a matrix describing gene transmission by aging. The elements in R represent the genes contributed by selected parents to the progeny while those in Q are either zeros or ones, where ones denote aging. The aging of genes originating from selected parents was described by equation [4] while [5] described the flow of the offspring's genes through the population age-classes by reproduction and aging.

In this study, CDE were summed over the four selection pathways: SS, SD, DS and DD. For Kenya, an additional selection pathway, young sires to breed daughters (YD) was also included for some breeding strategies. A discounting rate of 5% was used to estimate the CDE. This value falls within the range of discounting factors recommended when evaluating animal breeding programs (Smith, 1978; Bird and Mitchel, 1980). Two alternative discounting rates (0 and 10%) were also assumed to investigate the effects of discount rates on selection efficiencies.

3.2.3. Assumptions for the simulated breeding strategies

Four breeding strategies with a single breeding unit (nucleus) were considered in this study. These strategies utilized conventional PT and MOET was not considered. Smith (1988) recommended for developing countries the adoption of breeding strategies based on nucleus breeding schemes using MOET. Utilization of MOET nucleus schemes in developing countries has been evaluated (Mpofu et al. 1993a; Vargas and van Arendonk, 2004). Even though the results were better than conventional PT in terms of genetic response, the costs of such programs are prohibitive (Mpofu et al., 1993b). Also efficient dissemination of embryos would require a developed infrastructure, which is partially or completely lacking (Kahi et al., 2000; Kosgey et al., 2005). The four breeding strategies included:

Closed progeny testing scheme (CPT)

The assumption was that a PTS was initiated within the local population. Five hundred young bulls were tested annually on 20% of the recorded cows bred by AI. These cows were assumed to be daughters of bulls selected from the local PTS. Each bull was assumed to have fifty daughters with complete lactations. Only one and five percent of the test bulls were selected as SS and SD, respectively. Five percent of the cows in their third and fourth lactations were selected as DS while ninety percent of the cows in the nucleus were selected as DD. The selection intensities for each selection pathway were corrected for finite population where necessary (Smith, 1969; Burrows, 1972).

Continuous semen importation (CSI)

This strategy assumed that there was no selection being done in Kenya and therefore improvement is based on imported semen from proven bulls and all cows are inseminated using this semen. This strategy has been recommended in situations where the exotic stock are superior to local stock, the breeding goals in the exporting and importing countries are similar, and where there are no major effects of G x E (Smith, 1988). It was assumed that all semen imports were from the USA, which has a long-standing PTS with a large dairy cattle population. Semen importation was done on an annual basis with a new batch from bulls higher in genetic merit than the previous batch. Two thousand young bulls were tested annually on fifty percent of the recorded cows bred by AI. Each test bull had one hundred daughters with complete

lactations. This means that any improvement in genetic merit would be due to imported semen.

Young bull system (YBS)

This strategy involved utilization of untested young bulls from the local proven bulls (PLB) and those sired by foreign bulls (PIB). The YBS was defined as a strategy where untested young bulls selected on pedigree information are used to sire dams in the nucleus. These bulls are slaughtered after semen has been collected and stored until their daughters' records are available to select semen from the best bulls for future mating. Their population parameters are similar to those in CPT but in this strategy 10% of the test bulls were young sires (YD) selected based on pedigree information.

In all breeding strategies, the generation of genetic gain, performance and pedigree recording and sire selection were the major activities in the nucleus in Kenya and the USA. A total population size of 500,000 cows was considered for CPT and YBS strategies. It was further assumed that the nucleus population size was 20% of the total population while the proportion of bull dams was 5% of the nucleus population. In the USA, a total population of 5 million cows was assumed; 50% of these in the nucleus out of which 5% were bull dams. In all strategies, a hundred percent use of AI was assumed. In addition to these parameters, other population structures and parameters for Kenya and the USA are presented in Table 4.

Table 4. Population parameters and structure for a progeny testing scheme in Kenya and the USA

Population parameters	Kenya	USA
Assumed cow populations	500,000	5,000,000
% of cows bred by AI and milk recorded	20	50
% of bull dams from milk recorded cows	5	5
Young bulls tested per year	500	2,000
Daughters per young bulls	50	100
Proportions selected		
Sires to breed sons	5/500	20/2,000
Sires to breed daughters	25/500	100/2,000
Young bulls to breed daughters	50/500	-
Dams to breed sons	500/10,000	12,500/250,000
Dams to breed daughters	90/100	117/130
Generation intervals (years)		
Sires to breed sons	6	6
Sires to breed daughters	6	6
Young bulls to breed daughters	3	-
Dams to breed sons	5	5
Dams to breed daughters	5	5

3.2.4. Prediction of selection response

In this study, selection response was predicted using the selection index methodology. The selection index weights (b) for traits were derived using the following equation (Hazel, 1943):

$$b = P^{-1}Gv \qquad [7]$$

where P is the variance-covariance matrix between traits in the selection index, G the variance-covariance matrix between traits in the selection index and breeding goal and v a vector of economic values of traits in the breeding goal. The consistencies of P and G matrices were tested using the procedure of Foulley and Ollivier (1986). Genetic response (GR) was defined as genetic superiority of each trait (j) achieved by one round of selection for each selection pathway. Genetic response of each trait was estimated as;

$$GR_j = \left(\frac{ib'G}{\sigma_I} \right) \qquad [8]$$

where i is the selection intensity , σ_I the standard deviation of the index ($\sigma_I = \sqrt{b'Pb}$) while b and G are as described in equation [7]. Economic response in US$ (ER) was defined as the sum of genetic responses for all traits in the breeding goal, each weighted by its discounted economic value. The economic response in US$ per year in each selection pathway was estimated as:

$$ER_l = \frac{\sum_{i=1}^{j} \left(GR_j \text{ x } CDE_j \text{ x } v_j \right)}{L_l} \qquad [9]$$

where CDE_j is the cumulative discounted expressions of trait j and L_l the generation interval of selection pathway l. Equation [8] was multiplied by the genetic correlation (r_g) between breeding goal traits in Kenya and the USA to estimate the genetic response for breeding strategies that involved importation of semen to Kenya.

Using animal and sire models, genetic correlations of 0.49 and 0.58, respectively, between the breeding values for MY of HF sires in Kenya and exporting countries have been reported (Ojango and Pollott, 2002). Usually, the use of an animal model in evaluating genetic correlations between populations, especially where sires are the major connectors, is not justified because it weakens the genetic links between populations leading to underestimates (Sigurdsson et al., 1996).

Therefore, for Kenya the genetic correlation of 0.58 is close to reality. This genetic correlation estimate was used as a reference point. However, initial genetic gains from imports were calculated assuming a genetic correlation of one between Kenya and the USA. The effect of genetic correlation between the two populations was further examined using different levels of r_g that ranged from 0 to 1. The effect of initial differences in genetic merit between the two populations was also investigated at three different levels, i.e., 1.25, 1.5 and 2.0 standard deviations.

Genetic and phenotypic parameters for traits in the selection criteria and breeding goal were derived from previous studies conducted in Kenya (Rege, 1991; Ojango and Pollott, 2001; Kahi et al., 2004). Where such estimates were missing in Kenyan studies, the comprehensive review of Lôbo et al. (2000) on genetic parameters for beef and dairy cattle in the tropical regions was consulted. In cases where estimates for genetic correlations were available and phenotypic ones were missing and vice versa, then the two correlations were assumed to be the same (Koots et al., 1994a and b). Genetic and phenotypic parameters for selection criteria and aggregate genotype traits used in this study are presented in Table 3. These parameters were assumed to be equal for Kenya and the USA to ensure that any differences observed in the genetic response was due to differences in breeding strategy rather than genetic parameters.

In CPT, PLB and PIB, traits in the selection criteria were MY, FY and AFC. For CSI strategy, they included MY, FY and PY. For selection pathways SS, SD, YD (in PLB and PIB), DS and DD, information sources included records on dam, dam's dam, sire's dam, and five half-sib sisters. In addition, the sire (SS and SD) and dam (DS and DD) selection pathways included records on their daughters and own performance, respectively. Sires in CPT and CSI were assumed to be selected based on information from, correspondingly, 50 and 100 daughters.

Inbreeding is important in breeding programs, especially in the CPT scheme, but less important when imports are utilised. The reduction in genetic variance due to inbreeding was assumed to be negligible for the period considered and was ignored. The reduction in performance because of inbreeding was, however, considered and its rate calculated using the Wright's formula (Falconer and Mackay, 1996). No inbreeding was expected in the CSI strategy because semen from different bulls was imported annually. Rates of inbreeding found in this study were within 0.005-0.01,

which is the annual acceptable rate of inbreeding in a breeding program (Bijma, 2000) and are therefore not reported. The accumulation of inbreeding in a breeding program should not, however, be a major problem as it can continuously be monitored and new animals introduced if its rate is considered to be too high.

3.3. Results and discussion

3.3.1. Cumulative discounted expressions

Table 5 shows the CDE for each selection pathway calculated using three different discount rates (0, 5 and 10%). The CDE differed between selection pathways as a result of the differences in the initial moment of gene introduction and the first time genes are expressed in the population (Groen, 1990; Hirooka and Groen, 1999). Among the sire selection pathways, YD had the highest and SS the lowest CDE. The CDE for the productive traits were the same at each discount rate and pathway since these traits are expressed at the same time in the life of an animal. The CDE were very sensitive to changes in discount rates and time of evaluation. They decreased with increase in discount rates (Table 5) but increased with increase in time horizon (results not shown). This is consistent with earlier studies (e.g., Brascamp, 1975; Hirooka and Groen, 1999; Kosgey et al., 2005).

Table 5. Cumulative discounted expressions of traits per selection pathway for different discounting rates

Selection Paths	Traits in the breeding objective[a]			
	MY	FY	PY	AFC
Discounting rate 0%				
Sires to breed sons	0.33	0.33	0.33	0.04
Sires to breed daughters	0.62	0.62	0.62	0.05
Young bulls to breed daughters	0.82	0.82	0.82	0.07
Dams to breed sons	0.95	0.95	0.95	0.09
Dams to breed daughters	0.65	0.65	0.65	0.08
Discounting rate 5%				
Sires to breed sons	0.13	0.13	0.13	0.02
Sires to breed daughters	0.31	0.31	0.31	0.02
Young bulls to breed daughters	0.43	0.43	0.43	0.04
Dams to breed sons	0.44	0.44	0.44	0.04
Dams to breed daughters	0.32	0.32	0.32	0.05
Discounting rate 10%				
Sires to breed sons	0.05	0.05	0.05	0.01
Sires to breed daughters	0.17	0.17	0.17	0.01
Young bulls to breed daughters	0.26	0.26	0.26	0.02
Dams to breed sons	0.22	0.22	0.22	0.02
Dams to breed daughters	0.17	0.17	0.17	0.03

[a]MY = milk yield; FY = fat yield; PY = protein yield; AFC = age at first calving.

Differences in the time of realization of CDE were also observed between the selection pathways based on the traits considered (results not shown). The reproductive traits expressed their CDE one year earlier than productive traits. The CDE for the SS were first realized in the 13th and 14th year, SD realized CDE for the first time at 8th and 9th year while both DS and DD realized CDE at the 7th and 8th year. The young bulls (YD) expressed their first CDE in the 5th and 6th year, earlier than the other pathways. This earlier expression is due to their short generation interval, which allows faster dissemination of genes in the population compared to proven bulls.

Use of CDE in estimating economic values is important even if the effects are small (Ponzoni and Newman, 1989). The CDE are especially useful when combining different groups of traits in the breeding goal (e.g., milk production, beef production and functional traits). Therefore, ignoring CDE will lead to sub-optimum genetic responses (Groen et al., 1997). In this study, CDE estimated at a discounted rate of 5% were used to predict selection response in traits in the breeding goal for the different breeding strategies.

3.3.2. Selection responses in breeding strategies

The genetic responses in traits in the breeding goal achieved after one round of index selection for the four breeding strategies studied are presented in Table 6. Among the productive traits, MY had the largest and PY the lowest genetic superiority in all breeding strategies. The genetic responses in AFC in CPT and PLB were larger than in strategies involving the use of imported genetic material. The presence of AFC in the breeding goal of CPT contributed little to the index gain because it had a negative economic value. Based on the economic values used in this study, MY and FY had the largest contribution to the general economic response in CPT and PLB while FY and PY were the major contributors in CSI and PIB strategies. Vargas and van Arendonk (2004) also reported PY and FY as the major contributors to economic response in Costa Rica (importing country) and the USA (exporting country). In that study, contribution of MY in Costa Rica was small because it had a negative economic value.

Table 6. Genetic response in the breeding goal traits and economic responses (ER) for breeding strategies based on closed progeny testing (CPT), continuous semen importation (CSI), young bull system progeny of local bulls (PLB) and progeny of imported bulls (PIB), assuming a genetic correlation of one between traits in the breeding goal in Kenya and the USA

Paths	σ_I	σ_H	r_{IH}	i	Genetic response[a]				
					MY (kg)	FY (kg)	PY (kg)	AFC (days)	ER (US$/yr)[b]
CPT									
Sires to breed sons	972.08	1433.00	0.68	1.60	410.50	13.29	11.09	90.88	4.32
Sires to breed dams	2341.40	3451.00	0.68	1.31	410.50	13.29	11.09	90.88	8.52
Dams to breed sons	2906.10	4884.00	0.60	1.32	366.20	10.49	8.87	101.60	12.79
Dams to breed daughters	2149.20	3613.30	0.60	0.41	366.20	10.49	8.87	101.60	2.94
Total ER									**28.57**
CSI									
Sires to breed sons	1107.50	1582.14	0.70	2.67	432.70	21.68	21.06	0.37	8.21
Sires to breed dams	2661.96	3802.80	0.70	2.06	432.70	21.68	21.06	0.37	15.23
Dams to breed sons	2906.10	4884.00	0.60	1.32	366.20	10.49	8.87	101.60	12.79
Dams to breed daughters	2149.20	3613.30	0.60	0.41	366.20	10.49	8.87	101.60	2.94
Total ER									**39.17**
PLB									
Sires to breed sons	972.08	1433.00	0.68	1.60	410.50	13.29	11.09	90.88	4.32
Young bulls to breed daughters	1688.40	4865.20	0.35	1.18	222.40	4.41	4.04	89.59	11.07
Dams to breed sons	2906.10	4884.00	0.60	1.32	366.20	10.49	8.87	101.60	12.79
Dams to breed daughters	2149.20	3613.30	0.60	0.41	366.20	10.49	8.87	101.60	2.94
Total ER									**31.12**
PIB									
Sires to breed sons	259.47	373.53	0.70	2.67	432.70	21.68	21.06	0.37	8.21
Young bulls to breed daughters	1688.40	4865.20	0.35	1.18	222.40	4.41	4.04	89.59	11.07
Dams to breed sons	2906.10	4884.00	0.60	1.32	366.20	10.49	8.87	101.60	12.79
Dams to breed daughters	2149.20	3613.30	0.60	0.41	366.20	10.49	8.87	101.60	2.94
Total ER									**35.01**

[a]MY = milk yield; FY = fat yield; PY = protein yield; AFC = age at first calving.
[b]Economic response given for CSI corresponds to gains achieved in Kenya when selection is based on the breeding goal in the USA.

Generally, the economic response for breeding strategies that involved use of imported semen (CSI and PIB) was higher than for breeding strategies based on local selection programs when the genetic correlation between Kenya and the USA was assumed to be one. This was in agreement with the results reported by Mpofu et al. (1993a) and Vargas and van Arendonk (2004) for Zimbabwean and Costa Rican HF dairy cattle populations, respectively. The higher genetic response in strategies based on imported semen in this study was a result of higher accuracies and intensities of selection in the sires. In the USA, a large number of daughters with complete lactations whose records could be used to evaluate sires were assumed, leading to increased accuracies of selection. The large number of available test bulls led to intense selection of proven bulls, and therefore high selection intensities. In the USA, there is a long-standing and efficient PTS, which is lacking in most developing countries (Smith, 1988; Meuwissen, 1990; Kahi et al., 2004; Kosgey et al., 2005).

When local breeding strategies (CPT and PLB) were compared, the PLB strategy was 9.1% superior in economic response (Table 6). In CPT, old bulls are selected based on information from their progeny and therefore high accuracy of selection, but this is offset by the short generation interval in PLB. This is inline with previous studies, which also have reported higher economic responses in YBS compared to schemes utilizing progeny tested bulls (Mpofu et al. 1993a; Nitter, 1998; Kosgey et al., 2005). Nitter (1998), however, noted that YBS are only superior to old bull systems in terms of profit but are slightly inferior in genetic gain since they were selected on pedigree information. Mulder and Bijma (2005) recommended the use of PTS only in situations where the generation interval of the progeny tested sires is short, which is not common with dairy cattle.

3.3.3. Variation and parameter sensitivity analyses

Figures 3 and 4 show the effects of genetic correlation and initial differences in genetic merit between Kenya and the USA on economic response in CPT, PLB, PIB and CSI. Changing the genetic correlations between traits in the two countries evaluated the effects of G x E. The existence of G × E between the two populations was evident. The economic response for import strategies improved with increased initial genetic merits. At a genetic correlation of 0.58, it was observed that imports from countries that are 1.50SD above the local population were slightly better than CPT but were still inferior to PLB in terms of economic response (Figure 3). This means that if CSI strategy is to be used at a genetic correlation of 0.58, then only semen from countries which are 2.00SD above the Kenyan population should be imported. Otherwise, the use of local selection programs, especially

PLB, would be more preferred. On the other hand, at this genetic correlation level, the PIB strategy is inferior to the local strategies at all levels of initial genetic differences (Figure 4). Mpofu et al. (1993a) also reported superiority of local strategies to those based on the use of PIB for the Zimbabwe dairy cattle population.

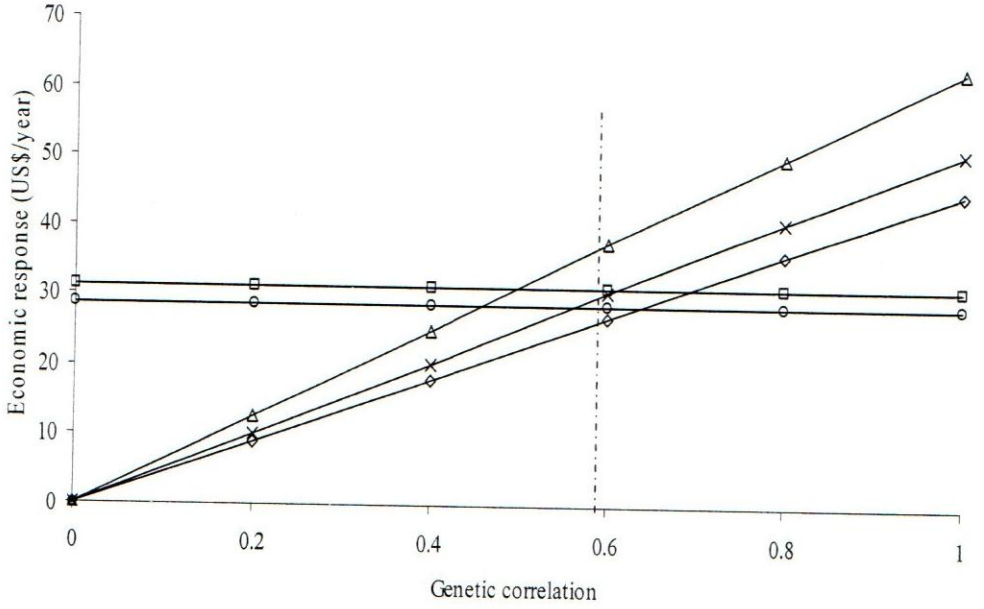


Figure 3. Impact of changing the genetic correlation between traits in the breeding goal in Kenya and the USA on economic response (US$/year) for breeding strategies based on closed progeny testing (O), young bull system progeny of local bulls (□), and continuous semen importation assuming initial genetic differences of 1.25 (◊), 1.50 (x) and 2.00 (Δ) standard deviations. The points of intersection between the vertical dotted line and the other lines correspond to the economic responses achieved on the Y-axis when the genetic correlation is 0.58.

As the genetic correlation between the two countries approached unity, the strategies based on imports became superior to local strategies (Figures 3 and 4). The points of intersection in Figures 3 and 4 are important because they represent the level of genetic correlations when the economic response is the same in any two strategies. Strategies based on imports are superior to local strategies at correlations above the intersection points. For example, if the aim is to utilize the PLB strategy, the use of imported semen from countries with a dairy population that is 1.25SD above the Kenyan population can only be justified when the genetic correlation between the two countries is greater than 0.70 (Figure 3). This genetic correlation is higher (>0.85) when there is utilization of PIB (Figure 4). The minimum threshold for accepting imports is therefore 0.70 (Figure 3).

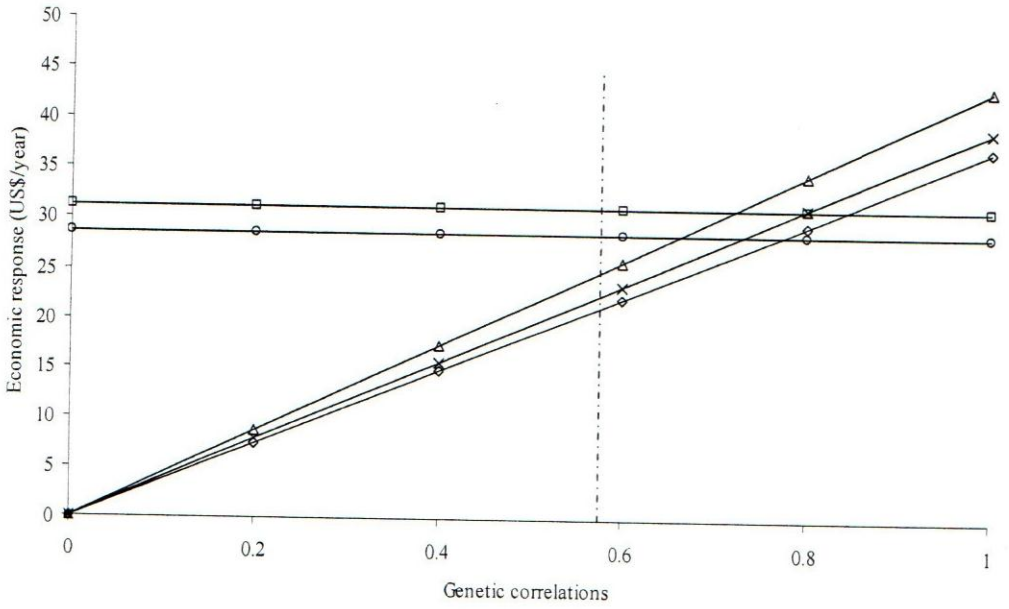


Figure 4. Impact of changing the genetic correlation between traits in the breeding goal in Kenya and the USA on economic response (US$/year) for breeding strategies based on closed progeny testing (O), young bull system progeny of local bulls (□), and young bull system progeny of foreign bulls assuming initial genetic differences of 1.25 (◊), 1.50 (x) and 2.00 (Δ). The points of intersection between the vertical dotted line and the other lines correspond to the economic responses achieved on the Y-axis when the genetic correlation is 0.58.

The genetic correlation of 0.58 reported for Kenya indicates the existence of G × E, which may reduce the potential benefits of strategies utilizing imported semen. However, lower estimates of 0.42 and 0.50 have been reported between the USA sires used in Ecuador and Brazil, respectively (Powell et al., 1990). Powell and Wiggans (1991) reported correlations of >0.90. The low genetic correlation reported for Kenya means that wholesome importation as a way of achieving substantial genetic progress in Kenya is a less optimal solution. Previous studies on breeding strategies (Mpofu et al., 1993a; Vargas and van Arendonk, 2004) and the effect of G × E (Smith, 1988; Costa et al., 2000; Zwald et al., 2003) stated that countries relying on imported genes for genetic improvement would have to switch to establishment of local breeding schemes at some point. Mulder et al. (2006) recommended the establishment of environment specific breeding programs when the level of genetic correlation between environments is less than 0.7.

3.3.4. Practical implications

This study compared breeding strategies in terms of selection response assuming discrete generations of selection with animals selected only once for breeding. In practice, however, overlapping generations where both young and older animals are eligible for

selection exist, but this requires additional input resources to maintain both young and old animals (Ruane and Thompson, 1991). The genetic responses achieved at the projected 25 years in this study are therefore considered upper bounds. This is because responses to selection achieved are usually much less than the responses predicted theoretically due to selection for several traits (some of them not economically important to the producer), low selection intensities than predicted and losses from natural selection (van Vleck, 1986).

Since pre-independence, breeding of dairy cattle in Kenya has been based on the use of semen acquired locally and internationally. The liberalization of the dairy sector in 1992 (DANIDA, 1991) led to massive importation of HF semen from different countries. However, only about 44% of the response to selection achieved in the exporting countries can be expressed in Kenya (Ojango and Pollott, 2002). This confirms that the effects of G x E are significant and therefore selection within the local population is important. The results from this study also confirm that, although sires in temperate countries tend to have higher breeding values in their native environments, the expression of their genetic superiority in the Kenyan environment are low due to the effect of G x E between the two populations. There is therefore need for selection of better performing dams within the Kenyan production environments to be used as bull dams, and within-country selection and evaluation of bulls.

The establishment and running of efficient local PTS in developing countries, and particularly in Kenya, has been unsuccessful due to various constraints (Rege and Wakhungu, 1992; Kahi et al., 2004; Kosgey et al., 2005). Therefore, imported germplasm may still play major roles in genetic improvement of dairy cattle in most developing countries. Ojango and Pollott (2002) suggested that in the absence of procedures to select sires based on proofs calculated in-country, tropical countries should use conventional equations (Wilmink et al., 1986) to determine a threshold below which estimated breeding values for imported semen should not fall.

3.4. Conclusions

This study has shown that the alternative breeding strategies compared, if effectively utilitized under conditions in Kenya, will result in genetic improvement of dairy cattle. For strategies that depend on imported semen, their effective utilization will be influenced by the level of G x E and the differences in genetic merit between Kenya and the exporting country. This study showed that with a genetic correlation of 0.58, semen should only be imported from countries with a dairy cattle population that is 2.00SD above the Kenyan population. The use of semen from countries with a dairy cattle population that is less than 1.25SD is only

justifiable when the genetic correlation between the two countries is greater than the minimum threshold, which is 0.70. In addition to genetic comparison of breeding strategies for improvement of dairy cattle in Kenya, the general economic benefits of these strategies should also be considered. Consequently, there is the need to ascertain the profitability of breeding strategies under the local production conditions.

CHAPTER FOUR

ECONOMIC EVALUATION OF BREEDING STRATEGIES FOR IMPROVEMENT OF DAIRY CATTLE

4.1. Introduction

Kenya, like other developing countries, has created nucleus dairy herds from imported breeds but still heavily relies on imported genetic material, especially semen to breed them (Rege and Wakhungu, 1992; Ojango and Pollot, 2002). Importation has been done without taking into account the effect of G x E between the importing and exporting populations. This is because improvement methods like PT commonly used in developed countries are rarely practiced due to the costs involved. Nitter (1998) noted that, unlike breeding programs in developed countries where the paramount interest is to maximize genetic gains, the cost-effectiveness of the breeding programs in developing countries, where modern dairy cattle breeding strategies are not yet fully developed, should be considered. The economic evaluation of breeding strategies is therefore important. Many studies have evaluated the cost-effectiveness of breeding programs and strategies for different livestock species, both in developed and developing countries (e.g., Kizito, 1976; Miller, 1977; Bird and Mitchell, 1980; Fewson, 1989; Dekkers and Shook, 1990; Holmann et al., 1990; Mpofu et al., 1993) but such studies are lacking in Kenya. In this chapter, the economic merits of breeding strategies are determined using cost-benefit analysis with NPV as the economic evaluation criterion.

4.2. Materials and methods

4.2.1. Breeding strategies, revenue from, and costs of genetic improvement

The breeding strategies presented in Chapter 3 were considered in this study. The economic response per year estimated for these strategies are presented in Table 7. These economic responses were halved since the predicted genetic gains are usually higher than genetic responses achieved in practice (van Vleck, 1986; Mpofu et al., 1993). The effect of using the full theoretical predicted genetic gains on the economic ranking of the breeding strategies was also investigated.

Table 7. The predicted and practically achievable economic responses per year[a] (US$) and net present value (US$) for breeding strategies

Breeding strategies[b]	Economic responses (US$/year)		Net present values (US$)
	Predicted	Achievable	
CPT	28.57	14.29	0.18
PLB	31.12	15.56	1.13
CSI	39.17	19.59	-42.70
PIB	35.01	17.51	-0.78

[a]Multiply by 10^6 (genetic correlation = 1.00, initial genetic difference = 1.00SD, discount rate = 5% and an exchange rate of 1 US$ = KSh 70).
[b]CPT = Closed progeny testing; PLB = Young bull system progeny of local bulls; CSI = Continuous semen importation; PIB = Young bull system progeny of imported bulls.

Revenues and costs were expressed in US$, and only benefits resulting from genetic improvement were considered. The costs of genetic improvement were classified as production, investment and operational costs. Production costs included those incurred for feeding and veterinary services and were estimated as US$ 257.5 and US$ 26.85 per cow per year, respectively (Kahi and Nitter, 2004). Investment and operational costs were obtained from the CAIS (2005). This station is mandated to acquire bulls or bull calves and produce good quality semen for use in Kenya. The investment costs in local selection programs (CPT and PLB) included costs incurred in setting up and equipping the bull station because test bulls are raised in the station and costs incurred in replacing investment items. Items that lasted beyond the evaluation period were given a salvage value. In Kenya, the bull station already exists and therefore only the costs for replacing investment items (US$ 142,857.14) were included in the analysis. The operational costs are recurrent expenses incurred in running the strategy. For local selection programs, it was assumed that 30 bulls were raised in the breeding station at any one time. The operational costs included bull maintenance costs per year (US$ 782.14) and semen collection (US$ 0.29), storage (US$ 1.43) and distribution (US$ 0.71) costs per straw. Other costs included those incurred during PT and the waiting period (US$ 142.86), and for data recording and processing per year (US$ 71.43).

For CPT, it was assumed that the whole cow population was inseminated with semen from progeny tested bulls while for PLB this semen was used only on 5% of the cow population (bull dams) with the remainder being inseminated by semen from young bulls (Chapter 3). The cost per straw of semen from progeny tested bulls and young bulls were US$ 5.00 and US$ 2.57, respectively (CAIS, 2005). For strategies involving importation of semen (CSI and PIB), the investment costs of CSI are low and include costs of facilities for semen storage and distribution (US$ 7,142.86). The operational costs are high, and in addition to the costs of storage and distribution, they also included costs of semen importation (US$ 85.71)

per straw. The investment costs of PIB were similar to those of CPT but also included the costs of semen imports that are used on 5% of the cow population.

The cost per straw of semen from PIB was assumed to be the same as the cost of semen from PLB. Generally, the number of straws required was determined by the total cow population bred by AI and the number of services per conception. In PIB, the number of straws imported was dependent on the proportion of cows used as bull dams, which was assumed to be 5%. In this study, a total cow population of 2,500 was assumed and was bred by AI and conceived after two services. One percent more straws were required to allow for losses that may occur during storage and distribution (CAIS, 2005). The average annual costs were estimated as US$ 204,050.00, 192,402.71, 515,178.57 and 208,840.71 for CPT, PLB, CSI and PIB, respectively.

4.2.2. Method of evaluation

Cost-benefit analysis was used to assess the economic merit of the four breeding strategies. The two types of cost-benefit analyses used in analyzing agricultural projects include financial and economic analyses. Economic analysis using NPV as the evaluation criterion was used in this study. This is because it assesses the viability of projects by considering the welfare of the whole nation compared to financial analysis, which assesses projects from an individual's or agency's point of view (Gittinger, 1982; Randall, 1987). The net present value has been used in earlier studies to ascertain the economic viability of breeding programs and strategies (e.g., Kizito, 1976; Dekkers and Shook, 1990; Mpofu et al., 1993). The project is considered economically viable when the NPV is positive. The NPV for each breeding strategy was estimated as;

$$NPV = \sum_{t=0}^{T} \left(\frac{b_t - c_t}{(1+r)^t} \right) \qquad [10]$$

where T is the evaluation period (25 years), b_t the annual benefits of genetic improvement calculated as achievable genetic response per cow per year (Table 7) multiplied by the total cow population bred by AI, c_t the costs of genetic improvement and r the discount rate (assumed to be 5%). This discount rate falls within the range of discount rates recommended when evaluating animal breeding programs (Bird and Mitchel, 1980). Two alternative discount rates (0 and 10%) were also assumed to investigate the effects of discount rates on NPV and ranking of the breeding strategies. In addition, sensitivity of the results to changes in genetic correlation, initial genetic difference between the Kenyan and the USA dairy cattle

populations, price of imported semen and exchange rate between the US$ and the Kenya Shilling (KSh) on ranking of strategies involving imports was also investigated.

In most developing countries, the production and marketing conditions are dynamic, and interest and inflation rates are high. Therefore, changes in the breeding goal, selection criteria and other aspects are inevitable. This means that an investment period of 25 years (equivalent to five generations in dairy cattle) is considered to be too long. The effect of investment period on NPV ranking was therefore investigated.

4.3. Results

The NPV of the four breeding strategies studied assuming standard parameters (genetic correlation = 1.00, initial genetic difference = 1.00SD, discount rate = 5% and an exchange rate of 1 US$ = KSh 70) are presented in Table 7. As expected, there were differences in the ranking of breeding strategies based on economic response and NPV. Based on economic response, the strategies involving use of imported semen (CSI and PIB) ranked above those utilizing local selection programs (CPT and PLB). The NPV ranking using standard parameters, however, changed as the local selection programs were superior to strategies involving imports. Although CSI ranked highest in economic response and also had the highest NPV (Table 7), it ranked low because NPV was negative, indicating that the benefits cannot offset the costs.

The NPV of the four breeding strategies assuming different levels of genetic correlations and initial genetic differences between Kenya and the USA are presented in Table 8. The NPV of the strategies involving imports was sensitive to changes in the magnitude of genetic correlations and initial genetic differences between Kenya and the USA. The CSI had a large negative NPV at all levels of genetic correlation and initial genetic difference between the two populations. The PIB also had a negative NPV at all levels of genetic correlation and initial genetic difference between the two populations considered, apart from at 2.00SD where it had a positive NPV and ranked above CPT. The NPV for the importing strategies generally increased with increase in the levels of genetic correlations and initial genetic differences between Kenya and the USA.

Table 8. Net present values[a] for breeding strategies at different levels of genetic correlation and initial genetic difference between Kenya and the USA

Breeding strategies[b]	Level of genetic correlations				Initial genetic differences (SD)		
	0.30	0.58	0.90	1.00	1.25	1.50	2.00
CPT	0.18	0.18	0.18	0.18	0.18	0.18	0.18
PLB	1.13	1.13	1.13	1.13	1.13	1.13	1.13
CSI	-42.82	-42.78	-42.73	-42.70	-42.75	-42.73	-42.68
PIB	-2.35	-1.71	-1.00	-0.78	-0.67	-0.35	0.31

[a]Divided by 10^6.
[b]CPT = Closed progeny testing; PLB = Young bull system progeny of local bulls; CSI = Continuous semen importation; PIB = Young bull system progeny of imported bulls.

Table 9 shows the NPV for breeding strategies at different discount and exchange rates. The NPV of all strategies was sensitive to changes in discount rate. Increase in discount rate led to a decrease in NPV for CPT, PLB and PIB but an increase in NPV for CSI. This is because CSI had higher operational than investment costs. The exchange rate had a negative impact on NPV of importing strategies. A depreciated shilling was associated with reduction in NPV for CSI and PIB.

Table 9. Net present values[a] for breeding strategies at different discount and exchange rates

Breeding strategies[2]	Discount rates (%)			Exchange rates (US$:KSh)		
	0	5	10	1:50	1:70	1:90
CPT	1.54	0.18	-0.23	0.18	0.18	0.18
PLB	3.69	1.13	-0.01	1.13	1.13	1.13
CSI	-75.70	-42.75	-27.10	-30.00	-42.75	-54.10
PIB	1.37	-0.67	-1.38	-0.25	-0.67	-1.11

[a]Divided by 10^6.
[b]CPT = Closed progeny testing; PLB = Young bull system progeny of local bulls; CSI = Continuous semen importation; PIB = Young bull system progeny of imported bulls.

Figure 5 shows the impact of price of imported semen on NPV ranking of the breeding strategies. The points of intersection between lines representing local strategies and those based on imported genetic material indicate the price of semen above which use of imported genetic material becomes uneconomical. The dotted line shows the average cost of importing average quality semen in Kenya (US$ 85) (CAIS, 2005).

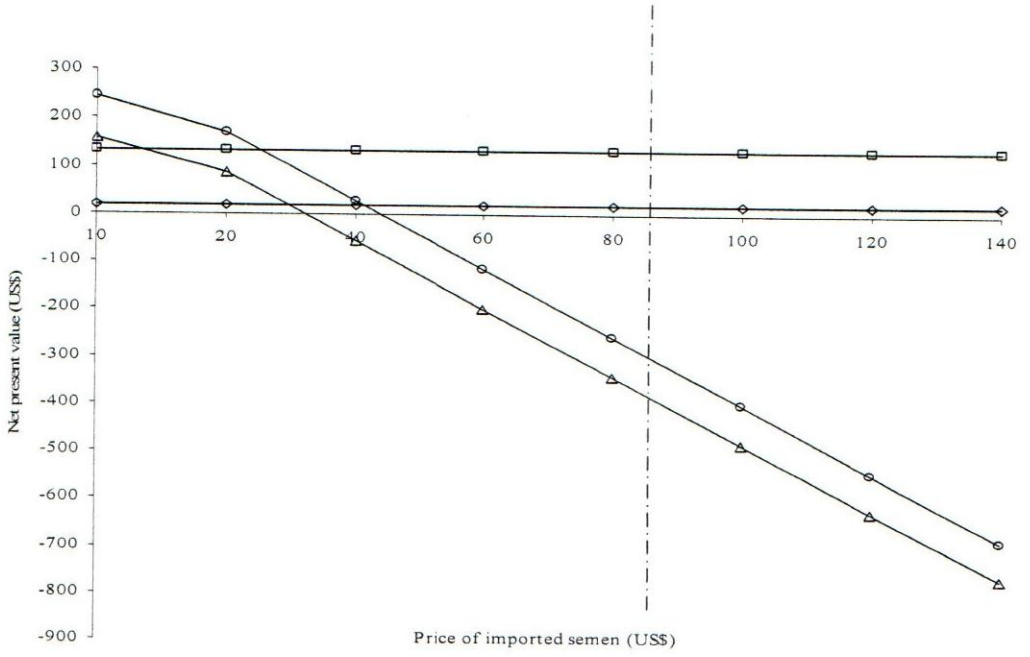


Figure 5. The impact of price of imported semen on NPV (US$x10^4) ranking of the four breeding strategies: closed progeny testing (◊), young bull system progeny of local bulls (□), continuous semen importation (Δ) and young bull system progeny of imported bulls (○).

Generally, increase in price of the imported semen negatively affected NPV and ranking of the strategies involving imports. The strategies involving imports ranked above the local strategies when the price of imported semen was low. The price ceiling above which use of imported genetic material becomes uneconomical was US$ 40, represented by the point of intersection between the lines representing CPT and PIB. An increase in the price of imported semen was associated with a decrease in the economic merits of strategies based on imported genetic material, which therefore ranked below strategies based on local selection programs.

The effects of using achievable and full theoretical economic responses (Table 7) on NPV ranking of breeding strategies are presented in Figure 6. When achievable economic responses were used assuming set standard parameters, only the local selection programs were profitable. If the full theoretical predicted economic responses could be realized under the Kenyan production conditions, then all the breeding strategies will be economically viable apart from CSI. The use of full theoretical economic responses did not, however, affect the NPV ranking as local strategies were still superior. But as the shilling appreciates against the dollar (1:50) or when the cost of imported semen is ≤US$ 40 per straw, PIB ranked above CPT, but was still inferior to PLB (results not shown).

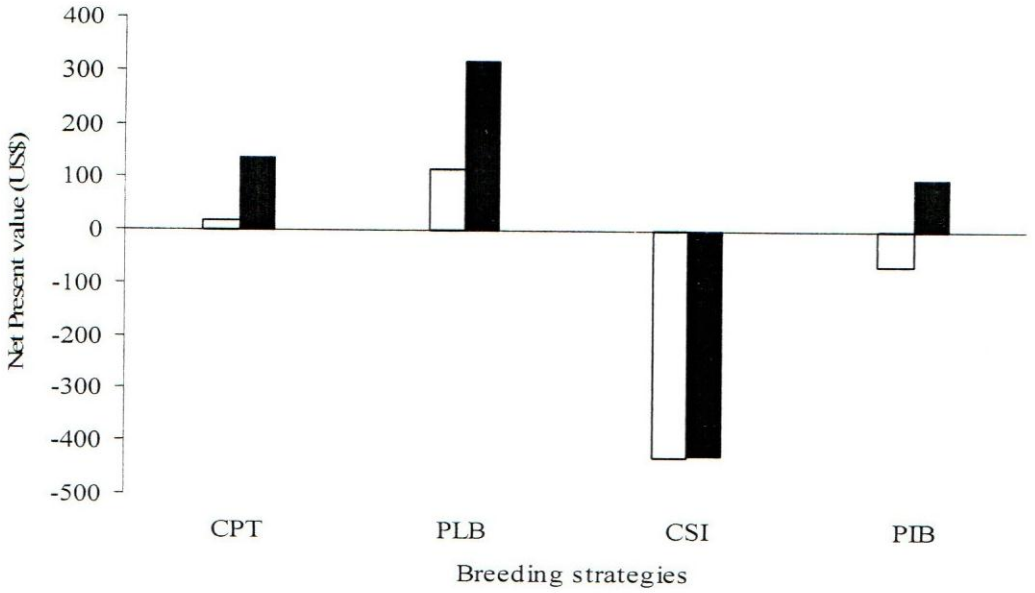


Figure 6. Net present values (US$x10^4) at the projected period of 25 years for the achievable (□) and full theoretical predicted (■) economic responses for the four breeding strategies (genetic correlation = 0.58, initial genetic difference between Kenya and the USA = 1.25SD, exchange rate of 1 US$=Ksh 70 and a discounting rate = 5%). CPT, Closed progeny testing; PLB, Young bull system progeny of local bulls; CSI, Continuous semen importation; PIB, Young bull system progeny of imported bulls.

Change in investment period did not affect the NPV ranking of the strategies and therefore the results are not presented. The four strategies had a negative NPV when the investment was ≤20 years and therefore could not recover the costs apart from PLB, which had a positive NPV at 20 years. The positive value for PLB could be attributed to the short generation interval for the young bulls and the low investment costs when compared to PIB. When full theoretical economic responses (Table 7) were used, only PLB had a positive NPV at 15 years.

4.4. Discussion

The aim of this study was to determine the economic merits of breeding strategies for genetic improvement of dairy cattle in Kenya. In this study, NPV might be overestimated because some of the constraints such as decrease in dairy product prices due to high supply arising from genetic improvement, limited budget for importing genetic material and other production expenses other than feeds and veterinary services were ignored. If such constraints could be identified, then linear programming could be used to analyze different alternatives as it can account for all known constraints compared to cost-benefit analysis (Kizito, 1976). The results were, however, realistic and therefore could be used in the ranking of the breeding

strategies. The ranking of the breeding strategies based on their NPV in this study is consistent with those reported by Mpofu et al. (1993) in Zimbabwe.

The CSI had the highest but negative NPV in all the cases analyzed, meaning that the benefits of this strategy cannot offset the costs. This could be explained by the high operational costs involved in importing semen annually. The current findings concur with those reported by Mpofu et al. (1993) for the use of imported semen to improve HF dairy cattle populations in Zimbabwe. In that study, it was observed that continuous importation of commercial semen had the highest but negative NPV over all the nine breeding strategies considered. When the ranking of CPT, PLB and PIB were compared under different levels of genetic correlations, the NPV ranking changed, with PIB ranking below the local breeding strategies at all levels of genetic correlations considered (Table 8).

Generally, PLB was superior to PIB in NPV under all the genetic and economic parameters considered (Table 8 and 9) but inferior in economic response (Table 7). This change in ranking could be explained by additional investment costs involved in PIB as a result of importing semen and the high exchange rate between the US$ and the KSh (1:70). The CPT scheme ranked below PLB because in CPT proven bulls have a longer generation interval compared to young bulls. This is in agreement with previous studies, which compared the profitability of old and young bull schemes (Mpofu et al., 1993; Nitter, 1998; Kahi et al., 2004). At a genetic correlation of 0.58, the actual level of G x E between Kenya and the exporting countries (Ojango and Pollot, 2002), the utilization of PLB is recommended because it had the highest NPV (Table 8).

The results of this study indicate that the use of CSI is not economically viable under Kenyan production conditions while use of PIB strategy can only be profitable if young bulls used were sons of sires from countries whose dairy cattle population is ≥2.00SD above the Kenyan dairy cattle population (Table 8). Semen imports from such countries may be expensive and unaffordable to many farmers, especially the smallholder dairy farmers who own 70% of the dairy cattle population in Kenya and live below the poverty line (Ojango and Pollot, 2001; Bebe et al., 2003; Kahi et al., 2004). Utilization of imported semen from countries that are 1.25SD above the Kenyan dairy cattle population in genetic merit can also be an alternative but the semen must have a price ceiling of US$ 40 per straw (Figure 5) since importation of semen above this price may not be profitable. Finding semen in the international markets with such price conditions might not be possible. If the average price of high genetic merit semen of US$ 85 (CAIS, 2005) is something to go by, then running of local selection programs is more profitable than the utilization of strategies based on imported

genetic material. Establishment of a dairy industry from imported cattle or genetic material (semen and embryos) is costly (Kizito, 1976) and is advisable for well-managed herds (Holmann et al., 1990).

4.5. Conclusion

Economic evaluation of breeding programs is the most important process in the identification of the most optimal breeding strategy to be used for genetic improvement. This study has shown that the economic merit of breeding strategies, especially those involving importation of semen, is mainly dependent on the level of G x E, initial genetic difference between importing and exporting dairy cattle populations, price of imported semen and the exchange rates. Although most dairy cattle farmers in Kenya use imported semen for genetic improvement, the utilization of local semen, especially from PLB, is more profitable because benefits from CSI cannot offset the costs. If importation of semen has to continue, then PIB is an alternative strategy, but only semen from populations that are ≥2.00SD above the Kenyan dairy cattle population should be imported. But if imports are to be from countries that are 1.25SD above the Kenyan dairy cattle population, then the price of the semen becomes the focal point. This is because use of such semen can only be economically viable at low prices (≤US$ 40).

CHAPTER FIVE

GENERAL DISCUSION AND CONCLUSIONS

5.1. Aim of the study

Dairy cattle breeding in Kenya, is based on the use of genetic material (i.e., semen and embryos) sourced both locally and internationally (Rege, 1991; Ojango and Pollot, 2002; Bebe et al., 2003). The local material is usually from untested young bulls and progeny-tested bulls that are either sons of local or imported sires. Due to the costs involved, semen from locally bred bulls are rarely used for production of embryos in MOET programs. In certain cases, breeding strategies involving continuous semen or embryo importation are utilized in some large-scale farms. The aim of using breeding strategies based on either local or imported genetic material is to improve milk production. However, the choice of each of these strategies has often been done without due regard to their genetic and economic efficiency. The strategies have been studied in other countries but their evaluation under conditions in Kenya to quantify their efficiency in terms of genetic gain and profitability is rare. This means that these strategies are currently being utilized with the assumption that they can be as effective as in other countries where they have been successfully adopted. This assumption, however, might not be true since different countries have different production systems and operate under different environmental conditions. This current study therefore aimed at genetically and economically evaluating breeding strategies for genetic improvement of dairy cattle in Kenya. The study was based on three research questions: (i) what genetic progress is achieved when local selection programs are utilized to improve milk yield and fertility traits? (ii) what genetic progress is achieved when imported genetic material is utilized to improve milk yield and fertility traits? and (iii) what are the economic merits of local selection programs and continuous importation of genetic material in genetic improvement of dairy cattle?

5.2. Study methodology

5.2.1. Genetic evaluation

The Gflow program (Hill, 1974) as described by Brascamp (1978) and the selection index methodology (Hazel, 1943) were used to estimate the CDE and response to selection of traits in the breeding goal, respectively. The four breeding strategies evaluated included, CPT, PLB, CSI and PIB. The CPT and PLB were considered as strategies based on local selection programs while CSI and PIB were strategies involving semen importation. These four

breeding strategies reflected the sources of genetic materials (semen) used for dairy cattle breeding in Kenya. In all breeding strategies, only one breeding unit (nucleus) was considered. It was further assumed that the generation of genetic gain, performance and pedigree recording and sire selection were the major activities in the nucleus in both the importing and exporting country.

Traits in the breeding goal for the importing country (Kenya) included MY, FY and AFC while those in the exporting country (USA) were MY, FY and PY. The genetic and phenotypic parameters of traits in the selection criteria and breeding goal were assumed to be equal for Kenya and the USA (Table 3). This was to ensure that any difference observed in the genetic response was due to differences in the breeding strategies and not parameters employed. Because the biological parameters used in all the strategies were similar, there was no sensitivity analysis done to ascertain the effects of changing these variables to the ranking of the strategies, because it was expected that a change in a variable would have similar effects in all breeding strategies. The discounted economic values used in the analysis were different as the two countries studied (Kenya and the USA) have different traits in the breeding goal and marketing systems (Kahi and Nitter, 2004; Holstein USA, 2006). The correlations between traits in the breeding goal in the two countries were estimated as described by Gibson and van Arendonk (1998) as breeding strategies with different breeding goals cannot be directly compared. A discount rate of 5% was used when estimating the CDE for a projected period of 25 years. Sensitivity of the results to changes in discount rate was also investigated at two different levels 0 and 10% (Table 5).

5.2.2. Economic evaluation

Cost-benefit analysis using NPV as the evaluation criterion (Gittinger, 1982; Randall, 1987) was used to assess the economic merits and rank the four breeding strategies studied. Only benefits from genetic improvement (Table 6) were considered in the analysis while secondary economic benefits because of the improvement program were ignored. The benefits of genetic improvement were calculated as economic response (Table 6) multiplied by the total number of cows in the nucleus (2,500) bred by AI and pedigree recorded. The costs for genetic improvement were classified as production, investment, operational and contingency costs and were obtained from large-scale dairy farmers and government and private institutions involved in genetic improvement of dairy cattle in Kenya.

5.2.3. Limitations of methods used

Models to evaluate breeding strategies can either be deterministic or stochastic. When a model is deterministic, mathematical theories are used to predict outcomes of interest with absolute certainty while stochastic models those that involve generation and propagation of a population at the animal level (Brown and Rothery, 1993). In this study, a deterministic model was used, indicating that the results are completely determined by the input biological and economic parameters. Changes in the parameters in the model based on the breed, production systems and production circumstances in question are always recommended. In this model, however, the biological and technical parameters for both the importing and exporting country were assumed to be constant during the evaluation period and only one round of selection was considered. This is the major drawback of the model employed for genetic evaluation of breeding strategies in this study. However, the results serve to rank the breeding strategies considered.

The major limitation of cost-benefit analysis using NPV as the evaluation criterion to predict the economic efficiency of the breeding strategies is that it overestimates the economic merits because it assumes some eventualities, i.e., decrease in price of dairy products due to high supply arising from genetic improvement, limited budget for importing genetic material and other production expenses (Kizito, 1976; Mpofu et al., 1993b). Generally, the two models (genetic and economic) employed in this study assumed only productive traits in the breeding goal for the USA while in reality fertility and conformation traits have been included in the USA breeding goals.

5.3. Genetic and economic comparisons of breeding strategies

The basic objective of this study was to compare the genetic and economic performances of breeding strategies utilizing local genetic material (CPT and PLB) and those using imported semen (CSI and PIB). On the basis of results obtained, possibilities of using local breeding strategies for genetic improvement of dairy cattle in Kenya should be explored. Between the two breeding strategies utilizing local selection programs evaluated in this study, PLB was found to be superior to CPT in terms of genetic gain and economic merit (Table 7). The superiority of PLB over CPT could be explained by the short generation interval of the young bulls compared to that of progeny tested bulls. Selection response is inversely proportional to the generation interval (Rendel and Robertson, 1950) and therefore the longer the generation interval the lower the selection response. The long generation interval of progeny tested bulls also had a negative impact on the economic merit of CPT. In CPT, bulls

were raised in the bull station for a long time while waiting for their daughters' records to be used in genetic evaluation. This increased the operational costs, leading to lower profits than in PLB. In PLB, young bulls were selected at a young age based on sib selection. The findings of this study are inline with previous studies, which compared the genetic and economic merits of breeding programs and strategies utilizing old and young bull schemes (i.e., Mpofu et al., 1993a and b; Nitter, 1998; Kahi et al., 2004: Kosgey et al., 2005). When comparing breeding programs and strategies for genetic improvement of dairy cattle in the developing countries, these studies generally concluded that use of YBS was superior to OBS, both in genetic response and profitability.

This study has also showed that utilization of imported semen is dependent on the level of G x E, initial genetic differences between importing and exporting countries (Figure 3 and 4) and on the economic parameters such as exchange and discounting rates (Table 8), and price of imported semen (Figure 5). The correlation between traits in the breeding goal for the importing and exporting countries was approaching unity (0.97) and therefore did not affect the ranking of the breeding strategies. When the local selection programs were compared with importing strategies assuming standard genetic parameters (genetic correlation = 1.0 and initial genetic difference = 1.0), the strategies involving imports ranked above local strategies (Table, 6). This ranking, however, changed with introduction of different levels of genetic correlation and initial genetic differences. It was observed that utilization of imported genetic material can only be justified when the level of genetic correlation between Kenya and the USA is ≥ 0.7. This level of genetic correlation is higher than 0.58 reported between Kenya and the exporting countries (Ojango and Pollott, 2002), meaning that the effect of G x E is significant and therefore should not be overlooked when deciding on the breeding strategy to adopt. Ignoring it may lead to random fluctuations in genetic progress.

The result of the current study concurs with those reported in earlier studies (Mpofu et al., 1993a; Vargas and van Arendonk, 2004). Those studies observed that the major hindrance in utilization of imported semen is the magnitude of G x E between importing and exporting countries. They recommended use of imported semen only in situations where the level of G x E between importing and exporting counties is ≥ 0.75. Otherwise, establishment of local selection programs is justified. An alternative to the use of imported semen is the PIB strategy, but the imports have to be from countries with dairy cattle populations that are 2.0SD above the Kenyan population in genetic merit. Such semen might be too costly to most farmers, especially the small-scale farmers. The economic evaluation of the four breeding strategies in this study has confirmed that the profitability of imported semen depends on the

price (Figure 5). It has also shown that strategies involving imported semen are only profitable when imports are currently bought at US$ $\leq$ 40. Getting semen of high genetic merit at such a low cost might be impossible because of the demand for animals of high genetic value. Due to the above-mentioned obstacles hindering utilization of imported genetic material, this study therefore calls for the design of a local breeding strategy.

5.4. Establishment of a breeding strategy for genetic improvement in Kenya

5.4.1. Establishment of a local breeding program

In the present study, it was observed that utilization of imported genetic material, which is the current routine among the dairy cattle farmers in Kenya is not justified. This is because of the magnitude of G x E between Kenya and the exporting countries, price of imported semen and current exchange rate between the US$ and the KSh. This leaves Kenyan dairy cattle farmers with an option of developing a local breeding program. Establishment of local selection programs as suggested in this study has also been recommended in other developing countries, which relied on the use of imported semen for genetic improvement (Mpofu et al., 1993a; Vargas and van Arendonk, 2004). The two local selection programs evaluated in this study were CPT and PLB. These strategies reflect the major sources of local semen used by dairy cattle farmers in Kenya. Although most large-scale dairy farmers use imported semen, some serve their animals with semen from local proven bulls. The price of proven semen (US$ 5) per straw in most cases is too high to most small-scale farmers and therefore they buy semen of unproven bulls (US$ 2.57 per straw) or they use the young bulls which are progeny of proven bulls for natural mating. This study has demonstrated that utilization of PLB strategy is not only genetically superior to CPT but is also profitable. Therefore, establishment of a local selection program utilizing the young bull system (PLB) is recommended.

The implementation of local breeding programs such as PT in developing countries has been difficult to realise because such schemes require participation of a large number of farmers in milk recording and efficient utilization of AI, which is lacking (Rege and Wakhungu, 1992; Mpofu et al., 1993a; Vargas and Van Arendonk, 2004). In Kenya, for instance, the PTS for the Sahiwal herd failed because of organizational problems, lack of pedigree and milk recording in the commercial population, and insufficient funds due to over-reliance on donor funding (Rege and Wakhungu, 1992). To overcome these problems the use of nucleus breeding schemes has been suggested because such schemes do not require

expensive infrastructure and rely less on the information collected from the commercial cow population as recording and evaluation are mainly done within the nucleus (Smith, 1988; Kinghorn, 2000; Vargas and van Arendonk, 2004). Previous studies in Kenya recommended the use of an open nucleus breeding system utilizing young bulls (Kahi et al., 2004), which is in line with the current study. Establishment of an open nucleus scheme, may, however, still experience the problems incurred earlier because such schemes require on-farm performance recording and evaluation, which is not characteristic of small-scale dairy cattle farmers in Kenya.

The major question would therefore be how this program (open nucleus breeding scheme utilizing PLB) can be established and operated in Kenya without repeating the past mistakes. This can be achieved through introduction of the programs in two phases. The first phase should be introduction of a closed nucleus breeding scheme in a number of existing private large-scale herds or herds owned by parastatal or research institutions. Establishment of a closed nucleus scheme initially has the advantage of blocking unimproved genetic materials from the lower tiers in order not to compromise the genetic gain made in the nucleus (James, 1977). The number of herds to be used as a nucleus should be determined by the herd size, infrastructure, the total population size and the willingness of farmers to join the breeding program and co-operate with other participating nucleus herds (Kahi et al., 2004). As most of these farms and institutions usually compete with one another, bringing them together to participate in the formation of a breeding program might be difficult. This, however, can be solved by providing incentives such as retention of a given percentage of profit raised from sale of semen from bulls bred and raised in the herd, long-term contracts for supply of bulls to farmers for natural mating, discounts on electronic data processing and breeding advice to participating farmers (Kahi et al., 2004).

Dairy cattle breeding programs in developing countries are mostly run by governments (Mpofu et al., 1993b). The governments could therefore also fund them in the initial stages to avoid reliance on donor funds, which are always unreliable. The government could also provide incentives to participating herds by reducing stiff competition from imported semen and other dairy products through imposition of high import duties on such products. The incentives would not only reduce competition among the private large-scale farmers and research institutions but would also encourage many farmers to participate (Kahi et al., 2004).

The second phase of the program should be the opening of the nucleus once some substantial genetic improvement has been achieved, both in the nucleus and in the commercial

population. Opening nucleus breeding schemes allows movement of genetic material from the nucleus to the lower tiers and vice-versa. The movements reduce inbreeding in the nucleus and are also recommended because some offspring in the commercial population may be superior to the average performance of certain parents in the nucleus (Garrick, 1993). Open nucleus schemes have been found to be 10% superior to closed systems of the same size in genetic gains because there are more animals which are potential candidates for selection (Bondoc and Smith, 1993; Roden, 1994). Opening up of the nucleus should be done by finding farmers who are willing to join the scheme and their specific needs, social circumstances and ecological constraints should be considered in the breeding goal (Sölkner et al., 1998). Selection of the farmers should be based on certain criteria, i.e., possession of a land title deed, farm accessibility by road, water availability, herd size, ability to keep performance records, to supplement animals during drought and the willingness to give good animals to be used in the nucleus or for elite mating using semen from the nucleus (Kahi et al., 2004). For the program to work efficiently, motivation of the farmers in the lower tiers (i.e., commercial population) is important as some of them may be reluctant to allow their best animals to be used in the nucleus or for elite mating. Providing incentives like the transfer of profit made from sale of milk to the farmer or lease of quality animals to the nucleus is a good option. The farmers could also retain their good animals so that the elite matings are done on-farm. This would encourage more farmers to participate in the program (Kahi et al., 2004). It is important to remember that establishment of nucleus breeding schemes in the Kenya might be difficult because of organizational, management problems or lack of funds. This means that utilization of international breeding values to select good genetic material for local production systems may still play a very important role in the genetic improvement of dairy cattle.

5.4.2. Utilization of international breeding values

Although this study has proposed establishment of a local breeding program utilizing a YBS, the implementation of such programs in the developing countries might be tricky because open nucleus schemes require on-farm recording and evaluation. Constraints such as small herd sizes, lack of systematic identification, lack of funds, organizational and managerial problems, among others (Kahi et al., 2004; Kosgey et al., 2005), might result to inefficiency of such programs. Since the current trends in dairy breeding lean towards globalization of breeding programs, it is expected that international breeding companies will still continue to play an important role in genetic improvement of dairy cattle in the

developing countries (Vargas and Van Arendonk, 2004). In Kenya, like other developing countries, the use of international breeding strategies has been on-going (Rege, 1991; Ojango and Pollott, 2002; Bebe et al., 2003). But importation has been done without taking due consideration of the effect of G x E, which is the major obstacle in the utilization of imported genetic material. This has resulted in low genetic response achieved locally because only 44% of the genetic response achieved in the exporting countries could be expressed in Kenya (Ojango, 2000). This means that developing countries have to determine the most appropriate strategy to adopt when using imported semen and define the threshold level below which a sire should not be selected. In this study for instance, the utilization of PIB strategy has been recommended as an alternative for Kenya. It was also observed that the use of PIB can only be justified if imports from the USA are ≥2.0SD above the Kenyan dairy cattle population in genetic merit. But since semen used for genetic improvement come from different countries, it would be advisable for developing countries in the tropics to participate in the international evaluation of sires under the guidance of INTERBULL (Ojango 2000; Vargas and Van Arendonk, 2004).

Using the procedures of MACE, INTERBULL would be able to rank bulls for each country according to the needs of that country (Philipsson, 1998). This would help to match each country with genotypes which are suitable for existing production conditions, thereby resulting in reduced effects of G x E. Figure 7 is an illustration of how INTERBULL plays an important role using MACE to rank sires as per the requirements of each country. For example, it can be observed that sires bred in-country tend to rank higher than the imported sires, i.e., X_1 and Y_1 ranked higher in country X and Y, respectively. If imports were to be used then sire X_2 would perform well in country Y production conditions than sire X_1, which was the best sire in its native environment. Such information would help countries that use imported genetic material to make wise decisions on which sires to choose when importing. Use of the INTERBULL ranked sires will also depend on the economic parameters, i.e., price of semen, discount and exchange rates between the importing and the exporting countries.

An alternative to the use of INTERBULL ranking is utilization of conversion equations (Wilmink et al., 1986) to determine the threshold level below which EBVs of imported semen should not fall. This would help developing countries relying on imported semen but cannot participate in INTERBULL evaluations to convert proofs calculated in the exporting countries to local production conditions before deciding from which country to import.

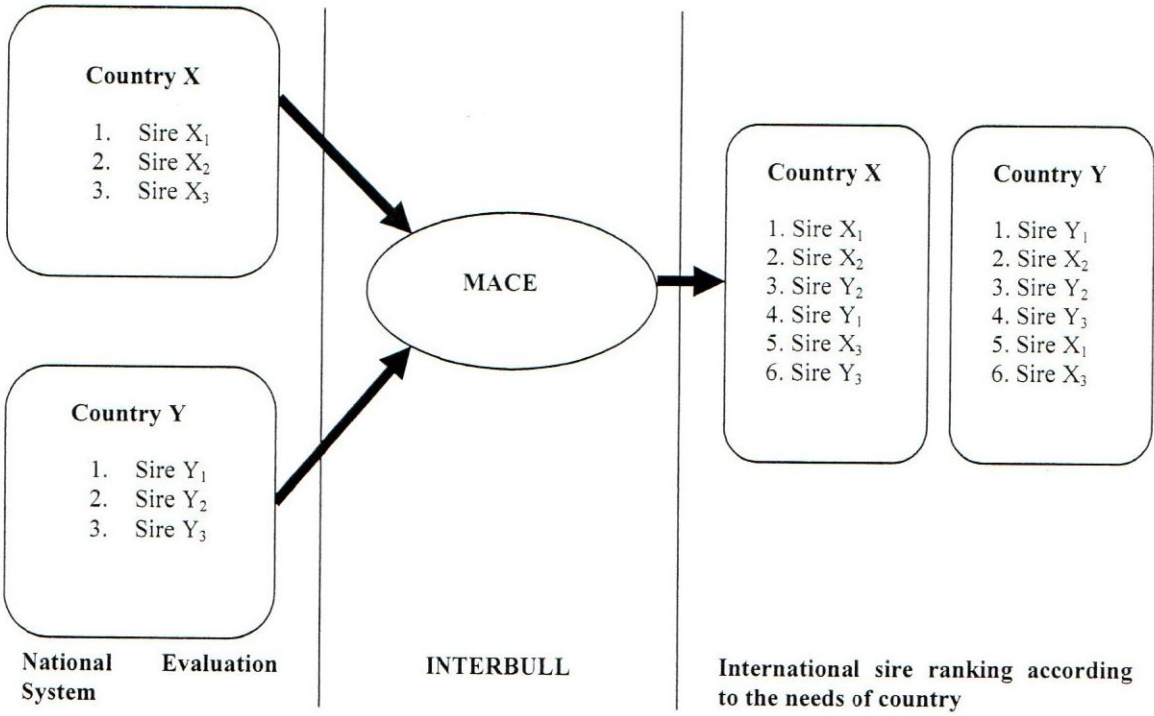


Figure 7. Schematic illustration of multiple across-country evaluation (MACE) (Source: Philipsson, 1998).

5.5. Conclusions

This study has provided first-hand information on the most appropriate breeding strategy to be utilized for genetic improvement of dairy cattle productivity under the local Kenyan production conditions. It has demonstrated that developing countries like Kenya have to switch to local selection programs. The study has shown that when establishing such schemes, the strategy to be employed should be PLB because this strategy was found to be genetically superior and more profitable than CPT.

The genetic gain achieved through strategies involving imported semen were found to be mainly dependent on the level of G x E and the initial genetic differences between importing and exporting countries because no significant differences in the traits in the breeding goal were observed. Because of the low level of genetic correlation between Kenya and the USA (0.58), the utilization of strategies based on imported semen is not justified from the genetic point of view. However, it was observed that if the use of imported semen is to continue, then imports should only come from countries that are ≥2.00SD above the Kenyan dairy cattle population in genetic merit. The economic analysis demonstrated that the use of CSI strategy is not economically viable under the local production conditions while the PIB

are only profitable when imports are from countries that are ≥2.00SD. It was also observed that at that level of genetic difference (≥ 2.00SD), the PLB strategy was still superior.

The economic rankings of strategies involving imports were mainly dependent on economic parameters (price of imported semen, exchange and discounting rates) while the genetic parameters did not affect the ranking. Although use of a nucleus breeding scheme utilizing the PLB strategy has been recommended in this study further research should be done to investigate the magnitude of G x E between the nucleus and the commercial populations and its effect on genetic improvement of the commercial population using bulls selected in the nucleus. It should also be noted that, although Holstein Friesian dairy cattle breed was used in this study, the results and recommendations are applicable across other dairy cattle breeds.

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