Genetic and economic evaluation of alternative breeding objectives and schemes using deterministic simulation in Kenya

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Abstract

Deterministic simulation was used to evaluate alternative breeding objectives and schemes in a synthetic cattle breed in Kenya. A two-tier open nucleus breeding scheme and a young bull system (YBS) were assumed. Apart from one breeding scheme in the beef objective, all breeding objectives and schemes realized profits. In the breeding objective that assumed that payment is based on fat content, the difference in profit per cow between the scheme that assumed records on fat yield (FY) were available for use as selection criteria and that, which assumed no records on FY were available, was small. Therefore, under the current production and marketing conditions, a breeding scheme that requires measuring of the fat content seem not to be justified from an economic point of view. There is evidence that a well-organised breeding programme utilizing an open nucleus, a YBS and the smallholder farms as the commercial population could sustain itself.

Keywords: Breeding objectives; Dairy cattle; Selection; Synthetic breeds; Tropics

Introduction

In most of the tropics, any genetic improvement programme that is targeted at the smallholder dairy sector has a major impact (Walshe et al., 1991). To utilise the resources of between breed variations, the synthetic breed strategy has been recommended as the most realistic approach in this dairy sector because of its organisational simplicity (Syrstad, 1996; Kahi et al., 2000a and b). Developing a synthetic breed necessitates a strategy for within breed genetic improvement. So far, there are no effective genetic improvement programmes in Kenya, owing to various constraints, e.g. small herd size, lack of systematic identification, inadequate animal performance and pedigree recording, organisational shortcomings etc. Nucleus breeding programme can be a good strategy for genetic improvement in developing countries which lack the money, expertise and structure required for operating an efficient improvement programme based on AI and milk recording in the whole population (Smith, 1988).

It has been shown that a young bull system (YBS) has lower costs and gives more profit than the conventional old bull system and that it has an advantage when the time horizon considered is short, the resources are limited and interest rates are high (Owen, 1975; Mpofu et al., 1998; Nitter, 1998). The latter two are the common problems that characterise most of the non-industrialized countries. This paper therefore examines using deterministic simulation, a two-tier open nucleus breeding scheme using the YBS with a view of evaluating the genetic and economic efficiency of various breeding objectives and breeding schemes.

A synthetic breed is taken as an example, however, the results can also be applied to other breeds. The synthetic breed is assumed to be fully established (hence managed as a purebred population) and well distributed throughout the country. According to the structure of livestock production in Kenya, private large scale herds or herds owned by the government or parastatal organisations are considered to be the nucleus while other smallholder herds considered to be the commercial sector supplied by young bulls from the nucleus.

Material and methods

Breeding objectives

Four breeding objectives (i.e., the choice of traits to be genetically improved because they influence the producers income) were defined. These traits included: milk yield (MY), fat yield (FY), lactation length (LL), preweaning daily gain (DG), age at first calving (AFC), calving interval (CI), postweaning daily gain (PDG), mature live weight (LW), herdlife (HL), preweaning survival rate (SR) and postweaning survival rate (PSR). The objectives included three dual purpose objectives, which represented the present (objective 1 - dual purpose), smallholder (objective 2 - dual purpose with limited LW) and future production situations (Objective 3 - dual purpose with fat based milk price), and one beef objective and differed from one another by the traits included and their economic values. Table 1 shows the economic values of the various traits estimated for each breeding objective. The economic values were un-discounted and calculated as the partial derivative of the profit with respect to the trait considered, keeping all other traits constant at the mean value (Kahi, 2000) and were calculated for each objective after considering all the assumptions.

Table 1. Marginal economic values per unit (v) for the various traits

Trait[a]	Objective 1 v (KSh, per unit)	Objective 2 v (KSh, per unit)	Objective 3 v (KSh, per unit)	Objective 4 v (KSh, per unit)
Milk production traits				
MY (kg)	18.9*	18.9*	16.1*	0
FY (kg)	-2.8	-2.8	79.4*	0
LL (days)	-22.6*	-22.6*	-22.6*	0
Reproductive traits				
AFC (days)	4.8*	4.8*	4.8*	4.8*
CI (days)	11.4*	11.4*	11.4*	11.4*
Growth traits				
DG (g/day)	2.8*	2.8	2.8*	2.8*
PDG (g/day)	9.1*	9.1	9.1*	9.1*
LW (kg)	7.0	-7.0	-7.0*	7.0*
Longevity and survival traits				
SR (%)	10.9*	10.9*	10.9*	10.9*
PSR (%)	87.5*	87.5*	87.5*	87.5*
HL (days)	3.4	3.4	3.4	3.4

[a]MY = Milk yield; FY = Fat yield; LL = Lactation length; AFC = Age at first calving; CI = Calving interval; DG = Preweaning daily gain; PDG = Postweaning daily gain; LW = mature live weight; SR = Preweaning survival rate; PSR = Postweaning survival rate (to 18 months); HL = Herdlife.
[b]*indicates that the trait is included in the selection index.

Selection groups

A two-tier open nucleus breeding scheme and a young bull system (YBS) were assumed with intensive recording and 100% artificial insemination

(AI) in the nucleus and 35% AI in the commercial population. The nucleus (N) is the tier that generates genetic gain and where sire selection is the main activity. Selection of old bulls (OB) occurs to produce both bulls and cows used in the nucleus (old bulls to breed sires, $S_N^{OB}\varepsilon S_N$ and old bulls to breed dams, $S_N^{OB}\varepsilon D_N$) while young bulls (YB) are the sires of dams (young bulls to breed dams, $S_N^{YB}\varepsilon D_N$). A small collection of semen is stored per young bull until the first batch of daughters has been tested.

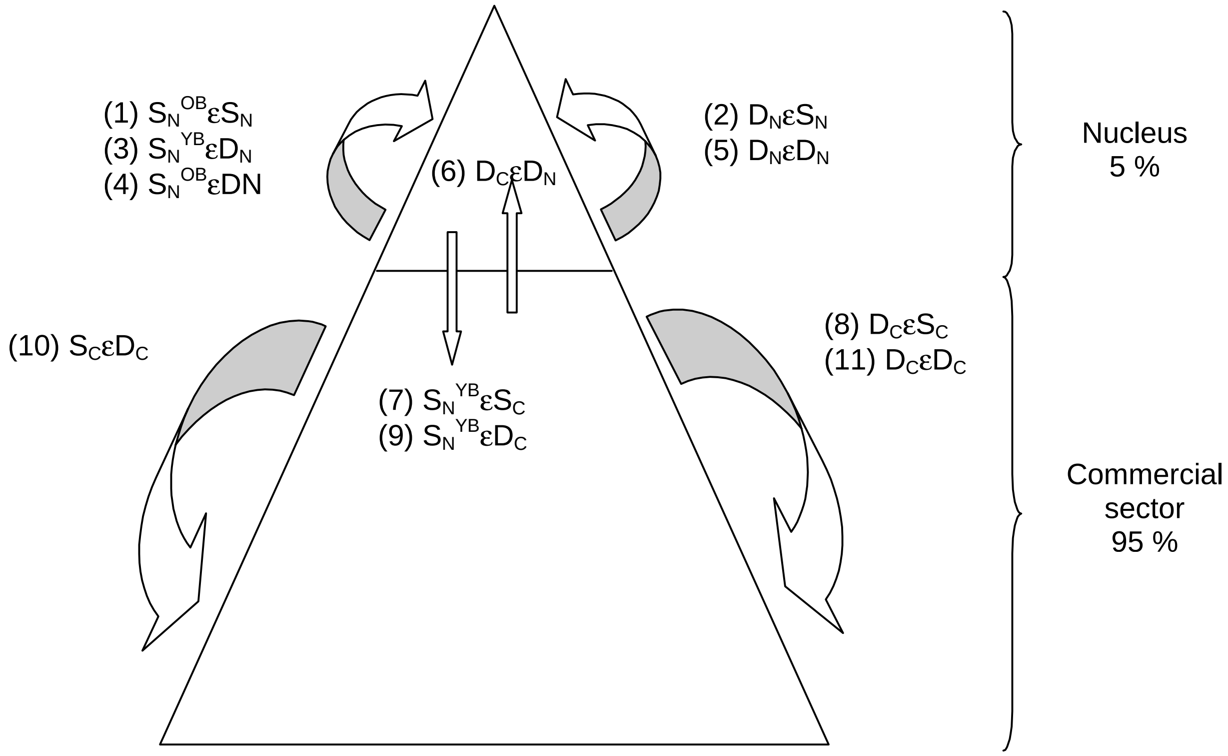

Figure 1. The breeding structure and selection groups coded from 1 to 11: S_N^{OB}, S_N^{YB} and D_N = Old bulls, young bulls and dams, respectively, in the nucleus; S_C and D_C = sires and dams, respectively, in the commercial sector

Selection of dams also occurs to improve both bulls (dams to breed bulls, $D_N\varepsilon S_N$) and cows (dams to breed cows, $D_N\varepsilon D_N$). In the nucleus, the last selection group is complemented by dams from the commercial sector, which are selected subjectively in their first lactation. This is a separate group to produce cows in the nucleus ($D_C\varepsilon D_N$). The bull dams (i.e., in the $D_N\varepsilon S_N$ selection group) are inseminated with stored semen from the best bulls (i.e. old bulls). Only young bulls are used in the commercial sector to produce cows ($S_N^{YB}\varepsilon D_C$) and to sire bull calves that are kept for use to mate a proportion of the cows in this sector ($S_N^{YB}\varepsilon S_C$). These calves become sires that are used in this sector to produce cows ($S_C \varepsilon D_C$) but their sons are not used for breeding. The dams in the commercial sector are used to produce both bulls and cows in this sector ($D_C \varepsilon S_C$ and $D_C \varepsilon D_C$). Figure 1 shows the breeding structure and selection groups coded from 1 to 11.

It was assumed that there is intense recording of performance in the nucleus but none in the commercial population. Therefore selection of cows is restricted to the nucleus but the best cows in the commercial sector that join the nucleus after their first lactation are selected subjectively. This is based on milk yield on a particular test day for the breeding objectives 1 to 3 and AFC for objective 4. These traits were assumed as the information for an index of this group (group 6). In some smallholder production systems, technical performance at the individual farm level is low (because of low reproductive rate, high wastage, etc) resulting in, at best, a stable herd size, and probably a declining herd indicating that the scope for selection amongst replacements is small. The potential for movement of cows from an individual smallholder farm to the nucleus herd may therefore be limited. Consequently, it was assumed that the commercial population comprises of 100 participating village herds each with several individual smallholder farms and therefore a considerable number of cows from which replacements can be selected.

Genetic and phenotypic parameters

Genetic and phenotypic parameters for the selection criteria and the traits in the aggregate genotype are required in order to calculate the composition and the accuracy of selection indices. Ideally such estimates should come from experiments with the particular population used in the breeding system and should include all important traits. This is difficult to achieve and estimates are usually developed from a search of the literature (Koots et al., 1994a and b). Therefore estimates were derived from a search of the literature and are reported elsewhere (Kahi, 2000).

Computer programme, population structure and biological, technical and economic parameters

Based on the biological, technical and economic parameters, ZPLAN calculates selection indices for breeding animals and applies order statistics to obtain adjusted selection intensities for populations with finite sizes (Karras et al., 1997). Reduction of the genetic variance due to selection and inbreeding is ignored. Different biological and technical parameters were used for the nucleus and the commercial population. Variable and overhead costs occur exclusively in the nucleus. The fixed costs were those incurred in one round of selection and are the overhead costs of running the nucleus of 2500 cows. The average time when fixed costs occur is assumed to be the mean generation interval, which was assumed to be 3.2 years. The biological, technical and economic parameters were based on Kahi (2000). Both variable and fixed costs only affect the profit but not the genetic response. The return was discounted at a rate of 5 % and costs at a lower rate of 3 %. An investment period of 25 years is considered.

A total population of 50,000 cows was considered and the size of the nucleus with performance and pedigree recording was 5% (2500 cows) of this population. Seventy percent of bulls for the commercial sector come from the nucleus. In commercial sector, the bull to cow ratio was 1:500 and 1:50 for AI and natural mating, respectively. Twenty percent of the dams in the nucleus come from the commercial population. An important parameter for the population structure was the proportion of bull dams, which was assumed to be 5% of the nucleus. The annual monetary genetic gain and profit per cow in the population were used as evaluation criteria.

Breeding schemes, selection criteria and index information

Breeding schemes were defined which differed in the records available for use as selection criteria as well as in the costs and investments parameters. Breeding schemes, which require increased levels of performance recording and genetic evaluation have increased costs, which are directly attributed to the scheme.

Table 2. The available selection criteria for each breeding objective and scheme

Breeding objective	Breeding scheme	Traits recorded[a] AFC	CI	SR	PSR	LL	MY	DG	PDG	FY	LW
	1	X	X	X	X	X					
1	2	X	X	X	X	X	X				
	3	X	X	X	X	X		X	X		
	4	X	X	X	X	X	X	X	X		
2	1	X	X	X	X	X					
	2	X	X	X	X	X	X				
	1	X	X	X	X	X					
	2	X	X	X	X	X	X				
3	3	X	X	X	X	X		X	X		
	4	X	X	X	X	X	X	X	X		
	5	X	X	X	X	X	X	X	X	X	
4	1	X	X	X	X						
	2	X	X	X	X			X	X		X

[a]AFC = Age at first calving; CI = Calving interval; SR = Preweaning survival rate; PSR = Postweaning survival rate (to 18 months); LL = Lactation length; MY = Milk yield; DG = Preweaning daily gain; PDG = Postweaning daily gain; FY = Fat yield; LW = mature live weight.

Table 2 shows the available selection criteria for each breeding objective and scheme. Selection was on an index that was based on the available criteria. These traits were chosen because their recording is possible and apart from CI, SR and PSR, because of their reliable heritability and correlation estimates among them and with the other traits in the breeding objectives.

Results

The annual monetary genetic response, returns, costs and profit of alternative breeding objectives and schemes representing different levels of investment in performance recording are shown in table 3. Generally, within each objective the annual monetary genetic response was highest for the breeding scheme representing the highest level of investments. For example, in objective 3 the highest annual monetary genetic response was obtained in scheme 5 which had the highest number of traits used as selection criteria within this objective and in comparison to the other objectives.

Table 3. Annual monetary genetic response, returns, costs and profit of alternative breeding objectives and schemes representing different levels of investment in performance recording

Breeding objective[a]	Breeding scheme[a]	Annual monetary genetic response (KSh)	Total return per cow (KSh)	Profit per cow (KSh)
	1	254.11	1370.81	934.34
1	2	361.95	1983.11	1513.16
	3	298.97	1591.47	1149.40
	4	400.08	2140.16	1664.62
2	1	253.03	1365.25	928.77
	2	360.29	1974.62	1504.67
	1	290.63	1571.04	1134.56
	2	396.85	2031.45	1561.50
3	3	321.25	1703.15	1261.09
	4	400.40	2142.32	1666.79
	5	407.45	2178.61	1628.95
4	1	32.95	164.59	-271.88
	2	105.35	603.59	157.66

[a]See text for the description of breeding objectives and

Table 3 for the available selection criteria and hence level of investments for each breeding scheme.

A comparison of the annual monetary genetic response of scheme 4 of breeding objectives 1 and 3 shows very little difference in the monetary response indicating that there is little benefit including FY as a trait in the breeding objective but not having fat content as a selection criterion. The lowest annual monetary genetic response was obtained in objective 4, which was a specific objective (beef objective) and much different from the others.

The objectives and schemes that ranked highly for annual monetary genetic response and total return per cow did not rank the same in profit per cow in all cases. For example, scheme 5 in objective 3 had the highest annual monetary genetic response and total return per cow but ranked third for profit per cow. This was probably due to the high costs incurred for milk sampling, laboratory determination of fat content and recording FY. However, the difference in profit per cow between this scheme and scheme 5 of the same objective was small (approximately 2%).

Discussion

Usually in establishing a breeding and recording scheme, the major question is that of return on investments. Therefore there must be a compromise between achieving a certain degree of genetic gain and maximizing of profits. As shown in, profit per cow in the population was lowest in objective 4, which was the beef objective. It has been shown that the YBS is more competitive in a dual-purpose breed than in a single purpose breed (Niebel and Fewson, 1978; Moll, 1987). It is recommended that the advantages of the YBS should be considered in the improvement of the synthetic breed or any other pure exotic or indigenous breeds in the tropics. The system could then gradually change to the old bull system at full establishment and after a certain level of expertise has been achieved.

Results demonstrated that breeding objectives that have a dual-purpose nature would represent an efficient and realistic objective. In order to achieve this under the current production conditions, selection should be based on all the traits represented in the aggregate genotype but with no measurement of fat content and LW. Recording of FY in scheme 5 of objective 3 resulted in profits that were similar to those obtained in scheme 4 which assumed that there was no recording of FY (table 3). Therefore, under the prevailing conditions, a breeding scheme that requires records on FY seems not to be justified from an economic point of view especially in situations where these records are to be obtained from all cows in the nucleus, which was assumed in this study. To reduce the overall costs of recording FY in the nucleus, simplified recording methods can be adopted, for example by reducing the number of cows tested and samples taken from each cow per lactation period. Alternatively, a reduction in recording costs of fat content is also possible by testing for fat on pre-determined test days. Use of test-day records instead of cumulative lactation totals for genetic evaluation of potential parents results in improved genetic information and accurate estimated breeding values (Schaeffer et al., 2000). While the possibility of payment based on fat content rather than on milk volume and hence of widespread use of fat recording in Kenya seems unrealistic for the next several years, this suggestion could serve as a guideline for future breeding activities.

Conclusions

The information from this study is a prerequisite for successful establishment of breeding programmes for a synthetic breed or any purebred exotic or indigenous breed. There is evidence that under the current production and marketing conditions, a well-organised nucleus utilizing the smallholder as the commercial population could sustain itself. However, before any breeding programme is established on a large scale, pilot selection schemes should be developed first and shown to work. During all the establishment stages, the needs and interests of the producers as well as the ecological conditions should seriously be taken into consideration. There is therefore the need for further studies on how this can be realized and improved genetics delivered to cattle owners, especially smallholder producers.

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