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Original Article

Economic and Biological Values for Pasture-Based Dairy Cattle Production Systems and their Application in Genetic Improvement in the Tropics

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Abstract

Economic and biological values for milk yield (MY), milk butter fat (FY), daily gain (DG), weaning weight (WWT), mature live weight (MLW), calving interval (CI), pre-weaning survival rate (PreSR), post-weaning survival rate (PostSR), age at first calving (AFC), and productive life time (PLT) were estimated under fixed herd (FH) and pasture (FP) production circumstances assuming milk marketing based on volume, and volume and butter fat. Further, economic values were estimated involving risk using the Arrow Pratt coefficients at two levels. For the former economic values for the traits ranged from KSh. -17.246 to 100.536 while the biological values ranged between -1.29 to 0.791. Economic values with higher Arrow-Prat coefficient of absolute risk aversion (λ=0.02) were lower than those reported under λ=0.0001 indicating that the uncertainty of the future market is important and should be considered during the estimation of economic values. Genetic improvements targeting MY and growth traits would be recommended to production system with unlimited feed supply for profit maximization. However, since dairy production systems in the tropics are characterised by feed scarcity, fixing the herd and concentrating on genetically improved animals would result to more profitability than increasing animal populations.

Keywords: Breeding, economic, biological, dairy, risk.

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Introduction

According to statistics, each Kenyan, on average, consumes 145 litres of milk per year, which is triple the average in Uganda (Kenya Dairy Board, 2012), and the per capita milk availability is increasing (Bebe *et al.,* 2002). This makes the production efficiency of small scale dairy cattle a challenge to meet that high and increasing demand for dairy products. Milk production has increased majorly through increased animal population and not by improved productivity (Nicholson *et al.,* 2001; Mwai *et al.,* 2005; Wambugu *et al.,* 2011). Sustainable performance can be attained through genetic improvement. Feed resource is also a constraint in the tropics in terms of both quantity and quality, particularly as the land sizes decrease due to increasing human and cattle populations. Consequently, most farmers, especially the smallholders, have problems to maintain sufficient replacement stock. To sustain an effective improvement programme, infrastructure is important, since it can result to poor communication, inefficient recording systems, poor data collection or processing procedure, and un-standardised methods of evaluation (Bondoc *et al.,* 1989).

Sustainable systems are lacking or are not effective in addressing the actual production circumstances in dairy cattle production in the tropics. Genetic improvement requires the definition of breeding objectives. The breeding objective should contain traits which are to be improved due to their influence on returns and costs to the producer, and these traits should be identified by the farmers themselves (Kahi *et al.,* 2000; Kahi and Nitter, 2004). Breeding objectives can be defined in terms of money or energy and/ or protein (Wilton, 1979; Groen, 1989) and, consequently, the importance of economic and biological values, respectively.

An economic value of a trait expresses the value of a unit change in the trait, while keeping all the other traits in the breeding objective constant (Bekman and van Arendonk, 1993) or it can be the value in money units of one unit of a trait (Falconer and Mackay, 1996). Economic values have been derived for dairy cattle but the model that was used did not include most variable relationships due to scarcity of production information at that point in time (Kahi and Nitter, 2004). Economic values are important in selection index theory where the aggregate genotype is defined as a linear function of traits to be improved and each trait is multiplied by its economic weight (Smith *et al.*, 1986; Bekman and van Arendonk, 1993). Economic values can be derived using the normative approach (data simulation or bio-economic modelling) or the positive approach, which involves analysis of field data. Bio-economic simulation models can be used to examine changes in the profit or production efficiency due to genetic change and to derive economic values. Biological values are also important, especially in cases where economic information is deficient. The biological value of a trait is the change in biological efficiency due to a unit change in genetic merit of a trait of interest, all other traits being constant. Profits, returns on investment and costs per unit production should be the main goal in any livestock improvement programme (Dickerson, 1970; Harris, 1970), but economic efficiency is a more appropriate basis for estimating economic values (Smith *et al.,* 1986). In the current study, the breeding objective was expressed as production efficiency and not profit.

In Kenya, effective improvement programmes are absent for any cattle breed because of constraints like low effective population size, high cost of reproductive technologies, lack of systematic identification, poor animal performance and pedigree recording, genotype by environment interaction and organizational shortcoming, among others (Kosgey *et al.,* 2011; Kahi *et al.,* 2004). A study by Okeno *et al.,* (2010) evaluated the breeding strategies for improvement of dairy cattle in Kenya and used the breeding objective and economic values from a study by Kahi *et al.,* (2004). The influence of economic values on genetic improvement has not yet been adequately addressed. The objective of this study was to estimate economic and biological values of production and functional traits and investigate their effects on selection indices and genetic response in pasture-based dairy production systems. Kahi and Nitter (2004) reported that a breeding objective with dual-purpose nature (i.e. milk and meat) is efficient and realistic for the improvement of dairy cattle under pasture-based production systems. In Kenya, dairy cattle production is mainly dual-purpose, with milk payment mainly based on volume, but FY is of interest for future markets. Additionally, fat yield is correlated to energy requirements for production, which translates to feed requirements and, subsequently, costs (Korver, 1988).

Materials and Methods

Risk Rated Model

The bio-economic model developed to estimate the economic efficiency of different dairy cattle production circumstances was used in the current study. Briefly, the model incorporates risk and was able to simulate a pasture-based dairy production system, and derive economic and biological efficiencies. The traits that influence the efficiency of production were generally categorized as production and functional traits. Production traits have been defined as characteristics of an animal associated with a product, while functional traits are the characteristics that influence the efficiency of production by reducing or increasing the cost of production (Groen *et al.,* 1997; Vargas *et al.,* 2002). The economic efficiencies for production and functional traits were estimated based on milk sold in terms of volume, and volume and butter fat content. They were computed as the ratio of returns to costs.

The returns were derived from sale of culled cows, male calves, culled heifers and milk, while costs included feed and non-feed inputs like health, reproduction, labour, marketing and fixed costs. The input variables used for estimation of biological and economic efficiency are as presented in Table 1.

Estimation of Economic Values

The economic values were estimated using both simple and risk-rated models. The simple model assumed perfect knowledge of the production systems and market dynamics and, therefore, estimated economic values as the difference between economic efficiency after a unit change in genetic merit of a trait in the breeding objective and economic efficiency before genetic improvement (Hirooka *et al.,* 1998).The risk-rated model assumed imperfect knowledge of the production environment and accounted for future costs and price variances of inputs and outputs. The risk-rated economic values were, consequently, estimated following the procedure of Robinson and Barry (1987) and Kulak *et al.,* (2003). Like in Kulak *et al.,* (2003), the general risk-rated economic values (REV) were computed as shown in equation 1:

$$(1)\ \mathrm{REV}=\mathrm{E}\left(\mathrm{EE}_t\right)-0.5\lambda\mathrm{Var}\left(\mathrm{EE}_t\right)$$

Where E (EE_t) is the expected values of economic efficiencies, λ the Arrow-Pratt coefficient of absolute risk aversion and Var (EE_t) the variance of the economic efficiency. E (EE_t) was computed as indicated in equation 2:

$$(2)\ \mathrm{E}\left(\mathrm{EE}_t\right)=\frac{\mu_{po} f\left(g,e\right)}{e\mu_{pi}}$$

While Var (EE_t) was estimated as:

$$(3)\ \mathrm{Var}\left(\mathrm{EE}_t\right)=\mathrm{E}\left[\mathrm{EE}_t\text{-}\mathrm{E}\left(\mathrm{EE}_t\right)\right]^2$$

Where μ_{po} and μ_{pi} are the expected values of input and output prices, respectively, *g* the vector of the variables determined by the genotype of the animal (genetic traits), *e* the vector of the variables determined by the environment and EE_t is as defined in equation 1. The risk-rated economic values were, therefore, was computed as depicted in equation 4:

$$(4)\ \mathrm{REV}=\frac{\mu_{po}\mathrm{f}\left(g,e\right)}{e\mu_{pi}}\text{-}0.5\lambda\mathrm{E}\left[\mathrm{EE}_t\text{-}\mathrm{E}\left(\mathrm{EE}_t\right)\right]^2$$

When the λ is equated to zero, it indicates that the decision-maker or producer is risk neutral and, therefore, ranks alternatives according to expected efficiency, while positive λ shows that individuals require higher returns. Arrow-Pratt coefficient values are scarce and, consequently, hypothetical values of 0.0001 and 0.02 were used (Kulak *et al.,* 2003). An inflation rate of 3.67% from the KNBS, (2014) (Table 1) was used to estimate the price variations.

Table 1: Assumed values of biological input variables in the simulation.

Variables	Units	Symbols	Value
Milk yield per cow per parity	Kg	MY	4557
Milk fat yield	g/kg	FY	0.0323
Mature live weight	Kg	MLW	435
Pre-weaning daily gain	g/day	PreWDG	313
Post-weaning daily gain	g/day	PostWDG	506
Birth weight	Kg	BWT	30.42
Weaning weight	Kg	WWT	69
Gestation period	Days	Gest	278.34
Woods parameters		B	0.121
		C	-0.025
Cow mortality		Cmort	0.02
Calf pre-weaning mortality		Calfmort	0.09
Metabolizability		Q	0.6*
Dry matter content of concentrates	%	DMconc	89
Dry matter content in pastures	%	DMpast	20
Energy content in concentrates	MJ of NE_L/kg DM	ECconc	7.19
Energy content in pastures	MJ of NE_L/kg DM	ECpast	5.65
Management variables			
Period from birth to weaning	Days	PBW	126
Period from weaning to 18 months	Days	PW18	414
Period from 18 months to first calving	Days	P18FC	476
Maximum reproductive cycles		Cmax	6
Ooestrus detection rate		Edr	0.75
Age at first mating	Days	AFM	741
Maximum inseminations	Days	Imax	3
Period from calving to 1st oestrus cycle	Days	E	85.8
Price of calf	Kes	Pmilk	1000
Price per kg live weight	Kes	Plvwt	56.18
Price of milk per kg	Kes	Pmilk	20
Price butter fat per kg	Kes	Pfat	92.35
Cost of concentrates/MJ	Kes	Cconc	1.62
Cost of pasture/MJ	Kes	Cpast	0.1
Cost of silage/MJ	Kes	Csilage	0.64
Health cost for; a heifer/day	Kes	Chealthh	0.48
a cow/day	Kes	Chealthc	4.48
Reproductive cost for; a heifer	Kes	Creprh	0.69
a cow	Kes	Creprc	0.81
Cost of labour/head/day	Kes	Clabour	4.63
Cost of labour / cow/day	Kes	Clabourc	4.63
Milk marketing cost/kg	Kes	Cmilkm	1.12
Live weight marketing cost/kg	Kes	Clvwtm	2.81
Male calf marketing cost	Kes	Cmalecm	45
Fixed cost/head/day	Kes	Cfixed	1.12

DM: Dry Matter, NE: Net Energy, MJ: Mega Joules, g: grams, kg: kilograms, Kes: Kenya Shillings (Sources: Osei *et al.*, 1991; Rege, 1991; Hirooka *et al.*, 1998; Ojango and Pollot, 2001; Ageeb and Hayes, 2004; Kahi and Nitter, 2004; KNBS, 2010).

Estimation of Biological Values

Biological value is the change in biological efficiency after a unit improvement in each trait in the breeding objectives while holding the other traits constant. The biological efficiency of milk production (BE_{MP}) and live weight (BE_{LWP}) were estimated as shown in equations 5 and 6 below:

$$BE_{MP} = \frac{\sum_{n=1}^{N} TMY_{cow}}{\sum_{n=1}^{N} TME_{cow}} \tag{5}$$

$$BE_{LWP} = \frac{\sum_{n=1}^{N} \left(TLW_{ccow} + TLW_{cheifer}\right)}{\sum_{n=1}^{N} \left(TME_{ccow} + TME_{cheifer}\right)} \tag{6}$$

Where N is the maximum allowed reproductive cycles, TMY_{cow} the total milk yield from the lactating cows and TME_{cow} the total metabolisable energy (ME) utilized by the lactating cows. TLW_{ccow} and $TLW_{cheifers}$ are the total live weight of culled cows and heifers, respectively, while TME_{ccow} and $TME_{cheifer}$ denotes there corresponding total ME utilized. The difference between biological efficiency after a unit increase in genetic merit of a trait in the breeding objective and before the improvement was considered as the biological value.

Production and Functional Traits

The traits that were considered for selection were milk yield (MY), daily gain (DG), weaning weight (WWT), calving interval (CI), milk fat yield (FY), productive lifetime (PLT), pre-weaning survival rate (PreSR), post-weaning survival rate (PostSR) and age at first calving (AFC). Age at first calving and CI are important because they determine the days a cow is in milk and the number of calves in the PLT for replacement or sale (male calves). Dry animals have a negative impact on profit due to the cost of maintaining them (i.e., feed, health care and labour). Mortality rate, both pre- and post-weaning are major constraints in developing countries and, therefore, the need to include survival in the breeding objective (Kahi *et al.,* 2000; Bebe *et al.,* 2003). The ability of an animal to survive and produce in a given period reflects its adaptability to the prevailing conditions and, consequently, pre- and post-weaning survival rate can be linked to adaptability (Kahi and Nitter, 2004). Productive life time is important in determining how long an animal remains productive in the herd and is related to survival, hardiness and productivity. This influences the replacement rate, which has a cost and also affects the herd composition (Groen *et al.,* 1997).

Prediction of Genetic Gains Using Economic and Biological Values

The genetic gains for traits in the breeding objectives were predicted using the selection index methodology (Hazel, 1943). Selection index methodology uses a deterministic modelling approach and, therefore, the outputs are determined by the input parameters. Estimation of the indices requires weighting factors and information on selected individuals. The information sources for the selected candidates were obtained from both own performance and pedigree information (BLUP). The weighting factors were derived from genetic and phenotypic parameters i.e. Best Linear Unbiased Prediction (Table 2) estimated from performance data of dairy cattle populations in Kenya (Rege, 1991; Ojango and Pollot, 2001; Amimo *et al.,* 2006). The risk-rated economic and biological values for traits in the breeding objective obtained in the present study were used in the estimation of genetic response. Since traits in the breeding objective were not expressed with the same frequency or at the same time, Gflow Computer Programme (Brascamp, 1978) was used to calculate the cumulative discounted expressions to discount the economic and biological values. A discounting rate of 5% with an investment period of 25 years was considered.

The economic and biological values and genetic responses for breeding objective traits were estimated under two production systems: fixed-herd (FH) and fixed-pasture input (FP). In the FP, the number of animals in the model was determined by pasture availability and, consequently, excess animals were culled. In the FH, a fixed-herd size was assumed and the energy requirements of these animals were assumed to be met. In each production system, the economic values were calculated assuming milk marketing based on volume (current marketing strategy) (MV), and milk volume and butter fat content (future marketing strategy) (MVFC) circumstances. The biological values adopted in the two production systems were evaluated assuming milk production and live weight. The genetic gains were, therefore, dependent on the economic or biological values adopted in the model.

Results

Economic and Biological Values

The risk-rated economic and biological values for traits considered in the breeding objective of pasture-based dairy cattle production, assuming FH and FP production systems and MV, and MVFC marketing circumstances are presented in Table 2. Generally, the economic values were affected by both the production system and marketing circumstance adopted in the model. The economic values estimated under FH were higher than those estimated under FP, while those derived assuming MV were superior to those obtained in MVFC irrespective of the production system adopted. When the λ was 0.02, the economic values for MY, CI and PLT under FP-MV were KSh. 85.478, 0.202, and 46.359, respectively, while their corresponding values under FP-MVFC were KSh. 81.591, 0.210 and 36.053. The negative economic value for FY under MV (KSh. -0.128) compared to the positive value of KSh. 5.317 in MVFC was expected as the former marketing circumstance did not account for fat content as a source of revenue. The economic values for growth (DG, WWT and MLW) and survival traits (PreSR and PostSR) and AFC were generally low and negative under the two marketing circumstances in FP.

The economic values obtained under the FH production system followed the same trend as those reported under FP, but were higher. For instance, the economic values for MY, CI and PLT were 14.98, 58.94 and 59.53%, respectively, higher than those obtained under FP-MV.

The risk-rated economic values assuming λ=0.020 were lower than those estimated for λ=0.0001 under the two production systems and marketing circumstances. The economic values for growth traits (DG, WWT and MLW) estimated under FP-MV assuming λ=0.020 were, correspondingly, KSh. -0.975, -1.765 and -6.678, while their respective values when a low value of risk aversion was applied were KSh. -0.846, -1.634 and -6.536 (Table 2).

The biological values obtained in the current study followed the same trend as observed under economic values (Table 2). For example, the biological values were sensitive to production systems and marketing circumstances (milk and live weight). Milk yield had positive biological values of 0.738 and 0.791 under FP and FH production systems, respectively, but reported negative corresponding values of -0.007 and -0.009 when marketing was based on live weight. The growth traits had negative biological values except WWT and MLW, which had positive values of 0.006 and 0.009 under FP and FH, respectively. Although the PLT and PreSR had positive biological values in all the production systems and the two marketing circumstances, they had negative values of -1.290 and -0.021, respectively, under FP and FH assuming milk marketing circumstance.

Assessment of the Effect of Economic and Biological Values on Genetic Gain

Table 3 shows the estimated genetic gains for the individual breeding objective traits. To predict genetic gain for the breeding objective traits, one round of selection was carried out on the selection index with a selection intensity of one. Generally, the genetic responses for individual traits in the breeding objective followed the same trend as observed under biological and economic values (Table 2). The gains were affected by both production system and circumstance considered in the model. The genetic responses for all traits in the breeding objective were higher under FH production system and MV production circumstances compared to FP and MVCF, except response for FY which was higher when MVCF was considered (Table 2). For instance, the genetic response for MY under FP and FH assuming MV were 3.459 and 4.068 kg, respectively, while the corresponding response under MVCF was 3.302 and 3.985 kg.

The level of risk aversion affected the rate of genetic gains of traits in the breeding objective. For instance, the adoption of economic values estimated assuming λ=0.0001 in the model resulted to higher genetic gains compared to λ=0.02. This is an indication that failure to account for risks undertaken by producers overestimate economic values and, therefore, genetic gains. As observed, underestimation of economic and biological values (Table 2) implies the use of biological values in the model resulted to low genetic gains for traits in the breeding objectives (Table 3). The positive values of 0.443 and 0.460 for MY assuming Milk as the marketable product is an indication of improved biological efficiency. The negative values for growth traits, i.e., -0.034, -0.078 and -0.257 for DG, WWT and MLW, respectively, under FP (Milk) is a confirmation of the negative interaction between growth traits and MY.

Table 2: Biological and economic values (KSh., 1US$ = KSh. 86.00) for traits in the breeding objective under different production and marketing circumstances.

System	**Circumstance** [b]	**Traits** [a]									
		MY	**DG**	**WWT**	**MLW**	**CI**	**FY**	**PLT**	**PreSR**	**PostSR**	**AFC**
Economic values when the λ=0.02											
Fixed-pasture	MV	85.478	-0.975	-1.765	-6.678	0.202	-0.128	46.359	-0.124	-0.236	-14.982
	MVFC	81.591	-1.144	-2.125	-7.698	0.210	5.317	36.053	-0.185	-0.293	-17.246
Fixed-herd	MV	100.533	-1.808	-5.051	-3.858	0.492	-0.133	114.560	-0.566	-0.259	-0.133
	MVFC	98.479	-2.102	-5.902	-4.457	0.542	5.431	113.720	-0.695	-0.320	-0.176
Economic values when the λ=0.0001											
Fixed-pasture	MV	85.485	-0.846	-1.634	-6.536	0.328	-0.001	46.399	0.003	-0.109	-14.820
	MVFC	81.615	-0.973	-1.952	-7.509	0.377	5.471	36.132	-0.017	-0.125	-17.031
Fixed-herd	MV	100.536	-1.672	-4.907	-3.716	0.623	-0.001	114.560	-0.433	-0.126	-0.001
	MVFC	98.491	-1.922	-5.711	-4.271	0.716	5.592	113.724	-0.518	-0.145	-0.001
Biological value[c]											
Fixed-pasture	Milk	0.738	-0.056	-0.131	-0.428	0.000	0.000	-1.290	0.000	0.000	0.000
	Live weight	-0.007	0	0.006	-0.004	0.000	0.000	0.044	0.002	0.000	0.000
Fixed-herd	Milk	0.791	-0.091	-0.288	-0.234	0.000	0.000	0.598	-0.021	0.000	0.000
	Live weight	-0.009	-0.001	-0.001	0.009	0.000	0.000	0.106	0.003	0.000	0.000

[a] MY: milk yield (kg), DG daily gain (kg): WWT, weaning weight (kg): CI, calving interval (days): FY, milk fat yield (kg): PLT, productive lifetime (days): PreSR, pre-weaning survival rate (%): AFC, age at first calving (days).

[b] MV: milk marketing based on volume, MVFC: milk marketing based on volume and fat content.

[c] Economic and biological values are x10^{-3}.

Table 1: Genetic gains in individual traits in the breeding objective estimated under fixed-pasture and fixed-herd production circumstances, with milk marketing based on volume (MV) or volume and butter fat content (MVFC) and biological values for milk and live weight production.

Indices[a]	**Circumstance**[b]	**Traits**[c]								
		MY	**DG**	**WWT**	**MLW**	**CI**	**FY**	**PLT**	**PreSR**	**AFC**
I_{rrev} (λ=0.02)										
Fixed-pasture	MV	3.459	-0.061	-0.111	-0.420	0.013	-0.008	2.913	-0.008	-0.941
	MVFC	3.302	-0.072	-0.134	-0.484	0.013	0.334	2.265	-0.012	-1.084
Fixed-herd	MV	4.068	-0.114	-0.317	-0.242	0.031	-0.008	7.198	-0.036	-0.008
	MVFC	3.985	-0.132	-0.371	-0.280	0.034	0.341	7.145	-0.044	-0.011
I_{rrev} (λ=0.0001)										
Fixed-pasture	MV	3.460	-0.034	-0.066	-0.265	0.027	0.000	3.759	0.000	-1.201
	MVFC	3.303	-0.039	-0.079	-0.304	0.031	0.437	2.927	-0.001	-1.380
Fixed-herd	MV	4.069	-0.068	-0.199	-0.150	0.050	0.000	9.281	-0.035	0.000
	MVFC	3.986	-0.078	-0.231	-0.173	0.058	0.447	9.213	-0.042	0.000
I_{bv}										
Fixed-pasture	Milk	0.443	-0.034	-0.078	-0.257	0.000	0.000	-0.774	0.000	0.000
	Live weight	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fixed-herd	Milk	0.460	-0.053	-0.167	-0.136	0.000	0.000	0.348	-0.012	0.000
	Live weight	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000

[a] I_{rrev} (λ=0.02) index derived with economic values risk-rated at λ=0.02, I_{rrev} (λ=0.0001) index derived with economic values risk rated at λ=0.0001, I_{bv} index derived with biological values,

[b] MV: milk marketing based on volume, MVFC: milk marketing based on volume and fat content.

[a] MY: milk yield (kg), DG daily gain (kg): WWT, weaning weight (kg): CI, calving interval (days): FY, milk fat yield (kg): PLT, productive lifetime (days): PreSR, pre-weaning survival rate (%): AFC, age at first calving (days).

Discussion

The positive economic values for MY, CI and PLT obtained in the current study is an indication that selection targeting these traits would lead to improved profitability of the farm enterprise. The positive genetic gains obtained for these traits under the two production circumstances investigated in the present study confirm this phenomenon. However, it should be noted that the positive genetic gain obtained for CI is undesirable because it reduces the number of offspring per cow's productive life time. This may pose far reaching effects, especially in developing countries in the tropics where breeding or replacement stocks are scarce. The positive economic values for MY, CI and PLT have also been reported in dairy cattle in developing countries (Kahi and Niter, 2004; Komlosi *et al.,* 2009; Krupová *et al.,* 2010). The negative economic values for growth traits (DG, WWT and MLW) and FY obtained in this study could be attributed to the increased energy demands by the animals due to the higher growth rate and weights. Genetic improvement for DG and WWT would have more negative effects on the economic efficiency of production because of increased energy demands of the growing stock. The negative economic values of DG and WWT indicate that revenues from sale of culls would not compensate high costs emanating from the corresponding rise in energy requirement. Animals with large body sizes have also been demonstrated to consume more feed as they require more energy for maintenance compared to small sized animals, and this tend to increase the cost of production (Vischer *et al.,* 1994). There is also a positive correlation between increased butter fat production and requirement for high energy content feeds (Hurtaud *et al.,* 2010). Although the results obtained in the current study agree with previous studies that have reported negative economic values for MLW and FY in developing countries, the negative economic values for DG and WWT contradicts the positive values reported in the literature (Kahi and Niter, 2004; Krupov'a *et al.,* 2009; Komlosi *et al.,* 2010). Inclusion of AFC as a breeding objective trait aims at reducing the unproductive life of the cow (Kahi and Nitter, 2004) and shortening the generation interval. By reducing the AFC, the herd replacement policy is influenced, especially for the FP production system, which in return affects the production levels and replacement rate that then influences the product output levels of heifers and adult cows (Kahi and Nitter, 2004). The negative economic value and genetic gains of this trait is desirable and concur with previous studies (Kahi and Nitter, 2004; Komlosi *et al.,* 2010). The negative economic values for PreSR under the FH circumstance could due to the increased number of young stock. This, therefore, affects the culling policy and the herd feed demands particularly for the growing animals.

The differences between the economic values for traits in the breeding objectives assuming an Arrow-Pratt coefficient of absolute risk aversion of 0.0001 and 0.02 obtained in the present study is a confirmation that not accounting for risks may lead to overestimation of economic values in a breeding programme. The difference between the economic values with and without risks has been demonstrated to range from −47.26% to 67.11% (Kulak *et al.,* 2003; Bett *et al.,* 2011; Okeno *et al.,* 2012), and such differences could lead to loss in efficiency of selection index by up to 76% (Vandepitte and Hazel, 1977). This is confirmed in genetic evaluation in the current study where the genetic response for traits in the breeding objective were higher when a value of $\lambda = 0.0001$ was used compared to $\lambda = 0.02$. This, therefore, indicates the need to consider risks, such as changes in future costs of inputs and price of outputs when estimating economic values.

The differences between risk-rated economic and biological values obtained in the current study were very large and affected the genetic gains of traits in the breeding objective. Although, the use of economic values to define breeding objectives in different livestock species has been widely used (Kahi and Niter 2004; Banga *et al.,* 2009; Komlosi *et al.,* 2010), there is a need to also consider the biological values. The use of biological values are critical, especially when developing breeding objectives targeting genetic improvement in smallholder dairy cattle production systems because they are characterized by poor or lack of economic and biological data necessary for computing economic values (Hirooka *et al.*, 1998; Bett *et al.*, 2011). The differences between biological values observed under FH and FP production circumstances, and milk and live weight scenarios was an indication that the biological values and, therefore, biological efficiencies are sensitive to production scenarios as economic values. For instance, the biological efficiency of producing milk and live weight was mainly affected by the MY, growth traits (WWT and MLW), CI and PostSR, which are the traits that greatly influenced the energy requirements of the individual animals. Due to the increased energy demands, MY had negative effects on the biological efficiency for live weight production, but positive for milk production. The positive biological values for MY, WWT, CI and PostSR show that improvement in these traits could lead to improved profitability because of increased efficiency of feed conversion. This analysis shows that feed availability is a major limitation to profitability. Kahi and Nitter (2004) suggested breeding for animals, which can efficiently utilize tropical pasture since they are readily available and concentrates are expensive. Such strategies will benefit smallholder farmers who own majority of dairy cattle in Kenya. It should, however, be noted that efforts should be made to estimate economic values to define breeding objectives in smallholder dairy production systems once the economic and biological data become available. From the present study, it has been demonstrated that genetic responses for individual traits achieved when economic values were used were higher than those obtained when biological values were employed. This could be explained by the fact that not all inputs and output could be defined in terms of energy (Hirooka *et al.*, 1998; Kahi and Nitter, 2004).

The high genetic gain for MY under MV compared to MVCF under the two production systems was expected because milk was sold only based on volume. The low genetic response observed under MVCF and positive response for FY is an indication of the antagonistic relationship between these traits. The genetic gains achieved under FH were generally higher compared to those realized under FP apart from the gains in DG, WWT and PreSR which were lower. Although increase MY had a positive impact on genetic gains for AFC and longevity of the animal (PLT), it resulted to long calving intervals, which is undesirable, particularly in developing countries where breeding stocks are scarce.

Conclusion

This study has shown that definition of the breeding objective for pasture-based dairy production system in Kenya would result to faster genetic gains when economic values are used compared to use of biological values. The notable difference between the economic values with-and without risks and their effect of genetic gains is a pointer that failure to account for risks undertaken by producers could result to overestimation of the genetic merit of a breeding programme. Application of biological values in the definition of breeding objectives could be an alternative, especially where input and output parameters are scarce or difficult to measure. Genetic improvement of milk yield, calving interval, productive life time and age at first calving could result to increased profitability under situations of feed and land space limitations. Improvement of fat yield, growth and body weight traits result to an increased energy and nutritional requirement which reduces the economic efficiency due to increased cost of feeding. Increased economic and biological efficiency could also be obtained when milk marketing is based on the quality rather than on quantity alone. In all these circumstances genetic improvement in a fixed herd scenario has been found to have a potential to increase productivity under the tropical conditions where there is a challenge of feed quantity and quality as well as land availability.

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References

Ageeb AG, Hayes JF (2004). Reproductive responses of Holstein-Friesian cattle to the climatic conditions of central Sudan. Trop. Anim. Health Prod., 32: 233-243.

Amimo JO, Mosi RO, Wakhungu JW, Muasya TK, Inyangala BO (2006). Phenotypic and genetic parameters of reproductive traits for Ayrshire cattle on large-scale farms in Kenya. Livest. Res. Rural Dev., Vol. 18, Article #147. Retrieved on 2nd September (2008) from http://www.cipav.org.co/lrrd/lrrd18/10/amim18147.htm.

Banga CB, Neser FWC, Westhuizen J van der, Garrick DJ (2009). Economic values for dairy production traits under different milk payment systems in South Africa. South Afr. J. Anim. Sci., 39: 112-115.

Bebe BO, Udo HMJ, Rowlands G, Thorpe W (2003). Smallholder dairy systems in the Kenya highlands: Cattle population dynamics under increasing intensification. Livest. Prod. Sci., 82: 211-221.

Bebe BO, Udo HMJ, Thorpe W (2002). Development of smallholder dairy systems in the Kenya highlands. Outlook on Agri., 31: 113-120.

Bekman H and Van Arendonk JAM (1993). Derivation of economic values for veal, beef and milk production traits using profit equations. Livest. Prod. Sci., 34: 35-56.

Bett RC, Kosgey IS, Kahi AK, Peters KJ (2011). Definition of breeding objectives and optimum crossbreeding levels for goats in the smallholder production systems. Small Ruminant Res., 96: 16-24.

Bondoc OL, Smith C, Gibson JP (1989). A review of breeding strategies for genetic improvement of dairy cattle in developing countries. Anim. Breed. Abstr., 57: 819-829.

Brascamp EW (1978). Methods on Economic Optimization of Animal Breeding Plans. Report B-134, Research Institute for Animal Husbandry "Schoonoord," Zeist, the Neth., pp. 1-117.

Delgado C, Rosegrant M, Steinfeld H, Simeon E and Courbois C (1999). Livestock to 2020. The next food revolution. Food, Agriculture and the Environment Discussion Paper 28. (FAO, IFPRI, ILRI), pp. 1-73.

Dickerson GE (1970). Efficiency of animal production-molding the biological components. J. Anim. Sci., 30: 849-859.

Falconer DS, Mackay TFC (1996). Introduction to Quantitative Genetics. 4th Ed., Longman, England, UK.

Groen AF (1989). Cattle breeding goals and production circumstances. PhD. Thesis, Wageningen Agri. Univ., Wageningen, the Neth.

Groen AF, Steine T, Colleau JJ, Pedersen J, Pribly J, Reinsch N (1997). Economic values in dairy cattle breeding, with special reference to functional traits. Report of an EAAP-Working Group. Livest. Prod. Sci., 49: 1-21.

Harris DL (1970). Breeding for efficiency in livestock production: Definition the economic objectives. J. Anim. Sci., 30: 860-865.

Hazel LN (1943). The genetic basis for constructing selection indexes. Genet., 28: 476-496.

Hirooka H, Groen AF, Hiller J (1998). Developing breeding objectives for beef cattle production. I. A bio-economic simulation model. Anim. Sci., 66: 607-621.

KDB (Kenya Dairy Board website) (2012). http://kenyadairy.com/dairy-market-production (Accessed on 12th April 2012).

Hurtaud C, Faucon F, Couvreur S, Peyraud JL (2010). Linear relationship between increasing amounts of extruded linseed in dairy cow diet and milk fatty acid composition and butter properties. J. Dairy Sci., 93: 1429-1443.

Kahi AK, Nitter G, Thorpe W, Gall CF (2000). Crossbreeding for dairy production in the lowland tropics of Kenya. II. Prediction of performance of alternative crossbreeding strategies. Livest. Prod. Sci., 63: 35-65.

Kahi AK, Nitter G (2004). Developing breeding schemes for pasture based dairy production systems in Kenya. 1. Derivation of economic values using profit functions. Livest. Prod. Sci., 88: 161-177.

Kahi AK, Nitter G, Gall CF (2004). Developing breeding schemes for pasture based dairy production systems in Kenya. II. Evaluation of alternative objectives and schemes using a two–tier open nucleus and young bull system. Livest. Prod. Sci., 88: 179-192.

KNBS (Kenya National Bureau of Statistics) (2014). Consumer Price Index and inflation rates for the month of January 2013. http://www.knbs.or.ke/. (Retrieved on 22nd October, 2014).

Komlosi I, Wolfova M, Wolf J, Farkas B, Szendrei Z, Beri B (2009). Economic weights of production and functional traits for Holstein-Friesian cattle in Hungary. J. Anim. Breed. Genet., 127: 143-153.

Komlósi I, Wolfová M, Wolf J, Farkas B, Szendrei Z, Béri B (2010). Economic weights of production and functional traits for Holstein-Friesian cattle in Hungary. J. Anim. Breed. Genet., 127(2): 143-153.

Korver S (1988). Genetic aspects of feed intake and feed efficiency in dairy cattle: A Rev. Livest. Prod. Sci., 20: 1-13.

Krupová Z, Huba J, Dano J, Krupa E, Oravcová M, Peškovicová D (2009). Economic weights of production and functional traits in dairy cattle under a direct subsidy regime. Czech J. Anim. Sci., 54(6): 249-259.

Kulak K, Wilton J, Fox G, Dekkers J (2003). Comparisons of economic values with and without risk for livestock trait improvement. Livest. Prod. Sci., 79: 183-191.

McClintock AE, Cunningham EP (1974). Selection in dual-purpose cattle population: defining the breeding objective. Anim. Prod., 18: 237-247.

Mwai O, Malmfors B, Anderson-Ekrund L, Philipsson J, Rege JEO, Hanotte O, Fulss R (2005). Capacity building for sustainable use of animal genetic resources in developing countries. ILRI-SLU project progress report for the period 1999-2003. SLU (Sweden University of Agriculture Sciences), Uppsala, Sweden and ILRI (Int. Livest. Res. Inst.), Nairobi, Kenya, pp. 65.

Nicholson C, Tambi E, Staal SJ, Thorpe W (2001). Patterns of change in dairy production and consumption in developing countries from 1985 to 1990. Market-oriented smallholder dairy research working document No. 7, ILRI, Nairobi, pp. 73.

Ojango JMK, Pollot GE (2001). Genetics of milk yield and fertility traits in Holstein-Friesian cattle on large scale Kenyan farms. J. Anim. Sci., 79: 1742-1750.

Okeno TO, Kahi AK, Peters KJ (2012). Genetic and Economic Evaluation of Alternative Breeding Objectives for Adoption in the Smallholder Indigenous Chicken Improvement Program. Tropentag, September 19th - 21st, (2012) in Göttingen, pp. 4.

Okeno TO, Kosgey IS, Kahi AK (2010). Genetic evaluation of breeding strategies for improvement of dairy cattle in Kenya. Trop. Anim. Health Prod., 42: 1073-1079.

Omore A, Muriuki H, Owango M, Staal S (1999). The Kenyan Dairy Sub-Sector. A Rapid Appraisal Report by Ministry of Agriculture and Rural Development-Kenya Agricultural Research Institute - International Livestock Research Institute Smallholder Dairy (Research And Development) Project. Int. Livest. Res. Inst., Nairobi, pp. 50.

Osei SA, Effah-Baah K, Karikari P (1991). The reproductive performance of Friesian cattle bred in the hot humid forest zone of Ghana. Revista Mundial de Zootecnia. 68(3): 52-59. http://www.fao.org/ag/AGAInfo/resources/documents/WAR/war/U4900B/u4900b0j.htm.

Rege JEO (1991). Genetic analysis of reproductive and productive performance of Friesian cattle in Kenya. 1. Genetic and phenotypic parameters. J. Anim. Breed. Genet., 108: 412-423.

Robinson LJ, Barry PJ (1987). The competitive firm's response to risk. Macmillan Publ. Co., New York, pp. 324.

Smith C, James JW, Brascamp EW (1986). On the derivation of economic weights in livestock improvement. Anim. Prod., 43: 545-544.

Thorpe W, Muriuki HG, Omore A, Owango MO, Staal S (2000). Dairy development in Kenya: The past, the present and the future. Annual Symposium of the Animal production society of Kenya 22nd-23rd. K.A.R.I. Headquarters, Nairobi, pp. 10.

Vandepitte WM and Hazel LN (1977). The effect of errors in the economic weights on the accuracy of selection indexes. Annales de Génétique et de Sélection Anim., 9(1): 87-103.

Vargas B, Groen AF, Herrero M, Van Arendonk JAM (2002). Economic values for production and functional traits in Holstein cattle of Costa Rica. Livest. Prod. Sci., 75: 101-116.

Vischer PM, Bowman PJ, Goddard ME (1994). Breeding objectives for pasture based dairy production systems. Livest. Prod. Sci., 40: 123-137.

Wilton JW (1979). The use of production systems analysis in developing mating plans and selection goals. J. Anim. Sci., 49: 809-816.