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Agricultural Systems 88 (2006) 111–124

AGRICULTURAL SYSTEMS

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Comparative economics of Holstein/Gir F_1 dairy female production and conventional beef cattle suckler herds – A simulation study

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Received 17 October 2003; received in revised form 18 February 2005; accepted 18 February 2005

Abstract

Three cow–calf production systems were compared using simulation: N (straightbred Nelore), AN (Nelore cows producing Angus by Nelore calves) and HG (Gir cows producing Holstein by Gir calves). All three systems produced their own straightbred replacement females. Male calves were sold at weaning and female calves in excess of those required to keep the herd size constant were sold at one year of age. In the base situation, F_1 HG females were priced at twice as much as the price per kg of the beef male calves, according to present market values. Typical 1000 ha beef cattle farms were simulated for each system, based on *Brachiaria brizantha* pastures managed according to recommended practices. Herd dynamics were controlled by reproduction and survival. Literature figures on monthly pasture nutrient production, live weights and milk yield were used to estimate nutrient requirements to match stocking rate to nutrient availability in each system. For calving rate set to 0.8 in all three systems, the total numbers of cows for the N, AN and HG systems were, respectively, 803, 795 and 885 and the total live weight sold annually was 129,070, 133,120 and 127,680 kg. The annual economic

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doi:10.1016/j.agsy.2005.02.004

return on investment was 5.21%, 5.81% and 10.84%, respectively, for the N, AN and HG systems. Reducing the relative price of the HG heifers diminished the economic superiority of this system over N and AN. The difference was zero when the price of HG heifers was reduced to approximately 1.2 times the beef calf price. This also happened when the calving rate of the Gir cows was set to 0.6 keeping N cows at 0.8 or higher.

Keywords: Beef cattle; F_1 Holstein × Gir; F_1 Angus × Nelore; Nelore; Economic performance

1. Introduction

Most dairying in Brazil is conducted in low to medium-input systems, which are appropriate to the local circumstances, as in many other regions (Madalena, 2002a). F_1 Holstein × dairy zebu hybrids have been shown to excel in profit in the prevailing production systems in the Country, due to the presence of significant heterosis for most economically important traits (Madalena et al., 1990).

A simple scheme for the sustainable production of F_1 females was proposed (Madalena, 1993), based on stratified crossbreeding, already adopted by some progressive farmers. In this scheme, illustrated in Fig. 1, dairy farms buy replacement F_1 females, as in the poultry or swine industries. Those females are produced in areas of less expensive land, using Holstein semen on mainly Gir or Guzerá females, the more important Brazilian dairy zebu breeds (Madalena, 2002b).

The growing awareness of economic benefits from F_1 dairy hybrids has resulted in very high prices for these females (Madalena, 1998). A programme to promote such a scheme has recently been implemented by the Government of the dairy-oriented

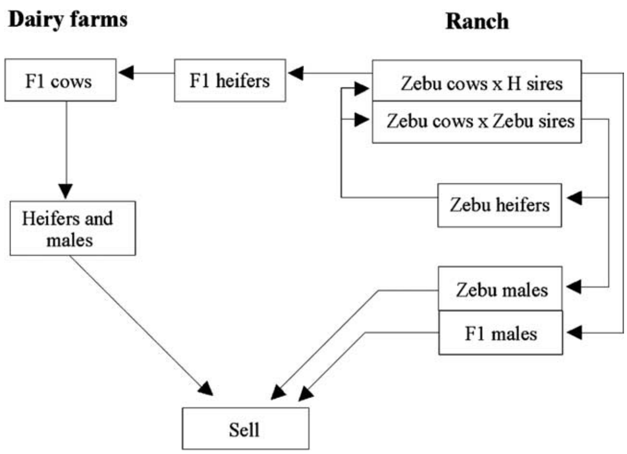

Fig. 1. F_1 replacement scheme (reproduced from Madalena, 1993). H, Holstein.

State of Minas Gerais (Machado, 2002), which produces about one third of the total milk in Brazil (6.4 billion ton/year in 2002; Agronegócio, 2003).

Producing F_1 dairy hybrids is then a possible economic alternative for a conventional suckler-herd beef ranch selling weaner beef calves. However, for the F_1 scheme to be sustainable, part of the zebu herd needs to be mated to zebu bulls to produce replacements. An F_1-producing ranch would also carry zebu male and female calves, of lesser value. Because farmers consider Gir females to be less fertile than Nelore (the most popular beef breed), the economic outcome for both alternatives is not straightforward. For this reason a simulation study (Brockington, 1997) was undertaken to compare these alternatives, using a model described by Cezar (1980, 1982). A third alternative producing F_1 Angus × Nelore weaner calves, was also compared.

2. Methodology

A deterministic simulation was implemented in order to compare three alternative production systems:

1. N – Nelore suckler herd selling straightbred calves,
2. AN – Nelore suckler herd selling F_1 Angus × Nelore calves, and
3. HG – Gir suckler herd selling F_1 Holstein × Gir calves.

The three systems were initially compared in a base situation, which was thereafter extended using sensitivity analysis, by varying farm size, calving percentage and prices of land, F_1 heifers, Gir cows and Gir semen.

The two crossbreeding systems were set to sell as many crossbred heifers as possible, i.e., the proportion of the breeding herd mated to zebu bulls was the minimum required to keep herd size constant.

The simulation was carried over with a deterministic model developed at the Brazilian Agricultural Research Organization – Embrapa (Chudleigh and Cezar, 1982; Cezar, 1982), which considers an already developed farm, whereupon pastures, fences and infrastructure are in place and the herd category numbers are stabilised. Income was generated by the sales of male weaner calves, excess-over-replacement heifers and cull-for-age cows. The model calculates monthly the numbers of animals in each category from input calving and mortality rates and ages at first calving and disposal/sale (all cows were assumed to calve in October but deaths occurred monthly), then determines stock carrying capacity on the basis of input monthly pasture production and animal requirements, and excess animals are sold. However, in this study the herd composition in each alternative production system was obtained by trial and error, running the model so that there were no excess animals, because the number of breeding cows wintered was adjusted to the limiting stock carrying capacity in that season (the dry season), assumed to be equivalent to one 450 kg dry cow/ha. The herd composition then remained constant for the 10-year period studied.

To calculate costs, the model sets the number of workers at one per 600 cow or fraction, with a minimum of two for a 300-cow herd. Three horses per worker are considered. Half of the workers are married and need a house each and singles are accommodated up to four per house. A corral is needed for 1.500 head of cattle and an extra one is considered provided the farm area is larger than 3.800 ha. A vehicle and an administrator's house are considered, irrespectively of ranch size. Operations for establishing pastures and fertilizing of established pastures are worked out by the model on the basis of input information on area, pasture species and months of fertilizing. Artificial insemination, a model option, was used in this study.

Based on input prices and interest rates, the programme works out the monthly and aggregated discounted cash flow. Specific user supplied depreciation rates are considered for different items. The biological and economic performance indicators calculated are described below.

2.1. Farm and management

In the base situation, a typical 1000 ha farm on *Brachiaria brizantha* (cv. Marandu) pastures, managed according to standard recommended practises, was considered. Infrastructure consisted of housing for the administrator (1) and farm workers (2), corral (1), fences (42 km), a vehicle and working horses.

Monthly pasture nutrient production was obtained from the literature (Euclides et al., 1993; Macedo et al., 1993; Zimmer and Euclides Filho, 1997; Corrêa et al., 2000) and unpublished reports (Euclides and Macedo, personnal comunication). Application of chemical fertilizers (300 kg/ha of NPK 0-20-20) every three years and daily consumption of 11.1 g/100 kg live weight of a mineral supplement were assumed (composition, g/kg: 160 Ca, 0.2 Co, 1.6 Cu, 10 S, 1 Fe, 0.8 Fl, 85 P, 0.19 I, 10 Mg, 1.4 Mn, 0.035 N, 0.032 Se, 110 Na and 6 Zn). Vaccinations for clostridial diseases, brucellosis and foot-and-mouth disease and drenching for gastrointestinal parasite control (ivermectin, three times/year) were practised.

The reproductive parameters, assumed as common to all three systems are shown in Table 1. Annual mortality rate was 0.04 for calves from birth to weaning, 0.02 for calves from weaning to one year of age and 0.01 for all other categories. Age at first

Table 1
Annual calving rates used in simulations (common to all three systems)

	Low	Medium	Base[a]	High
Calving rate				
First calving	0.73	0.78	***0.85***	0.94
Second calving	0.40	0.46	***0.50***	0.75
Third or higher calving	0.61	0.73	***0.85***	0.92
All parities	0.60	0.70	***0.80***	0.90
Culling rate				
1-year-old heifers	0.62	0.68	***0.72***	0.75
Cows	0.10	0.10	***0.10***	0.10

[a] Values for the base situation in this column (bold italic).

Table 2
Live weight and milk production assumed in simulations[a]

Category	System[b]		
	N (kg)	AN (kg)	HG (kg)
Weaner male calf, straightbred[c]	180	180	140
Weaner male calf, crossbred[c]	–	205	180
1-year-old females	174	174	150
2-year-old females	295	295	248
3-year-old females	380	380	325
Adult cows	440	440	383
Cull cows	441	441	384
Peak daily milk yield[d]	5.00	5.00	5.00
Average daily milk yield[d]	3.65	3.65	3.65

[a] *Sources:* Mattoso (1959); Santiago (1984); Santos and Santos (1986); Tonhati et al. (1986); Perotto et al. (1997); Corrêa et al. (2000); Sumário Nacional de Touros das Raças Zebuínas (2001, 2002); Embrapa – CNPGC.

[b] N, Nelore; AN, Angus × Nelore; HG, Holstein × Gir.

[c] Female weight assumed to be 0.9 male weight and average suckling-calf weight 0.5 weaner weight.

[d] Espasandin et al. (2001) for Nelore, Gir assumed to be the same.

calving was 3 year. Male calves were sold at eight months of age and female calves not needed for replacement were sold at one year of age. Cows were culled for age at 12 year.

2.2. Nutrient requirements

NRC (1996) recommendations were used to estimate energy requirements to adjust stocking rate in preliminary runs, based on live weights and milk production figures for each system (Table 2).

2.3. Economic evaluation

The price of land was US$ 258.6/ha, typical of beef cattle areas in the State of Minas Gerais and the value of buildings and fences in the base situation was US$ 34,041.00 (Anuário da Pecuária Brasileira, 2002). Breeding cow herd size-dependant expenditures were: vaccination, drenching, veterinary costs, minerals, artificial insemination and marketing taxes (2.25% of revenue). Other costs included fertilizers, maintenance/repairs, depreciation of buildings and fences, horses and tax on land.

Prices of animals were obtained from deflated historical data and other prices from market data (Guimarães, 2003) (Table 3). The price of Holstein × Gir heifers is much higher than for other categories (Madalena, 1998) and was set in the base situation at twice as much as the price per kg live weight of male calves.

The following economic variables were considered: residual to remunerate owner/administrator (total income minus total expenditure, depreciation and interest on

Table 3
Prices of animals and inputs (five-year averages deflated to April 2002)[a]

Item	Unit	Unit price (US$)
Male weaner calf, Nelore, Angus × Nelore or Gir	kg	0.70
Male weaner calf, Holstein × Gir	kg	0.52
Cull cow	kg	0.52
1-year-old heifer, Nelore or Angus × Nelore	kg	0.58
1-year-old heifer, Holstein × Gir	kg	1.40
Vaccine, brucelosis	dose	0.17
Vaccine, foot and mouth disease	dose	0.39
Vaccine, clostridial diseases	dose	0.26
Ivermectin	dose	0.13
Salt and minerals	kg	0.30
Semen (Nelore, Angus or Gir)	dose	4.09
Wages	One man-month	86.20
Fertilizer	1000 kg	215.52

[a] Guimarães (2003).

capital), net present value of cash flow (NPV) in a 10-year horizon and discounted, to account for inflation, at 10% annual rate and returns on capital. Following Frank (1978), specific annual interest rates were adopted for: annual expenditure, (6%, similar to that in the inflation free savings account), fixed operational capital (animals, tools, machines; 4.8%), building and fences (3.6%) and land (3%).

2.4. Sensitivity analysis

Levels of factors simulated in addition to the base situation are shown in Table 4. The calving rate was varied because no reliable comparative breed performance figures were found in the literature. The price of the Holstein × Gir F_1 heifers is currently very high, but may conceivable come down if supply increases more than demand. Because the price of straightbred dairy zebu females is currently increasing in Brazil, three cow price levels were simulated, with the Gir cows priced at thrice, double and the same price as the Nelore cows (base situation). The price of Gir semen is likely to increase because of growing demand for progeny tested dairy zebu sires, so two situations were considered, 3.95 US$/dose, equal for Gir and Nelore (base) and 1.5, 2.0 and 2.5 times higher for the first breed, keeping the second constant. The price of land was also varied to accommodate variation between regions

Table 4
Levels of factors considered in sensitivity analysis (base situation in bold italics)

Calf price per kg live weight (ratio Holstein × Gir F_1 heifer/Nelore male weaner)	2.4	***2.0***	1.6	1.2	0.8
Price of cow (ratio Gir/Nelore)	3	2	***1***		
Price of semen dose (ratio Gir/Nelore)	2.5	2	1.5	***1***	
Price of land, ratio to base situation price	4	2	***1***	0.5	
Farm size (ha)	***1000***	300			

in this respect. A situation of a smaller, 300 ha farm, was also considered. In this case, the model recalculated the infrastructure needed on the basis of herd size as described above.

3. Results

3.1. Biological performance

The herd composition for each system is shown in Table 5, along with some indicators of biological efficiency. Because of the smaller size of the Gir, a higher number of cows were sustained in the HG than in the N or AN systems, leading also to higher numbers of calves and heifers. Live weight sold and its proportion to live weight stocked was slightly higher for the AN system, due to the larger size of the crossbred Angus calves.

Well managed *Brachiaria* sp. pastures stocked at one cow/ha would support the feed requirements of suckler herds with reasonable conception rates as reported in the Brazilian literature (Santos and Santos, 1986; Corrêa et al., 2000; Martins et al., 2000; Naves, 2001). In fact, the simulated farms were under-stocked except in August–December, although the extra pasture produced above the herd requirements was the same for all three systems compared.

3.2. Income and costs

Only those costs dependent on the number and size of animals varied somewhat among systems, otherwise they were the same for all three. The fixed cost was US$ 6787.63 per annum. The variable costs were, respectively, US$ 43,688.5, US$ 43,649.6 and US$ 44,322.03 for N, AN and HG. The cost structure for each system is shown in Table 6.

The annual income for each system, averaged over the 10-year period, is shown in Table 7. Income from weaner males was slightly higher in the AN than in the N

Table 5
Average herd composition in January and biological performance variables for the 10-year period

Category	System[a]		
	N	AN	HG
Suckler calves (both sexes)	638	630	704
Females 1- to 2-year-old	86	85	95
Females 2- to 3-year-old	85	84	93
Females older than 3 year	800	792	882
Total	1609	1591	1774
Animals sold/year	613	606	675
Live weight sold, ton/year	129	133	128
Live weight sold/live weight stocked	0.297	0.305	0.295

[a] N, Nelore; AN, Angus × Nelore; HG, Holstein × Gir.

Table 6
Costs and returns structure (%) in three simulated production systems

Item	System[a]		
	N	AN	HG
Costs			
Fixed costs	13.5	13.5	13.3
Variable costs	86.5	86.5	86.7
Labor + taxes[b]	12.5	12.5	12.3
Chemical fertilizers	47.0	47.0	46.4
Mineralised salt	10.1	10.1	10.0
Artificial insemination	9.9	9.9	10.8
Others[c]	7.0	7.0	7.2
Total costs	100.0	100.0	100.0
Returns			
Weaned males	49.8	52.4	31.0
Cull cows	21.9	20.9	16.1
Surplus heifers	28.3	26.7	52.9
Total returns	100.0	100.0	100.0

[a] N, Nelore; NA, Angus × Nelore; HG, Holstein × Gir.
[b] Including pension, health and compulsory social contributions.
[c] Vaccines, drenching, medicines, taxes, vehicle maintenance.

Table 7
Annual income, costs and economic indicators in three simulated production systems (10-year average)

	System[a]					
	N		AN		HG	
	US$	%	US$	%[b]	US$	%[b]
Returns						
Weaned males	39,734	100	43,148	109	32,768	82
Cull cows	17,430	100	17,210	99	16,991	97
Surplus heifers	22,545	100	21,999	98	55,825	248
Total returns	79,709	100	82,357	103	105,584	133
Costs						
Fixed	6,788	100	6,788	100	6,788	100
Variable	43,688	100	43,650	99.9	44,322	101
Depreciation	5,314	100	5,314	100	5,314	100
Interest on capital	17,460	100	17,380	99.5	17,091	98
Total cost	73,250	100	73,132	99.8	73,515	100
Indicators						
Residual to remunerate owner/administrator	11,773	100	14,540	124	37,358	317
Invested capital	461,830	100	460,178	99	454,641	98
Net present value of cash flow[c]	233,757	100	251,812	108	404,503	173
Return on invested capital	24,060	100	26,748	111	49,304	205

[a] N, Nelore; NA, Angus × Nelore; HG, Holstein × Gir.
[b] Relative to N system = 100.
[c] For 10-year horizon and discount rate 10%.

system, on account of the higher weaning weight of the crossbred calves. Weaner males accounted for approximately half the income in the N and AN systems. while in the HG system, approximately half of the income was derived from the sale of the much more valuable heifers. Although selling less animal live weight, this system had income 32% and 28% higher, respectively, than the N and AN systems.

3.3. Economic performance

The residuals to remunerate owner/administrator were 217% higher in the HG and 24% higher in the AN than in the N system (Table 7). Indicators of financial investment performance were also much higher in the HG system, followed by the AN and N systems. Return on capital was more than double in the HG system, and 12% higher in the AN than in the N system. The return on capital figures in Table 7 may be compared with the (above inflation) savings account annual interest rate of 6.17%.

3.4. Sensitivity analysis

The proportion of the breeding herd used for crossing in systems AN and HG increased with calving rate, with values of 0.62, 0.68, 0.72 and 0.75, respectively, for calving rates of 0.6, 0.7, 0.8 and 0.9, leading to a non-linear increase in the comparative economic advantages of these systems over the N, as exemplified in Fig. 2.

The superior economic performance of the HG system decreased with the reduction in F_1 heifer price, becoming equal to the N system when the price per kg live weight of the F_1 HG heifers was approximately 1.2 times the price per kg of the N male calves, and inferior at lower relative prices (Fig. 3).

Simulation of high prices for Gir cows reduced the economic performance of the HG system, but this remained superior even when prices were three times higher than the price of N cows (Fig. 4). Changes in the price of Gir semen had a minor effect on economic performance.

An increase in price of land reduced return on capital in all three systems, but more so in the HG system (see Fig. 5).

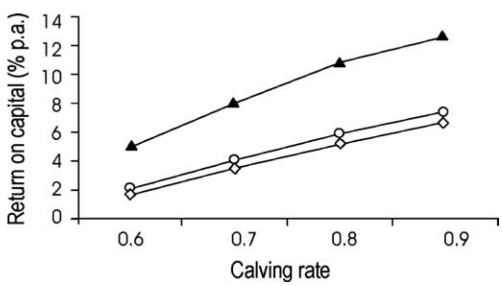

Fig. 2. Effect of calving rate on the return on capital in systems N (◇), AN (○) and HG (▲).

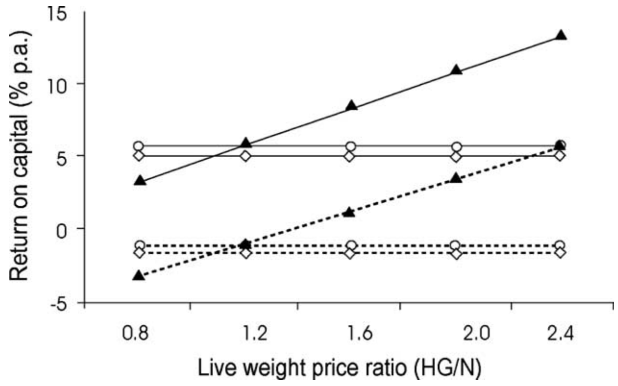

Fig. 3. Effects of F_1 HG heifer price, relative to N male calf price, on the return on capital in systems N (◇), AN (○) and HG (▲), in farms of 300 (dotted lines) or 1000 ha (solid lines).

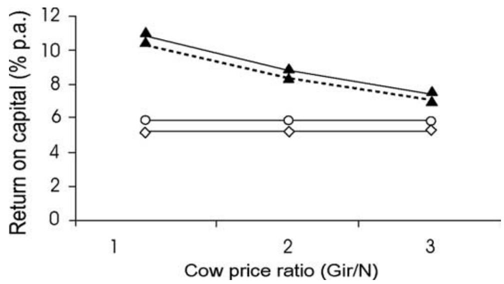

Fig. 4. Effects of the relative Gir and N cow prices on the return on capital in systems N (◇), AN (○) and HG (▲). Two prices of Gir semen were considered, Gir price equal to N price (solid line) and Gir price equal to 2.5× the N price (dotted line).

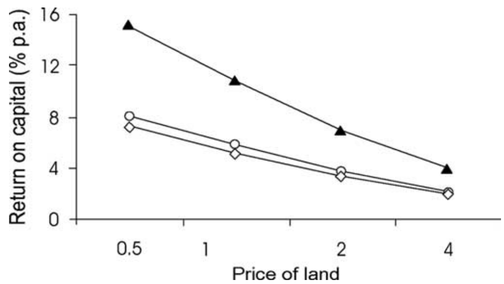

Fig. 5. Effect of price of land (relative to the base situation) on the return on capital in systems N (◇), AN (○) and HG (▲).

Because fixed costs were spread over less animals, reducing the farm area to 300 instead of 1000 ha reduced the residual to remunerate the owner/administrator, which was negative (US$ −2953 and −2136) in the N and AN systems, but still positive in the HG system (US$ 4842). Corresponding values for return on investment were −1.46%, −0.96% and 3.60%.

4. Discussion

A simple, deterministic, model was chosen, as the study aimed at exploring the difference between the dairy and beef heifer production systems on average conditions, rather than at examining the fluctuations caused by different factors, such as year-to-year price variability, that may affect each system's results. For example, the standard deviations of beef male calf, female calf and cull cow prices were 0.08, 0.05 and 0.04 US$/kg, so important yearly variation may be expected in the economics of these systems. However, the relative performance of the N and AN systems would not be affected, as prices were the same in both systems and costs were very similar (Table 7). Costs were also very similar in the HG and beef systems, and cull cow price was the same, while the prices of male HG weaners, although smaller, had a 0.96 correlation with the beef calf prices. Thus, fluctuations in prices would affect the relative performance of the dairy and beef systems only through variation in the price of HG heifers relative to beef calves. No statistics are available for the first price, but the effect of changes in the relative price may be assessed from the sensitivity study (discussed below).

The AN had modestly better economic performance than the N system on account of the higher weight weaned. The relative performance of these two systems would be sensitive to changes in the relative prices of weaner calves, which although assumed equal in this study, vary considerably among regions and packing plants.

The above result cast doubts on the economic feasibility of suckler beef herds such as the N when managed according to technical recommendations, as opposed to more traditional practices. A major component of cost in this simulation was the use of fertilizers, accounting for almost one half the effective cost of production. Although many beef cattle ranchers are unlikely to use fertilizers as recommended, fertilization is required to prevent pasture deterioration.

It may be argued that a typical beef cattle ranch using natural service would not have as many paddocks as those required in this simulation for artificial insemination. The latter practice is mandatory in most F_1 HG producing ranches, because Holstein bulls do not cope with the climate and harsh conditions. A survey of 270 F_1-producing farms showed that 72% practiced artificial insemination (Madalena, 1998). Although costs would be lower with natural service, so would the weaning weight, as sires used in artificial insemination have higher breeding values, as simulated herein.

Milk production was assumed to be the same for the Gir and the N dams, although the Gir, a dairy zebu, is perceived as a having higher milk yield. The only comparative evaluation found in the literature on milk yield of suckler cows of both breeds indicated 1.96 and 3.04 kg/d for Gir and N (Albuquerque et al., 1993), but it referred to beef-type Gir, rather than dairy.

Comparative figures for calving rate of Gir and N females were not available, so four rates were simulated, as this trait is of paramount importance for suckler beef herd economics. Gir females are generally perceived as less fertile than N females. However, as shown in Fig. 2, the HG outperformed the other two systems when the calving rate of Gir females was 0.7 or higher, and was not superior when the calving rates were 0.6 in the Gir and $\geqslant 0.8$ in the N. A well-documented HG F_1 ranch attained 0.816 calving rate on 1030 Gir females (Fiuza, 2001).

As the systems were scaled to maintain a constant herd size, reducing the calving rate results in a lower proportion of the breeding herd used for crossing. Madalena (1993) showed that this proportion is given by the ratio r/h, where r is the annual herd replacement rate (the proportion of the herd which actually are first calvers) and h is the potential number of first calvers per cow in the herd, given by the product of (1/2 calving rate) × (1 − mortality − culling rates).

The high prices paid for F_1 HG heifers reflect the dairy farmers' perception of their higher economic performance as dairy animals in the prevailing production circumstances of the tropical Brazilian regions. This is in agreement with research results indicating a superiority of 70% in net profit for F_1s over criss-crossing, the second best crossbreeding alternative (Madalena et al., 1990). Although the need for artificial insemination and good reproductive efficiency may deter the increase of F_1 production, the popularity of these animals continues to rise. In addition, due to low prices of milk in recent years, many dairy farmers are inseminating Holstein cows with dairy zebu breeds, such as the Gir or the Guzerá, and therefore it is conceivable that prices of HG F_1s may eventually decline due to increased competing supply. However, the simulated responses in Fig. 3 indicate that a substantial reduction in price would be needed to make the HG system less economically viable than the beef systems.

Prices of Gir cows have also increased in recent years. Multiplying the base price per cow (US$ 147.41) by 2× or 3× increased the invested capital by 23% and 46% and reduced return on investment of the HG system from 10.8 to 8.8 and 7.5, respectively. Nevertheless, the HG system outperformed the N and AN systems in all three cow price situations (Fig. 4).

Semen accounted for 11% of the total cost in the base situation. Multiplying the base price of Gir semen (4.09 US$/dose) by 1.5×, 2× and 2.5× increased total effective cost by 1.4%, 2.8% and 4.2%, because semen cost made up 12–14% of total cost, so this item was not a very important source of variation of return on investment, which was reduced from the base 10.8 to 10.4 in the more expensive semen situation.

Land accounted for 56–57% of the capital invested in each system, and therefore changes in its price caused important variations on the return on capital. In the HG system, reducing the cost of land by one half increased the return on investment by 39%, while doubling the price of land decreased it by 36% and a further doubling of price decreased return on investment by a further 42%. Nevertheless, the HG system showed 4.01% annual return on capital with the highest (4×) relative land price (Fig. 5).

5. Conclusions

Because of the high prices paid for HG F_1 dairy heifers, the system producing these animals out of Gir cows inseminated with Holstein semen economically outperformed both beef systems in most of the circumstances considered. The beef systems were superior only under unrealistic circumstances of very low HG F_1 prices or extreme differences in calving rate favouring N over Gir cows.

With no price premium for Angus by Nelore weaned calves, the Angus by Nelore system was generally more profitable than the straightbreed Nelore, but only by a modest margin.

Acknowledgements

The suggestions made by the reviewers are gratefully acknowledged. This research was supported with scholarships by the National Research Council (CNPq).

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