The influence of some elements of tropical milk production systems on breeding objectives is discussed. Expansion of demand for milk and meat should be expected from increased population and income growth. Relative commercial value of milk fat may be strongly influenced by government policies regulating the proportion of liquid milk consumed. Calf production is an integral part of cow performance under the common practices of hand milking and suckling. Milk letdown may be an important trait for milking in modern dairy parlours. Experimental economic evaluations have referred mainly to comparisons of breeds and crosses, indicating that European x zebu crosses outperformed purebreds in the environments studied. An evaluation of milking time in relation to milk yield of crossbred groups is presented. Results from a simulation study on tick control strategies allowed evaluation of genetic change in tick resistance.

INTRODUCTION

Man keeps cattle to obtain milk, meat and other products. Meat, and particularly milk, are products of high nutritional value, but their role in human nutrition depends on the complementary diet, including possible substitutes from cheaper protein sources (Kon, 1972). Breeding goals should be related to human needs (Maijala, 1976). Nonetheless, the production, transformation and distribution of cattle products generate economic activities, the efficiency of which can be improved by the use of animals capable of increasing product yield or quality per unit of resources (land, labour, capital) of a given production system. The objective of breeding plans may then be defined as the obtention of animal genotypes resulting in improved economic performance of the system, thus providing a basis for decisions on such aspects as choice of breeds, crossbreeding strategy and selection of individuals within a breed.

Economic evaluations of cattle breeding objectives in tropical countries have been scarce. This may be a consequence of there being few applications of modern improvement programmes, perhaps because artificial insemination and milk recording are used only on a small scale. In this paper, I would like to discuss some socioeconomic and ecological aspects of tropical dairy cattle systems, as they strongly influence the relative economic importance of different traits. A very brief review of theoretical aspects is initially presented to provide a general framework for the subject.

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THEORETICAL ASPECTS

Economic performance of a production system (breeding objective) may be measured as a profit \( P \) obtained from the difference between total receipts \( R \) minus costs \( C \), \( P = R - C \) (Moav and Moav, 1966), or, as return to investment \( R/C \) (Cartwright, 1970) or its inverse \( C/R \) (Dickerson, 1970).

Because of costly recording of total receipts and expenses of individual animals - or even of groups - selection is usually practised on a function of measurable traits - the selection criterion - which should be designed to maximize genetic progress in the breeding objective (James, 1982). A method to evaluate returns from investment in a breeding programme, which incorporates discounting of future genetic gains, was described by Hill (1971).

Hazel (1943) defined the breeding objective as the aggregate genotype, a linear function of single trait genotypes weighed by their economic importance, "the amount by which profit may be expected to increase for each unit of improvement in the trait". For the more general situation of non linear profit functions, Moav and Hill (1966) used as economic weights the partial derivatives of profit on traits, evaluated at mean present value for each trait. Goddard (1983) suggested that this procedure would generally (but not invariably) provide satisfactory approximations to maximize profit. Economic weights have also been derived experimentally from the partial regressions of measured profit per animal on single traits (Andrus and McGilliard, 1975). Pearson (1982) and James (1982) discussed the properties of different methods of estimation of economic weights.

Because genetic improvement must serve several industry sectors - like farmers, stud breeders, artificial insemination centres, milk processing plants - several authors have stressed the need to define whose profits are to be improved (Harris, 1970; Moav, 1973). Lack of integration between sectors could lead to conflicting interests which would reflect in divergent sectorial breeding objectives (Ponzoni, 1982). James (1982) pointed out that definition of breeding objective as profit \( (R-C) \) or as an efficiency ratio \( (C/R) \) would lead to different relative economic weights of traits. Brascamp, Smith and Guy (1985) showed that relative economic weights would become the same for any basis of evaluation in a zero profit situation, that is, including "normal profit" as a part of the production cost. They argued that, in the long run, temporary advantages of one sector over others would spread over all sectors and the benefits would be passed over to consumers. This may require perfect competition between sectors and some other theoretical economic conditions. However, the argument would certainly apply to an agency responsible for genetic improvement at the national level, which should consider a profit equation for all sectors involved in the production system.

Economic weights of traits depend on the role the breed has in the industry (Ponzoni, 1982). Different population breeding strategies were considered by Mason (1974) and Cunningham (1979). Full advantages from crossbreeding and progeny testing may be limited to the small fraction of herds under controlled breeding, and improvement schemes may then require a layer of multiplier herds to provide bulls for natural service. Hill (1974) and Brascamp (1978) presented methods to optimize breeding plans in structured populations.

The establishment of breeding objectives requires a definition of the production system in which animals will perform (Harris, Stewart and Arboleda, 1984). Ecological and socioeconomic factors influencing the relative economic weight of traits should be specified, and future trends in prices of products
and inputs should be evaluated, since improvement of future generations is sought (Pearson, 1982). Some aspects of production and consumption are discussed below, with special reference to Brazil and Latin America.

**CONSUMER TRENDS**

Per capita consumption of milk and meat is very low in tropical countries (FAO, 1984). Low income is a major cause for it. Sere and Vaccaro (1984) indicated that the lowest income quartile of the population of major Latin American urban centres spent 7 to 13 percent of total food expenditure in milk and dairy products, for which income elasticity of demand ranged between 0.87 and 1.16. Gemente and Yamaguchi (1980) quoted income elasticity of 0.80 for the same products in two Brazilian studies. Data in Table 1 show the expansion in calorie intake from beef, milk and dairy products expected from increased income, for different income groups in Brazil. Future demand of those products should be expected to expand due to combined effects of population and income growth (Hrabovszky, 1981).

**TABLE 1 - Characteristics of calorie intake from beef and milk in Brazil.**
*Adapted from Gray (1982)*

<table>
<thead>
<tr>
<th>Income group</th>
<th>Lowest 20 percent</th>
<th>Middle 50 percent</th>
<th>Highest 30 percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean per capita daily calorie intake, ca</td>
<td>1876</td>
<td>2162</td>
<td>2369</td>
</tr>
<tr>
<td>Percent calorie intake provided by milk</td>
<td>2.3</td>
<td>3.2</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>3.2</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Income elasticities for calorie intakes beef</td>
<td>1.33</td>
<td>0.71</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td>0.60</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>1.16</td>
<td>0.67</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>0.37</td>
<td>0.19</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**PRICING OF MILK COMPONENTS**

Because of its high digestibility and biological value, milk protein is an outstanding nutrient (Kon, 1972). Rendel (1979) suggested that protein production should be selected for, independently of prevailing pricing system. However, considered as a commodity, milk is generally valued on fat content. Based on market requirements for milk components, Jollans (1981) indicated increased fat production as a main breeding objective for EEC countries, where only 18 percent of milk is consumed liquid. He suggested the same principle might apply in developing countries. However, the value of fat would be lower in countries where a higher proportion of liquid milk is consumed, and may be subjected to strong governmental influence. For instance, in Brazil, 46 percent of milk is consumed liquid (Table 2), the remaining 54 percent being manufactured into more than 74 products, mainly cheese, dried milk powder, butter and condensed and fermented milks (Frensel, 1980). Processing plant receipts and
profits from dairy products are more than proportional to milk input in their manufacture, as exemplified in Table 3. Liquid milk - but not dairy products - prices are fixed by the government. The fat differential for the last quinquenium was equivalent to 0.0043 l of quota base milk per 0.1 percent above base content of 3.3 percent. This compares unfavourably with a corresponding figure of 0.0142 kg worked out from USA prices (Wiggans, Norman and Powell, 1984).


<table>
<thead>
<tr>
<th>Annual milk input (1000 tt)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total production</td>
<td>8958</td>
</tr>
<tr>
<td>Liquid milk</td>
<td>4100</td>
</tr>
<tr>
<td>Dried milk</td>
<td>1070</td>
</tr>
<tr>
<td>Cheese</td>
<td>1907</td>
</tr>
<tr>
<td>Butter</td>
<td>627</td>
</tr>
<tr>
<td>Other</td>
<td>1254</td>
</tr>
</tbody>
</table>

Most pasteurized milk for liquid consumption in Brazil is standardized to a fat content of 3.2 percent, while fat content of milk received at the processing plant is 3.6 percent. At many farms milk is partially skimmed (in unknown quantities) before being sent to the plant. Recent programmes of free milk distribution to schoolchildren would tend to reduce the commercial value of fat.

TABLE 3 – Utilization of milk by two dairy plants in Brazil, processing A, 16.76 tt and B, 73.88 tt milk/day

<table>
<thead>
<tr>
<th>Product</th>
<th>Liquid milk</th>
<th>Butter</th>
<th>Cream</th>
<th>Cheese</th>
<th>Soft toffee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production 1, tt</td>
<td>4054</td>
<td>33</td>
<td>-</td>
<td>200</td>
<td>45</td>
</tr>
<tr>
<td>Milk input, %</td>
<td>66.7</td>
<td>-</td>
<td>-</td>
<td>31.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Receipt from product/total plant receipts, %</td>
<td>57.5</td>
<td>4.4</td>
<td>-</td>
<td>34.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Product price in milk equivalent, kg/kg</td>
<td>1.6</td>
<td>15.1</td>
<td>-</td>
<td>19.8</td>
<td>9.0</td>
</tr>
<tr>
<td>Plant B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production 2, tt</td>
<td>21164</td>
<td>69</td>
<td>33</td>
<td>87</td>
<td>-</td>
</tr>
<tr>
<td>Milk input, %</td>
<td>95.5</td>
<td>0.4</td>
<td>0.2</td>
<td>3.9</td>
<td>-</td>
</tr>
<tr>
<td>Profit from product/total plant profit, %</td>
<td>75.6</td>
<td>18.6</td>
<td>2.3</td>
<td>3.5</td>
<td>-</td>
</tr>
</tbody>
</table>

1. Annual 2. Ten month period 3. Price paid to farmers per kg quota milk.

Projections of milk fat offer should consider the decreased fat content expected from improved milk yield resulting from better husbandry practices. Madalena et al. (1982) reported fat percentages of 3.82 and 4.15, respectively, for farms grouped in two management levels with 2689 and 1517 kg average lactation yield. Protein percentage, however, was similar for both management levels, 3.11 and 3.17, respectively.
Water content of milk increases transport and processing costs and it is penalized in some pricing systems (Pearson and Miller, 1981). These costs will vary locally. In southern Minas Gerais they have been estimated at 5.1 percent of farmers' milk receipts (A.T. Gomes, personal communication).

MILKING PRACTICES

It is only recently that management practices for tropical dairy herds have received research attention. Machine milking and artificial calf rearing should not be adopted a priori just because they are widely used in developed countries. Hand milking may be chosen in regions where capital is scarce and labour abundant. From a national point of view, it may be preferable to favour rural employment - even if some efficiency is lost - to diminish migration to overpopulated cities. For an individual farm manager, lack of trained operators and maintenance/repair services - or even energy - may rule out machine milking. The reverse may, of course, be true for more developed regions.

The choice of milking technique may also be influenced by the type of cattle available. Many zebu and Criollo cows and low grade crosses of these with European breeds need the calf suckling stimulus for milk letdown (Mahadevan, 1966; Bodisco and Abreu, 1981) and they cannot be milked in modern parlours where there is no space for calves. In some populations calf removal has caused a high incidence of short lactations (AMZ, Hayman, 1974; AFS, Reason, Clark and Goodchild, 1979; Holstein x Brahman, Alvarez and Saucedo, 1982), whereas in other populations this has not been the case (Holstein-Friesian x Gir, Madalena et al., 1980, 1983). Poor management reduces lactation length, particularly of high grade European crosses (Madalena et al., 1982). Divergent results may be due to genetic differences between zebu populations. In the new Australian breeds - which originated from a very small zebu sample - incidence of short lactations was rapidly reduced by selection. Stokoe and Waldron (1982) reported that variation in this trait in the AFS breed was higher among Sahiwal than among AFS sires.

CALF PRODUCTION

Tropical milk production systems vary widely in their degree of specialization, even within the same country (Wilkins et al., 1979; Madalena, 1981). In southern Minas Gerais, for example, sales of milk and dairy products make up 70 to 73 percent of farm receipts from cattle (A.T. Gomes, personal communication). Sales of cattle are not very important because most male calves are sold at an early age. In other regions there are extensive beef ranches where milk is "extracted" from a fraction of the cows, milked once a day during the favourable season. Paladines (1980) quoted two studies in which milk sales accounted for 13 to 33 and 22 to 50 percent of farm receipts, the lower values corresponding to the larger ranches. Plessow (1985) reported receipts from milk ranging between 17 to 48 percent of total receipts in Venezuelan farms. Intermediate situations, characterizing dual purpose systems are also found (Paladines, 1980; Ruiz, 1982; Cubillos, 1982; Seré and Vaccaro, 1984). Preston (1977) showed the economic advantages of dual purpose systems and pointed out that systems specializing solely in milk or beef production would only be acceptable in countries still having large areas for extensive beef production. Seré and Vaccaro (1984) indicated narrow beef/milk price ratio as the main reason for the predominance of dual purpose systems, coupled with flexibility to vary relative outputs from milk or animal sales, to adjust to fluctuations in that
Farmers control the amount of milk left for the calves by incomplete milking, by milking once or twice a day (or still milking twice a day only the high yielding cows) and by the time interval the calves are left with their dams.

Calf rearing by suckling has also been advocated for tropical systems to avoid expensive milk substitutes and to reduce calf mortality and incidence of mastitis. Detrimental effects on cow reproductive performance may be reduced by restricting suckling periods (Preston and Ugarte, 1971; Alvarez and Saucedo, 1982). Calves are predominantly reared by suckling even at farms using machine milking and high grade European crosses in South Central Brazil, although those cows do not need the calf suckling stimulus for milk letdown. Thus, in the majority of tropical dairy systems, calf production is an integral part of cow performance (Vaccaro, 1982; Vaccaro, Vaccaro and Perez, 1983). Large scale recording of weaning weights would however be extremely difficult, so substitute criteria based on milk yield and calf survival may have to be developed.

The beef/milk price ratio also affects future milk production at the national level by influencing the number of heifer calves retained for milking. Diniz (1976) reported that the crossed elasticity of Brazilian milk production on year t with beef price on year t-4 was 0.957.

**EXPERIMENTAL ECONOMIC EVALUATIONS**

A few economic comparisons of cattle breeds and crosses have been published. Ram and Singh (1975), Patel et al. (1976), Parmar and Dev (1978) and Kanchan and Tomar (1984) used cost per litre of milk as a measure of economic performance. Sales of milk and manure were the only income sources considered - the latter being deducted from cost of milk production. Reddy and Bassu (1985) used a profit function which also included receipts from sales of calves and cull cows. Items included in costs varied among studies. In the comprehensive investigation of Patel et al. (1976) information was obtained at fortnightly visits to 350 households on quantities and prices of the following: green and dry fodder, concentrates, milk for calves, mineral mixture, veterinary aid, labour inputs, utilization of cattle manure, repairs, interest on loans and taxes. The general conclusion from these studies has been that European x zebu crossbreds have better economic performance than purebreds and buffaloes, grades above 1/2 European being preferable to those below that fraction. Heterosis for economic value was 28 percent of estimated parental mean (Parmar and Dev, 1978).

**TABLE 4** - Milking traits of Holstein-Friesian (HF) x Guzera crosses. Aggregate value H = Ym - Tl, where Y = milk yield and T = milking time (estimated from breed additive + heterosis model), m = gross margin for 1 kg of milk and l = cost of 1 min labour.

(a) present values, m = 0.48, l = 0.03, both in kg milk equivalent.
(b) m = 0.48, l = 0.12. From Madalena et al. (1986).

<table>
<thead>
<tr>
<th>N</th>
<th>Daily milking time (min)</th>
<th>Daily milk yield (kg)</th>
<th>Avg. rate of milk flow (kg/min)</th>
<th>Expected aggregate value (H)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(a)</td>
</tr>
<tr>
<td>1/4</td>
<td>17</td>
<td>9.41</td>
<td>5.11</td>
<td>0.64</td>
</tr>
<tr>
<td>1/2</td>
<td>32</td>
<td>10.89</td>
<td>9.37</td>
<td>0.91</td>
</tr>
<tr>
<td>5/8</td>
<td>19</td>
<td>9.31</td>
<td>6.59</td>
<td>0.71</td>
</tr>
<tr>
<td>3/4</td>
<td>25</td>
<td>8.94</td>
<td>8.28</td>
<td>0.95</td>
</tr>
<tr>
<td>7/8</td>
<td>31</td>
<td>8.19</td>
<td>7.15</td>
<td>1.03</td>
</tr>
<tr>
<td>HF</td>
<td>18</td>
<td>8.12</td>
<td>7.53</td>
<td>1.01</td>
</tr>
</tbody>
</table>
Milking labour costs were evaluated for six Holstein-Friesian x Guzerá crossbred groups at 27 farms in Brazil (Madalena et al., 1986). Groups with higher milk yields were not the ones with higher milk flow, but the benefits from extra yield more than outweighed the increased milking time (Table 4).

An interesting study was conducted by Sutherst et al. (1979), allowing economic evaluation of genetic change in tick resistance. They used a deterministic simulation model to study the effects of dipping, pasture spelling and utilization of resistant cattle, in various combinations, on tick control. Alternative strategies were compared on the economic loss from tick damage on liveweight gain and cost of tick control. The results were based on previous data specifying tick damage (0.26 kg liveweight/tick/year) and tick reproductive parameters controlling population growth in different seasons. Cattle resistance levels corresponded to those of European breeds and 1/2 European x zebu crosses. Some of their results are reproduced in Table 5. The value of genetic tick resistance is, of course, dependent on the control strategy chosen. Further genetic improvements in tick resistance should probably come from selection, since small differences exist between 1/2 and 3/4 zebu crosses (Lemos et al., 1985) and decreasing European grade below 1/2 would reduce performance in other important traits (Madalena et al., 1982).

TABLE 5 - Estimated losses from tick damage and tick control costs (A$/head) on first year of application of three control methods, with an initial population of 100 000 eggs/animal in pasture. From Sutherst et al. (1979).

<table>
<thead>
<tr>
<th>Cattle type</th>
<th>Dipping</th>
<th>Pasture spelling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rotational</td>
<td>Single</td>
</tr>
<tr>
<td>Non resistant</td>
<td>4.58&lt;sup&gt;5&lt;/sup&gt;</td>
<td>4.35</td>
</tr>
<tr>
<td>Resistant</td>
<td>1.63&lt;sup&gt;1&lt;/sup&gt;</td>
<td>3.70</td>
</tr>
</tbody>
</table>

<sup>5, 1</sup>: optimal number of strategic dippings.

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