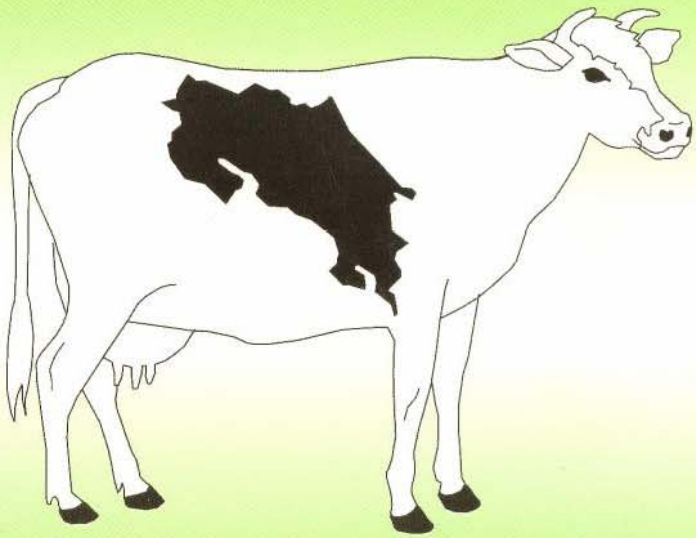
Bioeconomic modeling to support management and breeding of dairy cows in Costa Rica



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Abstract

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During the past decades, genetic improvement of dairy cattle in Costa Rica has depended upon massive importation of germplasm from temperate countries. This may not be an optimal alternative if genetic × environment interactions are significant or production goals differ among countries. The purpose of this dissertation was to develop a bioeconomic model to describe performance of dairy cows under production circumstances found in Costa Rica. Several studies were undertaken to quantify the effect of genetic and environmental factors on milk yield and reproduction performance of the local cattle population. The final model was used to optimize replacement and inseminations policies for herds with different feeding strategies and to determine the economic values of production and functional traits to be included in a breeding goal. Finally, a study was conducted to compare several breeding strategies on the basis of the genetic response achieved after twenty-five years of selection. When significant genotype × environment interactions were assumed strategies based on selection within the local population performed better than strategies based on importation of semen.

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Summary

The general goal of this dissertation was to develop a bio-economic model to support breeding and management in dairy herds of Costa Rica. Specific objectives were to determine important factors contributing to the variation in production and reproduction performance and to make use of this information to develop a model describing performance and merit during lifetime of a dairy cow. The resulting model was used to compare optimum replacement and insemination policies in a dairy herd used different feeding strategies. The model was also used to determine optimum recording schemes and breeding goal for Holstein cattle of Costa Rica on the basis of the relative economic values of production and functional traits. Alternative breeding strategies using this breeding goal were compared on the basis of the rate of genetic response achieved.

In **chapter 1** a general description was given of the milk production systems in Costa Rica for aspects related to management, nutrition, breeding, market structure and biological and economic efficiency. Due to the high diversity of climatic conditions, geography, and availability of feed resources, different production systems have evolved according to the specific conditions of each region. Three main production systems are identified: specialized dairy farms, lowland dairies and dual-purpose farms. Specialized dairy production systems have the highest productivity per cow and per unit of land, but production costs are the highest. Lowland dairies and dual-purpose systems are less efficient, but production costs are substantially lower. Past research in breeding of dairy cattle indicated that the increase in productivity levels found in Costa Rican farms have been caused mainly by improvement of management conditions and to a lesser extent by breeding. It seems also that Genetic × Environment effects have a significant impact in these dairies. Milk production systems in Costa Rica play an important role by providing milk in quantity and quality needed to satisfy the local demand, with some scope for an increased participation in markets within the region. Perspectives in the area of milk production were briefly analysed according to global trends in milk production and market structures. It is concluded that specialized production systems will need to be transformed into systems that are less dependent on costly external inputs.

In **chapter 2** variance components for test day yields in Holstein cows were calculated in order to assess the degree of genetic variance for milk production in the current population. Estimates of variance components for test day records were calculated with an animal model that considered multiple traits over multiple lactations, using REML methodology. Test day records were classified within first and later lactations. Missing ancestors in the

relationship matrix were classified in genetic groups. Data were collected from Costa Rican dairy farms. Estimates of components for phenotypic and additive genetic variance were clearly heterogeneous during the lactation. Heritabilities for traits in first parity ranged between 0.15 and 0.23, and for later parities between 0.13 and 0.24. Higher heritabilities were found for midlactation records. Phenotypic and genetic correlations for adjacent test days were close to one. Phenotypic correlations were lower than genetic correlations. Heterogeneity of variances during the lactation suggested the adequacy of a test day model for multiple traits to describe milk yield during the lactation. When missing ancestors were allocated to a single base population, instead of genetic groups, the estimates of residual variance were lower, and the estimates of genetic variance and genetic correlations were higher. When standardized records were used instead of actual test day records, the estimates of residual and total variance were lower, and the estimates of genetic variance were higher. Consequently, estimates of heritability and genetic correlations were also higher. Therefore, the use of standardized data obtained by interpolation procedures is not advised for estimation of genetic variance components in a test day model.

In **chapter 3** an analysis was made on factors affecting reproduction performance of dairy cows of Costa Rica. Traits analysed were age at first calving, days to first breeding and days open during the first lactation of Holstein, Jersey and Brown Swiss heifers. Use was made of event-time methodologies. A proportional hazard model was used that included fixed effects of herd-year, year-season, breed type, herd weight category and heifer weight category. Body weights were recorded at 390 d of age on average. The model for days open and days to first breeding included two additional fixed effects of herd and heifer milk yield at 100 d. A significant effect of heifer weight category on age at first calving was found. The chance of calving was consistently higher for herds and heifers with higher body weight at 390 d, and decreased linearly from the top to the lowest quartiles. Effects of herd weight category on days to first breeding and days open were significant. Heifers in herds with a higher average body weight were less likely to be bred, and heifers in herds with lower average body weight were less likely to get pregnant. The effect of heifer weight category on days to first breeding or days open was not significant. The effect of herd milk yield on days to first breeding was significant. Heifers in herds with lower yield were more likely to be bred. The effect of heifer milk yield category on days to first breeding and days open was significant, but no linear trend was found for the estimates of the hazard ratios. The chance of a heifer being bred and becoming pregnant was similar

among the first three quartiles, and lower for heifers in the lowest quartile. It was concluded that the probability of reaching a first calving can be improved by increasing the body weight at 390 d. Body weight at 390 d did not have a large effect on reproductive performance after first calving. High milk yield appears not to have a large negative effect on days open, within the production levels analysed in this study.

In **chapter 4** nine mathematical models were compared on their ability to predict daily milk yields in standard 305-d and extended lactations of Holstein cows of Costa Rica. Lactations were classified according to parity, lactation length and calving to conception interval. Of the nine models, the diphasic model and lactation persistency model resulted in the best goodness of fit as measured by adjusted coefficient of determination, residual standard deviation and Durbin-Watson coefficient. All other models showed a lower accuracy and residuals were positively correlated. In extended lactations, models were also fitted using only test day records before 305 d, which resulted in a different ranking. The diphasic model showed the best prediction of milk yield in standard and extended lactations. It was concluded that the diphasic model provides accurate estimates of milk yield for standard and extended lactations, although the interpretation of parameters needs further study due to the large variation observed. As expected, the interval calving to conception had a negative effect on milk yield for cows with a standard lactation length. In extended lactations, these negative effects of pregnancy on milk yield were no longer observed.

In **chapter 5** parameters calculated in the previous chapters were used to develop a bio-economic model that permits the analysis of interaction between management and breeding aspects in dairy herds. The bio-economic model was the result of the integration of a dynamic performance model and a model that optimized culling and insemination policies in dairy herds using dynamic programming. The performance model estimated daily feed intake, milk yield and body weight change of dairy cows on the basis of availability and quality of feed, potential milk yield, and feed intake constraints. A set of cow-states was defined by lactation number, calving interval, potential milk yield and stage of lactation. Biological and economical parameters used in the model represented actual production circumstances in Costa Rican herds. Eight feeding strategies combining two forages and four concentrate allocation systems were simulated. Different feeding strategies resulted in maximal changes of 6.8 mo in optimal average herd-life, US$26.1 in monthly income per cow and 1.9% in replacement rates, while average calving interval was not affected. The

main difference was found between feeding strategies based on flat ratios compared to feeding strategies based on daily milk yield. Feeding flat ratios altered the course of profitability due to the restriction of feed costs and its effect on animal performance. Average herd-life and monthly income under the optimal feeding strategy were highly sensitive to changes in price of milk, and less sensitive to changes in price of concentrates or price of forage. Calving interval was not sensitive to any of the factors. Comparison of optimal policies against actual parameters obtained from field data indicated that cows are being culled close to the optimal herd-life with calving intervals longer than optimum. The model is an efficient tool to study the interactions between nutrition, reproduction and breeding at the animal and herd level.

In **chapter 6** the bio-economic model was used to analyse possible traits to be included in the breeding goal for dairy cattle in Costa Rica. Economic values for production traits (carrier, fat, protein, and dressing percentage) and functional traits (conception rate, survival rate, body weight, and rumen capacity) were calculated for Holstein cattle of Costa Rica. Three evaluation bases were considered: fixed herd-size, fixed concentrate-input and fixed milk-output. With a fixed herd-size all traits had a positive economic value. Traits with the highest economic values were rumen capacity and fat yield; followed by protein yield, survival rate, conception rate, dressing percentage and body weight. Economic value for carrier was close to zero. With a concentrate-input limitation all traits except body weight and rumen capacity had significantly lower economic values compared to fixed herd-size. Economic values for body weight and rumen capacity did not change. With a milk-output limitation, economic values for all traits were significantly lower than for fixed herd-size. Sensitivity analysis indicated that economic values of fat, protein and rumen capacity increased significantly with higher prices of milk solids. Other traits were less sensitive to change in price of milk. Changes in price of concentrate or forage did not alter economic values significantly. The results of this analysis suggest that genetic improvement of fertility, health and cow-efficiency traits will have a positive significant effect on profitability of Holstein cows in Costa Rica.

Finally, in **chapter 7** an analysis was made to compare alternative breeding strategies for Holstein cattle in Costa Rica. At first, a local breeding goal was defined on the basis of results found in chapter 6. This breeding goal was compared to a typical breeding goal for an exporting country. Efficiency of breeding goals for selection of sires was assessed on the basis of genetic response in economic units, assuming equal selection intensities, accuracy

of selection, and genetic parameters for traits in the breeding goal and selection index. Differences in genetic response were less than 3%, and the correlation between breeding goals was 0.99. Therefore it was concluded that the differences between breeding objectives is not a major factor in evaluating importation of semen and breeding schemes on the local Holstein population. An additional analysis was performed to assess the possible effect of changing the current trends in breeding of local dairy cattle, based on semen importation, against alternative breeding strategies based on selection within the local population. Local strategies considered in this analysis were a progeny testing scheme and a closed nucleus breeding scheme. Selection intensities and accuracy of selection were defined according to actual population sizes and reproduction efficiency parameters. When genetic × environment interactions were ignored semen importation was the strategy with the highest genetic response, 2.9% above closed nucleus breeding scheme and 30.3% above progeny testing. Genetic × environment interactions were considered by defining a correlation between breeding values in both countries lower than one. This resulted in permanent effects on the relative efficiencies of breeding strategies, because of the reduction in the rate of genetic response when imported semen was used. When the genetic correlation was assumed lower than 0.77, the genetic response achieved with semen importation was reduced at the same level as local progeny testing. When an initial difference in average genetic merit of the populations was assumed, this only had a temporal effect on the relative ranking of strategies, which is reverted after some years of selection because the rate of change in genetic responses remain unchanged. Given that the actual levels of genetic correlation between countries may be around 0.6, it is concluded that a local breeding scheme based on a nucleus herd could provide better results than the current strategy based on semen importation. However, the current trend towards globalisation of breeding programmes may result in more attractive alternatives within the next years.