Population Structure and Phenotypic Characterization as a Basis for Conservation and Sustainable Use of Reyna Creole Cattle in Nicaragua

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Cover: Nicaraguan Reyna Creole cow with calf
(photo: Roldan Corrales)

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Abstract

The Reyna Creole cattle in Nicaragua is a local breed originating from the *Bos taurus* cattle brought to Latin America during the Spanish colonization in the fifteenth century. Reyna Creole cattle are today found in five herds. The primary use of the breed is to produce milk. The breed comprises about 650 purebred female animals. The main objective of the thesis was to characterize the population structure and productivity in terms of milk production and some reproduction traits, and to discuss options for conservation and improvement of the breed.

The inbreeding level was 13% on average, primarily due to use of individual bulls for long periods. An effective population size of 28 to 46 animals was estimated, showing that the Reyna Creole cattle breed is endangered, close to critical status.

Average birth weight was 27.8 kg, age at first calving 37.4 months and calving interval 14.0 months. Large differences between herds were observed for all traits. Heritabilities were 0.34, zero and 0.20 for the respective trait. Average lactation yield for 534 Reyna cows with 1,750 lactations was 1,319 kg with large variations between herds and time periods. Test-day records on milk yield and fat and protein contents were collected monthly during one year for three Reyna herds and two herds with crossbred cows. Commercial dairy breed crosses had the highest production, and Reyna the lowest, but large differences were noted in management between the herds. The heritability for lactation yield in Reyna cattle was 0.18.

Large variation between and within the Reyna herds suggest good opportunities to increase productivity of the Reyna breed by improving management and breeding strategies. It is proposed to keep all females in the herds, develop mating plans and to apply a recording scheme for keeping pedigrees and records on reproduction and milk production traits. Only young bulls, selected from the best cows for milk production and calving interval, are proposed to be used for 1-2 years each to manage inbreeding and keep generation intervals short.

Keywords: Inbreeding, effective population size, endangered, birth weight, calving age, calving interval, milk production, heritability, repeatability

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Dedication

To my mother Mercedes and my late father,
and to my family, Nydia, Nestor and Fatima

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred by Roman numerals in the text:

I Corrales, R., Näsholm, A., Malmfors, B. and Philipsson, J. (2010). Population structure of Reyna Creole cattle in Nicaragua. *Tropical Animal Health and Production*, 42(7), 1427 - 1434.

II Corrales, R., Näsholm, A., Malmfors, B. and Philipsson, J. (2011). Birth weight, reproduction traits and effects of inbreeding in Nicaraguan Reyna Creole cattle. *Tropical Animal Health and Production*, in press, doi 10.1007/s11250-011-9814-4.

III Corrales, R., Lunden, A., Näsholm, A., Malmfors, B. and Philipsson, J. (2011). Milk production in Reyna Creole cattle and some breed crosses in Nicaragua. (manuscript).

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Abbreviations

AFC	Age at first calving in months
AI	Artificial insemination
BLUE	Best linear unbiased estimator
BW	Birth weight in kg
CI	Calving interval in days
DMY	Daily milk yield in kg
EBV	Estimated breeding value
FAO	Food and Agricultural Organization
Fx	Individual inbreeding coefficient in percentage
Fxd	Dam inbreeding coefficient in percentage
LL	Lactation length in days
Ne	Effective population size
NS	Natural service
PEC	Pedigree completeness index
TMY	Total milk yield per lactation in kg

Introduction

In Nicaragua the agriculture crops and livestock play important roles in the economy. According to the Nicaragua Central Bank (BCN, 2010) these commodities represent 30.8% of the total export value. Bovine meat, live animals and dairy products are the major livestock contributions.

According to INEC (2003) Nicaragua has 2.65 millions of bovine heads. The livestock cattle production systems in Nicaragua are based mostly on dual purpose animals (>85%). The systems are often characterized by low productivity and low technological level. The cattle consist to about 80% of extensively managed crosses between *Bos taurus* (mainly Brown Swiss or Holstein) and Zebu (FAO, 2004). In this context the Reyna Creole cattle breed, with about 650 purebred female animals, is a small population primarily used to produce milk, while male calves are raised for beef. The small number of animals in a limited number of herds suggests that inbreeding might be a problem that questions the sustainability of the breed.

Why conservation of Reyna Creole cattle? This Creole breed is the only cattle breed in Nicaragua originating from the Spanish colonization in the 15^{th} century, and it was declared a national patrimony by the government in 1988. The Reyna Creole cattle generally have been considered valuable for tropical conditions as studies and experiences of Creole cattle in general indicate that those have good temperament, parasite resistance and fairly good milk production (Casas and Tewolde, 2001; De Alba, 1981; Primo, 1992; Salgado, 1988).

Due to the risk status of the Reyna Creole cattle breed it has been considered important to characterize the breed as regards population structure and the most important production and reproduction traits. Thereby, the potential of the breed could be better assessed and options for conservation and sustainable use be investigated.

Background

Origin of Creole cattle in Latin America

The Creole cattle originate from the *Bos taurus* brought to Latin America during the Spanish colonization in 1493. Primo (1992) reviewed the history and reported that all the animals came to the island named 'The Spanish', actually the Dominican Republic and Haití countries. Spanish breeds, e.g. the 'Retinta', 'Berrenda', Cacereña' and 'Andaluza negra' were considered as founders. Since 1524 South America had bovine cattle which entered primarily through Colombia and Venezuela. Later they were spread from Peru (Lima) to several other countries (Bolivia, Paraguay, Chile, and Argentina). Brazil also was a dispersion center since 1534. Under the Jesuit influence the Creole cattle expanded further within Latin America. Over time, Creole cattle have developed different morphological characteristics, behavior and production ability, under different ecological systems and breeding practices.

Presently most countries in Latin America have particular Creole cattle populations A number of Creole cattle breeds in different countries have been reported into the FAO database DAD-IS. However, the information is not always updated. Examples of Creole breeds reported are, for instance Caracú cattle in Brazil; Limonero and Llanero cattle in Venezuela; Harton del Valle, Romosinuano and San Martinero cattle in Colombia; Reyna Creole cattle in Nicaragua; Barroso Salmeco in Guatemala; Tropical Dairy Criollo in Mexico, and Dominican Criollo in Dominican Republic (DAD-IS, 2011).

Reyna Creole cattle in Nicaragua and the Central American Milking Creole cattle in Costa Rica

The Reyna Creole cattle in Nicaragua is a local *Bos taurus* breed that constitutes a branch of Creole cattle developed in Latin America. It is the only remaining local breed in the country. However, between 1500 and 1950 little is known about this kind of cattle. During the 1950s a Nicaraguan breeder, Joaquin Reyna who was a farmer dedicated to the conservation and selection of this kind of animals ('ganado antiguo'). He collected animals with characteristics of Creole cattle, e.g. wrinkles around the eyes and neck, scarce hair on the tail tassel, and founded a herd in the Rivas province (Departamento), southern Nicaragua. The phenotypic selection within this herd, which eventually comprised around 200 females, was focused on red coat colour (sorrel) and milk yield. At the beginning of the rainy season, milking cows that yielded less than 6 liters per day were discarded. During the 1950s Joaquin Reyna received technical advice from the Inter-American Institute of Agricultural Sciences (IICA). He also collaborated with IICA for establishment of a recording system for the Reyna cattle. The herd progressed towards more intensive management (milking without calf at foot) until the death of the owner in 1960. After that, the herd reverted to one milking per day and calf at foot (De Alba, 1985; De Alba and Kennedy, 1985).

No official pedigree information was available for Reyna Creole cattle until the 1970s, when the government started an official inventory (De Alba, 1985). Nowadays, purebred Reyna Creole cattle in Nicaragua are found only in five herds and in four of those the owners keep records. There are also some herds with Reyna Creole cattle crosses (*Bos taurus* × *Bos indicus*) in the country. In 1988, Reyna Creole cattle were declared a national patrimony of Nicaragua.

Reyna Creole cattle partly contributed to formation of The Central American Milking Creole (CLAC), which was basically developed in Turrialba, Costa Rica, between 1947 and 1983. During this period, animals with Creole characteristics from Honduras and Nicaragua were introduced. The influence of Reyna Creole cattle on CLAC has been evident, chiefly due to export of eight Reyna sires to Costa Rica. The selection in CLAC has mainly been focused on milk production and less on coat colour. Reyna Creole cattle have also contributed semen, or live animals, to other Creole cattle herds, e.g. to Limonero Creole cattle in Venezuela and to Creole cattle in Mexico and The Dominican Republic. Creole cattle have also been imported to Nicaragua, as semen from two sires each from Costa Rica and the Dominican Republic, and from four sires from Mexico.

Phenotypic appearance of Reyna Creole cattle

As mentioned already, the founder of the first Reyna herd, Joaquin Reyna, favoured animals with red (sorrel) coat colour and milk production. Red is still the main coat colour in Reyna cattle, although the colours vary from light red to dark red (see Figure 1). The animals have horns, but are usually dehorned early in life.

Figure 1. Examples of red coat colours in Nicaraguan Reyna Creole cattle

Within the Reyna breed there are animals that show specific phenotypic attributes, such as slick hair, dark spot around the vulva and dark spots around the eyes (see Figure 2). A typical characteristic of Reyna cattle is a high tail insertion (high Sacrum bone).

Animals with slick hair have a very short and glossy type of hair. The difference in hair type between a slick hair and a non-slick hair animal is seen when comparing the two upper photos in Figure 2. Frequencies of specific attributes and their possible importance have not been investigated in Reyna cattle in Nicaragua.

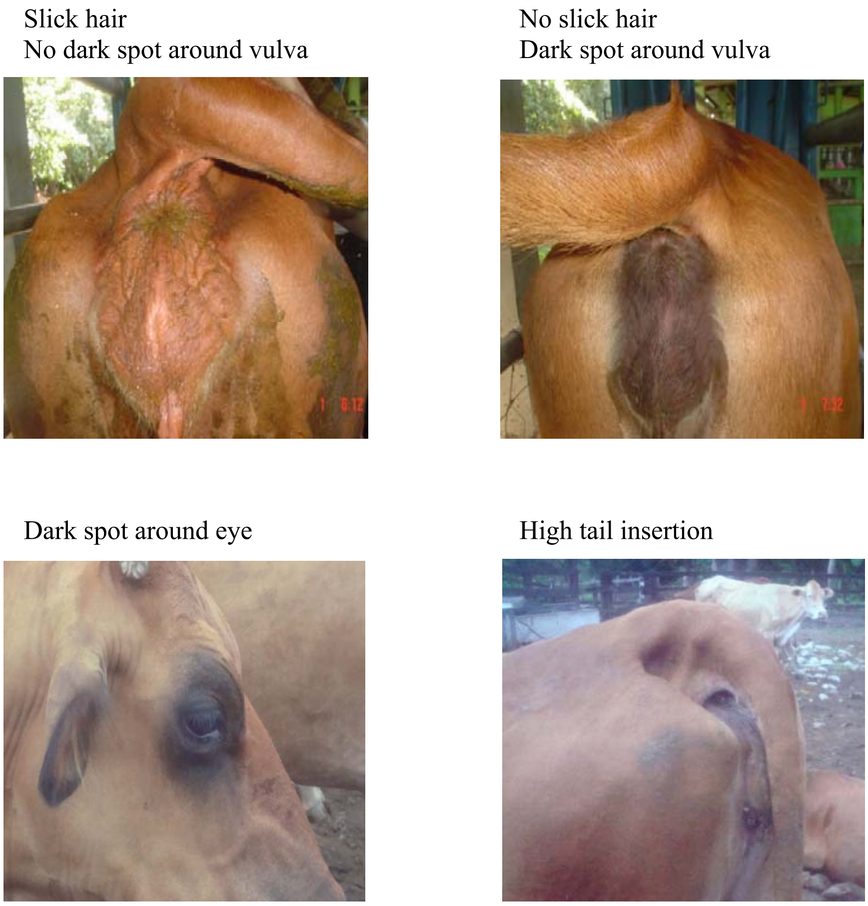

Figure 2. Examples of specific phenotypic attributes in Reyna Creole cattle.

What is known and what is unknown in Reyna Creole cattle?

Since the establishment of the breed in the 1950s until 1988 no research was done regarding Reyna Creole cattle. In 1988, the Nicaraguan government declared Reyna Creole cattle as national patrimony; yet no official interventions to establish a conservation and breeding program were developed. However, a small project sponsored by Italy started activities in order to rescue and promote the Reyna breed in dual purpose production systems. During the project some studies on milk production and reproduction traits were initiated, but the results were based on too little information and still remain without any application. However, reproduction and production performance of Reyna Creole cattle in the period 1982–1991 was summarized for a few herds with limited information in a project report 1999 (unpublished).

Although the Reyna Creole cattle characteristics have been largely unknown, characteristics of CLAC have been better documented. Those animals are in general known to have acceptable milk production levels and milk composition; they show genetic variability in these traits and heterosis effects on milk production are evident in crosses between CLAC and Jersey (Salgado, 1988). Creole cattle have also the reputation to have milk suitable for making yoghurt and cheese because they have the desired kappa-casein and beta-lactoglobulin varieties in high frequency (De Alba, 1997; Rojas *et al.*, 2009; Rojas *et al.*, 2010).

Until the present study was conducted the genetic status of the Reyna Creole cattle breed was unknown. There were no estimates of the level of inbreeding within the breed, although inbreeding could be expected due to use of few bulls over many years in the herds. Only preliminary phenotypic and genetic parameters of some traits were available and effects of various environmental factors on milk production, e.g. number of milkings per day and feeding practices were unknown. A breeding strategy to sustainably conserve the breed is lacking

Official statistics of Nicaragua show that there are probably 900–1,000 purebred Reyna Creole animals, all sexes and ages included (FAO, 2004). The number of purebred females amount to about 650, and the number of recorded cows to around 260 (in 2009). Reyna cows are found in five herds of which four keep records of identity, and to some extent also pedigrees, calving and production data. Natural service (NS) dominates (~85%), but artificial insemination (AI) is also used (~15%).

The Reyna Creole cattle breed has been considered worthy of conservation, not only because of its heritage, but also because of perceived good characteristics as reported for other Creole cattle breeds and in some preliminary studies on Reyna cattle (Corrales, 1993).

Main issues

As facts are lacking or rare about the genetic status of Reyna Creole cattle and its phenotypic characteristics a number of researchable issues were raised.

The first issue to clarify is the present population structure of Reyna Creole cattle considering such basic indicators as inbreeding level, effective population size and generation intervals. These population parameters are valuable in order to organize appropriate mating schemes that ensure minimum loss of genetic variability and to prevent negative inbreeding effects on economically important traits.

A second issue concerns characterization of production and reproduction traits in order to include those in a conservation program. Phenotypic and genetic parameters are needed for future genetic evaluations, as well as for optimization of the breeding program. No information has so far been available on the main milk composition traits (fat and protein content) and would be desired to further explore the potential use of the milk.

A third issue concerns the design of a breeding program that allows the effective population size to grow and how that may be balanced with selection for production. A special issue is what weights should be given on milk production vs. reproduction in such a program, in order not to get a decline in fertility as a result of selection for milk yield.

Because the management and feeding strategies in Reyna Creole cattle herds has been changed over time a particular issue is to what extent the Reyna Creole cattle are affected by such environmental factors. Usually, in the dual purpose production systems in Nicaragua, a practice of one milking per day is common. In Reyna cattle, however, both one and two milkings have been practiced and it would be desirable to know the effects of one vs. two milkings per day in order to fix the feeding strategies.

Aims of the thesis

The overall objective of the thesis is to characterize the population structure, the milk production and some reproduction traits of Reyna Creole cattle, as well as to discuss options for a conservation and genetic improvement program. The aims were particularly to:

- Describe the population structure of Reyna Creole cattle in Nicaragua in terms of inbreeding levels, effective population size, and generation intervals, based on records from three purebred Reyna herds.
- Characterize phenotypically the birth weight (BW), age at first calving (AFC), calving interval (CI) and milk production traits, and to evaluate the potential of Reyna Creole cattle for sustainable use.
- Estimate the genetic variation (heritability) in those traits, as well as the effects of inbreeding on BW, AFC and CI.
- Estimate for reference the production of some common crosses between *Bos taurus* and *Bos indicus* as well as for commercial dairy breed crosses raised under dry tropical conditions in Nicaragua.
- Discuss options for a breeding strategy to conserve and improve Reyna Creole cattle for sustainable use in Nicaragua.

Summary of investigations

Materials and methods

Participating herds

In total records were used from five herds geographically located in the pacific coastal region of Nicaragua (Rivas Departamento). Three herds with purebred Reyna Creole cattle, A, B and C were described in detail in Paper I. Herds A and B had records in some cases going back to 1958, whereas herd C was established much later and has records from 2002. Herd B consisted in reality of cattle at two farms belonging to the same owner. As animals were regularly exchanged between those two farms they had to be treated as one herd in the analyses. Two more herds were added to the study in a pilot scheme for recording of daily milk yields and milk composition. Herd D comprised crosses *Bos taurus* × *Bos indicus* and herd E consisted of dairy breed crosses *Bos taurus* × *Bos taurus* (Brown Swiss, Jersey and Holstein Friesian).

Data used and variables of study

The study of the population structure (Paper I) included 2,609 pedigree records coming from the three purebred Reyna Creole cattle herds recorded from 1958 to 2007: 1,648 from herd A, 699 from herd B and 262 from herd C. In general, the sires and the dams had their origin from Nicaragua (91.6%), Costa Rica (2.5%), Mexico (2.0%), Dominican Republic (0.9%) and of unknown origin (3.0%).

The variables of the study included inbreeding coefficient for animals with a pedigree completeness index (PEC) of at least 0.8 considering five generations to get as accurate estimates as possible. Effective population size (Ne) for the years 1985, 1990, 1995, 2000 and 2005 as well as generation interval (in years) considering four selection paths (sire-son, sire-daughter, dam-son and dam-daughter) also were estimated. Individual and dam inbreeding coefficients (Fx, Fxd) were used as co-variables in order to estimate their effects on several traits.

The first part of the phenotypic characterization (Paper II) included information from the herds A and B. Variables of study and their corresponding number of observations and time period comprised birth weight in kg (BW, n=1097, 1989-2007), age at first calving in months (AFC, n=449, 1975-2004) and calving interval in days (CI, n=1,347, 1972-2004).

The studies on milk production (Paper III) included information from the three purebred Reyna Creole cattle herds (A, B and C), and the two herds with crossbred cows, D and E. Two data sets were used. Data set 1 included information from the herds A, B and C from 1982 to 2008. Variables of study and number of observations were total milk yield per lactation in kg and lactation length in days (TMY, LL, n=1,750). Data set 2 was based on a pilot scheme for monthly recording of milk yield and milk composition. The milk recording took place from November 2005 to October 2006. The variables of study were daily milk yield (DMY) and energy corrected milk (ECM) in kg per cow a day, and the percentages of fat and protein.

General statistical and calculation procedures

Inbreeding coefficients (Fx), as defined by Wright, (1922) were calculated according to Sigurdsson and Arnason, (1995) and pedigree completeness (PEC) index according to MacCluer et al. (1983). An approximate estimation of the effective population size (Ne) was estimated according to Falconer and MacKay (1996) considering just the number of active sires and cows every fifth year.

For analyses of the recorded traits (BW, AFC, CI, TMY, LL, DMY, EMC, fat% and protein%) the mixed linear models included relevant effects appropriate for each trait. The following fixed effects were used to various extent in the analyses: herd-year-season (HYS) or alternatively H and S, age at calving (Age), sex of calf (Sex), calving number (CN) and lactation stage (LS). Random effects of animal, permanent individual or maternal environment, and alternatively the effect of the cow, were used for estimation of phenotypic and genetic parameters by using the average information algorithm for restricted maximum likelihood with the DMU package (Madsen and Jensen, 2006). Analyses of DMY, ECM, fat% and protein% were based on too few cows for estimation of genetic parameters and were thus done with procedure MIXED of the Statistical Analysis System (SAS, 2009). The descriptive statistics for all the quantitative traits were obtained with procedure MEANS of SAS.

Main findings

Population structure for Reyna Creole cattle in Nicaragua

A pedigree completeness index higher than 0.8 was required to obtain reliable estimates of the level of inbreeding, and this criterion was met for 367 animals (14 %) in two herds. The average level of inbreeding was 13.0%, with individual values ranging from zero to 43.8%. Herd A showed the highest average inbreeding level (21.6%), primarily due to long periods in which the same bulls were used for mating, leading to excessive frequencies of matings between closely related animals. The effective population size ranged from 28 to 46 animals, showing that the Reyna Creole cattle breed is endangered, close to critical status. The average generation interval was 6.9 years with values as high as 19.1 years for some sires that were used for AI over a long period of time. The high level of inbreeding and the small population size observed in Reyna Creole cattle suggest urgent actions to be taken for the development of a breeding program to protect the breed and support its sustainable utilization.

Birth weight, reproduction traits and effects of inbreeding in Nicaraguan Reyna Creole cattle

Overall means for BW (27.8 kg), AFC (37.4 months) and CI (424 days) of Reyna Creole cattle seem normal for Creole cattle under tropical conditions. However, the large differences between the herds observed for these traits represent great opportunities for management interventions, mainly to improve reproduction results. The heritability for BW was 0.34. CI showed a relatively high heritability (0.19) and additive genetic standard deviation (36 days), values indicating opportunities for genetic improvement. The effects of inbreeding of the individual itself were not significant, but significant effects were shown of dam inbreeding level on all traits. For each percentage of increased inbreeding BW decreased with 0.06 kg, AFC increased with 3.5 days and CI increased with 1.4 days. Although Reyna Creole cattle have shown high inbreeding level, the breed still has relatively good reproduction traits.

The overall mean for TMY was 1,321 kg and for LL 274 days with a large variation between herds and time periods due to variable feeding and management practices. TMY means ranged from 850 to 1,750 kg between herd/time periods, and from 247 to 305 days in LL. Individual lactation milk yields varied from about 100 to nearly 3,800 kg.

The heritability for TMY was 0.35, but it was lower (0.18) when individual permanent environmental effects were considered, which must be the case in genetic evaluations. In the study of DMY and ECM the average yields were lower for Reyna in relation to the groups of crossbred cattle. However, the Reyna cows had the clearly highest protein content of the milk, although direct comparisons between breed groups were not possible due to confounding between breed groups and herds. Repeatabilities of daily records across the lactation were acceptable for all production traits, indicating a well functioning pilot scheme for milk recording.

The large variation among herds and time periods, and the individual variation among cows within herds suggest great opportunities to improve production results by better feeds, feeding regimes and management practices, and by genetic improvement.

Options for conservation and genetic improvement

Background

The study on population structure of the Reyna Creole cattle (Paper 1) pointed at the needs for implementing a conservation program due to the high level of inbreeding (13%) and small effective population size (varying between 28 and 46 animals). In order to justify a conservation program there is also a need to know if the breed has such phenotypic characteristics that it could be used commercially. Results in Papers 2 and 3 show that Reyna Creole cattle cows have production and reproduction traits that are well in line with what other Creole cattle in Latin America possess. This would specially be the case if management and feeding practices were optimized. Thus, it seems justified to develop a conservation program. However, it would not be enough to preserve the breed if it is not going to be sustainably used. It needs to be continuously improved by selection to stay competitive.

The goals to be achieved for implementation of a realistic breeding program of the Reyna Creole cattle could be summarized as follows:

1. Break the present level of inbreeding and develop a mating plan to avoid inbreeding in each herd.
2. Increase the number of milking cows.
3. Develop/expand a simple milk and pedigree recording scheme.
4. Use present and future records on milk production and calving interval for monitoring and management purposes as well as genetic evaluation.

It is considered important to concentrate a selection scheme on the most important production trait together with a measure of reproduction efficiency, as these two traits show an unfavorable genetic correlation of the order 0.2–0.4, as found by e.g. Berry et al., (2003), Philipsson and Lindhé (2003) and Roxström et al., (2001). Calving interval is a possible measure of reproductive efficiency as it picks up both the ability of cows to come into estrus and to conceive when mated. It is commonly used internationally (Interbull, 2011).

The purebred Reyna Creole cattle population in Nicaragua consists of about 650 purebred females, including calves, heifers and cows (FAO, 2004) distributed in five herds. Considering four herds with records the number of cows presently amount to 285. The Nicaraguan Ministry of Agriculture and Forestry has a Centre of Artificial Insemination with some facilities for collection and cryopreservation of semen. The general costs for any functioning artificial insemination (AI) program (e.g. for trained personnel, bull barns and laboratories, semen collection and storage, transportation, records keeping and estimation of breeding values for selection of best parents), are considerable. The results of the activities, therefore, must be predictable and seen valuable. For the small population of Reyna Creole cattle it may be difficult to initially justify an AI program, but costs for the AI service could be shared with other cattle breeders.

In Nicaragua there is also a Reyna Creole cattle breeder Association that should be involved in designing and implementing the breeding program. This organization has stored semen from ten national Reyna sires. However, 60% of them were born before the 1990s and would be difficult to use depending on the inbreeding situation of the breed. Thus, for practical purposes bulls born in Nicaragua could be used either through natural service (NS), as the number of cows mated per bull will be rather low, or with AI. Importation of semen from other Creole cattle populations, if found feasible, would of course require AI. Some options, such as semen from the CLAC in Mexico, Limonero Creole cattle in Venezuela and Caracu Creole cattle in Brazil could be considered according to breeding objectives. CLAC is more related to Reyna, followed by Limonero Creole, because these breeds have previously received genetic material from Nicaragua.

As a by-product of the studies on TMY (Paper III) it is possible to estimate breeding values through the BLUP Animal Model with the DMU-package (Madsen and Jensen, 2006) of all animals that have records and of their parents and progenies. Although these animals are old or culled by now, the genetic evaluation of these Reyna cows and bulls for production may be used for guidance on what pedigrees to specifically choose for further selection in order to balance inbreeding and production.

Genetic improvement for milk production by selection takes a long time. The generation interval in the Reyna breed was estimated to be 6.9 years (Paper I). Three generations of selection mean that you need to have at least a 20 years perspective on the program. One way of speeding up the genetic progress would be to use young bulls only and select cows as bull dams at a young age. The option genomic selection is practiced in some advanced breeding schemes today to speed up the progress, but there is no way of using that in the Reyna Creole breed without first having a functional breeding program with phenotypic recording and selection based on such records.

The aim of this simulation study was to predict the genetic response in four major selection alternatives for total milk yield per lactation (TMY) and calving interval (CI). Furthermore, the aim was to calculate the approximate effects on the effective population size. No progeny testing was considered in this study, and both AI and NS were regarded possible to use. Thus, the results should be considered as a guideline for choice of activities that could lead to conservation and further improvement of Reyna Creole cattle.

Methodology and alternative scenarios

A deterministic approach of calculation was applied to four main selection scenarios using the computerized breeding plan program developed by Dalin and Philipsson (1998), available on-line for download (Animal Genetics Training Resource, version 2, 2006). Annual genetic change was estimated according to Rendel and Robertson (1950), considering the contributions from two pathways, i.e. dam-son and dam-daughter. The selection index method outlined by Van Vleck (1993) was applied for selection of cows in the program. An approximated calculation of the effective population size was done according to Falconer and MacKay, 1996) for comparison between the selection scenarios.

Phenotypic means and variances, heritabilities and repeatabilities used in this simulation study were from Papers II and III. The genetic correlation between TMY and CI was assumed to be 0.30 (unfavorable). Parameters chosen are summarized in Table 1.

Table 1. *Parameters used in the calculation of genetic change in total milk yield per lactation in kg (TMY) and calving interval in days (CI)*

Parameters	TMY	CI
Overall means	1319	424
Heritability	0.18	0.19
Repeatability	0.33	0.19
Phenotypic SD	417	81
Additive genetic SD	177	35
Genetic correlation with TMY		0.30

Breeding objective

In some scenarios (1 and 2) the breeding objective was to increase TMY, whereas in scenario 3 the breeding objective was to consider TMY and CI with equal weights per genetic SD. In the last scenario (4) TMY was given twice the weight of CI. In all cases the genetic change was calculated per year in both TMY and CI.

Increasing the active cow population

A total of 285 existing cows coming from four purebred herds were considered as a base population. An increase of the cow population would be possible to achieve in a five years period assuming the following:

1. 285 cows produce 240 calves per year with a calving interval of 424 days (120 females).
2. A culling rate of 20% per year means that initially that 57 cows need to be replaced by heifers annually to keep herd size unchanged.
3. 120 - 57 heifers = 63 heifers.
4. 63 - (3% mortality per year) = 57 replacement heifers of three years of age available for increase of the cow population.

Considering a period of five years, the surplus of heifers would sum to a total of 285 females, without taking into account the effects of the annually increased population. The cow population would then be doubled to 570 cows. However, if the culling rate is increased to 30% the annual number of surplus heifers is reduced to 31, and the cow population would then increase to 440 cows in five years. To be on the safe side 465 active cows were assumed for the scenarios with an extended Reyna cow population.

Selection and use of bulls

Bull calves were recruited from the four herds out of their best cows. It was assumed that each young bull was used from 30 months of age in 12, alternatively 36 months, and that they produced 10, alternatively 20 daughters each. It is assumed that 1.5 services are required per calf born, and that 4 mated cows are required to obtain a lactating daughter.

Selection of parents

In order to immediately break the inbreeding it might be essential to import a small amount of bull sire semen from a number of unrelated bulls of another Creole cattle breed that may be considered of equal or better merit than the present Reyna Creole breed. Such semen should be used with those cows of the Reyna herds that fulfill requirement of good health, reproduction and conformation (especially udder and feet). It is assumed that selection of 20 cows based on TMY (on average 3 lactations), and in some scenarios also for CI, is required to obtain a bull calf for breeding.

As alternatives of importation of bull sire semen one might find some bulls with high breeding values (EBV) estimated on the past population, and that may be rather unrelated to the rest of the population. If so, grandsons of such bulls may be found or actively recruited for further breeding.

When recruiting cows within herds it is assumed that 90% of the best cows are used to produce replacement heifers when a steady state has been reached as regards the cow population size.

Results

The genetic changes per year for TMY and CI for various selection alternatives are shown in Table 2.

Table 2. *Impact of selection alternatives on predicted genetic change in TMY and CI, average generation interval (L) and effective population size (Ne)*

Scenario	No. of cows	Progeny group size	Use of bulls: No. sel. per year	Use of bulls: Period years	Economic value: TMY	Economic value: CI	Genetic change per year: TMY Kg	Genetic change per year: TMY %	Genetic change per year: CI days	L	Ne
1	285	10	6	3	1		4.6	0.35	0.36	5.1	63
	285	20	3	3	1		7.1	0.54	0.54	5.1	31
	285	10	6	1	1		5.1	0.39	0.40	4.6	96
	285	20	3	1	1		7.9	0.60	0.60	4.6	49
2	465	10	10	3	1		4.5	0.34	0.35	5.1	107
	465	20	5	3	1		7.1	0.54	0.54	5.1	54
	465	10	10	1	1		5.0	0.38	0.30	4.6	163
	465	20	5	1	1		7.8	0.59	0.60	4.6	86
3	465	20	5	3	1	–1	3.8	0.29	–0.85	5.1	54
	465	20	5	1	1	–1	4.2	0.42	–0.94	4.6	86
4	465	20	5	3	2	–1	6.1	0.46	–0.23	5.1	54
	465	20	5	1	2	–1	9.3	0.71	–0.22	4.5	80

In **Scenario 1**, illustrating the present situation with 285 cows, an increase of the effective population size is reached most rapidly by selecting many (6) young bulls per year and using each one of those for only one year. Genetic improvement for TMY is less though, but at this stage it is more important to break the present inbreeding situation. The generation interval stays at 4.6-5.1 years.

In **Scenario 2**, based on 465 cows, similar trends in genetic gains for TMY are achieved as in the first scenario, but the Ne values were all above 50, at most 163, due to an increased number of females in reproduction and a corresponding increase in number of young bulls used. Most rapid genetic gain in TMY was achieved when selecting 5 young bulls per year. In both of the scenarios 1 and 2 the CI increased with about 0.5 day per year, following the single-trait selection objective for TMY.

In **Scenario 3** equal weight was given to TMY and CI in the breeding objective. The genetic improvement in TMY was less than in the previous scenarios, but instead an improved calving interval of almost one day per year was achieved. The effects on Ne were acceptable, especially when the bulls were used for only one year each.

In **Scenario 4** the assumptions were the same as in scenario 3, except that the relative economic weight put on TMY was doubled, i.e. 2:1 for TMY vs. CI. In this case the largest genetic gain was achieved among all selection alternatives when 5 young bulls were selected per year and used for one year. This may assume an increased use of AI. At the same time CI improved by 0.2 days per year and Ne was 80. However Ne was close to a critical value with 36 months of use of bulls. A progeny group size of 20 will in the long run contribute to useful EBV:s if a BLUP animal model would be applied for genetic evaluations and future selection of bull sires.

In all the scenarios 76-86% of the genetic gain in TMY was attributed the selection of bull dams, whereas 14-24% of the gain originated from selection of cows within the herds.

Recommendations

Considering that the Reyna Creole cattle population is currently small, an improvement strategy should be implemented in two steps.

The first step would be to outline an economic study on the value of improved feeding and management procedures, as well as of genetic improvement based on a simple milk and pedigree recording scheme. It should be outlined and discussed jointly with farmers, government, research entities, and the dairy industry. Capacity building on the use of records for extension services, genetic evaluations and monitoring of progress are also important elements to include in the process. The proposal might consider the promotion of the breed in dual purpose production systems, in order to increase the number of herds. This step would also include development of an appropriate management and feeding plan to achieve the expected milk yield at one or two milkings per day under grazing conditions and supplement feeding. The stocking rate must be defined in every farm in order to create conditions for an increased Reyna population of at least 500 cows.

The second step should be directed towards a pragmatic development of the breeding program, based on genetic evaluation of the past and present population of purebred Reyna Creole cattle. It is of high priority to develop mating schemes for each herd so that on-going inbreeding can be stopped. Furthermore, possible (unrelated) bull sires within the Reyna population, or in related Creole populations abroad, should be identified and used with the best Reyna cows to produce young bulls for regular breeding, either with AI or NS. 5-10 young bulls, or 2-3 new young bulls per registered herd, should be introduced per year and each bull be used during a period of one year. Continuous genetic evaluation and monitoring of production, reproduction and inbreeding level should be part of the implemented breeding program.

General discussion

The economy of Nicaragua is based on crops and livestock production. The cattle population amounts to 2.65 millions of heads and more than 80% of the cattle production systems are dual purpose animals characterized mainly by low productivity and reproduction levels. The Reyna Creole cattle are considered as a dual purpose breed, but represents less than 0.05% of the total cattle population. However, the breed is considered worthy of conserving, both for its heritage and its perceived robustness with a fairly good fertility and good milk production under tropical conditions.

In the present study the population structure of the Nicaraguan Reyna Creole cattle was characterized, as well as important reproduction and milk production traits including milk composition (fat and protein percentages). In this discussion, urgent aspects on the genetic status of the Reyna Creole cattle, as well as their genetic potential for production and reproduction, will be emphasized in order to highlight the need to conserve and genetically improve the breed. The amount and quality of the information will also be focused to explain the main limitations of the study, as well as what is needed to meet the challenges to conserve and improve the breed.

Phenotypic characterization of Reyna Creole cattle

The characterization of phenotypic traits and their genetic variability have generally revealed normal values for all traits studied. Most striking are the large environmental effects on most traits as exemplified by large differences between herds and time periods. Yet the genetic parameters seem normal, indicating that the statistical models reasonably well accounted for the environmental effects. Thanks to owners of the Reyna cattle herds, records have been kept for a long period of time, although with some interruptions. Even if the data sets are limited in size or cow numbers, most traits have been possible to analyze with a genetic perspective. Thus, it has been possible to cover the most important reproduction and milk production traits. However, no reliable data was available for growth traits or live weight, except for birth weight.

Reproduction

The traits related to reproduction included birth weight, age at first calving and calving interval of lactating cows. These were the traits for which information was available together with pedigree data. The parameters obtained for BW are normal for Creole cattle. Large differences between the herds were noted indicating the role of environmental factors contributing to the weight of the calf at birth. Although the trait shows genetic variation, no interest should be focused on birth weight in selection due to its relation with calving difficulty and dystocia (Adamec et al., 2006).

Genetic variability in the other reproduction traits was evident for CI but not for AFC. This indicates the possibility to include CI in a genetic improvement strategy. The heritability estimated was rather high, 0.19, compared to most literature, but even if it is overestimated there is a substantial genetic variation in cow fertility worth considering in a breeding program. Another fact that supports the need to include CI in the selection of cows for breeding purposes is that unfavorable genetic correlations between milk yield and reproduction traits usually exist. In the tropical cattle breed Sahiwal in Pakistan, for example, an unfavourable genetic correlation was found between calving interval and milk production in the first lactation, although the reversed was noted in the third lactation (Dahlin, 1998). Nevertheless, both traits are generally used in international evaluations to either improve fertility or to avoid declining fertility as a correlated response from selection for milk production (Philipsson and Lindhé, 2003; Mrode and Coffey, 2010; Interbull, 2011). Studies would be desired, however, to estimate genetic correlations between production and reproduction traits in Reyna Creole cattle.

Both AFC and CI in this study were significantly affected by maternal inbreeding. Despite that, Reyna Creole cattle surprisingly maintain acceptable reproduction. This reveals the robustness of the breed. How the maternal inbreeding acts on CI can be somewhat confusing to understand as the relationships are complex. For instance, female heifers that had a low BW might have relatively high AFC, and also long CI, due mainly to poor growth from birth until AFC. Those are aspects that could not be included in this study. Possibly the differences in mating structure and management between the two herds studied played such a role that it may have been difficult to distinguish between direct and maternal effects. The amount and quality of the field data, as well as the incompleteness of pedigree information, might have affected the estimates of genetic parameters and the effects of inbreeding on the traits. Age at calving was more efficiently recorded than calving number. Besides that, a break of recording in between 1993 and 1997 caused loss of much data.

Milk production

The characterization of lactation milk yield revealed the phenotypic production potential of Reyna Creole cattle under very variable tropical environmental conditions. The yields were comparable to what has been reported for some Creole cattle breeds in Latin America, although under very different environments, as has been referenced in Paper III (Perozo et al., 1978; Barbosa da Silva et al., 2006 and El Faro et al., 2008).

The interpretation of the milk yield results has limitations because management and feeding practices varied considerably between herds and time periods. Still the characterization of TMY revealed phenotypic and genetic parameters that can be considered as relevant to use for genetic evaluation and selection.

Lactation yield is a highly repeatable and moderately heritable trait. The estimated heritability for TMY was substantially reduced (from 0.35 to 0.18) when individual permanent environment effects were considered in the statistical model. Thus, this effect must be adjusted for when estimating breeding values based on several lactations.

The pilot study on daily milk yield once a month with recording also of fat and protein percentages, showed normal values, except possibly for the low fat contents. No direct comparisons could be done between breed groups due to complete confounding between breed groups and production system conditions, which obviously represent a critical limitation of the results. However, Reyna Creole cattle on average produced less milk per day than the other breed groups, but had the highest protein content in the milk. There were also large differences between the Reyna herds in production.

The generally low contents of fat in our study could possibly be an effect of reduced dry matter intake of grass and forage due to climatic stress (temperature and humidity). Maust et al. (1972) found that heat stress increase the body temperature which causes depression on the feed intake. Moreover, in a review on conventional dairy cattle production, Sutton (1989) stated that amount of roughage as well as changes in forage:concentrate ratio can cause changes of milk fat content.

Population structure and breeding program

Considering the tremendous variation in milk production traits shown in this study over time and across herds, as well as between individual cows and lactations, it must be concluded that there are very good opportunities for increased productivity of Reyna Creole cows. The same conclusions are relevant for AFC and CI. However, improvements depend on adoption of better feeding practices and management of the herds, as well as a breeding program that takes account of both production and reproduction traits. Expansion of the simple milk recording scheme applied for the DMY and milk composition study (Paper III) would provide an important starting point for necessary interventions to happen.

Knowledge of the genetic status of a breed enables the breeders and researchers to design realistic breeding plans in order to optimize the genetic gain in the traits of interest under an approach of minimum yearly increased inbreeding rate. This study pointed at two interrelated problems: first of all, that the effective population size is very small. Secondly, that inbreeding has been going on for some time, probably unintended, but it has lead to generally high, and in individual cases, very high inbreeding levels. The incompleteness of the pedigree information suggests that the inbreeding problem might be even greater. Some historical facts could partially explain this situation as herd A constitutes the original herd of the breed, but had quite a lot of incomplete pedigrees. Herd A was founded with relatively few females (approx. 200) and the number of sires used still remains unknown.

Under these circumstances the Reyna herds might urgently need to develop recording schemes that keep records of identities, matings and calvings so that complete and accurate pedigrees can be obtained. Mating schemes need to be developed in order to stop further inbreeding.

The simulation study clearly showed the importance of increasing the size of the cow population, as well as using many bulls, each one for only a short period. In that way the effective population size can be doubled compared to the present situation. The results of the simulation study should be seen as what is expected to happen when an alternative has reached a steady state of development. The importance of considering both production and reproduction is illustrated by the annually increased CI following single-trait selection for TMY. When giving equal weight to both traits CI was shortened considerably, but the genetic gain in TMY was reduced substantially. A more realistic weight would be 2:1 for TMY vs. CI. As previously noted the estimated heritability for CI was rather high.

Assuming a lower heritability will reduce the effects on CI, but the directions will be the same.

When focusing on what needs to happen in the initial years of a breeding program it is crucial to consider a possible choice of sires, or sons of those, based on the genetic evaluations (EBV:s) that are possible to obtain as a by-product of the present study (Papers II-III). Also EBV:s of cows or dams may be useful. For the future, however, it is essential that a recording scheme is established, so that identities, matings and calvings, as well as milk production traits are recorded systematically. Information from such a recording scheme should be regularly used for both management and breeding purposes. It is important to have a good feed-back system with information to the farmers to maintain their interest in recording and use the information. An important activity related to the recording scheme would be to continuously monitor both the rate of inbreeding and the development of production and reproduction results.

In order to break the immediate inbreeding situation use of external bulls might be a necessity. Importation of bull sire semen would be an opportunity. Some assessments are needed in order to decide upon such an action, i.e. which populations and individual bulls would be of interest with regard to their characteristics. It is also essential to consider possible international barriers for importation/exportation. Furthermore, the acceptance of other Creole breeds by the Reyna breeders as regards morphological breed characteristics, such as coat and skin color, dark spots and other conformation details, should be important for introduction of new breeds into Nicaragua. Availability of EBV:s of foreign bulls could partially determine the imports from some countries (Costa Rica, Dominican Republic, Mexico, Venezuela, Colombia and Brazil) concerning different types of Creole cattle breeds. A general survey of the current state of the Creole animal genetic resources might be important.

According to Dickerson (1969) efficient breed utilization requires four important conditions to be fulfilled: *i*. biological objective and management conditions must be defined according to reality; *ii*. any crossing of the promising breeds must be biologically possible and ecologically compatible; *iii*. the more important products of the breed must be socially acceptable, and, *iv*. the products must be economically viable to produce. Reyna Creole cattle farmers need to discuss these issues in order to be more consistent over time with management and feeding practices in their herds. Otherwise the genetic evaluations will in a near future become difficult. Some products (i.e. milk, cheese, cream) might be promoted at supermarkets or product fairs organized by the farmers themselves, and thereby survey the consumer preferences.

Finally, for implementation of a systematic recording scheme and breeding program, it will be important to establish cooperation with other breeders and farmer organizations for a joint use of the investments. Capacity building for farmers and extension service staff, including both breeding and management aspects of dual purpose cattle production, would be important for the acceptance of introducing new approaches in breeding and management of the Reyna Creole cattle herds.

Conclusions

Pedigree information and data on reproduction and production of Reyna Creole cattle from a relatively long time period were statistically analyzed. The results allow the following conclusions:

A high inbreeding level of 13% and a critical effective population size ranging between 28 and 46 animals was revealed. Due to the risk status of the breed, a conservation and breeding plan is urgently needed.

Large phenotypic variation and acceptable reproduction levels were observed in the breed despite the significant effects of dam inbreeding on these traits. The results thus revealed the robustness of the breed under dry tropical conditions.

Lactation milk yields showed a large phenotypic and genetic variation. Results varied considerably between herds and time periods. Breed group effects were confounded with herd differences in management and feeding. There is a high potential for increased productivity in the Reyna Creole cattle herds.

Although the quality and amounts of pedigree, production and reproduction data were variable, the estimated phenotypic and genetic parameters seemed to be normal for Creole cattle, considering the environmental conditions in Nicaragua.

Milk yield and calving interval are considered useful for inclusion in a selection program for the breed. Reyna Creole cattle were found to have a relatively high protein content of the milk.

Simulation studies concerning alternative scenarios for a sustainable breeding program showed the importance to increase the number of recorded cows and to use many young bulls, 5-10 annually, in order to increase the effective population size and to improve milk production and reproduction.

Future research

As very little research has been devoted previously to the Reyna Creole cattle breed there are many areas of research that could be promoted. In the following some areas are suggested that naturally follow what would be desirable to do after the present study.

Reyna Creole Cattle are used as dual purpose animals. The present study has focused on milk production and reproduction traits, including birth weight, but no other live weights were available. Collecting information on weaning and yearling weights as well as adult cow weights, would allow analyses of the growth rate complex of traits. It might be interesting to also analyze the maternal effects on pre-weaning and post-weaning growth traits and estimate their possible genetic correlations with other economic traits.

Creole cattle are generally considered to have milk with good properties for making cheese and yoghurt. According to the present pilot milk recording study they also have relatively high protein content. It should be justified to analyze kappa-casein and beta-lactoglobulin varieties in the Reyna breed. Such information may support the importance of conserving the breed. Related characteristics, e.g. milk coagulation ability and cheese yield, could be included for a broader characterization of the breed.

Inbreeding effects on reproduction traits were shown, although the data sets used were small. Further studies are needed to clarify the role of direct vs. maternal effects of inbreeding. Then also renewed genetic analyses of CI should be done to verify its genetic variation and relationship with milk production. Furthermore, inbreeding effects on milk yield should be investigated along a continuous monitoring of the rate of inbreeding.

The simulation study showed that a breeding program should initially focus on selection of females (bull dams) to produce young bulls for breeding. That selection should include reproduction and production traits, and also health and conformation traits. Very little is known about health and conformation in Reyna cattle. A preliminary study on those traits should be initiated.

The ability of Reyna Creole cattle to adapt to dry tropical conditions has been proposed to have some connection with phenotypic attributes of the breed, such as dark spots around the eyes and the vulva, white spots on the udder, tail insertion, and slick hair. This issue should be clarified by analyzing possible relationships between such attributes and production, reproduction and health traits under prevalent tropical conditions in Nicaragua.

A particular question might be to what extent Reyna Creole cattle are efficient in grazing at pastures that are poor in phosphorus content. Dual purpose cattle in Nicaragua are performing on lands poor in this macro element. Thus, it seems useful to study the ability of this breed to produce under these conditions. Close collaboration between a nutritionist, pasture specialist and geneticist is required to illuminate this complex issue.

The interest in Reyna Creole cattle in Nicaragua is to some extent low. Perhaps this is because of unknown characteristics of the breed and its ability to combine with other genotypes, such as Brahman, Jersey or Brown Swiss, purebred or as F1 Brown Swiss x Brahman which is quite common in Nicaragua. It might be interesting to perform a demonstration experiment at farm level in order to study the crossing ability of Reyna Creole cattle (semen) with other breed combinations and study the effect of the breed on several important traits. For this it is required to design the project so that crossbreds and purebreds are kept in the same environment.

Resumen en Español

Estructura de población y caracterización fenotípica como base para la conservación y utilización sostenible del Ganado Criollo Reyna en Nicaragua

Introducción

El ganado Criollo Reyna en Nicaragua es una raza local, originada de los *Bos taurus* traídos a América Latina durante la colonización Española en el siglo XV. Constituye una rama del ganado Criollo adaptado y utilizado en el continente. El hato en su desarrollo inicialmente logró tener alrededor de 200 hembras. En Nicaragua, el primer registro oficial de esos animales se realizó en los 1970's y en 1988 el gobierno declaro la raza como patrimonio nacional. Actualmente, el ganado Criollo Reyna se encuentra distribuido en cinco fincas y según información oficial el tamaño de la población es de 900 a 1000 animales de raza pura. De estos, 650 son hembras las cuales podrían formar parte de programas de mejoramiento genético.

Los objetivos de producción se centran en la producción de leche para las hembras, mientras que los machos se utilizan para producción de carne. El interés para la conservación de la raza Reyna se basa en sus buenos caracteres lecheros, reproductivos y una buena tolerancia al calor y a la resistencia a parásitos externos así como un buen temperamento. Sin embargo, la realidad indica la carencia de un sistema de evaluación genética para el mejoramiento y conservación de la raza.

El objetivo principal de esta tesis fue caracterizar la estructura de la población y evaluar el grado de consanguinidad de la raza Reyna así como la productividad (producción de leche y algunos rasgos de reproducción), y discutir opciones para la conservación y mejoramiento de la raza.

Estudios y resultados principales

La primera parte del estudio se centró en la caracterización de la población en términos de consanguinidad, tamaño efectivo de población e intervalo entre generaciones. Se analizaron 2609 pedigríes de animales nacidos entre 1958 y 2007. Estimaciones del grado de consanguinidad fueron obtenidos para 367 animales con índice de integridad del pedigrí mayor que 0.8 los cuales pertenecieron a dos hatos y mostraron un promedio de consanguinidad del 13% con valores de 0 a 43.8%. El promedio de endogamia en un hato fue 21.6%, debido a largos periodos de utilización de los mismos sementales a través de monta natural, lo cual condujo a excesiva frecuencia de apareamientos entre animales muy emparentados. Como consecuencia, el promedio del tamaño efectivo de población se redujo a tan solo 37 animales con rango de 28 a 46. De acuerdo con los criterios de la FAO, la raza está en peligro y cerca del estado crítico de extinción.

El promedio del intervalo generacional fue estimado a unos 6.9 años con valores hasta 19.1 años para algunos sementales utilizados en inseminación artificial durante largos periodos. Debido al alto nivel de consanguinidad y al pequeño tamaño efectivo de población, se requiere un rápido desarrollo e implementación de un buen programa de cría que proyecte la raza y apoye su utilización sostenible.

Como segundo paso, se caracterizó la raza Reyna para obtener parámetros fenotípicos y genéticos sobre pesos al nacer (PN), edad a primer parto (AFC) e intervalo entre partos (IEP) como base parcial para un programa de conservación. Se estimaron los efectos de consanguinidad del propio individuo y de la madre sobre esos rasgos.

El promedio de PN fue 27.8 kg, de AFC fue 37.4 meses y de IEP fue 14.0 meses. Se observaron grandes diferencias entre hatos para todos los caracteres, lo cual sugiere oportunidades para una considerable mejora de los caracteres reproductivos mediante mejor manejo. La heredabilidad para PN fue 0.34, para AFC fue de cero y para IEP fue 0.20. La desviación estándar genética aditiva para IEP fue comparativamente alta (36 días). Los efectos de endogamia de la madre fueron significativos sobre todos los caracteres; por cada argumento en el porcentaje de consanguinidad, PN decreció en 0.06 kg, AFC incrementó en 3.5 días y IEP incrementó en 1.4 días. En conclusión el ganado Criollo Reyna muestra buenos caracteres de reproducción, a pesar del alto nivel de consanguinidad.

El tercer paso fue caracterizar caracteres de producción de leche y estimar sus parámetros genéticos en el ganado Criollo Reyna. También se presentó estadísticas correspondientes a algunos cruces de ganado *Bos taurus* con *Bos indicus* así como para algunos cruces comerciales de ganado lechero, *Bos* *taurus*, bajo las condiciones del trópico seco de Nicaragua. El estudio incluyó dos grupos de datos. El primero, con información sobre la producción total de leche por lactación en kg (PLTL) y longitud de lactancia en días (LL) registrados durante dos periodos de tiempo (1982-1993 y 1998-2008). La información proveniente de tres hatos con un total de 534 vacas y 1,750 lactaciones, fue analizada para ambos periodos.

El segundo conjunto de datos provino de un muestreo y análisis piloto realizado durante un año (Noviembre-2005 a Octubre-2006) sobre rendimiento de leche por día (PLD) en kg, leche corregida por energía por día (LCE) en kg y porcentajes de grasa y proteína. Se realizaron análisis por grupo racial de tres hatos de ganado Reyna (n=996), un hato con cruces de *Bos taurus* con *Bos indicus* (n=380) y de otro hato con cruces de ganado lechero (n=864). Los promedios de PLTL y LL fueron 1,319 kg y 278 días, respectivamente, pero se notaron grandes diferencias entre hatos y periodos causadas por variaciones en el manejo y alimentación.

Las estimaciones de repetibilidad para PLD y composición de la leche fueron como promedio ~0.35. La heredabilidad para PLTL fue de 0.18 cuando los efectos individuales de ambiente permanente se tomaron en cuenta. La heredabilidad para LL fue menor, 0.09, indicando la gran influencia de los factores ambientales sobre el parámetro.

Los factores ambientales, tales como el numero de ordeños por día, procedimientos para el amamantamiento de la cría previos al día del pesaje de leche y régimen de alimentación fueron diferentes entre los hatos, por lo que no fue posible comparar directamente los grupos raciales por su rendimiento de leche diario, contenidos de grasa y proteína. Sin embargo, el hato con cruces de ganado lechero mostró el más alto valor de PLD (9.1 kg) seguido por el hato con cruces de *Bos taurus* con *?lp fkaf`rp* (5.6 kg) y los tres hatos con ganado Criollo Reyna (3.9 kg). Sin embargo, también se notaron diferencias entre los hatos con Criollo Reyna (3.3–4.6 kg). Grasa y proteína fueron variables para ganado lechero (3.06, 3.02), *Bos taurus* x *?lp fkaf`rp* (3.71, 3.19) y Criollo Reyna (3.39, 3.45). Es notorio el alto porcentaje de proteína mostrado por el Criollo Reyna.

Estrategias de conservación y mejoramiento genético para uso sostenible

El nivel de endogamia y el actual tamaño efectivo de población del ganado Criollo Reyna evidencia su estado de peligro. Sin embargo, los caracteres de producción de leche y reproducción mostraron su potencial fenotípico y variabilidad genética. Considerando estos aspectos y asumiendo algunos resultados (medias, desviaciones estándar fenotípicas, asi como desviaciones estándar genéticas aditivas y heredabilidades de cada característica) estos fueron incluidos en un estudio de simulación deterministica para comparar cuatro estrategias de selección y su impacto en la ganancia genética anual para PLTL e IEP y sus afectaciones al tamaño efectivo de población.

Se utilizaron dos grupos de hembras (285, 465), dos periodos de utilización de sementales en monta natural (1 y 3 años) con eficiencia de 1.5 montas por preñez, dos tamaños de grupos de progenie (10 y 20), con una intensidad para madres de machos jóvenes de 0.05 (20 madres para un macho seleccionado). Pruebas de sementales no fueron incluidas. Dos ponderadores económicos en unidades de desviación estándar (1 y 2) fueron impuestas a la producción de leche y una a intervalo entre partos (-1).

Los resultados revelaron el impacto de aumentar el número de sementales jóvenes y el número de hembras efectivas sobre tamaño efectivo de población, y principalmente, cuando el periodo de uso de sementales fue corto: un año. Las ganancias genéticas en producción de leche anual variaron de 4 a 10 kg por año, con moderados incrementos o reducciones en reproducción. La utilización de sementales por tres años resulta en reducción sustantiva del valor de Ne. Los intervalos entre generaciones variaron de 4.6 a 5.1 años.

Conclusiones y recomendaciones

La gran variación observada entre hatos en caracteres de producción y reproducción, y la variación genética mostrada, demuestran que existen buenas oportunidades para incrementar la productividad de la raza Reyna, vía mejor manejo y alimentación, así como selección genética. Sin embargo, es evidente el efecto de consanguinidad sobre caracteres de reproducción. Aun así la reproducción del ganado Reyna es muy buena. Varias opciones para el manejo de la situación de consanguinidad y también para el mejoramiento de la productividad de la raza son valoradas. Por lo tanto, se propone retener todas las hembras en los hatos para incrementar el número de vacas Criollas Reyna puras, y establecer un esquema de registros de pedigrí existentes, muestreos sistemáticos de la producción leche y plan de apareamientos en todos los hatos. Se propone utilizar los machos seleccionados de las mejores madres en producción de leche e intervalos entre partos, por períodos de monta de uno a dos años para manejar consanguinidad, mantener cortos los intervalos entre generaciones y lograr ganancias genéticas en producción y reproducción. Para reducir la situación actual de consanguinidad podría ser necesario incorporar a los hatos semen de ganado Criollo procedente de países vecinos.

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