Improving quantity and quality of Alpaca fiber; using a simulation model for breeding strategies

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Abstract

Ninety two percent of the world Alpaca (Lama pacus) stock is in the Altiplano of Peru and Bolivia. Seventy eight percent is located in south east of Peru. Alpaca fiber and meat are the main products of the alpaca production systems. Meat has local and regional demand. The alpaca fiber has an international demand, however, little effort has been made to improve its quantity and quality. Usually, the alpaca fiber is sold by weight fleece, which has a negative phenotypic correlation with fiber length (-0.16), and positive correlation with diameter of fiber (0.40), which in turn presents, a negative correlation with length of wick (–0.20). Consequently, there are complaints from the market demand, which indicate that fiber quality has declined over years. A simulation model "ALPAGEN" was constructed to describe the dynamic of a herd in yearly steps by animal. The model can fit different herd management effects (birth rate, mortality) and breeding strategies; including selection intensity (sire, dam) and offspring culled by using a composite index selection, based on the total economic merit. This includes weight of fleece, length of wick and diameter of fiber. Fifteen scenarios were analyzed using a composite rotatable design including reproduction (birth rate), management effects (mortality rate) and selection. Results over 10 years showed that is possible to increase by 13.8%, 33.3, and 6.5 % the weight fleece, length of wick and fiber diameter, respectively by using a composite index selection instead of an independent selection for weight fleece.

INTRODUCTION

Ninety two percent of the world Alpaca (Lama pacus) stock is in the Altiplano of Peru and Bolivia. Seventy eight percent is located south east of Peru. Two breeds of Alpaca, the "Suri" and the "Huacaya" are recognized. The "Suri" presents better form and shape of the length of the wick than the "Huacaya" but is found in less proportion (Bustinza, 1985; Pumayalla 1988).

Fiber is the main product of the alpaca production systems; meat has local demand (Pumayala 1988). Even though alpaca fiber has an international demand, little effort has been done to improve its quantity and quality. Usually the alpaca fiber is sold by fleece weight, which has a negative phenotypic correlation with fiber length (-0.16), and positive correlation with fiber diameter (0.40). Diameters in turn, present a negative correlation with length of wick (–0.20) (Leon-Velarde, 1997). There are complaints from the market indicating that fiber quality has declined over years.

In the alpaca production system, there is a lack of genetic information on the main bio-economic traits in relation to pressure of selection and herd management effects, which combined with the farm gate price, affect the genetic progress. At the level of the

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alpaca herd, low births and high mortality rates are found (Nolte, 1987; Bustinza 1968). Farmers leave animals to increase their capital, and level of selection pressure is reduced or nil, affecting possible genetic progress. They do not receive an incentive for fiber quality.

The genetic progress for the main bio-economics characteristics of the fiber can be assessed using an optimum selection program (Van Vleck, 1987). A system research approach based on simulation can address the problem (Leon-Velarde y Quiroz, 1999). Since the cost and the time required for conducting it would be unreasonable.

The objective of this paper is to evaluate how effective could be a composite index selection within a model simulation of alpaca production systems considering reproductive and management effects combined with selection pressure to visualize the implementation of a future genetic selection program.

ALPACA HERD MODEL AND BREEDING STRATEGIES

The model, “ALPAGEN”, estimate bio-economics results of an alpaca production system focused on fiber and meat. The model simulation is based in the dynamic of an alpaca herd by animal in yearly steps.

The model can fit different herd management effects (birth rate, mortality) and breeding strategies; including selection intensity (sire, dam) and offspring culled by using a yearly composite index selection. This includes weight of fleece, length of wick, diameter of fiber, length of fiber and live weight. The index was focused in the first three bio-economic traits. In alpaca farms, the weight fleece and length of wick can be measured. The diameter of fiber is measured in a laboratory.

The model considers all the animals of the herd, therefore the performance of each individual alpaca is included. Estimation of the fiber production per alpaca-year provides variation within the herd and allows estimation of the performance of the system as a whole. Each alpaca in the herd is assigned a set of parameters that describe its performance.

The model includes a subroutine to create an initial herd base structure by sex. The female structure was defined on 30, 40, 15, 10 and 5 percent for 2, 3, 4, 5 and 6 years of age, respectively. The male structure represents the 45, 30 and 25 percent for 2, 3 and 4 years old respectively. This initial herd creates an offspring based on a given birth and mortality rate. From this step the model calculates the dynamics of the herd for a designate number of years. The model also allows opportunity to expand or maintain constant the size herd or include new animals in the herd; sale of males for meat and reproduction as well as culled by age following a pattern in relation to the total genetic merit of each animal. Figure 1 shows the main steps and process of “ALPAGEN”. The attribute of each alpaca and the index used are important.

The attributes of each animal were identification, sire, dam, adult live weight, fleece weight, wick length, and fiber diameter. The model fits fiber length. The initial herd base start with unknown parents and the live weight is calculated based on the average plus a random normal deviate multiply by its deviation standard. However, since the fleece weight, wick length and fiber diameter are correlated the simulation of this attributes must be related among then. Therefore, the phenotypic variance-covariance matrix (V) was defined to obtain a triangular matrix (T) by using Cholesky decomposition (Statistical Analysis System, 1985). Thus, $V = T'T$. The simulation of phenotypic parameters for each alpaca was done by $Y = U + T R$. Where Y is a vector estimate of the bio-economic traits for each alpaca within herd. U is average characteristic of alpaca fibre (Table 1). T is a triangular matrix and R is a vector of random normal deviates. The values of the triangular matrix were estimated from a phenotypic variance and covariance matrix considering information of 2,758 observations (Leon Velarde, 1997) based on several reports (Trejo, 1986; Delgado, 1986; Paucar, 1984; Blanco, 1980; Ccopa, 1980; Avila, 1979). Information analysed also shows effects of the bio-economic traits over animal age allowing adjustment of fibre production to obtain selection base at three years and define cull age at six years (Figure 2). The elements of the triangular matrix (T) were:

$$\begin{bmatrix} 0.713 & -0.437 & 2.500 \\ 0 & 16.347 & -9.204 \\ 0 & 0 & 6.823 \end{bmatrix}$$

The selection index follows theory based in the total genetic merit defined as $T = a'g$ (Van Vleck, 1987). Were T is the total genetic merit, g is a vector of additive genetic, and a is the vector of economic weight for each trait considered.

Table 1. Genetic parameters considered for main bio-economic traits of alpaca fiber to define an index selection.

Bio-economic traits of alpaca fiber	Genetic variance	Heritability	Mean Deviation standard
Weight fleece (WG; kg)	0.122	0.38	1.95 ± 0.42
Length of wick (LW ;cm)	19.076	0.31	17.59 ± 6.54
Diameter (D; micron)	9.228	0.18	22.63 ± 5.99

Genetic variance covariance matrix were calculated based on $r = \sigma_{ij}/\sqrt{\sigma_i^2\sigma_j^2}$ ($r_{F\text{-}D}$ = 0.15; $r_{W\text{-}D}$ = -0.12; $R_{F\text{-}W}$ = -0.116)
(Average values; Velasco, 1980; Roque, 1985; Ruelas, 1985; Chavez, 1991; Bravo, 1983; Aedo 1985)

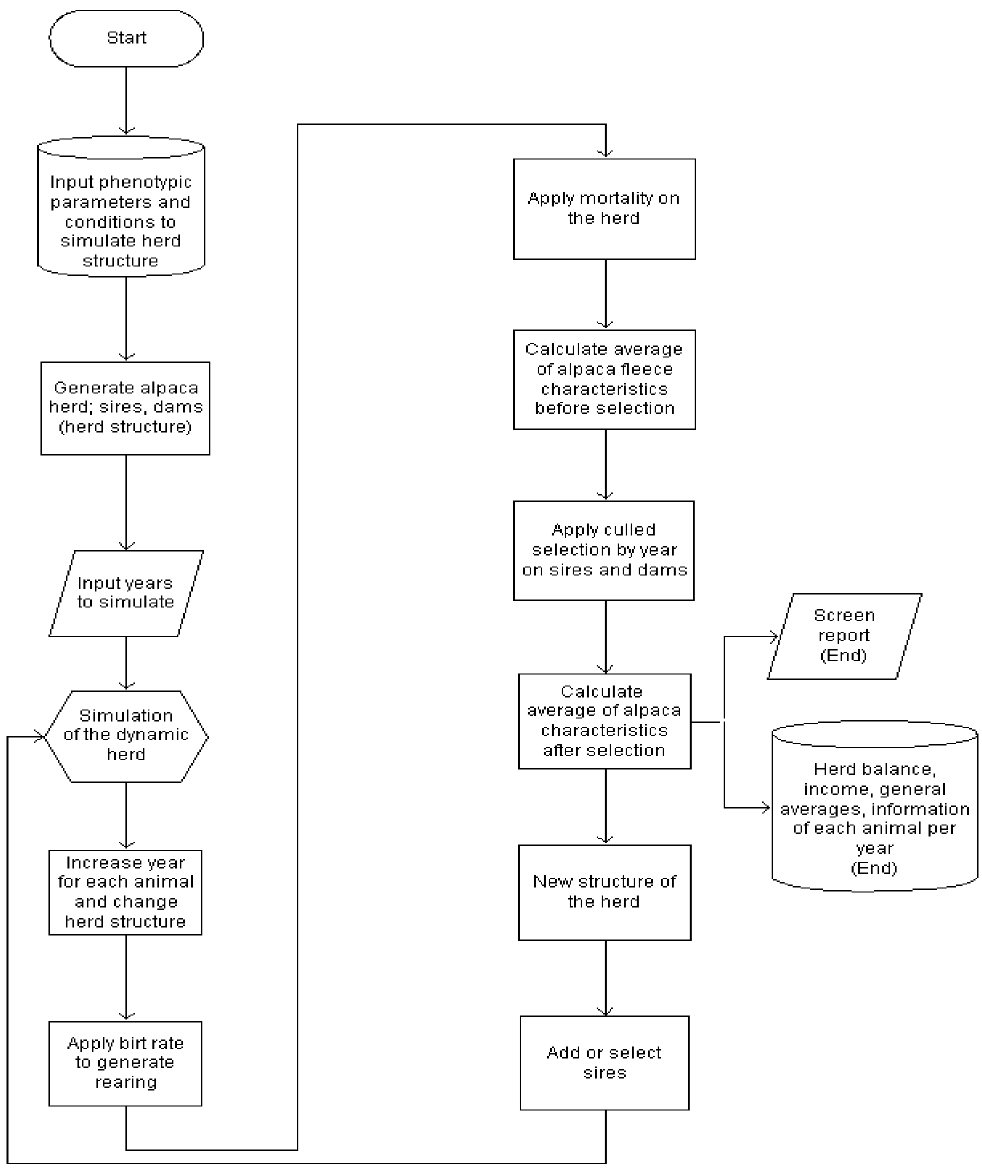

Figure 1. Schematic representation of the Alpaca system model "ALPAGEN" to analyze scenarios of herd management effects and selection breeding strategies

The index (I) was defined by I= b'p were the b vector is the genetic index weight for each characteristic calculated as [1.747 0.418 0.035], and p is a vector of deviations with respect to average of each trait (Table 1). The genetic index weight were calculated as b= $P^{-1}Ca$. Were P was the inverse of the phenotypic variance covariance matrix, C is the genetic variance covariance matrix and a was set arbitrarily to [1 1 –1] for each trait, respectively. The negative value was used to indicate a selection of animals with less fiber diameter.

Scenarios

ALPAGEN model was used to assess the levels at which reproductive effects (birth rate; BR), management effects (mortality rate; MR) and selection pressure (S) would maximize the genetic gain expressed as total genetic merit (T). The birth and mortality rate directly affects the composition of the herd, and both together modify the breeding selection strategy.

Consequently, the first question focused on the time course of changes in the bio-economics traits considered in the selection index. The second question addressed in the simulation study was what combination of birth rate (X_1), herd mortality (X_2), and selection intensity (X_3), will maximize genetic gain.

The ALPAGEN model simulation structure allows the evaluation of combinations of X_1, X_2, and X_3, giving theoretical and realistic scenarios. To be in agreement with a close relation between reproduction (birth rate) and management effects (mortality), a composite central, rotatable design (Montgomery, 1984) was used to simulate and evaluate 15 combinations given five levels of each factor. Three parts of the design were expressed as factorial treatments (2^3), axial treatments (2*3), and one central treatment repeated six times to mimic the existing levels of the variables used by farmers (León-Velarde and Quiroz, 1999). Therefore, using the composite rotatable design fifteen scenarios, including heard size management effects and selection intensity were analyzed. Other management variables were held constant.

The simulation process was carried out considering a herd of 1000 alpacas with a relation of 16 alpacas female by sire (DASA Project, 1997). The initial herd was used for each scenario analysed over 10 years. The annual average genetic merit of the herd was calculated after and before selection process. (Table 2).

Table 2. Factors, levels, and conditions used in a factorial experiment considering reproduction effects (birth rate), management effects (mortality rate), and selection intensity in the simulation of alpaca production system in conditions to the Altiplano to measure genetic gain and changes in fiber quality.

Variables	Treatment levels code[1]						
	-2	**-1.68**	**-1**	**0**	**+1**	**+1.68**	**+2**
Reproduction effects (birth rate), X_1	50	53.20	60	70	80	86.80	90
Management effect (mortality), X_2							
Sires and Dams	15	14.20	12.50	10	7.50	5.80	5
Rearing (born)[2]	30	28.40	25	20	15	11.60	10
Rearing (1-2 years)[3]	16	15.36	14	12	10	8.64	8
Selection intensity, X_3[4]							
Sires	30	26.8	20	15	10	6.6	5
	(70)	(73.2)	(80)	(85)	(90)	(93.4)	(95)
Dams	100	98.4	95	90	85	81.6	80
	(0)	(1.6)	(5)	(10)	(15)	(18.4)	(20)

[1]Codification allows to define the scenarios based in a rotatable design 2^k + 2*K + n (1), where k=3, and n = 6 to represent the central point of the central composite rotatable design. (e.g. treatment 3 was codified as –1, 1, -1 with 60 % of birth rate, 7.50, 15 and 10 for mortality rate, and 20 and 95 of selection pressure according figures in table 2.

[2,3]Alpaca baby, and alpaca from 1-2 years old.

[4]Selection pressure expressed in percentage; culled between brackets. In all treatments ten percent of offspring was applied at born.

RESULTS AND DISCUSSION

Herd Management

In the Altiplano the alpaca production systems have special form of management. Basically depends of the herd size, pasture and, mortality and birth rate. Some farmers prefer to enlarge their herd to increase assets and consequently no real process of selection is done. Moreover, keeping adult animals until an advance age, specially sires and dams result in a high level of consanguinity, which with a simple sires interchange among herds is reduced (PRODASA, 1997). Analysis of the information of weight fleece, length and diameter of the fiber over age is shown in Figure 2. The weight fleece tends to increase over year due to increase of corporal surface. In similar way, it is notorious the increase of fiber diameter, reaching an asymptotic diameter from six years. This effect can be attributable to the characteristic of the alpaca fiber. In contrary form the wick length decrease due the annually shear. Some farmers left the shear biannual getting more weight and length of fleece. This facts were considered in the model to adjust the weight fleece, length and diameter of fiber at three-year age.

The results obtained also show that a herd management could be divided in two parts. The first part up to three years to consolidate the future sires and dams selection. Allowing that great part of males can be culled, between two and three year of age for meat, leaving also some females, but after having at least one "alpaca baby" before leaving the herd. The second part, up to six years, allows keeping the best female with a new replacement sire. In this form is possible to obtain enough number of animals with less age related to quantity and quality of fiber. However this scheme is possible if the herd has a high birth rate and low mortality, which does not usually occur. Get better parameter levels is a challenge that needs to be considered.

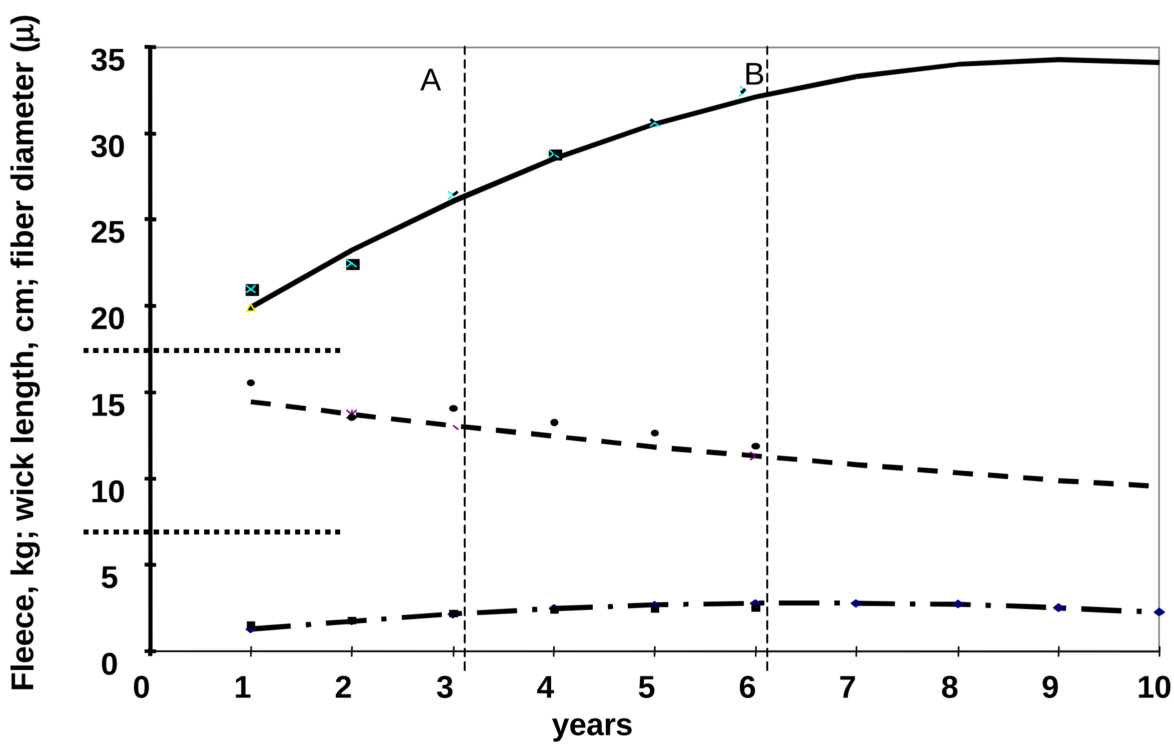

Figure 2. Average values observed and quadratic effect for weight fleece, wick length and fiber diameter estimated by regression. Line [A] indicates possibilities to increase herd management up to three shear. Line [B] represents the possible year for keep females for reproduction after culled.

Compensate index selection; results

Traditionally, farmers' sales fleece by weight affects the quality of fiber. There is no price incentive for quality so it will be very difficult to introduce a process of selection. Nevertheless, at level of large alpaca operation it is possible to use a selection process, especially for those dedicated to sale sires. In this way, indirectly better animals can be introduced into the small farms. An index selection was used in ALPAGEN model. Using the total genetic merit, the index shows an accuracy (r_{TI}) of 0.503 contributing the weight fleece, length and diameter of fiber in 27.1; 37.1 and 35.85 percent respectively, The index has an emphasis over weight fleece equal to 44.6 percent. The genetic progress per generation expressed as $\Delta G/L = r_{TI}\ \sigma_T\ D/L$, equal to 0.932 D, where D is the selection pressure (Van Vleck, 1987), and L is the interval of generation (three years). Figure 3 shows the change of the bio-economic traits under study over 10 years of continuous selection using the index proposed. The estimation was done with the central point of scenario defined in Table 2. An increment of fleece weight and wick length as well as a decrease of fiber diameter is evident, showing possibilities to improve quantity and quality of alpaca fiber.

Scenarios

Several alpaca farm management conditions can be found in practice. The common denominator is an effect on low birth and high mortality rates. Both affect the possibilities to apply a correct process of selection. Moreover without any incentive for better fiber price the farmers usually do not invest in infrastructure, especially to protect animals from the severe weather from June to August (Bustinza, 1968) and high proportion of abortion.

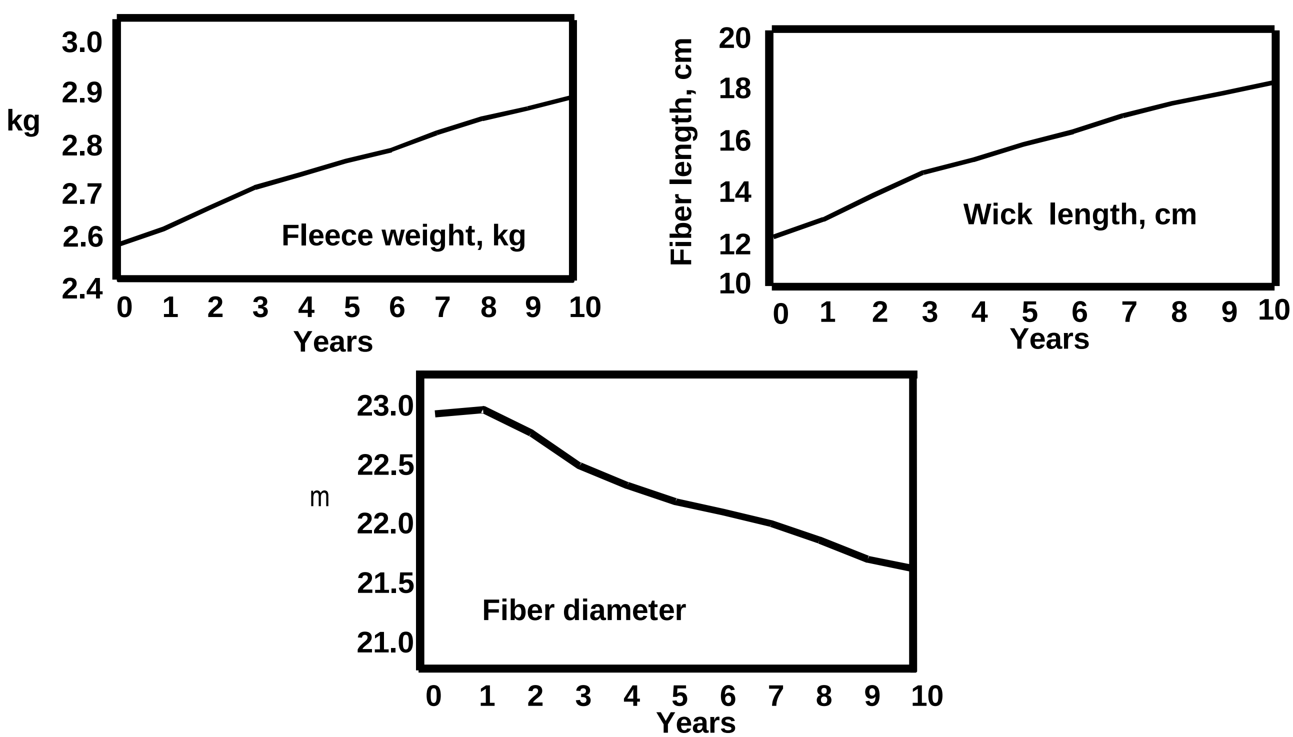

Figure 3. Change of bio-economic traits of fiber quality, expressed as fleece weight (kg), wick length (cm) and fiber diameter (micron) over years by using a composite index selection with and average farm scenario (Table 2).

The model was run with fifteen combinations, being treatment 15 the central point (Table 2). Result of the analysis of variance (Table 3) shows fit for the analysis proposed. The lineal regression explained 93 percent of the total variation (P 0.01); the quadratic and crossproduct explained the 4 percent (P 0.06). The factor of selection was significant (P 0.01). In the treatments were the birth rate was low and mortality rate high, the size herd were reduce to practically a half from the initial herd (1000 heads). Table 4 shows the coefficient for surface response described in Figure 4. The effects of selection considering [A] a birth rate with a constant average of mortality and [B] with mortality rate with constant birth rate (Table 2). Figure 4 A and B shows that decreasing mortality a better genetic gain per year could be possible to obtain although level of birth rate is around average alpaca farm. A balance of these two parameters is necessary to apply high levels of selection as well as to increase herd size to a profitable level.

Table 3. Analysis of variance for total genetic merit for a breeding strategy scenario of selection in alpaca production systems including birth and mortality rate in a central composite rotatable design (values analyzed by percent of genetic gain per year)

Source of variation	Degree of freedom	Means squares and coefficients of determination	
		Genetic gain % year[1]	R^2
Regression	9	0.0285 **	0.97
Linear	3	0.0815 *	0.93
Quadratic	3	0.0021 *	0.02
Crossproduct	3	0.0020 *	0.02
Error	10	0.0006	
Lack of fit	5	0.0005	
Factors			
Birth rate	4	0.0013	
Mortality rate	4	0.0001	
Selection	4	0.0637 **	

[1]Genetic gain expressed in difference from a average of total genetic merit (3.8) of the initial herd base.
** ($P \leq 0.01$); * ($P \leq 0.06$)

Table 4. Coefficient and standard error of response surfaces for average and percentage of genetic gain (difference) per year with reproductive effects (birth rate), management effects (mortality rate) and selection pressure as main.

Independent variable	Coefficients and standard error of dependent variables; genetic gain % year[1]	
Intercept	4.1948**	0.0099
Birth rate (BR)	-0.0005	0.0065
Mortality rate (MR)	0.0031	0.0065
Selection (S)	0.1338 **	0.0065
BR x BR	0.0070	0.0064
MR x BR	0.0090	0.0085
(MR) x (MR)	-0.0041	0.0064
(S) x (BR)	-0.0215 *	0.0085
(S) x (MR)	0.0148	0.0085
(S) x (S)	-0.0187 *	0.0064

[1]Difference in genetic gain per year expressed in percentage on the based of average oftotal genetic merit of initial herd (3.18)
** ($P \leq 0.01$); * ($P \leq 0.05$)

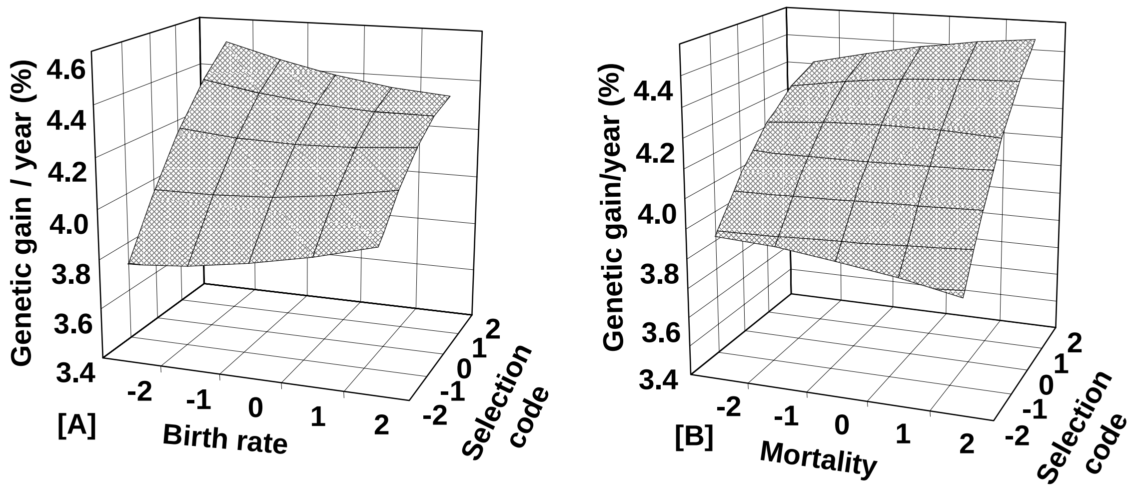

Figure 4. Response surface describing the effect of the selection pressure expressed in percent based from the difference of total genetic merit gain of the initial base herd over ten years of continue selection. [A] Variable birth rate with a constant mortality rate (code 0; Table 2); and [B] variable mortality rate with a constant birth rate (code 0;Table 2).

CONCLUDING REMARKS

The use of the computer model simulation "ALPAGEN" allows an estimation of genetic parameter changes of bio-economic traits of an Alpaca production systems. Although that the wide ranges of the results obtained in this kind of study are not found in practice, the model and procedure used allows an ex-ante analysis giving a sort of possibilities to use in a genetic program. The procedure used to analyze different alpaca systems was adequate in providing information on management effect, fertility and culling rates over the experimental point used.

The analysis of an alpaca herd allows modeling of the real and ideal system and its simulation was reasonable and would be useful in planning breeding alpaca, extension and teaching. Moreover, the index selection, expressed as total genetic merit, can be use to obtain a genetic progress in relation to the bio-economic characteristics of the alpaca fiber.

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