Efficiency in dairy units through data envelopment analysis

J. A Herrera[1], Grisel Barrios[2] and J. O. Flores[3]

[1]*Instituto de Ciencia Animal, Apartado Postal 24, San José de las Lajas, Mayabeque, Cuba*
[2]*Universidad Central de Las Villas. Cuba*
[3]*Universidad "Ezequiel Zamora", UNELLEZ, Guanare, Estado Portuguesa. Venezuela*
Email: jherrera@ica.co.cu

Thirty dairy units of the Genetic Cattle Breeding Enterprise "Valle del Perú" were evaluated from the perspective of relative efficiency through data envelopment analysis. The study was carried in the period 2006-2008. The dairy unit 1, of higher production, and number 23 were the only technically efficient during the three years. In terms of relative efficiency, the enterprise showed a marked irregularity. The overall technical efficiency mean was of 0.69. The pure technical efficiency mean revealed that inefficient dairy units needed to increase their productions by 31 % for reaching the efficient condition. The scale efficiency presented values higher than the remaining indices (0.87). There were higher pure technical efficiency indices in all years, in the dairy units of better productive performance (group I) regarding the dairy units of medium and low production level. The dairy unit 1 was used as reference in 39 opportunities, representing 40 % of the total possible. In 88 % of the cases, the typology of the yield scale was variable. The different efficiency indices estimated (overall, pure technical and of scale) demonstrated that there were difference among the dairy units studied in the evaluated period.

Key words: *technical efficiency, milk production, indices*

The efficiency, according to the pioneer study of Farrell (1957), is approached in two directions: the technical efficiency reflecting the ability of obtaining maximum production for a level of inputs or minimizing the levels of resources for attaining a certain production, and the assignative efficiency, representing the ability of an enterprise of using inputs in an optimum proportion, considering the prices of the products. These two combined concepts represent the economical efficiency.

Coelli (1996) indicated that the methods for estimating the efficiency can be divided by two: parametric, estimating a stochastic frontier by econometric techniques; and non-parametric, as the data envelopment analysis (DEA). This is based on the solution of a model by linear programming. The DEA was developed by Charnes *et al*. (1978) and it is used for estimating the relative efficiency of units, with the common objective in different fields. Flores and Gómez (2006) maintained that the DEA holds implicit a reference approach of great usefulness for agricultural planning. This approach establishes goals for inefficient farms on the basis of inputs or production levels necessary to attain the efficient frontier and to copy, insofar as possible, the practices of the leader farms (efficient). This serves, in turn, as reference to lay the foundations of an adequate transfer of technology program.

Information on the efficiency with which dairy enterprises operate by their directors is of great importance to correct, improve or maintain the operation of their small units (Arzubi *et al*. 2004 and Urdaneta *et al*. 2010). However, most frequently the procedures implemented do not facilitate a study of integral economical efficiency. Hence, there is the need of developing alternative procedures involving complementation between the technical and economical analyses. In this way, the establishment of comparative analysis contributes to increase the capacity of the productive systems allowing the directors to fix individual goals with greater objectiveness and perfectness possibilities. This will permit to ascertain their real potentialities, regarding the better use of inputs and labor force (Barrios 2008).

In accordance with the above mentioned, the objective of this study was to evaluate a group of dairy units of the Genetic Cattle Breeding Enterprise "Valle del Perú", from the perspective of the efficiency in the period (2006-2008) and by the DEA.

Materials and Methods

The study was conducted at the Genetic Cattle Breeding Enterprise "Valle del Perú", in the municipality of San José de las Lajas, Mayabeque province, Cuba. This unit has more than 13 542 ha assigned to cattle rearing.

The variables included in the model originated from a descriptive and multivariate analysis including a total of 18 variables about the productive and economical performance. These were selected on the basis of the availability and safety of the information of 30 dairy units, representing 54 % of the total. The analysis was based on a discriminating approach. Three groups of dairy units were formed a priori with a transversal cut on the basis of total milk production in the year (high, medium and low). The period analyzed was 2006-2008. Data collection was realized by semi-structured surveys. Data processing was developed in panel form.

The variables of the model (DEA) were selected according to the results of a discriminating analysis based on their discriminant power. Total cows and

total expenses of the productive process were used as inputs. As products were considered the annual milk production expressed in liters (discriminant variable) and births (Herrera *et al*. 2010). They were selected without restrictions, with initial weights equal or different from zero.

The general mathematical model of this technique coincides with the following expression:

$$\text{Max } h_0 = \sum_{r=1}^{s} u_r y_{ro} : \sum_{i=1}^{m} v_i x_{io}$$

Subject to

$$\sum_{r=1}^{s} u_r y_{ro} : \sum_{i=1}^{m} v_i x_{io} \leq 1$$

j= 1,……, n

Where:

h_o: efficiency index of the examined unit

s: number of result indicators evaluated

m: number of resource indicators evaluated

u_r: weight (positive and unknown) associated to the r-th result indicator

y_{ro}: amount (known and positive) of r-th result indicator in the examined unit

v_i: weight (positive and unknown) associated to the i-th resource indicator

x_{xo}: amount (known and positive) of the i-th resource indicator in the examined unit

j: number of productive units analyzed

The overall technical efficiency, the pure technical efficiency and the scale efficiency were estimated. In the case of the latter two, they were estimated by defect, as exit from the program used. In the first the following formula was applied:

OTE = PTE x SE

OTE = overall technical efficiency

PTE = pure technical efficiency

SE = scale efficiency

For measuring the technical efficiency a linear programming model was applied directed to the efficiency measurement toward the maximization of the production, at a given level of resources, with typology of variable yield scale. This meant the estimation of an index of pure technical efficiency.

The programs Win4deap version 2.1 (Coelli 1996) were utilized for the estimation of the different efficiency indices.

Results and Discussion

According to Arellano and Cortes (2010), when relative technical efficiency indices are calculated on the basis of a DEA model with constant yields at scale, the productivity and efficiency concepts are equivalent. On the contrary, when working with variable yields at scale, the efficiency concept fitted that of pure technical efficiency. In that sense, the individual pure technical efficiency scores of the dairy units involved in the study are shown from a longitudinal approach, based on the DEA model used (table 2). In relation to this, the dairy unit 1, of higher production, and the 23 were the only efficient in the three years studied. Although the dairy unit 23 was placed in the group of lower productivity, it showed better pure technical efficiency value than the rest. This was due, among other factors that it achieved with a lower number of cows (46), a higher production regarding the others with similar or higher number of animals. Likewise, total expenses were 10 % lower than the average of the sample.

Another important result was the case of unit 28, which was efficient in the first two years and, in the third, reached an extremely low score evidencing clearly a typology of decreasing yields at scale. This was due to a 48 % increase of total expenses in that last year regarding the previous ones; while milk production decreased by 10 %. Therefore, it was evident that there was no increase of products proportional to the increment of expenses. In a general way, in terms of pure technical efficiency, the group of dairy units of the enterprise showed marked irregularity. This performance was also noted by Arzubi *et al*. (2003) on studying the efficiency of dairy exploitations. This could be due, to a great extent, to social factors, especially of administrative nature.

On analyzing the efficiency of the groups per year, the dairy units of better productive performance (group 1) presented higher indices of pure technical efficiency in all years. In the dairy units of medium and low level of production, in the comparison between the remaining groups, it was observed superiority of the dairy units of medium productive level over the worst ones, except in 2007, when these latter were superior.

From a transversal approach, it was clearly evidenced the superiority of the groups of highest production. These results showed the differences and similarities among the conglomerates in the better use of inputs and in the productive levels attained. This was reported by Acosta and Guevara (2009) in analyses realized to dairy systems in Camagüey province in Cuba (figure 1).

The transversal rank distribution of the pure technical efficiency estimations is presented in figure 2. From the exploitations analyzed, 6 % operated with efficiency levels ranging from 50 to 60, respectively. In two occasions, 16 % operated at levels from 60 to 70 % and between 70 and 80 %. The summing up of these three ranks indicated that 33 % of the dairy units evaluated presented lower technical performance than the mean efficiency found for the total of the group. The remaining 43 % operated with performance levels between 80 and 100 %.

The indices of overall technical efficiency (OTE), pure technical efficiency (PTE) and scale efficiency (SE) (table 2) allowed the individual assessment of all dairy units. Number 1 had better productive performance

Table 1. Annual pure technical efficiency indices of the dairy units

Dairy units Group I	Pure technical efficiency index			Dairy units Group II	Pure technical efficiency index			Dairy units Group III	Pure technical efficiency indexa		
	2006	2007	2008		2006	2007	2008		2006	2007	2008
1	1.00	1.00	1.00	11	0.78	0.77	0.86	21	0.76	0.34	0.74
2	0.96	0.83	0.83	12	0.55	1.00	0.71	22	1.00	1.00	0.79
3	1.00	0.79	1.00	13	0.97	0.64	1.00	23	1.00	1.00	1.00
4	0.78	0.91	0.86	14	0.89	0.63	1.00	24	0.51	1.00	0.47
5	0.91	0.72	1.00	15	1.00	0.51	0.99	25	0.50	0.53	0.70
6	1.00	0.72	1.00	16	0.53	1.00	0.80	26	0.87	1.00	0.56
7	0.87	0.95	0.74	17	1.00	0.93	0.53	27	0.51	0.70	0.78
8	0.87	0.68	0.93	18	0.73	0.45	0.84	28	1.00	1.00	0.46
9	0.74	0.71	0.85	19	0.59	0.70	0.83	29	1.00	0.39	0.70
10	0.96	0.69	1.00	20	0.94	0.55	0.81	30	0.42	0.37	0.51

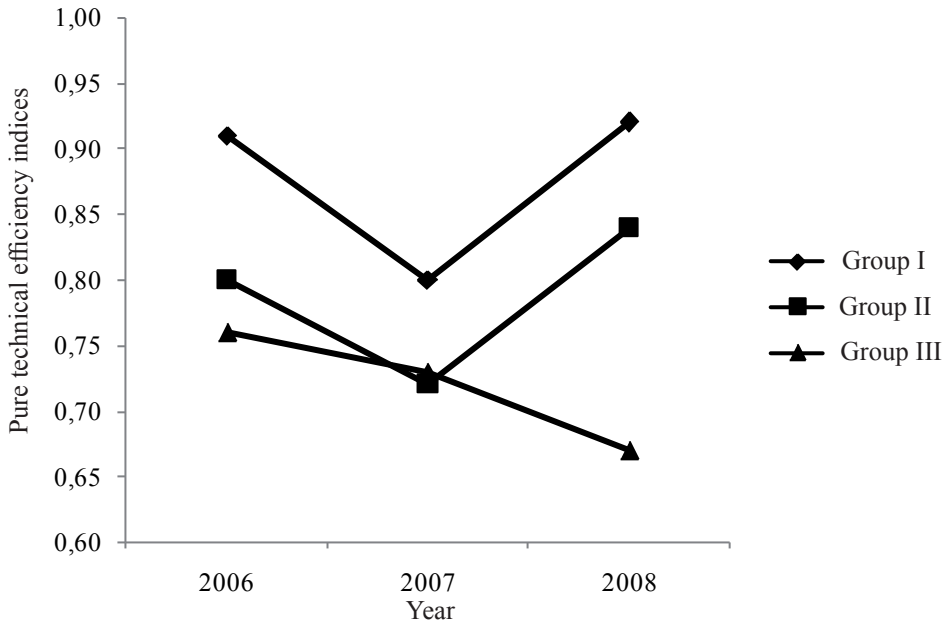

Figure 1. Annual pure technical efficiency indices of the groups per year

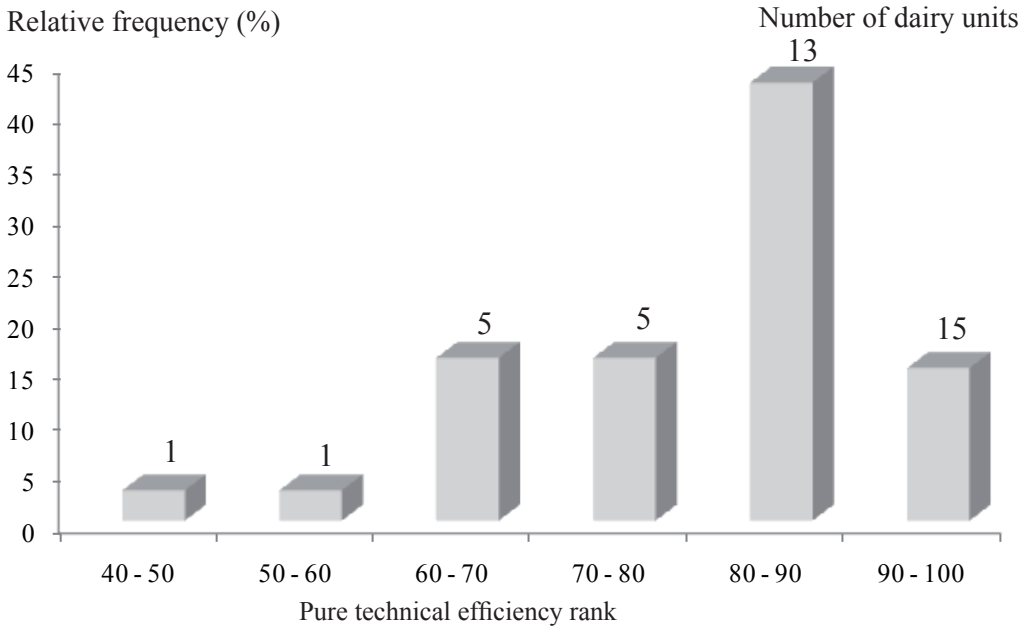

Figure 2. Ranking of the relative frequency of the technical efficiency of the dairy units

regarding the levels of inputs used, that is, higher milk production and 89 % of birthrate. Its total expenses were below the mean, presenting a value of 1 in all efficiency indices showing that it was at optimum scale. Also, there were no technical inefficiencies, not being thus of urgent need to increase its production. The exploitation 23 presented inefficiencies at operation scale (SE = 0.75), but not technical (PTE = 1). Therefore, in that case it is more important to improve yield regarding the scale than to improve the technology (Flores and Zambrano 2010).

Regarding the dairy units of worst indices, number 30 showed in the three-year period the lowest index of pure technical efficiency and the most distanced from 0.81. Arellano and Cortes (2010) considered that 0.81 is thepotentially feasible value for reaching the PTE. Differences encountered in all indices in the dairy units indicated the conditions in terms of relative efficiency of the enterprise.

The descriptive statistical summary of the types of efficiency (table 3) evidenced that the mean overall technical efficiency was 0.69. This implicated that, technically, the dairy units could produce the same amount of milk and births with 69 % of the total expenses and total cows, representing a savings margin of 31 % of inputs (Navarro and Torres 2011). The pure technical efficiency revealed that inefficient farms needed to increase their production by 26 % to become technically efficient, with the same amount of inputs or, on the contrary, to reduce inputs by 21 % (100 – 79.0), without changes in the productive levels reported. The scale efficiency showed higher values to the remaining ones with 0.87, indicating that 15 % (1/0.87) of the production can be increased from an adjustment of the productive processes of the institutions at their optimum scale. The typical deviation was not high in anyone of the cases.

As for the units of reference, Simón *et al*. (2007) and Zhu (2009) concluded that leader farms in efficiency must be taken as the best model for the rest of the exploitations of the enterprise. Figures 3 and 4 show the performance of the dairy units used as reference, with its respective frequency. Most relevant was the result of the dairy unit 1, which in the period analyzed was used as reference in 48 opportunities. This represented, in relative terms, 43 %. Another dairy unit presenting a good performance was number 23, referenced in 22 occasions.

In this order, Flores and Zambrano (2010) concluded that in a transference program or technological evaluation, the leader farms are more important as they are used as reference to more inefficient farms, since in this way is demonstrated their superiority regarding the rest and for that, are the main models to be followed. Likewise, the cited authors declared that if the appearance frequency is low this could indicate that it concerns farms showing very specialized or extreme productive processes, and their efficiency indices could result inaccurate (figure 3).

The annual typology report of yields for every dairy

Table 2. Overall technical efficiency indices (OTE), pure technical efficiency (OTE) and scale efficiency (SE) for the sample of 30 dairy units in the three-year period

Dairy units Group I	Efficiency index			Dairy units Group II	Efficiency index			Dairy units Group III	Efficiency index		
	OTE	PTE	SE		OTE	PTE	SE		OTE	PTE	SE
1	1.00	1.00	1.00	11	0.76	0.80	0.96	21	0.57	0.61	0.94
2	0.80	0.87	0.92	12	0.71	0.75	0.94	22	0.72	0.93	0.77
3	0.82	0.93	0.89	13	0.83	0.87	0.96	23	0.75	1.00	0.75
4	0.73	0.85	0.86	14	0.82	0.84	0.98	24	0.51	0.66	0.77
5	0.72	0.87	0.83	15	0.81	0.83	0.98	25	0.48	0.57	0.84
6	0.82	0.90	0.91	16	0.73	0.77	0.95	26	0.62	0.81	0.76
7	0.75	0.85	0.88	17	0.74	0.82	0.90	27	0.54	0.66	0.82
8	0.65	0.82	0.79	18	0.60	0.67	0.90	28	0.55	0.82	0.67
9	0.71	0.76	0.93	19	0.57	0.70	0.81	29	0.51	0.69	0.74
10	0.87	0.88	0.99	20	0.72	0.76	0.95	30	0.36	0.43	0.83

Table 3. Mean statistical summary of the three types of efficiency

	Types of efficiency		
Statistical	OTE	PTE	SE
Maximum	1.00	1.00	1.00
Minimum	0.35	0.43	0.67
Mean	0.69	0.79	0.87
Typical deviation	0.13	0.12	0.08

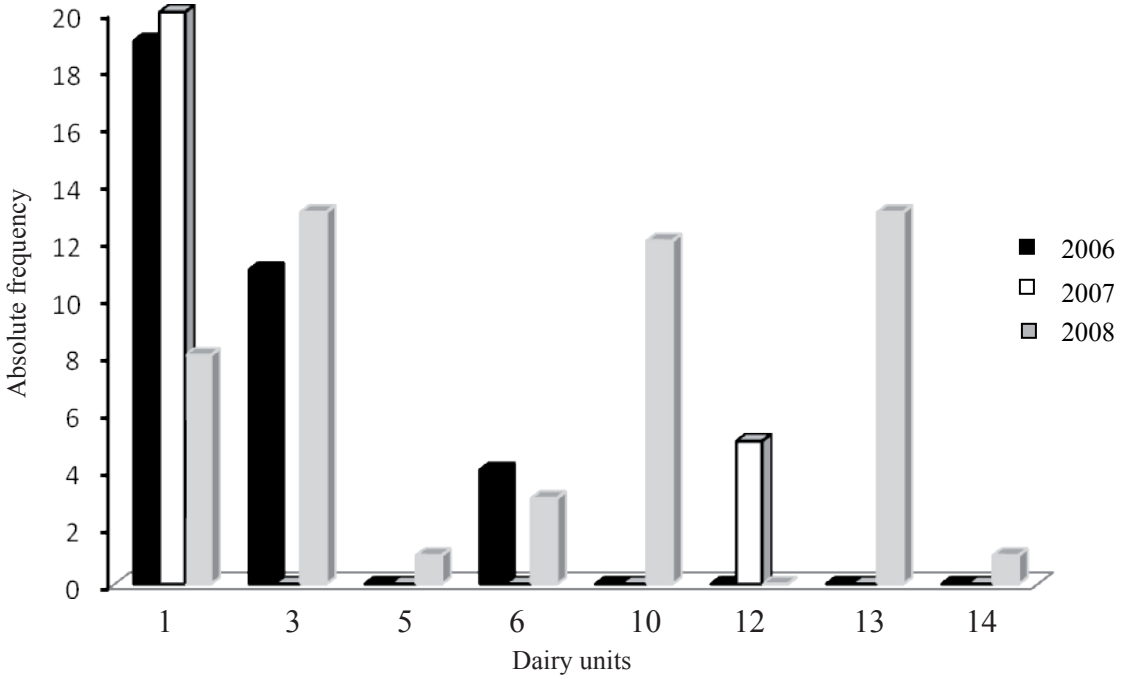

Figure 3. Absolute frequency of the reference dairy units

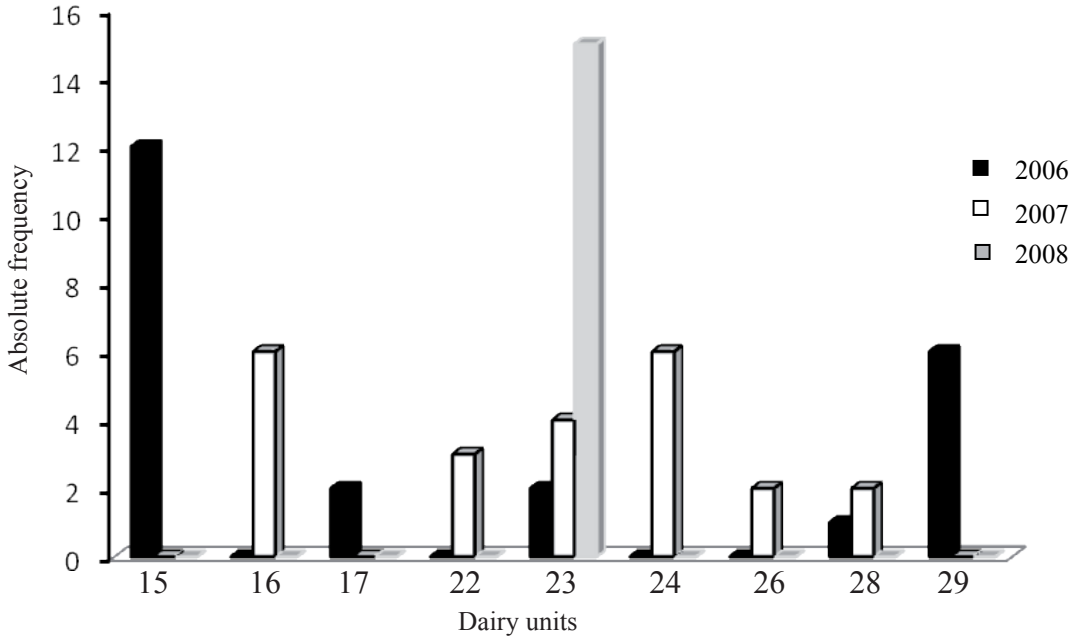

Figure 4. Absolute frequency of the reference dairy units (continuation)

unit (table 4) evidenced almost absolute predominance of the variable yields at 88 % scale. The dairy unit 1 was the only one with constant yields at scale in all years. This result agreed with the efficiency indices attained which were analyzed and argued at great length. Among the possible cases, 11 % experimented constant yields at scale, implicating proportional increase of the productions on augmenting the inputs. Consequently, they exhibited in those years efficiency values equal to 1. In 42 % of the occasions, there were decreasing yields and, thus, in those dairy units any percentile increment of the products was lower that that of the inputs. These operated above their optimum size. Forty six per cent of the cases obtained increasing yields at scale and, thus, these units augmented their production in higher proportion to the inputs used. These exploitations operated below their optimum size.

The different estimated efficiency indices (overall, pure technical and of scale) demonstrated that there was efficiency in the dairy units throughout the evaluated period. The typology of yields indicated that there were proportional variations, regarding the conversion of inputs (total cows-total expenses) in products (total births- annual milk production) according the envelopment analysis model of data applied.

The dairy unit 1 was the one which, to a greater extent, served as reference for the rest. This constitutes a significant argument for the selection of this unit as a

Table 4. Typology of yields

Dairy units Group I	Scale yield			Dairy units Group II	Scale yield			Dairy units Group III	Scale yield		
	2006	2007	2008		2006	2007	2008		2006	2007	2008
1	-	-	-	11	yds	yis	yis	21	yis	yis	drs
2	yds	yds	yds	12	yds	yis	yis	22	yis	yis	drs
3	-	yds	-	13	-	yis	yds	23	yis	yis	-
4	yds	yds	yds	14	yis	yis	yis	24	yis	yis	yds
5	yds	yds	yds	15	-	yis	yds	25	drs	yis	yds
6	yds	yds	yds	16	yis	yis	yds	26	yis	yis	yds
7	yds	yis	yds	17	yis	yis	yds	27	yis	yis	yds
8	yds	yds	yds	18	yds	yis	yds	28	yis	yis	yds
9	yds	yis	yds	19	yis	yis	yis	29	yis	yis	yis
10	yds	-	-	20	yis	yis	yds	30	yis	yis	yds

Yield at increasing scale (yis) yield at decreasing scale (yds) yield at constant scale (-)

successful model which in turn could function as guide to take strategic decisions to improve the performance of inefficient dairy units. Also, it could be used as reference for extension and transfer of technology programs.

This study produced important information for enterprise directors, in regard the need to deepen on the key indicators for the functioning of the dairy units showing lower values.

Acknowledgements

Thanks are due to the administrative staff and workers of the Genetic Cattle Breeding Enterprise "Valle del Perú" for their collaboration.

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Received: October 19, 2012