Classification of dairy units belonging to the Basic Units of Cooperative Production in Ciego de Avila, Cuba

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A case study was performed to classify the dairy units belonging to the Basic Units of Cooperative Production (UBPC) of the Ciego de Avila province, Cuba. A data matrix was created with physical, productive, and efficiency variables in 72 dairy farms. Principal components (PC) and hierarchical clusters methods were used for the formation of the clusters. Eight PC accounted for 87.7 % of the variance. The amount of cows and the milk yield accounted for 23.1 % of the variance in the PC1; and the dimension of the farm and the efficiency in the land use accounted for 19 % in the PC2. Six clusters of dairy farms were obtained. The 1 included 80.5 % of the cases and had lower total production, with 33.7 thousands of L, only 2.8 % of areas with improved pastures, 3 % with forages, and 242 L/ha. The cluster 3 with two cases, and the 4 with six, had higher efficiency, with 522 and 400 L/ha and 39.8 and 53.9 % of areas with improved pastures, respectively. Six clusters of dairy systems were classified according to the amount of cows, the annual milk yield, the land use efficiency, and the quality of the feeding basis. The dairy system based on natural pastures was predominant with lower efficiency, where the control of indices of sustainability should be applied and strategies of technological management should be elaborated.

Key words: *milk yield, dairy farms, multivariate analysis, efficiency.*

Milk yield systems are very complex, due to the great variety of technological, economic, environmental, and social factors affecting the productive process (Senra 2007). These factors need an adequate interrelation to enhance their management efficiency. The diagnosis and characterization of the milk yield systems are fundamental, because they permit determining the farmers' problems and classify the systems, according to their characteristics. This facilitates the elaboration of strategies of technological management and decision making.

Studies on dairy systems (Avilez *et al*. 2010) reported the importance of making analyses, specifically in geographical areas of economic interest, to determine the most important elements affecting the productive behavior, according to the conditions of each site.

In Cuba, Pérez-Infante *et al*. (1998) determined the variables of greatest productive effect in four dairy farms applying multivariate methods. Benítez *et al*. (2008) analyzed the land slope as one of the principal factors affecting the productive efficiency of cattle farms located in the mountain. Guevara (2004) characterized and classified dairy units of the milk production area of Camagüey, but from the dynamic standpoint. Acosta (2008), from an environmental approach, performed a study on cattle systems in a hydrographic basin. At present, in the Ciego de Avila province, Cuba, studies are required determining the factors affecting the most the complex processes of milk production in the cooperative sector, at the level of dairy unit, in a way that an adequate management of the dairy systems is attained. The object of this work was classifying the dairy farms belonging to the Basic Units of Cooperative Production (UBPC) of the Ciego de Avila province, Cuba.

Materials and Methods

A case study was performed in dairy farms belonging to the UBPC of the Ciego de Avila province.

Sample. Seven of the best milk producers were selected among the ten municipalities of the province. Seventy-two units were studied representing 90 % of the total. As selection criterion, the performance of the dairy activity was used in three years or more, as well as the regularity in the milk production throughout the year and the trustworthy productive information at cooperative level.

Data collection. The primary data about the quantitative elements were obtained permitting to characterize and classify the units through visits to them and to cooperative entities. The data were distributed in physical, productive, and efficiency variables.

Physical variables. Total area, area of natural pastures, improved pastures, sugarcane, king grass, sickle bush, protein bank area, number of paddocks, percentage of natural pastures, improved pastures, sugarcane, king grass, and sickle bush. The last five were calculated from the primary data.

Productive variables. Annual average of total cows, annual average of milking cows, annual milk yield, annual births, total annual deaths, and annual deaths of calves.

Efficiency variables. Percentage of milking cows, percentage of birth rate, milk yield/cow total, milk yield/ha, and stocking rate. These variables were generated from the primary data.

Statistical processing. A data base was elaborated as a matrix, including in the columns the information of the physical, productive, and efficiency variables, and in the rows those corresponded to the dairy units.

The methodology of Torres *et al*. (2006) was applied for the analysis, and the fulfillment of the mathematical assumptions was proved according to Torres *et al*. (2008). The analysis of principal components was used in iterated form to select the variables with greatest importance in the differentiation of the dairy units.

The principal components (PC) with Eigen value superior to 1 were determined, and the variables with weighed factors superior or equal to 0.70 were selected. The clustering of the dairy units was performed with the variables of greatest importance, according to the hierarchical cluster method. The average inter-cluster relation and the squared Euclidian distance was used as clustering criterion. The clusters were described by their means and standard deviations.

The exploratory analyses, descriptive statistics, correlation coefficients, principal components and of hierarchical clusters, were performed with the statistical software SPSS on Windows, version 11.5.1 (Visauta 1998).

Results and Discussion

The analysis of the dairy farms belonging to the Basic Units of Cooperative Production evidenced the existence of eight principal components (PC) or factors that accounted for 87.7 % of the total variance (table 1). In the first principal component (PC1), the variables of greatest importance were total of cows, milking cows, annual milk yield average and births, which accounted for 23.1 % of the variance. The variables related to the efficiency of the land use (stocking rate and production per hectare), along with the the total area, and the area of natural pastures, were those of greatest importance in the CP2, and accounted for 19 % of the variance.

Torres *et al*. (2008), in a study in dairy units with the introduction of the technology of Biomass Banks of *Pennisetum purpureum* cv. Cuba CT-115 as strategy for the dry season, did not find the milk yield per hectare as a variable of importance in the explanation of the variance for the second year of evaluation of this technology. This is explained because the four clusters of dairy units had high productions per hectare, between 1 465 and 2 719 L, which indicates the effect of the technology on the efficiency of land use.

The third PC accounted for 13.8 % of the variance. The variables that contributed the most were the area of improved pastures and the percentages of natural and improved pastures. The area and the percentage of king grass accounted for 8.8 % of the variability in the PC4. In the PC5, the variables percentage of milking cows, percentage of birth rate and L/total of cows were outstanding, which represented the biological efficiency. The mortality was important in the PC6, the area and the percentage of sickle bush in the PC7, and the area and percentage of sugarcane in the PC8. The PC4 and the PC8 accounted individually for less than 8 % of the variability, but together for 22.5 % of the variance, similar to the PC1. This explained that the total amount of milking cows, births, stocking rate and milk yield per hectare were the variables that explained the most the variability and, thus, they can be used to classify the dairy units.

Out of the cluster analysis, six clusters of dairy units were obtained. The amount of paddocks and the protein bank area were variables removed from the analysis by having weighed factor inferior to 0.5. Therefore, they were not important to account for the differences between the dairy units. Only in the clusters 3 and 4, which represented 11.1 % of the total, the amount of divisions for the grazing was of 21 and 10.3 paddocks, respectively. In the rest, it was lower, being noteworthy the 1 with 4.2 average paddocks; whereas the protein bank areas were scarce, only the cluster III had 1.25 ha for this goal.

The number of divisions is less important than the application of the fundamental principles of grassland management and animal nutrition (Senra 2005), because they permit readjusting the occupation and resting time to guarantee the grassland sustainability, according to the season. In dairy systems with few possibilities of divisions of the grazing areas, no more than two or three paddocks, or in the exploitation system, occupation times higher than eight could be applied, but not surpassing the stocking rate capacity of the grassland (Senra 2007).

In the cluster 1, the possibilities of establishing an adequate rotation were scarce, according to the principles of the rotational grazing, because these herds were, generally, divided into three clusters of animals for their management: milking cows, dried cows and calves. This brings about drawbacks, such as the little uniformity in the bromatological composition of the pasture by the variability in the intake, the overgrazed and the sub-grazed areas, being more accentuated as the stocking rate or the grazing pressure are lower (Senra 2005). As the availability per animal decreases or the grazing pressure increases, the least nutritive strata are consumed and, thus, production can be affected (Reyes *et al*. 2000), as well as the ecosystem sustainability, because as the amount of feed in the system decreases, and the number of system is not adjusted to the stocking rate, the productive and reproductive indices are affected and the mortality is increased.

The establishment of tree and shrub legumes, which

Table 1. Matrix of weighed factors between the principal components and the variables in the dairy units

Variables	Principal components							
	1	2	3	4	5	6	7	8
	Cows and production	Farm dimension and land use efficiency	Pastures	King grass	Biological efficiency	Mortality	Undesirable species	Sugarcane
Area of natural pastures	0.50	-0.77	-0.19	0.03	-0.15	-0.01	0.10	-0.03
Area of improved pastures	0.05	0.06	0.95	0.13	0.08	0.08	0.04	-0.04
Area of sugarcane	0.05	-0.50	-0.03	0.14	-0.16	-0.06	-0.05	0.72
Area of king grass	-0.11	-0.21	0.15	0.88	-0.08	-0.05	-0.09	0.14
Area of sickle bush	0.24	-0.30	-0.05	-0.04	-0.11	-0.01	0.86	-0.07
Total of cows	0.79	-0.16	-0.03	-0.09	-0.41	0.19	0.00	-0.05
Milking cows	0.87	-0.17	0.13	-0.16	-0.07	0.03	0.04	0.11
Annual milk yield	0.92	0.15	0.00	0.08	-0.01	0.09	0.15	-0.13
Annual births	0.90	0.15	0.06	-0.03	0.06	0.18	-0.02	-0.06
Total annual deaths	0.14	0.11	0.09	0.04	-0.07	0.95	0.09	-0.01
Annual deaths of calves	0.22	0.10	0.17	-0.01	-0.08	0.93	0.04	-0.01
Percentage of milking cows	-0.21	-0.24	0.14	-0.12	0.82	-0.15	-0.12	0.12
Birth rate percentage	0.01	-0.21	-0.87	-0.36	-0.11	-0.10	-0.03	-0.09
Percentage of improved pastures	0.05	0.20	0.94	0.14	0.12	0.10	0.06	-0.09
Percentage of sugarcane	-0.12	0.08	-0.07	0.05	-0.03	0.02	0.08	0.93
Percentage of king grass	-0.06	0.17	0.16	0.89	0.05	0.05	-0.02	0.11
Percentage of sickle bush	-0.06	0.11	0.18	-0.17	-0.13	0.16	0.88	0.13
Birth rate percentage	-0.06	0.21	0.11	-0.05	0.87	0.08	-0.19	-0.13
Milk yield/total of cows	0.01	0.32	0.05	0.19	0.82	-0.12	0.05	-0.17
Total area	0.30	-0.84	-0.08	0.18	-0.31	-0.07	-0.02	0.05
Milk yield/ha	0.29	0.84	0.22	0.15	0.13	0.07	-0.08	-0.11
Stocking rate	0.31	0.81	0.20	-0.07	-0.19	0.19	-0.09	-0.03
Eigen value	5.54	4.66	3.31	2.13	1.74	1.35	1.24	1.07
Variance, %	23.10	19.43	13.81	8.88	7.27	5.63	5.19	4.47

may serve to the animal intake in these dairy systems, should be one of the strategies contributing to the positive balance of nutrients and of the economy in the system (Simón *et al*. 1998 and Reinoso 2000), as well as to feed security and biological sustainability of the grassland ecosystem (Senra 2005).

The cluster 1 formed 80.5 % of the instances (table 2), represented per units of all the municipalities under study. The rest was composed of smaller number of facilities. The cluster 1 had predominance of dairy units with 269 ha as total area of great extension and with natural pastures, only surpassed by the clusters 5 and 6, which constituted three instances, with areas superior to 1 000 ha.

Table 2. Description of resources per clusters of dairy units

Variables	Cluster 1 (58)	Cluster 2 (3)	Cluster 3 (2)	Cluster 4 (6)	Cluster 5 (2)	Cluster 6 (1)
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
Total area, ha	269.2 ± 249.12	149.7 ± 118.68	117.5 ± 14.42	116.0 ± 21.26	1030.5 ± 467.19	1000.0
Area of natural pastures, ha	195.4 ± 161.31	107.3 ± 124.34	38.3 ± 46.69	52.56 ± 18.60	943.7 ± 406.18	1000.0
Area of improved pastures, ha	3.82 ± 8.67	1.67 ± 2.89	43.55 ± 33.30	62.03 ± 17.14	0.0	0.0
Area of sugarcane, ha	3.81 ± 5.77	12.6 ± 6.43	2.0 ± 2.83	0.9 ± 1.39	9.7 ± 5.25	1.0
Area of king grass, ha	2.87 ± 4.72	1.0 ± 1.73	28.95 ± 1.07	0.45 ± 1.1	0.0	1.0
Area of sickle bush, ha	25.0 ± 40.98	44.0 ± 49.33	3.36 ± 4.74	33.1 ± 19.55	15.0 ± 21.21	200.0
Total of cows, u	89.5 ± 56.46	102.3 ± 67.65	89.5 ± 53.03	103.8 ± 56.04	442.5 ± 242.54	261.0
Milking cows, u	33.2 ± 16.86	37.0 ± 16.52	33.0 ± 15.56	48.6 ± 23.64	115.0 ± 63.64	110.0

(): Number of cases per clusters
SD: Standard deviation

According to the surface and the total amount of cows from the herd, the cluster 1 had the possibility of increasing the amount of animals, although the surface for forage banks, with sugarcane and king grass, did not surpass six hectares. This is one of the negative elements that should be transformed to contribute to the feed security of these dairy systems and diminish the dependence on external inputs.

The forage areas evidenced the level of feed security and the sustainability of the dairy systems (Senra 2007). In this sense, the cluster 3 was outstanding, having larger areas for this productive purpose, whereas in the 4 the forage areas were smaller than two hectares. Torres *et al*. (2008) proved the effect of the CT-115 forage banks as milk production technology. As the CT-115 areas were increased in time, the level of losses in the dairy units and the dependence on the external feed were reduced.

The classification of these units has elements similar to the analysis performed in cattle systems (Gómez *et al*. 2002). In this respect, among the clusters defined, the former included 76.1 % of the systems, characterized by the lower productions per area and lower inputs, classified as semi-extensive. This demonstrated the need for transforming these systems to enhance the land use efficiency.

The productive level of the dairy units had high correlation with respect to the total amount of cows and milking cows. The clusters with larger amount of cows such as the 5 and the 6 were outstanding with higher average of total annual production (table 3). Nevertheless, the 1, with lower productive level, concentrated 70 % of the milk yield from the units under study.

The amount of milking cows is one of the factors involved in the annual averages of milk yield per units (Menéndez Buxadera *et al*. 2004). Thus, the clusters 5 and 6, regardless having the lowest productions per total of cows, had the largest annual average. These results can be related to the large areas of these clusters, and to the larger amount of animals, which hampers the better attention to the herd, although the largest production provokes higher income through milk sales.

The systems under study have few resources to have a highly technical production. They do not make investments to improve and maintain the grassland areas or to preserve the feeds. Besides, they do not control systematically fundamental indices of grassland and animal sustainability (Senra 2005). These conditions evidence the importance of the humans involved (Lerdon *et al*. 2008), the training, and the educational level, as social factors that take part markedly in the process of milk production (Avilez *et al*. 2010).

The clusters 3 and 4 were noteworthy due to their higher percentages of improved pastures (table 4),

Table 3. Productive indicators per clusters of dairy units

Variables	Cluster 1 (58)	Cluster 2 (3)	Cluster 3 (2)	Cluster 4 (6)	Cluster 5 (2)	Cluster 6 (1)
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
Milk yield, ThL[1]	33.7 ± 21.27	36.4 ± 21.9	59.7 ± 20.4	45.8 ± 17.2	98.4 ± 23.5	123.8
Births, u	45.0 ± 27.27	37.3 ± 17.79	59.5 ± 53.03	54.1 ± 19.87	119.0 ± 55.1	110.0
Total annual deaths, u	8.2 ± 11.28	6.3 ± 3.51	19.5 ± 20.51	13.6 ± 8.21	22.0 ± 16.9	8.0
Annual deaths of calves, u	4.7 ± 5.45	3.0 ± 2.0	11.0 ± 9.19	10.5 ± 6.98	12.5 ± 7.7	6.0

[1] thousands of liters
( ): number of cases per clusters´
SD: standard deviation

Table 4. Percentage of areas, birth rate and milking cows per cluster in dairy units

Variables	Cluster 1 (58)	Cluster 2 (3)	Cluster 3 (2)	Cluster 4 (6)	Cluster 5 (2)	Cluster 6 (1)
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
Percentage of natural pastures	94.08 ± 10.10	80.07 ± 21.74	31.8 ± 36.71	45.29 ± 13.06	98.7 ± 1.07	100.0
Percentage of improved pastures	2.88 ± 8.4	4.31 ± 7.47	39.83 ± 33.74	53.98 ± 13.31	0.0	0.0
Percentage of sugarcane	1.63 ± 1.95	15.12 ± 6.49	1.6 ± 2.26	0.65 ± 1.01	1.2 ± 1.0	0.1
Percentage of king grass	1.45 ± 2.08	2.59 ± 4.48	25.24 ± 2.15	0.32 ± 0.78	0.0	0.1
Percentage of sickle bush	11.6 ± 14.26	33.26 ± 13.15	3.19 ± 4.5	28.19 ± 17.11	2.2 ± 3.17	20.0
Percentage of birth rate	55.91 ± 21.84	40.64 ± 15.65	59.35 ± 24.09	60.58 ± 22.12	35.6 ± 32.0	42.1
Percentage of milking cows	43.61 ± 19.13	40.66 ± 14.53	38.48 ± 5.42	50.64 ± 13.98	35.2 ± 33.69	42.2

( ): Number of cases per cluster
SD: Standard Deviation

whereas in the rest of the clusters, which represented 88.8 %, the percentage of cultivated pastures was inferior to 5 % of the total area. In this sense, the annual percentage of milking cows only reached to 50 % in the cluster 4, whereas in the rest it was inferior. This result reflects the reproductive efficiency of these herds, which is considered low, as the birth rate percentage, which was only higher in the clusters 3 and 4. These values can be influenced by the methods of reproduction applied to these tow clusters, where artificial insemination was used. There was control of reproduction as compared with the rest, where direct mating was used, without reproductive records.

Avilez *et al*. (2010) found closer connection between high milk yields and the utilization of reproductive records, as well as closer connection between milk yields from low to middle, and the absence of reproductive records. However, other factors such as nutrition and energy balance, established in the first phase of the lactation, can affect the reproductive performance of the herds (Estrada *et al*. 2006).

The milk liters per total of cows (table 5) were only superior in the clusters 3 and 4. The same performance was reported in the milk liters per hectare. However, these values were considered lower than those of the tropical systems described by Martín and Rey (1998) for dairy systems based on natural pastures, with which productions higher than 1000 L/ha can be obtained.

The variables related to the feeding efficiency such as the forage areas of king grass, the pasture management and the ratio of improved pastures influenced directly on the milk yield efficiency of these clusters. This latter had marked difference between clusters and it is an indicator of quality and amount of feed (Senra 2007). The largest amount of milk produced per hectare corresponded to the cluster 3. The results of this study were considered lower than those of the dairy systems classified as of greater efficiency and intensity in Basic Units of Cooperative Production (Guevara 2004). They were superior to 1000 L, due to the grassland management, the supplementation and the greater presence of improved pastures.

Table 5. Stocking rate, milk yield per total of cows and per hectare in the clusters of dairy units

Variables	Cluster 1 (58)	Cluster 2 (3)	Cluster 3 (2)	Cluster 4 (6)	Cluster 5 (2)	Cluster 6 (1)
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
Milk yield/ total of cows, L	415.9 ± 169.45	373.8 ± 63.61	726.67 ± 202.78	511.16 ± 204.37	244.0 ± 80.74	493.80
Milk yield/ha, L	242.5 ± 200.34	309.3 ± 158.52	522.07 ± 237.47	400.47 ± 152.0	100.6 ± 22.76	123.80
Stocking rate, LAU ha^{-1}	0.55 ± 0.41	0.78 ± 0.26	0.77 ± 0.52	0.87 ± 0.38	0.41 ± 0.02	0.25

( ):Number of cases per cluster
SD: standard deviation

In the cluster 1, including 80.5 % of the cases, the production per hectare was comparable to dairy systems without paddocks or supplementation (Ruiz 2010). However, Acosta (2008) in studies of classification of cattle entities obtained clusters with similar results to those of the 5 and the 6, where the great land extension and the little efficiency of its use generated annual productions inferior to 200 L/ha. Sánchez *et al*. (2005) obtained productions per hectare superior to 2500 L, but in a system based on good quality pastures, such as *Panicum maximum* and *Cynodon nlemfuensis*, and legumes such as *Leucaena leucocephala* cv. Cunningham.

In the systems under study, with predominance of natural pastures, it is proved the need for investments for the establishment of an improvement program of the feeding basis, in a way that the land can be used adequately and higher production per animal can be obtained. According to Martín and Rey (1998), productions of 1806 L/ha can be obtained, based on low input technologies, with natural pastures, sugarcane, king grass and 0.33 kg of concentrate/cow/d, but with 1.5 cows/ha.

The stocking rate values in the cluster 1 demonstrated that these dairy systems have the possibility of increasing the number of cows to increase the land use efficiency. Besides, there was high correlation (0.85) between the stocking rate and the milk yield per hectare. Nevertheless, only in 2, 3 and 4, the stocking rate was superior, with 0.78; 0.77 and 0.87 LAU/ha, respectively. This could be related to the presence of higher level of forage areas and improved pastures, which would increase the annual biomass production (Martínez *et al*. 1994). Therefore, these units are less dependent on external feeds (Buysse *et al*. 2005). However, the amount of animals per hectare should be in agreement with the stocking rate capacity of the cattle systems.

It was concluded that six clusters of dairy systems were classified according to the following criteria: amount of cows, annual milk yield, land use efficiency and quality of the feeding basis. There was predominance of the dairy system based on natural pastures with insufficient forage areas and lower efficiency and total production.

Better results were obtained in the clusters of dairy units that had better technological conditions. The systematic use and control of fundamental indices of sustainability of the exploitation system are required to determine the problems and halt the impairment of the productive indicators and the efficiency of the dairy system. The results of this study may be applied to the elaboration of strategies of technological management in the dairy units that belong to the Basic Units of Cooperative Production in the Ciego de Avila province.

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