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A multivariate statistical analysis approach to characterize mechanization, structural and energy profile in Italian dairy farms

Giuseppe Todde *, Lelia Murgia, Maria Caria, Antonio Pazzona

Università degli Studi di Sassari, Dipartimento di Agraria, viale Italia 39, Sassari 07100, Italy

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ABSTRACT

The multivariate statistical approach is one of the most common techniques applied in livestock classification, where quantitative and qualitative variables are used throughout the statistical analysis to obtain farms descriptions. The aim of this study was to divide dairy farms on the bases of farm size, mechanization level, energy profile and availability of building and facilities. A population of 285 conventional dairy cow farms located in the south of Italy was involved in this project. Using the principal component analysis and the k-means cluster analysis allowed to obtain 3 different groups. Results showed a repartition where 156 farms were located in cluster 2 "semi-intensive, low structural and mechanized farms", 110 farms in cluster 1 "semi-intensive, high structural and mechanized farms", and 19 farms were positioned in cluster 3 characterized by "intensive, high structural and mechanized farms. Larger farms are equipped with a wide number of appliances, holding higher level of power installed, but when reported to the number of raised heads or to the cultivated land area as indices, larger farms resulted more efficient and utilized less power per unit.

1. Introduction

Dairy farming represents one of the most important agricultural systems in Italy, with about 35,177 farms and 1.86 millions of heads which annually produce more than 11 million tonnes of cow milk (ISMEA, 2013). Dairy farms are mostly located in the north of the country (65%) where about 77% of the national number of heads is raised, while the south of Italy and islands contribute to 29% of the whole sector in terms of farms and 17% in terms of heads (ISMEA, 2013). Across the different regions, there is a significant diversity in dairy farms for management, structural characteristics, technical performances and economic results.

Typification and characterization of farming and livestock systems have been performed in many studies by means of different methodologies and statistical techniques in order to describe and classify groups of farms. The multivariate statistical approach is one of the most common techniques applied in livestock classification, where quantitative and qualitative variables are used throughout the statistical analysis to obtain farms descriptions. Given the complexity of the agricultural production chains, the amount and the type of variables used in the analysis must be carefully planned in advance (Riveiro et al., 2013). The multivariate approach allows to manage a large amount of information: using the principal component analysis (PCA) the number of the original variables collected is simplified and, at the same time, it allows to avoid multicollinearity among them. Cluster analysis (CA) consists of grouping similar variables, where the number of clusters in a non-hierarchical method must be fixed before starting the analysis (Lletí et al., 2004). Köbrich et al. (2003) highlighted the most important aspects related to the use of multivariate statistical analysis for the typification of farming systems in Chile and Pakistan. The principal component analysis and the cluster analysis to identify groups of regional farming systems, have been applied by Usai et al. (2006) to characterize 151 Sardinian goat farms, as a base for suggesting future developing strategies. Alvarez et al. (2008), carried out a study concerning the characterization, typology and classification of dairy farms in Galicia (Spain) using basic variables such as land use, size classes and production systems. Description and typology, using multivariate statistical analysis, of Chios dairy sheep farms was developed in Greece to assess the intensified farming system, that was mainly associated to the land use and availability, capital investments and management skills. (Gelasakis et al., 2012). Another study (Abas et al., 2013), which involved 123 dairy farms in Central Macedonia (Greece), categorized farming systems into alternative profiles of environmental management practices, using a categorical principal component analysis and a two-step cluster

* Corresponding author.
E-mail address: gtodde@uniss.it (G. Todde).

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analysis. Riveiro et al. (2013) carried out a study to characterize, based on structural characteristics, 44 Assaf breed sheep farms in Spain. The aim was to define homogeneous groups of farms, characterizing the structural features (dimensional, organizational and investments on building, machinery and facilities) of the farms included in each group.

There is a limited knowledge regarding the actual mechanization level and the structural characteristics of dairy cow farming systems. These information would lead to better understand the energy demands of the milk productive systems. The energy related aspects are assuming, in the last years, more and more importance in the agricultural and livestock systems (Edens et al., 2003; Jäkel, 2003; Ludington and Johnson, 2003). The main issues are associated to the efficiency of the energy uses (Grisso et al., 2004; Institut de l'Elevage, 2009; Rossi and Gastaldo, 2012), to the environmental impact of using fossil fuels as energy sources in agriculture (Rotz et al., 2010) and to the increase in energy operating costs of milk production (+12% in the period 2008–12 in European farms). The rational use of energy is strictly related to the mechanization level, to the equipment's efficiency and to the type of farms management. Oversizing farm's equipment is excessively costly as investment and also it will lead to increase the energy consumptions in the production system. Having a thorough knowledge of the energy usages of dairy farms could address towards new management strategies in order to reduce energy consumptions and improve the efficiency of milk production.

The objectives of this study focused on typification and characterization of dairy cow farming in southern regions of Italy, using multivariate methodologies in order to describe mechanization levels, structural characteristics and energy profiles of representative dairy production systems.

2. Material and methods

2.1. Quantitative and qualitative data collection

A population of 285 conventional dairy cow farms located in the south regions of Italy (83 in Sardegna, 70 in Sicilia, 88 in Basilicata and Puglia and 44 farms in Calabria) was involved in this study. Data collection (harvest year 2010–2011) was performed through a questionnaire which contained general information such as herd size, animal categories, land use and ownership, milk quality and production, and a detailed description of cultivated crops, farm structures, equipment and machinery.

The questionnaire was structured in order to fit the overall information found at farm level, in view of the high variability among farms of different size, typology, level of mechanization and management. The inquiry form was filled-in by a specialized team of technicians which completed the questionnaire both by direct measures and manager's interview.

2.2. Statistical analysis

A multivariate statistical analysis was applied to all the variables in order to simplify the large amount of information collected in the survey. The first step was to create a database in Microsoft Excel which was then exported in Minitab 16 (Minitab Inc., State College, PA) for the principal component analysis (PCA) and successive cluster analysis (CA). The PCA allows to convert a set of variables, throughout an orthogonal transformation, into new linearly uncorrelated values named principal components (PC). The selected variables were standardized to allow comparison among different kinds of values (i.e. different units). The standardization was carried out subtracting the mean and dividing by the standard deviation of each variable. The PC with eigenvalues (set of scalar related to a linear system of equation) greater than 1 (Kaiser's rule; Kaiser, 1960) were selected for further analysis. The retained PC were used for *k*-means cluster analysis which allows to allocate the dairy farms into 3 groups. The aim was to divide the sample of 285 farms on the bases of farm size, mechanization level (with particular attention to the equipment type and power), availability and dimension of building and facilities.

The *k*-means CA is a method which, partitioning the observations into clusters, minimizes the sum of distance from each object to its cluster centroid (Lletí et al., 2004). To improve characterization and typology of the cluster's groups, a set of variables were added to the original selected variables. Moreover, frequencies, means and standard deviations were calculated for each variable to characterize the differences between them. Statistical differences ($P < 0.05$) between clusters were assessed using the Mann–Whitney test (software SPSS Inc., Chicago, IL).

3. Results

All the principal components obtained from the analysis were listed according to their eigenvalues, 10 PC have been selected (eigenvalues greater than 1) representing 76.7% of the total original variance. Each principal component represents a synthesized "weight" of the tested variables.

The distribution of farms according to the *k*-means cluster analysis shows that 110 farms were located in cluster 1, 156 farms in cluster 2 and 19 farms in cluster 3.

3.1. Cluster 1—semi-intensive, high structural and mechanized farms

Farms included in cluster 1, as shown in Table 1, were mostly located in valleys (61%) and hills (29%) where Holsteins account for 79% of the breeds raised. The average herd dimension was 159 heads with 72 lactating cows (which correspond on average to 46% of total heads). The yearly milk production per farm accounted for about 665 tonnes of FPCM (fat protein corrected milk), equivalent to 9013 kg per LC. Cluster 1 was also defined by a family farm management, where the average of total workers accounted for 3.3 units and the family labor (2.5 units) contributed to 76% of the total workforces.

The average cropped area was 50 ha per farm, with about 35 ha of rented land in more than the half of farms (59%). Irrigated areas were quite diffused: 69% of farms held an irrigation system, which served about 26 ha per farm. The on-farms feed selection was mostly based on the production of grass hay (23 ha) and corn silage (12 ha), followed by grass silage harvested both in winter and spring seasons. The majority of farms in this group (87%) were specialized on milk production, with a herd management mostly oriented to barn confinement (82%).

Table 2 shows the information related to milking and refrigeration systems. The most common type of milking parlor was the herringbone (89%), followed by the parallel type in only 8% of farms. The average number of milking units per installation amounted to 10 units, with a work capacity of 7.6 cows per unit. In the parlor routine, the daily time spent per each cow was 2.2 min, considering the duration of two milking sessions and washing cycles per day. The average power installed for the vacuum pump was 4.6 kW corresponding to about 75 W of power per lactating cow. The milk cooling tank average capacity was 3660 l, with an average power of 7.9 kW per farm. The availability of energy saving devices, at the milking process level, showed the heat recovery system (HRS) from the condenser of the refrigerator as the most adopted technology (46%). The milk pre-cooler (MPC) and the variable speed drive (VSD) connected to the vacuum pump of the milking machine, were installed respectively in 19% and 16% of farms.

Table 3 shows the results for the fleet equipment found in farms of cluster 1. The average number of tractors and self-propelled