Energy Reports 2 (2016) 129–134

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

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

ARTICLE INFO

Article history:
Received 15 December 2015
Accepted 19 May 2016
Available online 2 June 2016

Keywords:
Principal component
Cluster analysis
Milk
Typification

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).

http://dx.doi.org/10.1016/j.egyr.2016.05.006

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

Table 1
Quantitative and qualitative results for farms description; frequency, mean and standard deviation where applicable. Variables typed in bold where added after multivariate analysis to improve characterization of farms.

Items	Cluster 1 ($n = 110$)	Cluster 2 ($n = 156$)	Cluster 3 ($n = 19$)
Farm characteristics	***mean ± SD***	***mean ± SD***	***mean ± SD***
Total cows (n)	59.3 ± 75.0^a	58.7 ± 29.3^b	506.7 ± 275.9^c
Lactating cows (n)	72.4 ± 31.3^a	27.5 ± 13.6^b	226.5 ± 117.7^c
Milk production (t FPCM)	664.7 ± 339.0^a	181.2 ± 109.1^b	2110.7 ± 1116.2^c
Milk yield (t FPCM LC^{-1})	$\mathbf{9.0 \pm 1.9}^a$	$\mathbf{6.6 \pm 2.3}^b$	$\mathbf{9.3 \pm 1.6}^a$
Total Labor (Unit)	3.3 ± 1.4^a	2.1 ± 1.1^b	7.7 ± 4.0^c
Family Labor (Unit)	2.5 ± 1.2^a	1.9 ± 0.8^b	3.9 ± 2.7^c
Work load (cows worker^{-1})	$\mathbf{51.5 \pm 21.9}^a$	$\mathbf{30.5 \pm 16.1}^b$	$\mathbf{73.2 \pm 39.8}^c$
Work load (hectares worker^{-1})	$\mathbf{16.8 \pm 11.6}^a$	$\mathbf{12.5 \pm 8.9}^b$	$\mathbf{19.2 \pm 13.3}^a$
Total land (ha)	49.9 ± 27.5^a	25.8 ± 17.2^b	122.2 ± 68.8^c
Land occupancy (cows ha^{-1})	$\mathbf{3.9 \pm 2.6}^a$	$\mathbf{3.5 \pm 3.6}^b$	$\mathbf{5.9 \pm 7.1}^a$
Rented land (ha)	35.0 ± 39.4^a	22.5 ± 18.0^a	91.4 ± 89.9^b
Irrigated land (ha)	26.4 ± 24.6^a	10.5 ± 24.9^b	58.5 ± 34.3^c
On-farm Feed selection			
Grass hay (ha)	23.1 ± 20.1^a	18.4 ± 13.7^a	39.3 ± 29.4^b
Grass silage (ha)	6.0 ± 10.4^a	1.7 ± 4.2^b	34.8 ± 47.1^c
Hay and silage (ha)	4.8 ± 10.7^a	0.3 ± 3.3^b	6.6 ± 16.0^a
Corn silage (ha)	12.2 ± 12.4^a	0.6 ± 2.1^b	32.0 ± 38.6^c
Grains and straw (ha)	3.5 ± 9.9^a	3.9 ± 8.2^b	$19.3 \pm 47.1^{a\ b}$
Alfalfa (ha)	1.7 ± 3.6^a	0.6 ± 2.0^b	10.0 ± 13.2^c
Other crops (ha)	0.3 ± 1.5^a	0.2 ± 1.3^a	3.9 ± 14.0^a
Land characteristics			
Farms with rented land %	**59.1**	**69.2**	**63.2**
Farms with irrigated land %	**69.1**	**28.2**	**78.9**
Farm typology			
Specialized %	87.3	62.2	94.7
Not specialized %	12.7	37.8	5.3
Herd management			
Barn confinement %	**81.8**	**32.7**	**89.5**
Barn+Pasture %	**17.3**	**65.4**	**10.5**
Pasture based %	**0.9**	**1.9**	**0.0**
Breed			
Holstein %	**79.1**	**37.8**	**89.5**
Brown %	**4.5**	**10.9**	**10.5**
Local %	**0.9**	**0.6**	**0.0**
Mix %	**15.5**	**50.6**	**0.0**
Terrain position			
Valley %	60.9	21.8	57.9
Hill %	29.1	66.0	31.6
Mountain %	10.0	12.2	10.5

$^{a-c}$Values within a row with different superscripts letter differ ($P < 0.05$).

Table 2
Milking system characterization; frequency, mean and standard deviation where applicable. Variables typed in bold where added after multivariate analysis to improve characterization of farms.

Items	Cluster 1 ($n = 110$)	Cluster 2 ($n = 156$)	Cluster 3 ($n = 19$)
Milking parlor	***mean ± SD***	***mean ± SD***	***mean ± SD***
Milking units (n)	10.1 ± 3.6^a	4.5 ± 2.2^b	21.5 ± 10.8^c
LC milking unit^{-1}	$\mathbf{7.6 \pm 4.8}^a$	$\mathbf{6.7 \pm 3.0}^b$	$\mathbf{12.3 \pm 8.0}^c$
Daily milking time (minutes LC^{-1})	2.2 ± 0.9^a	4.4 ± 2.5^b	1.2 ± 0.8^c
Vacuum pump (kW)	4.6 ± 1.6^a	2.2 ± 1.1^b	6.3 ± 3.5^c
Power utilization (W VP LC^{-1})	$\mathbf{75.0 \pm 56.0}^a$	$\mathbf{94.7 \pm 58.4}^b$	$\mathbf{33.2 \pm 18.0}^c$
Refrigerator capacity (L × 100)	36.6 ± 18.4^a	15.3 ± 7.3^b	119.6 ± 67.3^c
Refrigerator power (kW)	7.9 ± 3.9^a	3.7 ± 2.2^b	22.2 ± 10.0^c
Power utilization (W ref t FPCM^{-1})	$\mathbf{15.6 \pm 21.2}^a$	$\mathbf{26.0 \pm 16.8}^b$	$\mathbf{11.7 \pm 5.1}^a$
Milking parlor type			
Herringbone %	89.1	37.8	63.2
Parallel %	8.2	6.4	31.6
Tandem %	0.9	3.2	0.0
Stanchion barn %	0.0	9.0	0.0
Cart %	0.9	43.6	0.0
AMS %	0.9	0.0	5.3
Saving devices			
Variable speed drive %	16.4	1.3	57.9
Milk pre-cooler %	19.1	0.0	36.8
Heat recovery system %	46.4	7.7	52.6

$^{a-c}$Values within a row with different superscripts letter differ ($P < 0.05$).

Table 3
Building and facilities characterization; frequency, mean and standard deviation where applicable. Variables typed in bold where added after multivariate analysis to improve characterization of farms.

Items	Cluster 1 ($n = 110$)	Cluster 2 ($n = 156$)	Cluster 3 ($n = 19$)
Fleet equipment	***mean ± SD***	***mean ± SD***	***mean ± SD***
Tractors+Self-propelled (n)	3.9 ± 1.3^a	2.3 ± 1.0^b	6.6 ± 3.3^c
Total power (kW)	280.6 ± 121.2^a	124.9 ± 62.2^b	561.6 ± 300.4^c
Power utilization (kW ha^{-1})	6.8 ± 4.8^a	6.6 ± 5.4^{ab}	5.2 ± 4.8^b
Land per tractor (ha tractor^{-1})	13.8 ± 7.8^a	11.7 ± 7.9^b	20.9 ± 12.0^c
Feeding machinery			
Mixer wagon+Self-propelled (n)	1.7 ± 0.7^a	1.3 ± 0.5^b	1.9 ± 0.8^a
Total power (kW)	115.0 ± 47^a	57.7 ± 15.4^b	169.4 ± 57.3^c
Power utilization (kW head^{-1})	0.8 ± 0.4^a	1.0 ± 0.5^b	0.4 ± 0.2^c
Mixer wagon availability %	**94.5**	**23.1**	**100.0**
Cargo capacity (m^3)	14.3 ± 3.4^a	9.6 ± 2.2^b	21.9 ± 7.4^c
Cargo utilization (m^3 100 heads^{-1})	11.0 ± 6.9^a	13.7 ± 6.2^b	5.0 ± 3.0^c
Other equipment			
Fan system availability %	**45.6**	**3.2**	**73.7**
Fan system power (kW)	3.3 ± 3.1^a	1.0 ± 0.4^b	10.8 ± 9.3^c
Power utilization (W head^{-1})	$\mathbf{19.6 \pm 24.2}^a$	$\mathbf{13.0 \pm 7.9}^a$	$\mathbf{21.2 \pm 10.7}^a$
Misting system availability %	**12.7**	**0.0**	**52.6**
Misting system power (kW)	1.1 ± 0.4^a	0.0	1.4 ± 1.4^a
Power utilization (W head^{-1})	$\mathbf{6.9 \pm 4.3}^a$	**0.0**	$\mathbf{2.3 \pm 1.2}^b$
Brushing system availability %	**24.5**	**1.9**	**73.7**
Brushing power (kW)	0.4 ± 0.3^a	0.6 ± 0.2^{ab}	1.6 ± 1.4^b
Power utilization (W head^{-1})	$\mathbf{2.5 \pm 3.2}^a$	$\mathbf{7.0 \pm 3.5}^b$	$\mathbf{3.5 \pm 3.4}^{ab}$
Buildings dimension			
Cowshed (m^2)	1768.9 ± 973.0^a	534 ± 394.1^b	5603.7 ± 2439.1^c
Cowshed occupancy (m^2 head^{-1})	$\mathbf{12.0 \pm 6.3}^a$	$\mathbf{9.9 \pm 6.8}^b$	$\mathbf{12.2 \pm 5.5}^a$
Hay barn (m^2)	428.0 ± 367.4^a	171.7 ± 200.9^b	1355.5 ± 895.0^c
Hay barn occupancy (m^2 head^{-1})	$\mathbf{2.7 \pm 2.3}^a$	$\mathbf{3.4 \pm 4.5}^a$	$\mathbf{3.5 \pm 3.4}^a$
Storehouse (m^2)	146.9 ± 218.4^a	39.5 ± 100.5^b	360.6 ± 603.0^a
Storehouse occupancy (m^2 head^{-1})	$\mathbf{1.0 \pm 1.7}^a$	$\mathbf{0.7 \pm 1.7}^b$	$\mathbf{1.1 \pm 2.8}^{ab}$
Milking barn (m^2)	134.1 ± 140.0^a	59.8 ± 101.5^b	646.0 ± 1152.3^c
Milking barn occupancy (m^2 head^{-1})	$\mathbf{1.0 \pm 1.4}^a$	$\mathbf{1.2 \pm 2.4}^b$	$\mathbf{1.6 \pm 3.5}^{ab}$
Silage silo (m^2)	545.6 ± 792.3^a	19.6 ± 82.5^b	1513.7 ± 993.2^c
Silage silo occupancy (m^2 head^{-1})	$\mathbf{3.3 \pm 4.3}^a$	$\mathbf{0.2 \pm 0.8}^b$	$\mathbf{3.2 \pm 2.3}^a$
Other facilities (m^2)	89.3 ± 257.4^a	16.0 ± 51.5^b	195.1 ± 373.7^a

[a–c]Values within a row with different superscripts letter differ ($P < 0.05$).

machinery amounted to about 4 units per farm, with 281 kW of total power. Additionally, the machinery used for feed preparation and distribution had an average motor power of 115 kW. The majority of farms in cluster 1 (94%) used a mixer wagon with a mean cargo capacity of 14.3 m^3 for feeding operation.

The presence and the characteristics of other electrical equipment are also listed in Table 3. Fan systems for ventilation of cattle sheds represented the most common technology (46%), followed by mechanical brushes (24%) and misting systems for air humidification (13%); the average power installed for this equipment was respectively 3.3 kW, 0.4 kW and 1.1 kW.

The characteristics and dimensions of buildings were also considered in this study: results showed an average area of 1769 m^2 for cowsheds, which represent the largest structures among all farm buildings. The covered surface of hay barns, storehouse and silage silo was 428, 147 and 546 m^2, respectively, while the milking parlor area was about 134 m^2 per farm.

The presence of farms with energy production systems from renewable sources like photovoltaic arrays, wind turbines and anaerobic digesters were determined. Photovoltaic installations were found in 15.5% of farms, with an average peak-power of 82 kW$_p$, while only 4.5% of farms used solar thermal panels for water heating.

3.2. Cluster 2 semi-intensive, low structural and mechanized farms

Most of the farms in this cluster (66%) were located in hills, and more than half of them raised a mix of cow breeds (51%). The average herd size consisted of 59 heads with a yearly milk production of 181 tonnes of FPCM. Farms in cluster 2 were largely characterized by family labor, with an average of 1.9 units per farm, which represents about 91% of the total workforce.

Farm land extension was on average 26 ha and 69% of farms held leased areas with a mean surface of 22.5 ha. The percentage of farms with irrigation systems was low, only 28%, corresponding to 10.5 ha of irrigated cultivations per farm.

The production of grass hay resulted the principal harvested feed (18.4 ha), followed by the production of cereals (grains and straw) cultivated on 3.9 ha. About 62% of farms in cluster 2 were specialized on cow milk production, while 38% had diversified agricultural production activities. The use of pasture associated with a barn confinement represented the most adopted type of herd management.

As shown in Table 2, the most common milking system was the cart type (43.6%), due to the small herd size, followed by the herringbone milking parlor (37.8%). The daily time spent for milking operations was about 4.4 min per lactating cow, with an average of 4.5 milking units per milking installation and 6.7 LC per unit.

The average vacuum pump's power was 2.2 kW, while the refrigerator's power corresponded to 3.7 kW, with an average tank capacity of 1530 l. Farms in cluster 2 showed a very low investment in energy saving measures: the most adopted technology was the HRS in only 7.7% of the installations.

Data about fleet equipment, listed in Table 3, indicate an average number of tractors and self-propelled machinery of 2.3 units, which corresponded to 125 kW of total power and 6.6 kW per hectare. Preparation and distribution of feed was provided by the use of 1.3 units of machinery with a total power of 58 kW. Only 23% of the farms had a mixer wagon for feeding operations with an average of 9.6 m^3 of cargo capacity, while in the rest of farms these operations were carried out manually.

The availability of other equipment underlines the low investments in technologies for cow comfort in barns. Only 3.2% of farms held a ventilation system (average power 1 kW), and only about 2% adopted the mechanical brushes (average power of 0.6 kW), while no misting systems were found in farms of cluster 2.

The section concerning the dimension of buildings shows that cowsheds were the largest structures in the farms (534 m^2), followed by the hay barns (172 m^2) and the milking parlor (60 m^2).

The presence of renewable energy production systems was very scarce: thermal solar panels were installed in 7.7% of farms, followed by photovoltaic technologies (5.8%), with an average power of 23 kW_p.

3.3. Cluster 3—intensive, high structural and mechanized farms

As shown in Table 1, cluster 3 was the smallest group, composed by 19 specialized farms, mostly located in valley (58%) and hills (32%). The herd management was principally based on barn confinement, and only 10% of farms were organized with pasture and barn confinement. The average herd size was 507 heads, mainly represented by the Holstein breed (90%). The average farm production of milk amounted to 2111 tonnes of FPCM per year, which corresponded to 9.3 tonnes of FPCM per milked cow. In this cluster's farms, the total workforce accounted to 7.7 units per farm, and about 51% was represented by family labor (3.9 units).

The average cultivated land area was 122 ha and around 63% of farms held leased land, with an average of 91 ha. Irrigation systems were presents in 79% of farms, with about 59 ha irrigated per farm. The production of on-farm feed was mostly oriented to grass hay (39 ha), grass silage (35 ha) and corn silage (32 ha).

The most common milking parlors were the herringbone type (63%) and the parallel type (32%), with an average of 21.5 milking units, each serving more than 12 lactating cows. The average daily time spent for milking operations amounted to 1.2 min per milked cow. The average power of vacuum pump and milk refrigerator amounted to 6.3 kW and 22.2 kW, respectively. The capacity of the milk tank corresponded to 11,960 l.

The equipment for energy saving were quite diffuse in farms of cluster 3: the most adopted equipment were the VSD (58%) and the HRS (53%), followed by the MPC (37%).

As showed in Table 3, the number of self-propelled machinery was on average 6.6 units, with 562 kW of total power per farm. Feeding operation at farm level denoted an average power of 169 kW and 1.9 units of self-propelled machinery available. The use of mixer wagon was diffused in all farms, with a mean cargo capacity of 22 m^3. Table 3 also shows the large presence of equipment such as fan system (74%), misting system (53%) and mechanical brushes (74%). The average power installed for these devices corresponded to 11 kW, 1.4 kW and 1.6 kW, respectively.

The average dimensions of farm building and facilities indicated cowshed as the largest building (5604 m^2), followed by silage bunker silos (1514 m^2), hay barns (1356 m^2) and milking barn (646 m^2).

The percentage of renewable energy systems shows that photovoltaic installations were present in 26.3% of farms, with 50.3 kW_p average power. Farms in this cluster were also equipped with other renewable energy systems (RES) such as anaerobic digestion systems (15.8%), thermal solar panels (5.3%) and wind turbines (5.3%).

4. Discussion

The multivariate approach allowed to simplify the large number of variables found at the dairy farms level. In this work a set of quantitative and qualitative variable has been used in order to characterize a sample of 285 dairy farms located in southern Italy.

The *k*-means cluster analysis allowed to partition the farms in 3 groups, reducing the variance among farms of the same cluster and maximizing the variance among clusters. Results showed a repartition where a wide number of farms (156, corresponding to 54.7% of the whole sample) were located in the group "semi-intensive, low structural and mechanized farms". In this group, named cluster 2, 37% of farms were located in Basilicata and Puglia, 35% of farms located in Sicilia and 21% in Calabria, while only the 8% of farms were situated in Sardegna. The majority of farms in cluster 1, which refers to "semi-intensive, high structural and mechanized farms", were located in Sardegna (57%), Basilicata and Puglia (23%), while only 13% and 7% of farms were situated in the regions of Calabria and Sicilia, respectively. Finally, 19 farms were positioned in cluster 3 characterized by "intensive, high structural and mechanized farms"; 36% of them were located in Sardegna, 32% in Basilicata and Puglia, 21% in Sicilia and 11% in Calabria. Observing the results showed in Table 1, great differences were recorded among clusters. The milk yield per lactating cow raised significantly ($P < 0.05$) when passing from farms of cluster 2 (6.6 tonnes FPCM) to those of cluster 1 (9.0 tonnes FPCM) and 3 (9.3 tonnes FPCM), due to the more intensive management level. The index related to the land used showed that bigger farms held more heads per hectare (5.9 in cluster 3) rather than small farms (3.5 heads in cluster 2). The average workload, expressed as number of cows per worker, increased ($P < 0.05$) when the size of farm increased, as already observed by Alvarez et al. (2008) in Galician dairy farms. This aspect is directly connected to the mechanization level that characterizes the different clusters, both as number of tractors and total power of field machinery. The energy indicators in Table 3 underline that farms of larger size that belong to cluster 3 held lower indices of machinery power utilization, in terms of both tractor's power (5.2 kW ha^{-1}) and feeding machinery power (0.4 kW $head^{-1}$), while farms of clusters 2 and 1 had similar indicators. The same trend of power utilization was observed in Spanish dairy farms by Alvarez et al. (2008). However, observing the power utilization index per unit of cultivated land (kW ha^{-1}) of the three clusters, no result was greater than the average coefficient 8 kW ha^{-1} indicated by Bodria et al. (2006) as the mean index in Italian dairy farms associated with forage and corn production.

Analyzing the characterization by the type of milking machines, farms of cluster 2 held more cart system than the other clusters, since the small herd size (27.5 $\pm$ 13.6 lactating cows) and their farm management oriented to a low investment in technology. In reference to the electric energy request for milking and milk refrigeration, it can be observed that when the farm average size decreased the indices related to the utilization of power increased: the power utilization for the vacuum pump (33 W, 75 W and 95 W per lactating cow) and the milk tank (12 W, 16 W and 26 W per tonne of FPCM) are greater when passing from cluster 3 to cluster 1 and 2, respectively. This indicates a better energy investment in larger farms both in terms of initial costs and energy efficiency.

The indices related to overall cowsheds occupancy expressed as m^2 per head, do not present large differences among the three clusters (Table 3), and were comparable to the results obtained in France from Institut de l'Elevage (2007) (9.1 m^2 per head) and in north of Italy from Rossi and Gastaldo (2007) (12.7 m^2 per head). However, the silage silo area was smaller in cluster 2 due to the low production of corn and grass silage in those farms.

5. Conclusions

The present study performed a multivariate statistical analysis to analyze the structure and the energy profile of Italian dairy farms representative of the southern regions of the country. Direct measurements throughout the survey gave a contribution to understand how the energy investments were related to the characteristics of different milk production systems. The multivariate statistical analysis (principal component analysis and cluster analysis) represented a valid method to simplify the large amount of information and to partition the sample of 285 dairy farms into three groups with different levels of investments, mechanization and productivity. Cluster 1 mostly represents farms located in Sardegna (53%) having characteristic ascribable to semi-intensive, high structural and mechanized farms; cluster 2 embodied the largest number of farms from Puglia and Basilicata (37%) and Sicilia (35%) characterized by semi-intensive systems with low structural and mechanization systems; cluster 3 held 19 intensive farms, mostly located in Sardegna (37%) and Puglia and Basilicata (32%) with high investments in machinery, buildings and facilities. The effect of the economy of scale influences the mechanization level when reported to the herd dimension: largest dairy operations usually generate revenues that allow more technological investments than most of the small and mid-size dairy farms. Likewise, larger farms are equipped with a large number of appliances, holding higher level of power installed, but when reported to the number of raised heads or to the cultivated land area (hectares) as indices, larger farms resulted more efficient and utilized less power per unit.

Acknowledgments

The authors wish to thank the "Filiera AQ s.r.l" to support the study with the "Dairy Carbon Footprint Project", the president Gianpiero Calzolari and Dr. Giampaolo Zanirato. Sincere thanks also goes to the 3A, ProgettoNatura, Granlatte and Assolac dairy plant co-operative and their technician for the valuable help with the collection of the data.

References

Abas, Z., Ragkos, A., Mitsopoulos, I., Theodoridis, A., 2013. The environmental profile of dairy farms in Central Macedonia (Greece). Procedia Technol. 8, 378–386.

Alvarez, C.J., Riveiro, J.A., Marey, M.F., 2008. Typology, classification and characterization of farms for agricultural production planning. Span. J. Agric. Res. 6 (1), 125–136.

Bodria, L., Pellizzi, G., Piccarolo, P., 2006. Meccanica Agraria. Vol 2: Meccanizzazione. Edagricole.

Edens, W.C., Pordesimo, L.O., Wilhelm, L.R., Burns, R.T., 2003. Energy use analysis of major milking center components at a dairy experiment station. Appl. Eng. Agric. 19 (6), 711–716.

Gelasakis, A.I., Valegakis, G.E., Arsenos, G., Banos, G., 2012. Description and typology of intensive Chios dairy sheep farms in Greece. J. Dairy Sci. 95 (6), 3070–3079.

Grisso, R.D., Kocher, M.F., Vaughan, D.H., 2004. Predicting tractor fuel consumption. Appl. Eng. Agric. 20 (5), 553–561.

Institut de l'Elevage, 2009. Les consommations d'energie en bâtiment d'elelevage laitier. Reperes de consommations et pistes d'economies. Collection: Synthese, Janvier.

ISMEA, 2013. Istituto di Servizi per il Mercato Agricolo Alimentare. Allevamento bovino da latte: L'orientamento delle imprese Italiane nel post quote.

Jäkel, K., 2003. Analyse der Elektroenergieanwendungund Einsparpotentialeam BeispielsächsischerMilchviehanlagen. Forschungsbericht Agrartechnik, 414, Mertin-Luther-Universitat Halle/Saale.

Kaiser, H.F., 1960. The application of electronic computers to factor analysis. Educ. Psychol. Meas. 20, 141–151.

Köbrich, C., Rehman, T., Khan, M., 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agric. Syst. 76, 141–157.

Institut de l'Elevage, 2007. Les consommations d'energie en batiments d'elelevage bovin. Chambre d'Agriculture de Bretagne et des Pays de la Loire. N° 050733008.

Lletí, R., Ortiz, M.C., Sarabia, L.A., Sanchez, M.S., 2004. Selecting variables for k-means cluster analysis by using a genetic algorithm that optimises the silhouettes. Anal. Chim. Acta 515, 87–100.

Ludington, D., Johnson, E., 2003. Dairy farm energy audit summary Report. Energy Research and Development Authority. New York State Energy Research and Development Authority.

Riveiro, J.A., Mantecon, A.R., Alvarez, C.J., Lavin, P., 2013. A typological characterization of dairy Assaf breed sheep farms at NW of Spain based on structural factor. Agric. Syst. 120, 27–37.

Rossi, P., Gastaldo, A., 2007. I costi di costruzione dei ricoveri zootecnici. Centro Ricerche Produzioni Animali. I supplementi di Agricoltura. 32, (suppl).

Rossi, P., Gastaldo, A., 2012. Consumi energetici in allevamenti bovini da latte. Inf. Agrar. 3 (Suppl), 45–47.

Rotz, C.A., Montes, F., Chianese, D.S., 2010. The carbon footprint of dairy production systems through partial life cycle assessment. J. Dairy Sci. 93, 1266–1282. http://dx.doi.org/10.3168/jds.2009-2162.

Usai, M.G., Casu, S., Molle, G., Decandia, M., Ligios, S., Carta, A., 2006. Using cluster analysis to characterize the goat farming system in Sardinia. Livest. Sci. 104, 63–76.