Characterization of Buffalo Dairy Production Systems in Egypt Using Cluster Analysis Procedure

S.A.M. Abdel-Salam*

Department of Animal Production, Faculty of Agriculture, Cairo University, Giza, Egypt

Abstract: The study objective was to characterize and classify buffalo dairy production systems in Egypt. Ten governorates having high buffalo population density were selected as the study area. The data were collected from 1811 dairy buffalo farms using survey. Buffalo holders were face to face interviewed by constructed questionnaire. The survey was applied in two years (2010 and 2011). Two-Step Cluster procedure (CA) was used and analysis was repeated several times until the cluster quality came good (average silhouette ≥0.5). The algorithm selected the number of clusters, after calculating the Akaike's information criterion (AIC). Statistics of CA showed that the numbers of farm in each cluster were 43 (2.4%) in cluster1 (CL1), 1364 (75.3%) in cluster2 (CL2) and 404 (22.3%) in cluster3 (CL3). CL1 farms had a good availability of facilities. The management practices were the higher in comparison with the farms in the other clusters. Management and feeding systems practices in CL1 ranged from medium to high. CL2 was the largest, with 1364 farms located in all the ten governorates. The availability of facilities and equipment were low or lacking. The management practices were the lowest in comparison with farms in other clusters. CL3 facilities availability were low to medium. The management practices were medium when compared with the farms in the other clusters. The results of the current study demonstrate the existence of a large variability among buffalo dairy production systems in Egypt. These systems variability should be taken into consideration for sustainable system development.

Keywords: Buffalo, production systems, typology, characterization.

INTRODUCTION

World population of buffalo has increased by 20 million heads during the last 10 years, of which about 90% of increment occurred in Asia [1]. The buffalo in Egypt plays an important role among livestock as a provider of milk and beef. Buffaloes are mostly reared in small holdings under harsh socioeconomic conditions leading to low productive and reproductive performances. Buffalo have a higher longevity and productive life than cattle, providing milk and calves up to twenty years of age. Numerous factors that restrict commercial milk production of buffaloes include late age at first calving and the long dry and calving intervals [2].

Traditionally, buffalo farming systems in Egypt have been classified into extensive or semi-extensive [3]. Generally, classifications of livestock farming system depended on herd size and production of milk that might not include all production parts. There are with big variations in inputs utilized between farms. Subsequently, an additional objective classification of livestock farms is required to detect the essential factors that reflect the level of intensity in their systems of production [4]. The typology of the farms of livestock into clusters is important to discover and determine the appropriate strategy for improvement. Information about weaknesses and strengths of various farming systems can support the improvement plans for development [5-7]. The multivariate statistical procedures are can be used to get more information regarding farm management intensity and characteristics and for comparing the obtained clusters in terms of profitability and viability and support the decision-makers and all other buffalo stakeholders to implement and maintain sustainable buffalo development programs. Therefore, the objective of this study was to develop a representative and appropriate classification and characterization of buffalo production systems in Egypt, using cluster analysis procedure.

MATERIALS AND METHODS

Questionnaire Design and Data Collection

The study areas were selected to include the governorates that have high buffalo population density. Ten governorates were selected: El-Behira, Kafr El-Sheikh, El-Qalubiya, El-Menoufia, El-Sharkia, El-Fayoum, Beni Suif, El-Minya, Assuit, and Sohag. The selected governorates have a significant contribution to agricultural production in Egypt and accommodate approximately 65% of buffalo population in Egypt [8].

The data were collected from 1811 dairy buffalo farmers using survey in two years (2010 and 2012). Buffalo owners were face to face interviewed using a structured questionnaire to collect information about education, herd description, cultivated area, type of cultivation, and management practices regarding milking procedures, nutrition, housing type,

*Address correspondence to this author at the Department of Animal Production, Faculty of Agriculture, Cairo University, Giza, Egypt;
Tel: +201001623153; E-mail: samehfs@agr.cu.edu.eg

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reproduction and milk production and products. In order to verify the final format and clarity of the questions a pre-testing was conducted on 20 farmers.

Stratified sampling method was used. The sampling frame is divided into ten non-overlapping strata (governorates). Method of random sampling was used to select a sample of subjects (buffalo holder) from each governorate.

Statistical Analysis

Means and standard errors of continuous variables or categorical variables were calculated. In order to exploit the large number of recorded variables in the most effective method a multivariate procedure was used. Statistical analysis was carried out using successive cluster analysis (CA). The analysis was performed using IBM SPSS Statistics for Windows, Version 25.0 [9]. The main descriptive statistics were calculated for each identified cluster to characterize and compare them. CA is a method of classifying cases of data based on the response's similarity to several variables [10]. Two-step cluster procedure was used in case of both continuous and categorical variables [11]. The two-step cluster is designed to analyze large datasets. In the present study, data were large and have continuous and categorical variables.

The two-step cluster analysis was repeated many times until the cluster quality was good (average silhouette ≥0.5). The total number of variables used in the first analyses was 49, whereas only 19 variables were used in the last cluster analysis. The silhouette value is defined as "a measure of how almost the same an object is to its own group compared to other groups". The value of silhouette varies from -1 to +1, where a high estimate indicates that the object is strong matched to its own group and weakly matched to neighboring groups. The clustering setup is appropriate if most objects have a high estimate values. The clustering setup may have too many or too few clusters, if many points have a low or negative value. The algorithm selects number of clusters, after calculating the Akaike's information criterion (AIC). It is optional to create a separate cluster for cases that do not fit well into any other cluster [10].

RESULTS AND DISCUSSION

Results of cluster analysis led to identifying three clusters. In automated cluster selection, the number of clusters is determined when the Akaike's information criterion (AIC) is small and the change in AIC between adjacent clusters is small [10]. Based on these criteria, the algorithm selected three clusters as shown in Table **1** with a number of farms in each cluster of 43 (2.4%), 1364 (75.3%) in 404 (22.3%) in Cluster 1 (CL1), Cluster 2 (CL2) and Cluster 3 (CL3), respectively.

Table **2** shows the buffalo and other animal's possession for buffalo farming systems in Egypt. Generally, CL1 was characterized by special features like a high number of buffalo and cattle stock. Farmers in CL1 had the highest percentage of milking buffaloes (66%) in the herd and the farmers in this cluster reared male calves for fattening and bulls for natural insemination. The farmers in CL2 had the lowest number of buffaloes.

The herd structure in the three clusters was different. CL1 had a highest numbers of milking

Table 1: Akaike's Information Criterion (AIC), AIC Change, Ratio of AIC Change and Ratio of Distance Measures of Auto-Clustering

Number of Clusters	AIC	AIC Change[a]	Ratio of AIC Changes[b]	Ratio of Distance Measures[c]
1	32099.727			
2	21491.361	-10608.366	1.000	2.773
3	17717.819	-3773.543	.356	2.424
4	16209.248	-1508.571	.142	1.215
5	14982.496	-1226.752	.116	1.359
6	14101.406	-881.091	.083	1.303
7	13444.159	-657.247	.062	1.025
8	12804.878	-639.280	.060	1.356

[a]The changes are from the previous number of clusters in the table.
[b]The ratios of changes are with respect to the change at the two clusters.
[c]The ratios of distance measures are based on the current number of clusters against the previous number of clusters.
[d]Since the distance at the current number of clusters is zero, auto-clustering will not continue.

Table 2: Means* ± SE of Herd Size, Herd Structure, and other Animals' Possession of the Three Clusters of Buffalo Farms in Egypt

Holding animals (Head)	CL1 N=43	CL2 N=1364	CL3 N=404
	mean ± SE	mean ± SE	mean ± SE
Buffalo	124.47[a]±3.01	3.57[b]±0.53	5.53[b]±0.98
Milking buffaloes	70.79[a]±1.86	1.98[b]±0.33	3.15[b]±0.61
First lactation buffaloes	6.98[a]±0.28	0.23[b]±0.05	0.32[b]±0.09
2nd to 3rd lactation buffaloes	18.91[a]±0.54	0.75[b]±0.09	1.16[b]±0.18
4th to 5th lactation buffaloes	22.49[a]±0.66	0.64[b]±0.12	1.07[b]±0.22
6th ≤ lactation buffaloes	22.42[a]±0.83	0.37[b]±0.15	0.59[b]±0.28
Breedable buffalo females	86.05[a]±2.28	2.31[b]±0.41	3.74[b]±0.75
Heifers < one year	14.00[a]±0.42	0.59[b]±0.08	0.92[b]±0.14
Heifers 1-2 year	15.26[a]±0.73	0.32[b]±0.13	0.59[b]±0.24
Male calves < 1 year	12.88[a]±0.46	0.42[b]±0.08	0.55[b]±0.15
Fattening male calves > 1 year	10.44[a]±0.49	0.22[b]±0.09	0.29[b]±0.16
Buffalo bulls	1.09[a]±0.04	0.03[b]±0.01	0.02[b]±0.01
Cattle	29.07[a]±1.90	2.07[b]±0.34	2.50[b]±0.62
Sheep & goats	11.88[a]±1.52	1.62[b]±0.27	1.79[b]±0.49

*Means, in the same row, followed by different superscripts differ significantly (P≤0.05).

buffaloes in fourth lactation or more, about 64% of milking buffaloes. Farmers in CL2 and 3 kept young heifers (< one year), 17%, more than the farmers in CL3, 11%, as a percentage from total buffaloes holding in the farm. On the contrary, for the replacement heifers, farmers in CL3 kept heifers (12%), more than the farmers in CL2 (8%) and CL3 (11%) as a percentage from total buffalo holding in the farm. Young heifers rearing is costly and needs a good management and feeding system [12, 13]. Boulton [14] stated that dairy heifers start to give a return on investment at first calving. The non-productive, rearing period time, is mainly controlled by farmer decisions on reproduction and nutrition management plane.

In CL2 and CL3 the highest number of milking buffaloes are located from first to third lactation. Buffaloes in the fourth lactation or more have the highest milk production. High yielding buffalo need a high and good amount of nutrients. The farmers in CL2 and CL3 did not prefer to keep buffaloes in fourth lactation or more because they lack good feeding system and feed cost for high yielding buffaloes [15]. FAO [2] reported that buffalo has a prolonged productive life, providing milk and milk calves up to 20 years of age.

All farmers in the three different clusters preferred to hold cattle, sheep and goats with buffaloes in the same farm. This may be due to the differences between buffalo and cattle in milk characteristics and to diverse production. Also, to reduce risk of low income per production unit. Sibhatu [16, 17 reported that on-farm diversity of production is positively related with variety of feeding in some situation, but not in all cases. When diversity of production is high, the relation is not important or even changes negative, because of foregone return benefits from specialty. [18] reported that the presence of cattle and buffaloes together may mean that the level of herd structure for these farms is good. System of cattle and buffaloes together is distinguished from the others by producing calves and manure as profitable farm products.

Table **3** shows the crop production in the three clusters. The largest average land possession was 9.3 ha in CL1 and the smallest was 1.1 ha in CL2. Farmers in CL1 cultivated, in winter, about 90% of their land by clover followed by farmers in CL3 (53%). The area of cultivated clover was positively correlated with the size of buffalo herd [19]. In summer, maize occupied the second cultivated area for all farms in the three clusters. 54% (0.7 ha) of the land area owned by farmers in CL3 was cultivated by maize, followed by farmers in CL2 (45% corresponding to 0.5 ha). The number of employees was positively correlated with the animal and land possession. Farmers in the three

Table 3: Means* ± SE of Land Possession, Cultivated Area and Annual Crop Production of Land Holding of the Three Clusters of Buffalo Farms in Egypt

Variable	CL1 N=43	CL2 N=1364	CL3 N=404
	mean ± SE	mean ± SE	mean ± SE
Land area (ha**)	9.7^{a}±0.5	1.2^{b}±0. 1	1.2^{b}±0.2
Cultivated wheat (ha)	2.0^{a}±0.1	0.4^{b}±0.0	0.5^{b}±0.0
Wheat production/year (ton)	17.5^{a}±1.1	3.8^{b}±0.2	4.6^{b}±0.4
Cultivated maize (ha)	3.4^{a}±0.3	0.5^{b}±0.0	0.7^{b}±0.1
Maize production/year (ton)	32.5^{a}±2.5	4.6^{b}±0.5	6.7^{b}±0.8
Cultivated clover (ha)	8.8^{a}±.8	0.6^{b}±0.1	0.7^{b}±0.3
Clover production/year (ton)	1087.2^{a}±97.3	64.8^{b}±17.3	79.7^{b}±31.7
Cultivated rice (ha)	1.3^{a}±0.1	0.2^{b}±0.0	0. 2^{b}±0.0
Rice production/year (ton)	12.9^{a}±1.1	1.9^{b}±0.2	1.9^{b}±0.3
Cultivated forage (ha)	1.5^{a}±0.1	0.2^{b}±0.0	0. 2^{b}±0.0
Forage production/year (ton)	98.2^{a}±7.3	14.1^{b}±1.3	11.5^{b}±2.4
Total employee no.	9.5^{a}±0.4	1.7^{b}±0.1	2.9^{c}±0.1

*Means, in the same row, followed by different superscripts differ significantly (P≤0.05).
**hectare(ha) =10000 m^2.

clusters cultivated wheat and rice for family use during the year. In addition, the by-products of wheat and rice crops were used for animal feeding. This result agrees with previous results [19] showing that farmers raising buffaloes cultivate their land with clover and maize forage to sustain milk production.

Table **4** presents buffalo farms production and reproduction performances. Total milk yield ranged from 1651 kg, in CL3, to 2110 kg, in CL1 and lactation length ranged from 208 days, in CL3, to 245 days, in CL1. Number of completed parities reflects the productive life of buffaloes. Farmers in CL1 kept buffaloes up to the sixth parity on average, while in CL2 farmers kept buffaloes until the fifth parity and the fourth parity in CL3. FAO [2] stated that buffaloes milk yield per lactation ranged between 1500 and 4500 kg. A high buffalo total milk yield can be obtained when care is taken in management and feeding [20]. Daily milk yield ranged from 6.8 kg/day in CL3 to 8.5 kg/day in CL1. Accordingly, Meena [20] stated that buffalo average daily milk yield was 6.01±0.5 kg/day/animal in India.

Table 4: Means*±SE of Production and Reproduction Traits of the Three Clusters of Dairy Buffalo Farms in Egypt

Variable	CL1 N=43	CL2 N=1364	CL3 N=404
	mean ±SE	mean ± SE	mean ± SE
Total milk yield (TMY, kg)	2110^{a}±91.20	1920^{b}±16.19	1651^{c}±29.76
Daily milk yield (kg)	8.54^{a}±0.30	8.00^{b}±0.05	7.80^{b}±0.09
Lactation period (month)	8.04^{a}±0.19	7.83^{a}±0.03	6.84^{b}±0.06
Calving interval (day)	407.85^{a}±8.41	388.37^{b}±1.22	399.86^{b}±2.25
Period from calving to first service (day)	56.16^{a}±3.96	49.42^{b}±0.68	59.40^{a}±1.25
Period from calving to conception (day)	67.74^{a}±5.24	67.88^{a}±0.89	70.89^{a}±1.66
Age at first calving (month)	32.30^{a}±0.68	31.79^{a}±0.13	31.43^{a}±0.26
No. of service per conception	1.55^{a}±0.10	1.64^{a}±0.18	1.55^{a}±0.03
No. of parities	6.02^{a}±0.38	5.19^{b}±0.07	4.46^{c}±0.13

*Means, in the same row, followed by different superscripts differ significantly (P≤0.05).

Table 5: Mean* ± SE of Yearly Buffalo Farm Products of the Three Clusters of Buffalo Farms in Egypt

Variable	CL1 N=43	CL2 N=1364	CL3 N=404
	mean ± SE	mean ± SE	mean ± SE
Milk production/year (ton)	160.31^{a}±4.49	3.99^{b}±0.79	5.58^{b}±1.46
Butter production/year (kg)	409.13^{a}±58.12	211.99^{b}±10.32	152.02^{b}±18.96
Cheese production/year (kg)	920.53^{a}±130.81	483.06^{b}±23.23	351.97^{b}±42.68
Milk Sales/year (ton)	156.22^{a}±4.41	1.85^{b}±0.79	4.01^{b}±1.46
Meat production/year (kg/live weight)	4167.86^{a}±207.78	99.63^{b}±36.46	131.44^{b}±66.99

*Means, in the same row, followed by different superscripts differ significantly (P≤0.05).

Lactation length in the three clusters ranged from 208 to 245 days. Average lactation length in the present study is lower than that previously reported in India [20]. The authors showed that the buffalo overall lactation length in the studied area was 299.91±5.01 and 276±14 days, respectively. Lactation length was affected, mainly, by parity. Singh [21] has shown a positive correlation between parity and length of lactation in Nilli-Ravi buffalo. The number of completed parities ranged from 4.5 parity in CL3 to six parities in CL1. In general, the number of completed parities is a good indicator of the quality of the management of buffalo herds and it is correlated with the feeding and reproductive strategies of the farm [22].

Table **5** shows the buffalo farms productions. The main product was fresh milk. Farmers in CL1 sold about 97% of milk produced yearly as fresh milk followed by farmers in CL3 (72%) and CL2 (46%). About 100% of the farmers in CL2 and 40% of farmers in CL3 manufactured milk products. The reason is that farmers are seeking added value to the low milk price by selling processed products (e.g. butter and cheese).

General Features of the Clusters

CL1 had lowest size with only 43 farms, mainly, located in three delta governorates (El-Behira, El-Sharkia and El-Quliubia). Farms had a good availability of facilities. The management practices were the highest when compared with farms in the other two clusters. CL1 was the highest in land size and animal holding size. Land possession ranged from zero to 92.4 ha. This cluster contained medium and large size herds of buffalo (from 6 to 680 buffalo heads). Cattle possession in this cluster ranged from zero to 500 heads. Management and nutrition system practices in CL1 ranged from medium to high. Some farmers use milking machine. About 98% from the farmers in cluster1 sold part of their milk production as a fresh milk and 27% of framers process part of milk production to dairy products. About 98% of those farmers using total mixed ration (TMR) in animal feeding.

CL2 was the highest, with 1364 farms, mainly, located in all governorates. The availability of facilities was comparatively low. The management practices were the lowest in comparison with farms in other clusters. CL2 was the lowest in land and animal possession. Land possession ranged from zero (landless) to 15.1 ha. This cluster involved small and medium size herds of buffalo (from 1 to 60 buffalo heads). Cattle possession in this cluster ranged from zero to 120 heads. Management and nutrition system practices in the CL2 were relatively from low to medium. All farmers use hand milking. About 76% from the farmers in CL2 sold their milk production as a fresh milk and 24% of the framers sold dairy products only. About 93% of the framers in this cluster process milk to dairy products.

CL3 was the midway between CL1 and CL2, with 404 farms absent mainly in four governorates (EL-Quliubiya, EL-Fayoum, Kafer EL-Sheikh and Beni-suef). The availability of facilities was relatively low to medium. The management practices were medium in comparison with other farmers in CL1 and CL2. CL3 was medium in land and animal possession. Land possession ranged from zero to 13.9 ha. This cluster contained small and medium size herds of buffalo (from 1 to 50 buffalo heads). Cattle possession in this cluster ranged from zero to 40 heads. Management and nutrition system practices in the CL3 were relatively medium. All farmers use hand milking. About 86% from the farmers in CL3 sold their milk production as a fresh milk and only 14% of the framers sold dairy products only. About 82% of the framers in this cluster process milk to dairy products.

The three clusters were mixed crop/livestock production systems. [23] stated that, in developing countries, smallholder farming systems could be considered as mixed crop/livestock production systems. The inputs of this system are derived from the household and whose outputs contribute to household needs. Common definitions of smallholder livestock are also derived by [23]. Those authors defined small holder livestock as having less than a certain number of livestock (e.g. < 10 unit of tropical livestock, an animal equivalent of “250 kg” live weight) or a certain land size (< 5 ha). From this point of view, the second and third clusters could be considered as one system which is small holder farming system (mixed crop/livestock production systems). This system has inadequate infrastructure and, poor management and low production level. This system can be considered as the most common buffalo farming system in Egypt. [24] stated that the dominant farming system in most developing countries practice was both crop/livestock production. The same authors mentioned that the small mixed farms production is low and could be raised by developing the skills of farmers and providing them with modern farm technology to enhance the utilization of their limited resources. Improving feeding and management system for buffalo farms, especially, in small farm holders for higher milk production and better reproductive efficiency is necessary [25].

Tabana A, 2000 [3] abstracted that the mixed crop/livestock production system is the main system of livestock production, in Egypt, with a semi-intensive or semi-commercial trend. The three different production systems in the current study need to be developed, because they lack in farm facilities, low feeding management system and low productivity. The development plans need to take this diversity and common features into account with other things like economic and social aspects [18].

CONCLUSION

The current study demonstrates how diverse buffalo dairy production systems in Egypt are. Three different production systems were characterized and found significantly different in many aspects. This confirms the need for different strategic plans which take this systems variability into consideration for effective and sustainable development. Social and economic aspects should receive further complementary research.

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