Iranian Journal of Applied Animal Science

Improve the Efficiency of Dairy Farms through a Typology Based on Dietary Management, in Central Macedonia Region, Greece

Research Article

I. Mitsopoulos[1*], V. Dotas[2], M. Tsiouni[1], A. Pavloudi[1], D. Kyrtsoudis[1] and D. Gourdouvelis[2]

[1] Department of Agriculture, School of Geoscience, International Hellenic University, Thessaloniki, Greece
[2] Department of Animal Production, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

Received on: 22 Jan 2022
Revised on: 3 May 2022
Accepted on: 27 May 2022
Online Published on: Dec 2022

*Correspondence E-mail: gmitsop@ihu.gr

Online version is available on: www.ijas.ir

ABSTRACT

The purpose of this study was to examine and classify dairy farms in Central Macedonia, Greece, in terms of the applied feeding strategy as well as their main characteristics. The data used in the case study was obtained from 123 dairy cow farms in the area. The data analysis included the categorization of the variables with Categorical Principal Component Analysis (CatPCA) and the clustering of farms by taking into account their dimensions with Two-Step Cluster Analysis (TSCA). Multinomial Logit (MNL) was used to examine the main characteristics of the emerged types of farms. The "average" Central Macedonian cow farms and the majority of farms have a 46.5% chance of being in the "efficient" cluster, 37.1% in the "inefficient" cluster, and 15.4% chance of being in the "semi-efficient" cluster. The results of the analysis indicated that the majority of farmers provide rational diets. However, in some cases where management practices (such as groupings, etc.) are not applied according to the nutritional requirements of cows, mainly metabolic diseases but also reproductive problems occur, which have a direct impact on the productivity of the farms.

KEY WORDS dairy farms, Categorical Principal Component Analysis, Two-Step Cluster Analysis, multinomial logit.

INTRODUCTION

In Greece, dairy cattle farming is an important sector of animal production. Among all livestock farming activities, it is the most land-dependent. This dependence of the dairy sector on areas cultivated for feedstuffs and pastures also creates intense competition as far as it concerns production factors with other sectors of animal production. In terms of production, size constitutes 19.2% of the Gross Product of animal farming in Greece, and 26.7% of cow farming's Gross Profit, including cattle farming (Hellenic Ministry of Rural Development and Food, 2019). In 2010, 4531 dairy farms in Greece had more than 50 cows, and 144000 cows were raised, but in 2019, these numbers have dropped to 3263 farms, with the number of dairy cows (85628) decreasing significantly (ELSTAT, 2013; EUROSTAT, 2019). During this decade, milk production remained relatively steady (from 680000 tons in 2010 it decreased slightly to 655.00 tons) (ELGO, 2019). The modern Greek entrepreneurship of dairy cow farming is concentrated mainly in the Region of Central Macedonia where there is 33.9% of the country's farms (826 farms over 50 cows), raise 42.5% of the total cow population (Mitsopoulos, 2012). Parameters such as breeding, nutrition, genetic improvement, and farm management have made significant progress in recent ten years, contributing to the increased productivity of dairy farms. Forming rational diets for each productive animal category has resulted in a considerable increase in production, a considerable improvement in milk quality, and also the promotion of animal health, always alongside an improvement in animal management conditions (Zerbas *et al.* 2004). The proper dietary farm management, and the improvement in the utilization of nutrients by the cows, have also become important factors for the economic viability of farms, as the price of feedstuffs in the EU and Greece has increased considerably in recent years (Kidane *et al.* 2018). In addition, using rational diets for dairy cows can reduce greenhouse gas emissions, where less food consumption and less gastrointestinal fermentation are key determinants of the environmental sustainability of dairy farms (Overgård-Lehmann *et al.* 2019). Using rational feeding management practices can significantly reduce the environmental footprint of Greek dairy production systems, reduce their production costs, and, thus, increase their viability (Kleftodimos *et al.* 2022). The feed cost of dairy cows represents 50-60% of the total production cost, making it the largest category of variable costs (Amaral-Philips, 2010). According to Sniffle *et al.* (1993), grouping cows based on their nutritional needs and yields results in maximizing production and minimizing feeding costs.

Grains and other feedstuffs, used in diets

Roughage and concentrated feeds are the two main components of dairy cow diets.. Roughage includes corn silage, grasses, hays of various legume plants (alfalfa, vetch, field pea), whole cereal grain plants (wheat, barley, oat, etc.) hays of those cereal plants, etc. Corn silage and alfalfa hay are the main roughage feeds that are being used in dairy cow diets (Owens, 2014). The hays derived from large-scale-industrial agricultural cultivation show great feeding potential, are suitable for consumption by ruminants and can be included as roughage in their diet (Hadjipanayiotou and Economides, 1997). The use of these products mainly applies to cows undergoing a dry period, to heifers, and a lesser degree to milked cows.

Concentrated feeds include corn, barley, and wheat seeds, wheat bran, soy meal, cotton seeds, rapeseed meal, etc. Of equal importance, in dairy cow diets, is the utilization of agricultural industry by-products such as sugar beets, pulps, molasses, and ground placentae of various oil-producing plants (sunflower meal, cottonseed meal) and byproducts of bioethanol production (Eastridge, 2006; Schingoethe *et al.* 2009). Moreover, the dairy cow diets include industrially produced mixes (TMR, total mixed rations), feed additives, biotechnology products, and vitamins and trace elements (Karalazos, 1997). Animal feed supplements and additives can improve the digestibility of animal feeds, improve the quality of milk produced (protein, fat content), promote growth (as average daily weight gain) in young animals (calves), and prevent metabolic disorders and diseases (Bicknell and Noon, 1993; Hutjens, 2011). A critical period in the nutrition and metabolism of dairy cows is when they begin milk production, which in conjunction with birth weakens the immune system (Bondan *et al.* 2021).

Health problems related to nutritional imbalances, deficiencies, and inappropriate management of cow nutrition programs are known as metabolic diseases. Management of cows in the dry period plays an important role in the prevention of metabolic disorders before and after calving (Mitsopoulos, 2012). In dairy cows, metabolic disorders after calving can negatively affect their health during the milking period (Siafakas *et al.* 2019).

Providing rations-cows management

Ruminant diets should always provide balanced nutrition to animals and promote and regulate the natural development of symbiotic phenomena inside the rumen. This can be achieved with the careful selection of the correct roughage or silage and its relation to the concentrated feeds of the diet (Bali *et al.* 2007). Even though roughage is always included in ruminant diets, these diets are considered two-part (mixed) diets (Zerbas *et al.* 2004).

Due to the limited availability of pastures and the high price of roughage, the majority of cow farms in Greece are stabled, and the provided feed is divided into basic and supplementary diets.

Basic diets provide animals with the nutrients they need for survival (basal metabolism) and a small portion of their milk production needs (5 to 15 liters per day). Occasionally concentrated feeds can be added to roughage.

Modern dairy farming utilizes the Total Mix Ration (TMR) system. Grant and Albright (2001) concluded that dairy cows should be divided into three groups during their milking fed different diets in proportion to their traits and milk yield to maximize feed efficiency. This practice is, however, highly dependent on the size of the farm, the means, and resources available, as well as the farm's unique environment (Siafakas *et al.* 2019).

All of the above are parameters of successful dairy farm nutritional management, and they are therefore used as variables for the cluster analysis. The main aim of this study was the establishment of a typology for dairy cow farms in the Region of Central Macedonia, regarding the applied feeding system, as well as the characteristics of each category of a farm. This typology should reduce the cost of feeds, meet the nutritional needs of animals and reduce metabolic and reproduction problems. The paper is organized as follows: section two presents the methodology, section three presents the results and discussion, and finally section four the conclusions.

MATERIALS AND METHODS

Data for the analysis were gathered from a sample of 123 suckler cow farms in Central Macedonia, Greece. The data were collected by a questionnaire and through personal interviews with the owners of the dairy cow farms, from September 2019 to August 2020, using a carefully laid out questionnaire, through personal interviews carried out in the field. The size of the sample was randomly selected through a stratified random sampling process (Farmakis, 2002), where each group consisted of a single Regional Unit of Central Macedonia.

The questionnaire completion time was estimated at 40 minutes per dairy cow farm. A pre-test survey took place, to ensure readability, and questions were adjusted when necessary. The pre-sampling procedure was conducted in a small sample of ten suckler cow farms.

The particular area is situated in the northern part of the country and shares borders with Bulgaria and the Republic of North Macedonia. Central Macedonia consists of seven Regional Units (Imathia, Thessaloniki, Kilkis, Pella, Pieria, Serres, Halkidiki). (Figure 1, source: “Hellenic Military Geographical Service”).

Figure 1 Map of Greece, where suckler cow farmers were surveyed

This area was specially selected because almost half of the country’s milk yield is produced there (ELGO, 2019). Moreover, in the proximity of the area, all types and sizes of farms can be observed, from the very small, family-run farms, to the large modernized (equipped with robotic milking parlors) ones. According to ELGO (2019), in the area of Central Macedonia, 3,140 cow farms were operating and producing 520442 metric tons of milk, which makes up for 48% of the total milk yield of the country.

The analytical framework employs the Categorical Principal Component Analysis (CatPCA) to reduce the original set of variables describing milking practices into a smaller set of uncorrelated components that represent most of the information found in the original variables. Using the components generated with the CatPCA method, the sampled farms are grouped into clusters/groups with common characteristics, applying the Two-Step Cluster Analysis (TSCA). In the CAtPCA, only those variables whose loading coefficients were greater than or equal to 0.5 were considered predictive variables in the categorical regression model (Çamdevýren *et al.* 2005). In the CATREG procedure, non-significant scores were excluded from the model by a "step-by-step" method of selecting variables (Pastrana *et al.* 2022). TSCA constitutes an extension of a typical cluster analysis aiming at the determination of clusters that share common characteristics based on categorical and/or continuous variables. For each cluster, the main characteristics of the farmers, as well as farm characteristics are investigated through the estimation of a Multinomial Logit (MNL) model (Greene, 2003), which enables a regression analysis with a categorical dependent variable.

RESULTS AND DISCUSSION

Table 1 presents the sum of all the eigenvalues given a total variance, in the context of dairy cow nutrition. The analysis resulted in three dimensions with the eigenvalues of 3.326, 2.682, and 1.459, of whom all can be accepted as none of their values are valid 1. A-Cronbach's (credibility) coefficient remains very high when considering all dimensions (0.938), relatively high for dimensions 1 and 2 (0.758 and 0.679 respectively), and acceptable for dimension 3 (0.341). The model represents 57.43% of the variance.

Table 2 presents the individual weight for every variable in every dimension, the examination of whom allows the identification of the dimensions. In the first Dimension the variables “Appearance of Acidosis” (0.799), “Appearance of Ketosis” (0.737), “Appearance of Abomasum displacement” (0.735), and “Appearance of Dairy Fever” (0.733), present the highest values, so this dimension was named “Metabolic Diseases”.

The second dimension presents higher values for the “Employment of Nutritionist” (0.636) and “Feeds chemical analysis” (-0.606) variables (Table 2). So, this dimension was named “Diet Formulation”, as it refers to the person in charge of rations composition and formulation.

The third dimension presents higher values for the “Water chemical analysis” (0.622) and “Origin of Water” (0.613) variables (Table 2). So, this dimension was given the name “Water Management”, because it is closely related to the water that is provided to the animals and its chemical analysis.

Table 3 presents the results of the Two-Step Cluster Analysis (TSCA), on the dairy cow farms of the sample, regarding the cow diet.

Table 1 Reliability analysis of nutrition-related categorical analysis results

Dimension	A-cronbach (coefficient)	Shown variance	
		Total (Eigenvalues)	% of variance
1	0.758	3.326	25.58
2	0.679	2.682	20.63
3	0.341	1.459	11.22
Total	0.938	7.467	57.43

Table 2 Dimensions and values of dairy cow nutrition variables

Variables	Dimensions			Cumulative variance
	1	2	3	
Roughage/concentrated feeds ratio	-0.299	-0.460	-0.524	0.576
The appearance of dairy fever	**0.733**	-0.452	-0.281	0.821
Ketosis	**0.737**	-0.515	-0.230	0.861
Employment of nutritionist	0.394	**0.636**	-0.025	0.560
Acidosis	**0.799**	-0.402	-0.021	0.800
Feedstuffs chemical analysis	-0363	**-0.606**	-0.004	0.499
Feedstuffs provision system	-0.531	-0.470	0.006	0.503
The appearance of abomasum displacement	**0.735**	-0.277	0.097	0.627
Dry matter excess	0.391	0.490	0.175	0.424
Milking cows grouping	-0.330	-0.488	0.263	0.416
Dry period cows grouping	-0.198	-0.475	0.425	0.455
Origin of water	0.274	-0.093	**0.613**	0.459
Water chemical analysis	0.179	-0.242	**0.622**	0.477

Table 3 Results of the two-step cluster analysis

Clusters	Cluster size		Cow diet dimensions					
			Metabolic diseases		Diet formulation		Water management	
	Number of farms	Percentage %	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
1	53	43.1	0.733	0.457	0.043	0.565	-0.450	0.650
2	44	35.8	-0.931	0.646	0.750	0.710	0.269	0.716
3	26	21.1	0.002	0.990	-1.354	0.703	0.458	1.546
Total	123	100.0	0.001	1.004	0.001	1.004	-0.001	1.005

Three clusters have been identified as a result of the analysis. The first cluster includes 53 farms (43.1%), the second 44 farms (35.8%), and the third 26 farms (21.1%). The formation of the clusters was based on the variables formed through Categorical Principal Component Analysis (CatPCA) of the “Metabolic Diseases”, “Diet Formulation” and “Water Management” dimensions.

Identification of clusters is based on the means and signs of the three dimensions mentioned above (Table 4), as well as the occurrence frequency of the variables that present the highest values in every dimension that resulted through CatPCA (Table 4).

As far as the first cluster is concerned the positive mean of the “Metabolic Diseases” variable, as well as the negative mean of “Water Management” suggest a dimension. As such, farms in this cluster present little, if any, metabolic diseases like dairy fever, ketosis, acidosis, and abomasum displacement (Table 4). Water consumed in these farms originates from the municipal water network (75.5%) from private water wells, under constant monitoring and evaluation via chemical analyses of the provided water.

Taking into consideration all the above, farms in this cluster are considered “Efficient”, because they do not present many cases of metabolic diseases. Many researchers came to similar conclusions, regarding the reduction of metabolic disease cases, during the starting period of milk production, according to feed serving, the balance between roughage and concentrated feeds, as well as dry period management of the cows (Goff, 1999; Ostergaard and Grohn, 2000; Espositoa *et al.* 2014).

Regarding the second cluster, positive means are observed for the “Diet Formulation” and “Water Management” dimensions and negative for the “Metabolic Diseases” one.

Diets are formulated or supervised by specialists (nutritionist or animal scientists) (79.5%) and chemical analysis of the used feed is carried out by 63.6% of the farms. However metabolic disease cases are common.

Table 4 Analysis of the frequencies of variables describing feeding practices

Item	Cluster 1 (53 farms)	Cluster 2 (44 farms)	Cluster 3 (26 farms)	Total (123 farms)
Dimension1 "Metabolic Diseases"				
Milk fever				
Yes	0	39	4	41
No	53	5	22	82
Appearance of acidosis				
Yes	4	37	2	45
No	49	7	24	78
Appearance of ketosis				
Yes	2	42	7	46
No	51	2	19	77
Appearance of abomasum displacement				
Yes	9	35	7	51
No	44	9	19	72
Dimension 2 "Diet Formulation"				
Feed chemical analyses				
Yes	27	17	5	49
Some times	11	11	2	24
No	15	16	19	50
Employment of nutritionist				
Scientist-specialist (veterinarian, animal scientist)	49	35	8	92
Farm owner	4	9	18	31
Dimension 3 "Water Management"				
Water chemical analyses				
Yes	51	41	12	104
No	2	3	14	19
Origin of water				
Municipal network	40	35	13	88
Private water well	13	9	13	35

Table 5 Variables used in the multinominal logit analysis

Variables	Description
Farm Pro	Farm profile regarding feeding model (1="Efficient" 2="Inefficient" 3="Semi-efficient")
TMF	Total microbial flora
SCC	Somatic cell count
GP	Gross Profit (€/cow)
Yield	Average milk yield (kg/cow/year)
Cows	Number of cows
Farm Edu	Farmer education (1=Yes, 2=No)
Educ	Educational level (1=primary school, 2=secondary sch., 3=advanced Sec. sch, 4=private profession establishment sch, 5=government profession establishment sch, 6=technical educational institutions, 7=university, 8= masters of science)
Age	Age (in years)
Abort	Frequency of abortions in a farm (1=never, 2=rarely, 3=sometimes, 4=frequently, 5=very frequently)
Lam	Frequency of lameness in a farm (1=never, 2=rarely, 3=sometimes, 4=frequently, 5=very frequently)
MetaDis	Frequency of metabolic disease in a farm (1=never, 2=rarely, 3=sometimes, 4=frequently, 5=very frequently)
Mastitis	Appearance of mastitis (1=<10%, 2=>10%)
HePlan	Implementation of health plan (1=Yes, 2=sometimes, 3=No)
Group	Grouping of cows (1=Yes, 2=No)

As far as water management, water is supplied by the municipal network and chemical analyses are undertaken in most cases where private water wells are used. Farms in this cluster are considered "Inefficient" because they do not fare well against metabolic disease cases (acidosis, alkalosis, abomasum displacement), even though they apply modern feeding methods. Those metabolic disease cases are interconnected with the bias of the farms towards upscaling productivity. The study by Ingvartsen (2006) concludes that improving genetic selection and management of cows will increase milk production, but there is the risk of increasing metabolic disease outbreaks and reducing productivity in the long run.

Farms of the third cluster reveal a negative mean for the dimension of “Diet Formulation” (and nutritional service). The main characteristic of the farms in this cluster is the diet formulation and preparation by the farmer himself (69.2%) without any necessary chemical analyses on rations or feedstuffs (73.1%). These farms are considered "Semi-effective", although metabolic diseases do not occur often, this is not due to the use of nutritionists’ knowledge. Having formed the three clusters, the next step was to determine their basic characteristics, utilizing a Multinomial Logit model, on which the dependent variable consists of three distinct results (its partaking in one of the three clusters). The described variables used in the logit model are presented in Table 5.

The distinct values, the dependent variable, exhibited in each case, correlate to the clusters formed. The estimations of all the models were conducted using the econometric package LIMDEP 8.0 NLOGIT 3.0.

"Mastitis", "FarmEdu", "Cows" and "Yield" variables were considered independent variables in terms of diet Cluster 3 "Semi-efficient" served as a basis for comparison. The results of the model evaluation are presented in Table 6, which derives the variables’ chance of being sorted in each cluster. However, the exact effect of each variable in its chance of being sorted can be outlined by taking into consideration the marginal results of the researchers, presented in Table 7. In all cases, the model has descriptive potential, since the LRT control for all factors produces an interpretation that is not zero, and the McFadden R2 interpretation, even though it is low (0.110), is nevertheless a valid interpretation.

Table 6 Multinominal logit analysis results regarding feeding I

Variables	**Factor**	**Standard error**	**Wald-statistic**
Cluster 1 **“Efficient”**			
Stable term	0.51444	1.37464	0.374
Mastitis	0.34163	0.44086	0.775
Farm Edu	-1.71865	0.59400	-2.893
Cows	-0.00238	0.00145	-1.639
Yield	0.00032	0.00014	2.346
Cluster 2 **“Inefficient”**			
Stable term	-0.70755	1.56649	-0.452
Age	1.20677	0.54188	2.227
Farm Edu	-1.93767	0.64887	-2.986
Yield	-0.00221	0.00148	-1.495
GP	0.00029	0.00014	2.045
Log-likelihood function	-115.838		
Likelihood ratio test	28.84*** (8 d.f.)		
McFadden R^2	0.111		

Table 7 Multinominal logit analysis results regarding feeding II

Variables	**Factor**	**Standard error**	**Wald-statistic**
Cluster 1 **“Efficient”**			
Stable term	0.25285	0.26387	0.958
Mastitis	-0.12723	0.09339	-1.362
FarmEdu	-0.08752	0.13521	-0.647
Cows	-0.00021	0.00023	-0.901
Yield	0.30024*10^-4*	0.16226*10^-4*	1.850
Cluster 2 **“Inefficient”**			
Stable term	-0.25555	0.27512	-0.929
Mastitis	0.22125**	0.10103	2.190
FarmEdu	-0.14928	0.13425	-1.112
Cows	-0.95548*10^-4*	0.00022	-0.441
Yield	0.10003*10^-4*	0.15356*10^-4*	0.651
Cluster 3**“Semi-efficient”**			
Stable term	0.00269	0.17289	0.016
Mastitis	-0.09402*	0.05602	-1.678
FarmEdu	0.23680***	0.07448	3.179
Cows	0.00030*	0.00017	1.747
Yield	-0.40027*10^-4*	0.15649*10^-4*	-2.558

Farmers in the "Efficient" cluster tend to have higher milk yields, with a chance of 0.0030% for every additional kilogram of milk per cow to participate in the cluster.

Owners of "Efficient" farms have higher average milk production, with a probability of participation of 0.0030% for every additional kilogram of milk produced.

Dairy cow farms in the “Inefficient” cluster, are more likely to exhibit higher percentages of mastitis, and, in the case that these occurrences surpass the 10% mark, their chance to participate in the cluster is lessened by 22.1%.

Farms in the “Semi-efficient” cluster tend to achieve lower average milk yield (with an increased chance to partake by 0.0040% for every less kg). Moreover, those farmers tend to own a larger number of cows (which increases the probability to participate by 0.03% for every extra cow), they do not have sufficient agricultural education (marginal result 23.7%) but they exhibit fewer cases (smaller percentages) of mastitis. According to the evaluated model, the probability of an average dairy cow farmer in Central Macedonia being classified in every cluster is 47.5% for the "Efficient" cluster, 37.1% for the "Inefficient" cluster, and 15.4% for the "Semi-Efficient" cluster. The above observations closely reflect the current situation in dairy farming. When it comes to farming management practices, feeding, and nutritional management, there is no question that the average is acceptable.

CONCLUSION

Dairy cow farming is a capital-intensive economic activity in Central Macedonia. Large farms with modern equipment, genetically improved animals, and access to the latest technologies ensure an acceptable financial return and notable sustainability in the new era of intensified competition. The results of the analysis suggest that the majority of farmers applied rational diets, which comes in agreement with the findings of Siafakas *et al.* (2019). However, in some cases, where management practices, such as cow groups forming according to the animals needs, are not taking place, metabolic disease cases, as well as reproduction problems appear, causing severe problems, and crippling the farm’s productivity. In some cases farmers compose their rations without considering how to fulfill the animals nutritional requirements (or even due to miscalculations in the process). This mainly results in the provision of insufficient diets, resulting in the reduction of animal productivity and increased feeding costs subsequently. The latter is closely related to the increase in production costs, reducing the farm’s throughput. There are several limitations to this study, including the limitation of the number of farms included in the analysis and the geographic area in which the study takes place, which limits our ability to generalize our results and extend them across the country. Even so, the analysis is still valid. Future research should be expanded into all regions where suckler cow farms exist in future given these considerations.

REFERENCES

Amaral-Phillips D. (2010). What does it cost you to feed your cows? Kentucky University Cooperative Extension. WebMD. https://afs.ca.uky.edu/files/what_does_it_cost_you_to_feed_your_cows.pdf Accessed Oct. 2021.

Bali G., Karadjole T., Mačešić N. and Karadjole M. (2007). A brief review of aetiology and nutritional prevention of metabolic disorders in dairy cattle. *Vet. Arhiv.* **77(6),** 567-577.

Bicknell E. and Noon T. (1993). Neonatal calf diarrhea. Animal Care and Health Maintenance. WebMD. http://ag.arizona.edu/arec/pubs/rmg/4%20animalcare&healthmaintenance/ 25%20neonatalcalfdiarrhea93.pdf.Accessed Oct. 2021.

Bondan C., Folchini J.A., Guimarães L., Noro M., Zanella R., Alves L.P., Fontaneli R.S. and Gonzalez F. (2021). Milk yield and composition in dairy cows with post-partum disorders. *Arq. Bras. Med. Vet. Zootec.* **73(3),** 639-646.

Çamdevýren H., Demýr N., Kanik A. and Keskýn S. (2005). Use of principal component scores in multiple linear regression models for prediction of Chlorophyll-a in reservoirs. *Ecol. Modell.* **181,** 581-589.

Eastridge M. (2006). Major advances in applied dairy cattle nutrition. *J. Dairy Sci.* **89(4),** 1311-1323.

ELGO (Greek Agriculture Organisation). (2019). WebMD. http://www.elgo.gr Accessed Jan. 2022.

ELSTAT (Greek Statistical Authority). (2019). WebMD. http://www. statistics.gr (In Greek)Accessed Jan. 2022.

Espositoa G., Irons P., Webb E. and Chapwanya A. (2014). Interactions between negative energy balance, metabolic diseases, uterine health, and immune response in transition dairy cows. *Anim. Reprod. Sci.* **144,** 60-71.

EUROSTAT. (2019). WebMD. http://epp.eurostat.ec.europa.eu/portal/page/portal/ agriculture/data/database Accessed Jan. 2022.

Farmakis N. (2002). Introduction to Sampling. Publications A & P. Hristodoulidhi, Thessaloniki, Greece.

Goff J. (1999). Dry cow nutrition and metabolic disease in parturient cows. *Adv. Dairy Technol.* **11,** 63-70.

Grant R. and Albright J. (2001). Effect of animal grouping on feeding behavior and intake of dairy cattle. *J. Dairy Sci.* **84,** 156-163.

Greene H. (2003). Econometric Analysis. Prentice Hall International Editions. Upper Saddle River, New Jersey.

Hadjipanayiotou M. and Economides S. (1997). Assessment of various treatment conditions affecting the ammoniation of long straw by urea. *Livest. Res. Rural. Dev.* Available at: https://www.fao.org/ ag/aga/agap/frg/lrrd/lrrd9/5/milt952.htm.

Hellenic Ministry of Rural Development and Food. (2019). Development of cattle farming in dairy and meat production. WebMD. http://www.minagric.gr/greek/ENHM_FYLADIAZWIKHS/ENHM_FYL_zoiki.htm Accessed Aug. 2021.

Hutjens M. (2011). Feed additives in dairy nutrition and management. WebMD. http://livestocktrail.illinois.edu/dairynet/paperDisplay.cfm?ContentID=642 Accessed Nov. 2021.

Ingvartsen K. (2006). Feeding-and management-related diseases in the transition cow physiological adaptations around calving and strategies to reduce feeding-related diseases. *Anim. Feed Sci. Technol.* **126,** 175-213.

Karalazos A. (1997). Applied Ruminant Nutrition. University Traditions. AUTh Publications Service, Thessaloniki, Greece.

Kidane A., Øverland M., Mydland K.T. and Prestløkken E. (2018). Interaction between feed use efficiency and level of dietary crude protein on enteric methane emission and apparent nitrogen use efficiency with Norwegian Red dairy cows. *J. Anim. Sci.* **96(9),** 3967-3982.

Kleftodimos G., Kyrgiakos L.S., Kleisiari C., Tagarakis A.C. and Bochtis D. (2022). Examining farmers' adoption decisions towards precision-agricultural practices in Greek dairy cattle farms. *Sustainability*. **14(1),** 411-419.

Mitsopoulos I. (2012). Study of livestock profiles management of Central Macedonia in relation to the milk production, milk quality, and environment. Ph D. Thesis. Democritus Univ., Thrace, Greece.

Ostergaard S. and Grohn Y. (2000). Concentrate feeding, dry-matter intake, and metabolic disorders. *Livest. Prod. Sci.* **65,** 107-118.

Overgård-Lehmann J., Mogensen L. and Kristensen T. (2019). Extended lactations in dairy production: Economic, productivity and climatic impact at herd, farm and sector level. *Livest. Sci.* **220,** 100-110.

Owens F. (2014). New technologies in forage varieties and production. WebMD. https://www.semanticscholar.org/paper/New-technologies-in-forage-varieties-and-Owens-Eastridge/de23fcb397d4977e133b26ebb24d9da7a44b0957 Accessed Sep. 2021.

Pastrana C., Navas González F., Pizarro Inostroza M., Arando Arbulu A., Delgado Bermejo J. and Ruiz Aguilera M. (2022). Study of variability of cognitive performance in captive fallow deer (Damadama) through g and c factors. *J. Vet. Behav.* **47,** 70-85.

Schingoethe D., Kalscheur K.F., Hippen A.R. and Garcia A.D. (2009). Invited review: The use of distiller's products in dairy cattle diets. *J. Dairy Sci.* **92,** 5802-5813.

Siafakas S., Tsiplakou E., Kotsarinis M., Tsiboukas K. and Zervas G. (2019). Identification of efficient dairy farms in Greece based on homegrown feedstuffs, using the Data Envelopment Analysis method. *Livest. Sci.* **222,** 14-20.

Sniffle C., Beverly R., Mooney C., Roe M. and Skidmore A. (1993). Nutrient requirements versus supply in the dairy cow: strategies to account for variability. *J. Dairy Sci.* **76,** 3160-3169.

Zerbas G., Kalaisakis P. and Feggeros K. (2004). Farm Animal Nutrition. Stamouli Publications, Athens, Greece.