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Classifying Milk Yield Using Deep Neural Network

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Authors' Contribution
MB and KKÇ designed and conducted the study, analyzed the data and wrote the manuscript. AB collected and recorded the data. KKC applied the material and method. All authors helped to interpret results.

Key words
Deep neural network, Milk yield, Lactation, First calving, Classification

ABSTRACT

This study aim to describe the impact of the number of lactation, lactation days, age at first calving and breeding, and number of insemination (ratio) on cattle milk yield (last seven days in average). For this purpose, the milk yields of 156 Holstein Friesian cattle were investigated according to different age, lactation, calving and insemination associated parameters. Optimum values in literature were organized by an expert in establishing classification data. The expert determined the classes of the outputs data (average milk) through the input data (calving age, milking days, number of lactation and insemination). Applying deep neural networks, we established that average classification success of the system was 69.23% as a result of 6-Layers Cross-Verification Test which is commonly used in the literature for small datasets. In these datasets, it was found that 84 animals had GOOD, 39 animals carried POOR and 33 animals possessed MEDIUM milk yield. It was revealed that there is provided animal raising conditions by 53,84% (84/156*100); therefore, there is no professional farm management. Taken together, the finding show that there is a need of additional controlled management on animal raising and mistakes of the enterprise need to be recovered as early as possible.

INTRODUCTION

The number of bovine animals in Turkey surpass to 13 million in 2015, and gradually increased to 14 million in 2016 and 15.9 million in 2017 (TSI, 2019). While the number of animals has increased to meet the needs of an increasing population, these bring additional challenges in terms of management, resources and animal welfare issues. Therefore, there is a need to increase the yield per animal by suitable maintenance, management and nutritional plans. In addition these measures, it is imperative to consider specific factors such as animal breeding to increase the meat and milk yield per animal. If the genetic structure of the animal is weak, the yield increase cannot exceed a specific limit regardless of the nature of the conditions and other parameters. Therefore, the breed of animals is of paramount importance in line with the chief goal to be acquired. A hybrid breed, Holstein, provides 6.000-9.000 kg of milk in Turkey; Brown Swiss (Montofon) gives 5.000-7.000 kg of milk; and Simental gives 5000-7000 kg of milk (Agriculture, 2019). These figures underlie the importance of appropriate genetic background in enhancing productivity of the livestock.

Optimum conditions such as heat, damp and wind speed for each of the animal breed are to be set appropriate. Owing to less feed consumption and more water use in hot air conditions, a decrease in milk yield may have resulted in cattle. On the other hand, animals consume more feed in cold weather to increase their body temperatures. Therefore, major part of the feed is exploited to adjust their body temperature (Agriculture, 2019).

The optimal temperature for dairy cows is between 5 and 15℃. Similar to body temperature, several different factors such as physiological state (age, number of lactation, and number of days in lactation) may affect the milk yield (Torshizi, 2016). Under these circumstances, the yield can be enhanced by providing required conditions to the animals. For another research, the crucial environmental factors that have no genetic effect on the milk yield are lactation phase, calving age, calving season and calving phase (Torshizi, 2016).

First insemination date and insemination period of animals can impose remarkable effects on the milk yield (Ettema and Santos, 2004). It has been revealed that there is less milk yield in the first lactation compared to heifers which are inseminated 700 days before; heifers which are inseminated before 751 days as well as the heifers which are inseminated between 700 and 750 days (Ettema and

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Santos, 2004). It is expressed in economic calculations about calving first-calf that interval of calving first-calf is optimal between 23th and 25th months for a professional animal raising. Farmers can easily achieve related dates if they organize development and feeding of the animals appropriately. This issue is the same for both milk breed and meat breed cattle (Niloforooshan and Edriss, 2004; Wathes *et al*., 2014). Similarly, reproduction features such as first calving age and calving intervals may economically affect the enterprise. Therefore, fertile life and profitability of cows are accountable for these parameters. Animals need to be inseminated for 22.5 and 23.5 months maximum (Do *et al*., 2013) as early calving has negative effects on milk yield, milk yield duration and milk fat percentage (Pirlo *et al*. 2000). If the calving age is early than 20-months or later than 30-months, calving ratio will be lower (Torshizi, 2016). Galiç *et al*. (2005) have studied the effect of age at first calving on milk yield for 305 days in Holstein cattle breeding. Records belonging to Holstein breed in İzmir province in 1996-2000 period showed that an average of first calving age is 27,5 ± 0,09 months and age at first calving significantly affects 305 days milk yield (P<0,05) (Galiç *et al*., 2005).

It has been reported that milk yield is high in heifers whose live-weight is higher. Therefore, Van Amburgh *et al*. (2011) highlighted that the milk breed calves need to grow early. This situation will cause increase in milk yield in yield period and also will avoid reproduction problems (Van Amburgh *et al*., 2011).

The number of lactation also pose impact on milk yield (Ray *et al*., 1992). It is emphasized that animals which are in 4th and 5th lactation carry more milk yield in comparison with the milk yield of animals in the first lactation. Moreover, impregnation rates in animals, which are in the first lactation, are lower. Milk yields of animals are different in spring, summer, autumn and winter months, and milk yield decreases in summer and autumn. There are problems with reproduction and impregnation rates in the spring and summer months (Ray *et al*., 1992). Novak *et al*. (2009) have studied the effects of hot months, lactation phase and a number of lactation on the milk yield. For their findings, milk yields gradually increased from May to June and decreased in December (Novak *et al*., 2009). On the other hand, Bouallegue *et al*. (2013) have reported that milk yield level of cattle was less in summer months.

Vijayakumar *et al*. (2017) have found that there is a relationship between the number of lactation, number of days in lactation, lactation phase-duration and the milk yield. There is observed relation between a number of lactation and the milk yield as well as the milk yield in the 3rd lactation. More milk yield can be observed in the early phase (55th-90th days) of the lactation. In addition, they noticed that milking frequency was significantly effective on the milk yield (3.5 kg/day). They also expressed that more milk yield can be obtained by two milking per day via an automatic milking system in comparison with the traditional system (Vijayakumar *et al*., 2017). Bayrıl and Yılmaz (2017) have noticed that lactation milk yield increases up to 3rd birth and decreases in the 4th. Lactation time increases by decreasing the number of births and, milk yield performance and lactation times of cows which calve in different seasons are similar as well (Bayrıl and Yılmaz, 2013).

Taken together, it is clear that number of lactation, number of days in lactation, calving age, age at first breeding, season and number of insemination (ratio) of dairy cows have different effects on the milk yield. Therefore, an automated system is required to effectively analysis these complex parameters and propose a system to estimate the impact of parametric-specific situations on milk yield. To this end, we first generated a classification data based on the status of parameters. Afterward, the models of these classifications were revealed via Deep Neural Network (DNN)-based computer software. 69.23% success percentage was obtained when training and testing data are analysed. Therefore, it has been seen that the DNN method can be used for milk yield.

MATERIALS AND METHODS

Preparing dataset

In this study, the number of lactation, lactation days, age at first calving and breeding, and number of insemination (ratio) on the milk yield (last seven days average) classification were modelled by deep neural network. Data were collected from 156 Holstein cattle which were in various age groups, different number of lactations and age of the first insemination from one special farm in Cukurova Region. First of all, calving age, milking days, number of lactation, number of insemination, age (month) and average milk yield of animals were utilized in the dataset (Table I).

Different previous studies have exploited these parameters and the general run of these studies relate to the age of insemination for the first is the 15th month, whilst age at first calving is the 24th month (Torshizi, 2016). Otherwise, there may occur metabolic problems in animals which are under or above the related months. The ideal number of insemination and vaccination in husbandry firms is 1. However, this value is affected by different factors such as reproduction power of herd is low when related value exceeds 1.7. There are also studies which express that increasing the milk yield causes a decrease in fertility. The number of lactation and the number of days

Table I. Milk yield classification dataset.

ID	Calving age	Milking days	Number of lact.	Number of insem.	Age (month)	Average milk (7 Days)	Class
1	14.00	21	1	0	23.00	10.4	Medium
2	15.00	25	1	0	24.00	12.6	Medium
3	14.00	19	1	0	23.00	12	Medium
4	23.00	288	2	5	44.00	16.4	Good
5	33.00	432	1	3	42.00	10.9	Poor
6	33.00	330	1	4	42.00	15.6	Poor
7	33.00	437	1	3	42.00	11.1	Poor
8	33.00	431	1	4	42.00	17.1	Poor
9	21.00	136	2	1	42.00	24.7	Good
10	32.00	227	1	2	41.00	21.9	Poor
11	31.00	317	2	4	52.00	17.4	Good
12	31.00	268	2	1	52.00	17.9	Good
13	19.00	22	3	0	52.00	32.3	Good
14	31.00	227	2	2	52.00	26.8	Good
…	….	….	….	….	…	…	…
152	35.00	3	4	0	80.00	12.9	Medium
153	47.00	226	3	2	80.00	23.4	Poor
154	23.00	156	2	0	44.00	26.8	Good
155	34.00	270	4	2	79.00	16.3	Good
156	34.00	228	4	2	79.00	21.5	Good

in lactation are remarkable indicators in milk yield of milking cows. Since the cows in the 1st lactation were still young, they yielded milk less than the cows in the 2nd and 3rd lactation. Milk yield of the animal after the 6th and 7th lactation was less in comparison with the animals in the 2nd and 3rd lactation (Vijayakumar *et al*., 2017). Regarding the number of days in lactation, it was observed that increase in milk yield between 0th and 70th days, the most yield as noticed between 70th and 140th days; a decrease in yield was observed between 140th and 305th days (Görgülü, 2002).

All parameters collected from 156 dairy cattle were grouped in different categories by an expert. Average daily milk yield was reviewed based on the data of first calving age, milking days, the number of lactation, the number of insemination, age (month). This classification was adapted to cluster all parameters into three groups as poor, medium and good (Table I). The dataset presented in in Table I was exploited in the Training and Test data in DNN.

Deep neural networks

Artificial intelligence (AI) is defined as the skills of being fulfilled the duties relating to reasoning, educing, generalization and learning from past experiences by a computer or a computer-controlled machine (Nabiyev, 2005). The concept of Artificial Intelligence that uses imitating behavior and thoughts of people as the base was first brought in literature by activity in USA-Dartmouth (McCarthy *et al*., 2006). Artificial Neural Networks (ANN) applications create a new system by imitating the process of the human brain in classification problems in AI applications (Çevik and Dandil, 2012).

ANN from AI techniques is generally utilized in classification problem and enterain the approaches that endeavour to generate a new system by imitating the human brain. There are learning and decision-making mechanisms based on learned-information in ANN which was established by benefiting from the structure of biological nerve cells in human brain (Çevik and Koçer, 2013).

Deep Neural Network is the feed-forward artificial neural networks that have more than one hidden layers between inputs and outputs. Each of the hidden layers uses the logistics function (this function may be the hyperbolic tangent) to compute the total of inputs. Here, x_j shows the digital status; y_j is the value that is sent to the upper layer (Hinton *et al*., 2012).

$$y_j = logistic(x_j) = \frac{1}{1+e^{-x_j}}, x_j = b_j + \sum_i y_i w_{ij}$$

b_j in equation is the bias value of the layer at j column; i is the bottom layer index value; w_{ij} is the connection weight value from i column to j column. j output layer turns x_j total input layers into p_j class probabilities by using "softmax" for multi-class classifications.

$$p_j = \frac{\exp(x_j)}{\sum_k \exp(x_k)}$$

k is the index value on all the classes.

DNNs can be trained by derivatives of a cost function that measures the inconsistency among the real values that are produced for target outputs and each of training status (DT) (Rumelhart *et al*., 1986). Natural cost function (C) is the cross-entropy between outputs of target probabilities (d) and softmax (p).

$$C = -\sum_j d_j \log p_j$$

The target probabilities that take a value as 1 or 0 are the supervised information that is provided to train DNN classification (Hinton *et al*., 2012).

DNNs can model nonlinear complex relations just as the shallow neural networks. DNN architectures produce compositional models that allow the compositions from the features of the bottom layers. Accordingly, this also provide a great learning potential and modelling skill for complex datasets (Deng and Yu, 2014; Kiani *et al*., 2017).

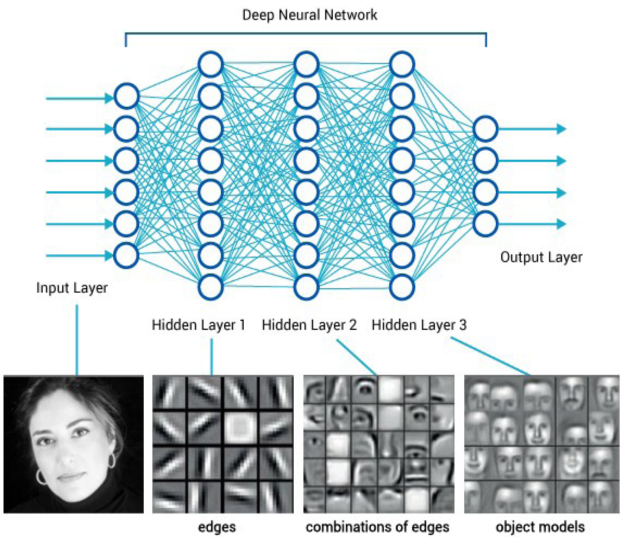

Fig. 1. Basic Deep Neural Network Model (Sachdeva, 2017).

DNN has a five input and an output value in addition to 7 hidden layers. Neuron numbers in each of the hidden layers are 64-12-256-512-256-128-64, respectively. Keras and Tensor Flow libraries in Python programming language were used in the application. The dense function was utilized in software while the layers were established. For each of the layers, 64-12-256-512-256-128-64-1 values were given to units parameters of this function. Relu (Rectified Linear Unit) was used as the activation function. The activation function of the last layer was accepted as softmax. Input dim value of the first Dense function was 5. Training phase analysis values for DNN was selected as Accuracy (metrics=['accuracy']). In conclusion, the deep neural network that is designed in Figure 2 was established in the program.

Table II. 6-Layers cross verification test results.

K	Real values	Values found			Success percentage
		Poor	Medium	Good	
1	Poor	4	0	2	%76,92
	Medium	0	2	4	
	Good	0	0	14	
2	Poor	5	1	0	%76,92
	Medium	0	1	5	
	Good	0	0	14	
3	Poor	3	2	1	%65,38
	Medium	2	3	1	
	Good	0	3	11	
4	Poor	7	0	0	%65,38
	Medium	1	4	0	
	Good	2	6	6	
5	Poor	6	1	0	%69,23
	Medium	1	2	2	
	Good	2	2	10	
6	Poor	3	0	4	%61,53
	Medium	2	0	3	
	Good	1	0	13	
Average	Poor	5	1	1	%69,23
	Medium	1	2	3	
	Good	1	2	11	

RESULTS

One hundred fifty six values with five inputs (calving age, milking days, number of lactation, number of insemination and age) and 1 output (milk yield class) were used as the dataset. One hundred thirty samples of the related dataset were shared for training whereas dataset consisted on 26 samples were shared for the test (since the k-value was determined as 6 in the k-layer cross-validation

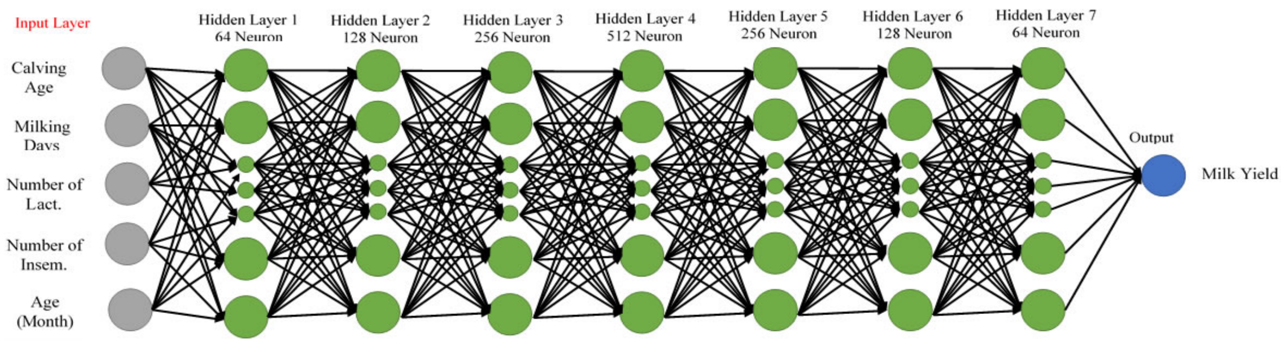

Fig. 2. DNN structure used in the study.

test used in the study 100/6 = 16% Test and 84% Training). Data for this differentiation transaction were randomly selected. However, a balanced distribution of these data was determined before data selection. There were 84 GOOD, 39 POOR and 33 MEDIUM classes pertaining to milk yield within the dataset. These classes were levelly distributed in every 26 data throughout dataset (i.e. 14 GOOD, 5 MEDIUM, 7 POOR). Because the number of data is low, K-Fold Cross Validation was used to ensure data reliability. The K-Fold Cross Validation, which is being frequently used in literature in models with fewer data, was applied to measure the general performance of the system. K was equal to 6, according to data set and the dataset was divided into 6 parts which consist of 26 samples. Training data was specified as another part (codomain with 26 data) in every stage of training. DNN was run for 500 iterations (step) in each stage of training. Confusion Matrix was utilized to evaluate the results. Table II show the values that are obtained for training and test data in each of the layers in 6-Layers Cross Verification.

DISCUSSION

Maintenance and feeding conditions need to be sufficient in professional farm management. This study analysed the effects of calving age, milking days, number of lactation, number of insemination, age of animal on the milk yield in 156 dairy cows. Based on ANN, a total of 84 GOOD, 39 POOR and 33 MEDIUM milk yield classes were predicted on a farm when the effects of these parameters on the milk yield was assessed. A high (69.23%) success percentage was obtained when training and testing data are analyzed in each layer in 6-Layers Cross Verification process.

At any enterprise or corporate, am increasing milk yield can be achieved by providing appropriate maintenance and feeding conditions. Some of the studies about this issue expressed that calving age may change by the factors such as first calving, the number of lactation and number of days in lactation (Galiç *et al*., 2005; Bayrıl and Yılmaz, 2017; Torshizi, 2016; Vijayakumar *et al*., 2017; Otwinowska-Mindur and Ptak, 2018).

Many factors such as physiological states (age, number of lactation or number of days in lactation) may effect the milk yield in animals. The optimal conditions for the animal needs should be to provide date of the first insemination and insemination periods which significantly effect the milk yield. I have been observed that 23th and 25th months are ideal for the first calving if there is a demand for professional raising of livestock. There is a need for increasing the yield per animal and making suitable the maintain and nutritional conditions at the same time. Meat and milk products per animal have importance when this situation is evaluated in terms of ruminant animals (Wathes *et al*., 2014). Niloforooshan and Edriss (2004) have pointed out that for maximum milk yield, calving age ought to be 24 months in the first lactation and 23-24 months are approperiate for Holsteins cattle (Nilforooshan and Edriss, 2004). On the other hand, Galiç *et al*. (2005) have expressed that first average calving age is 27.5 ± 0,09 months and age at first calving significantly affects milk yield during 305 days (P<0,01) (Galiç *et al*,. 2005). According to another study, animals should be inseminated to achieve maximum calving period from 22.5-23.5 months (Do *et al*., 2013).

Cobanoglu *et al*. (2019) were also investigated the effect of calving year (2011 and 2013) on milk yield and milk composition traits in Holstein and Jersey cattle raised in the Marmara and Black Sea Regions of Turkey, respectively. They found that milk yield and its composition in both Holstein and Jersey cows were significantly related to calving year.

The number of lactation can determine the milk yield. Milk yield of animals that are in the first lactation is higher than the milk yield of animals in the 4th and 5th lactation. Moreover, insemination ratio in the animals which are in the first lactation is less. Vijayakumar *et al*. (2017) have found a relationship between a number of lactation and milk yield. Maximum milk yield was observed in the 3rd lactation. Additionally, there was a high milk yield in the early phase (55^{th}-90^{th} days) of lactation. They also pointed out that milking frequency is significantly affecting the milk yield (Vijayakumar *et al*., 2017). Milk yield performance in dairy cattle is also affected by multiple factors such as age at first calving, calving season, lactation phase and the effect of the general herd. Lactation curve is affected by calving season and calving age. The best performance of lactation yield and continuity is in cows which are reproduced at the end of 24^{th}, 25^{th} and 26^{th} months (Torshizi, 2016).

Bayrıl and Yılmaz, 2017 conducted a study to research the effect of gender of calf, service period, a number of births and calving season on the milk yield performance. The effect of gender of calf and calving season on 305-days milk yield and lactation period was insignificant (P>0.05). Effect of service period and a number of births on 305-days milk yield and lactation period was significantly different levels (P>0.05). Moreover, they also found that lactation milk yields and lactation times of Holstein cows are similar. Lactation milk yield increased up to 3^{rd} birth and decreases in the 4^{th}. Lactation time was increased by decreasing the number of births. Milk yield performance and lactation times of cows which calve in different seasons are similar as well (Bayrıl and Yılmaz, 2017).

Considering these factors will guarantee professional farm management and an increase in the milk yield can be achieved. It was revealed that while 84 of 156 cows were raised in proper conditions, the same proper conditions could not be provided for 39 of 156 cows. Thirty-three cows were at a medium level that closes to a poor level. The results of this study revealed that the ratio of providing the proper conditions was 53.84% (84/156*100) in the farm and there was no professional farm management. The related farm should be controlled more about animal raising. There is a need for a person who has an overall knowledge about animal raising. It was suggested that such tests should be applied to determine the success rates of cow farms.

Statement of conflict of interest

Authors have declared no conflict of interest.

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