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RESEARCH ARTICLE

Determination of the Effects of Silage Type, Silage Consumption, Birth Type and Birth Weight on Fattening Final Live Weight in Kıvırcık Lambs with MARS and Bagging MARS Algorithms

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Abstract: This study was carried out to determine the effect of silage type, silage consumption, birth type (single or twin) and birth weight on live weight at the end of fattening in Kıvırcık lambs. In the experiment, 40 male Kıvırcık lambs aged 2.5-3 months were used and the animals were fattened for 56 days. During the fattening period, the lambs fed with 5 different types of silage (100% sunflower silage, 75% sunflower + 25% corn silage, 50% sunflower + 50% corn silage, 25% sunflower + 75% corn silage, 100% corn silage) pure and mixed in different proportions and concentrate feed. Data on fattening results were analyzed with MARS and Bagging MARS algorithms. The main objective of this research is to predict fattening final live weight (FFLW) of lambs using Multivariate Adaptive Regression Splines (MARS) and Bagging MARS algorithms as a nonparametric regression technique. Live weight value was modeled based on factors such as birth type, birth weight, silage type and silage consumption. Correlation coefficient (r), determination coefficient (R^2), Adjust R^2, Root-mean-square error (RMSE), standard deviation ratio (SD ratio), mean absolute percentage error (MAPE), mean absolute deviation (MAD), and Akaike Information Criteria (AIC) values of MARS algorithm predicting live weight were as follows: 0.9986, 0.997, 0.977, 0.142, 0.052, 0.2389, 0.086 and -88 respectively. Like statistics for Bagging MARS algorithm were 0.754, 0.556, 0.453, 1.8, 0.666, 3.96, 1.47 and 115 respectively. It was observed that MARS and Bagging MARS algorithms have revealed correct results according to goodness of fit statistics. In this study it has been determined that the MARS algorithm gives better results in live weight modeling.

Keywords: *Kıvırcık lamb, Silage type, Birth weight, Birth type, Data mining*

Kıvırcık Kuzularda Silaj Tipi, Silaj Tüketimi, Doğum Tipi ve Doğum Ağırlığının Besi Sonu Canlı Ağırlık Üzerine Etkilerinin MARS ve Bagging MARS Algoritmaları ile Saptanması

Öz: Bu çalışma, Kıvırcık kuzularında silaj tipi, silaj tüketimi, doğum tipi (tek veya ikiz) ve doğum ağırlığının besi sonu canlı ağırlığa etkisini belirlemek amacıyla yapılmıştır. Deneyde 2.5-3 aylık 40 erkek Kıvırcık kuzu kullanılmış ve hayvanlar 56 gün beslenmiştir. Kuzular besi döneminde 5 farklı silaj çeşidi (%100 ayçiçeği silajı, %75 ayçiçeği + %25 mısır silajı, %50 ayçiçeği + %50 mısır silajı, %25 ayçiçeği + %75 mısır silajı, %100 mısır) saf ve farklı oranlarda karıştırılmış ve konsantre yem ile beslenmiştir. Besi sonuçlarına ilişkin veriler MARS ve Bagging MARS algoritmaları ile analiz edilmiştir. Bu araştırmanın temel amacı, parametrik olmayan bir regresyon tekniği olarak Çok Değişkenli Uyarlanabilir Regresyon Splines (MARS) ve Bagging MARS algoritmalarını kullanarak kuzuların canlı ağırlığını tahmin etmektir. Canlı ağırlık değeri, doğum tipi, doğum ağırlığı, silaj tipi ve silaj tüketimi gibi faktörlere göre modellenmiştir. Canlı ağırlığı tahmin eden MARS algoritması için korelasyon katsayısı (r), belirleme katsayısı (R^2), Düzeltilmiş R^2, Hata Kareler Ortalamasının Karekökü (RMSE), standart sapma oranı (SD oranı), ortalama mutlak yüzde hatası (MAPE), ortalama mutlak sapma (MAD) ve Akaike Bilgi Kriterleri (AIC) değerleri sırasıyla 0.9986, 0.997, 0.977, 0.142, 0.052, 0.2389, 0.086 ve -88'dir. Bagging MARS algoritması için benzer istatistikler sırasıyla 0.754, 0.556, 0.453, 1.8, 0.666, 3.96, 1.47 ve 115'dir. MARS ve Bagging MARS algoritmalarının uyum iyiliği istatistiklerine göre doğru sonuçlar ortaya koyduğu gözlemlenmiştir. Bu çalışmada, MARS algoritmasının canlı ağırlık modellemesinde daha iyi sonuçlar verdiği ortaya çıkmıştır.

Anahtar sözcükler: *Doğum tipi, Doğum ağırlığı, Veri madenciliği, Kıvırcık kuzusu, Silaj*

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Introduction

Approximately 70% of the expenses of the enterprises engaged in animal production are roughage and intensive feed costs [1]. This is very important in terms of showing how effective and decisive the feed is in the development of livestock. Today, where the demand for animal products is increasing, more and more roughage and concentrate feed production is needed for more animal food production.

In order to obtain high efficiency from animals, it is necessary to meet the nutrient needs in a balanced and sufficient level, and for this purpose, it is necessary to use quality roughage and concentrate feed sources. Roughage is generally divided into two groups as dry and watery roughage. Dry roughage, hay, straw and products with a crude cellulose content of 18% or higher, roughage consists of green fodder plants such as alfalfa, sainfoin, vetch, silage, roots and tubers.

One of the main problems of animal husbandry is the difficulties in obtaining good quality, cheap and sufficient amount of roughage. Many countries are faced with important problems, especially in terms of meeting the need for quality roughage [2]. Problems in the supply of quality roughage is one of the most important reasons for the low yield per animal in many countries. It is only possible to reduce the amount of intensive feed used in animal feeding, which is expensive, by using quality roughage. In this context, one of the important sources to refer to is silage [3].

It is not possible to meet the nutritional requirements of ruminant animals only with concentrate feeds. It is possible to realize both economical and rational feeding by adding silage as well as concentrate and roughage to the rations. It is possible to meet the green feed requirements of animals fresh from nature only in certain periods of the year due to vegetation conditions. In countries located in the Mediterranean climate zone, the vegetation period is approximately 200 days. Therefore, the fresh and green roughage needs of animals have to be met from different sources during the rest of the year. Green and fresh roughage given to animals by grazing or mowing during vegetation periods cannot be stored for a long time without spoiling due to the high water content they contain. For this reason, water-rich roughage should be stored until the period of use with different methods.

Among the forage crops produced for silage, cereals such as corn, wheat and sorghum, which have high water-soluble carbohydrate content and low buffer capacity, come first, but in many countries, corn silage constitutes a very large part of the total silage production [4]. However, sunflower, which is an annual industrial plant in some regions, is thought to be one of the plants that can be an alternative to corn in silage production. Although sunflower is mostly cultivated as a second crop after grains, it is currently used as a source of roughage by ensiling or grazing. Although sunflower is grown for different purposes (oil, pulp and snack food, etc.) around the world, it is also grown as a silage plant in many countries. Sunflower cultivation is easier than corn, and it can be used for silage as an alternative to corn, especially in regions that do not receive much precipitation and irrigation facilities are limited. It is possible to benefit from sunflower as an important forage plant, thanks to its ability to be silage in a shorter time than corn, its tolerance to high and low temperatures, and its high adaptability to various soil conditions [5].

Although silage is one of the most important roughage sources used in the feeding of sheep and goats as well as cattle in countries with developed livestock, silage production and use are still insufficient in some countries. Especially, the use of silage is very low in small ruminant. However, it has been reported that silage feed has started to be used in the rations of small ruminant in recent years [6].

In recent years, it has been reported that there has been a decrease in the number of Kıvırcık sheep in the province of Balıkesir - Türkiye, due to the conversion of meadow and pasture lands into field crops production area, and sheep breeding tends towards intensive breeding [7]. Addition of yeast or malic acid to the feed did not have a statistically significant effect on performance in Kıvırcık lambs fed with high concentrate feed. At the end of the 60th day, the average live weight was 35.5 kg in those fed with yeast addition and 35.8 kg in those fed with malic acid addition [8]. The change in live weight until the adult period in sheep breeding gives an idea about whether the breeding programs and production system are appropriate.

In a study conducted at Istanbul University Faculty of Veterinary Medicine, 52 Kıvırcık lambs were included in the trial. It has been reported that the lambs reared with the concentrate-based system grew 30% faster than pasture-based system during the trial period [9]. Fifty-five Kıvırcık lambs selected from Balıkesir Sheep Breeding Research Institute herds in Türkiye was determined that birth weight, weaning weight and final body weight were significantly affected by gender and birth type [10].

In Kıvırcık lambs reared intensively, 211 g live weight gain and 33 kg body weight after fattening were measured during the 68-day fattening period [11]. In an another study, the daily live weight gains of Kıvırcık lambs raised by intensive method were reported as 276 g during the 63-day fattening period and 44.68 kg at the end of fattening [12].

The main hypothesis of this study is that factors such as silage type, silage consumption, birth type and birth weight significantly affect the live weight of lambs.

In this study, it was aimed to investigate the effects of different silage type, silage consumption, birth type (single or twin) and birth weight on the live weight of Kıvırcık lambs at the end of fattening by using some data mining methods.

Material and Methods

Ethical Statement

This study was carried out with the approval of Bursa Uludağ University Animal Experiments Local Ethics Committee dated 07.01.2020 and numbered 2020-01/02.

Material

This study was carried out in a semi-open barn in a sheep farm belonging to Bursa Uludağ University Agricultural Application and Research Center. In the study, 40 Kıvırcık male lambs aged 2.5-3 months and an average live weight of 23-25 kg were used as animal material. The fattening lambs were housed in individual compartments during the experiment and individual feeding was applied to the animals during the 56-day fattening period. During the trial period, the live weights and feed consumptions of the lambs were determined individually and in 2-week periods.

During the experiment, lambs were fed 5 different silages (100% sunflower silage, 75% sunflower + 25% corn silage, 50% sunflower + 50% corn silage, 25% sunflower + 75% corn silage, 100% corn silage) as pure and mixed. Lambs housed in individual chambers consumed the silage mixtures of their groups *ad libitum*. In addition to the silage mixtures consumed by the lambs, 700 g of concentrate feed per animal was given in the first 4 weeks of the experiment. Later, this amount was increased to 900 g for 4 weeks, and to 1400 g in the last 2 weeks of the experiment, taking into account the daily nutrient needs of the lambs.

The lambs were fed once a day at 09:00 in the morning. The remaining feed from the feeders in the individual compartments was collected and weighed daily before new feeding was made the next day, and the amount of silage mixture and concentrated feed consumed by each animal daily was determined. Fresh and clean drinking water was always available in front of the lambs. During the fattening period, the live weights of the lambs were determined by control weighing made every 14 days. Weights of the animals at the beginning of fattening and other control weights were made on an empty stomach.

Method

Data on fattening results were analyzed with MARS and Bagging MARS algorithms. MARS (Multivariate Adaptive Regression Splines) algorithm was proposed by Friedman [13] in order to study the non-linear relationships between independent variables and dependent variable(s). For the MARS algorithm, no assumptions about functional relationships between dependent and independent variables are needful. It is a nonparametric statistical method that takes a basis for a divide.

The MARS model is highly flexible with the combination of hinge functions and two of them multiplied together, allowing for bends, thresholds, and other departures from typical linear functions [14,15].

The optimization procedure of the MARS model primarily consists of forward and backward phases. During this process, the forward phase generates basis functions, and finds the location of potential knots in a stepwise manner, leading to overfitting and complexity. Thereby, the backward phase intends to increase the generalization ability of the model by calculation. Piecewise functions are divided into three: These are a constant, a hinge function and a product of two or more hinge functions for different predictors. A hinge function is as follows [13].

$$\max(0, x - t) = \begin{cases} x - t, & x \geq t \\ 0, & otherwise \end{cases}$$

here t location t is called knot for the basis function [16]. MARS model is established as a linear combination of basis functions and interrelation, explained as follow [13].

$$f(x) = \beta_0 + \sum_{i=1}^{N} \beta_i B_i(x)$$

here each $Bi(x)$ is the ith basis function. The coefficient β_0 is a constant, while β_i is the coefficient of the ith basis function, determined by the least-squares method, and f(x) produces the predicted value. The basis function, which demonstrates the largest decline in the training error, will be added to the model up to the specified maximum number of basis functions are achieved.

Model subsets are compared using generalized cross-validation (GCV). The GCV is a shape of regularization that trades off the goodness of-fit against the model complexity. The GCV of a model is defined as follows [17].

$$GCV = \frac{\frac{1}{n}\sum_{i=1}^{n}(y_i - f(x_i))^2}{\left[1 \frac{M + d(M-1)/2}{n}\right]^2}$$

here M is the number of basis functions, and d is the penalizing parameter. The optimal value of d usually falls in the range of $2 \leq d \leq 4$, and generally $d = 3$ is used [13].

The residuals are the difference between the values (x) predicted by the model and corresponding response values y. The residual sum of squares (RSS) is the sum of the squared values of residuals:

$$RSS = \sum_{i=1}^{n}(y_i - f(x_i))^2$$

The total sum of squares (TSS) is calculated as the sum over all squared differences between the response $\bar{y}$ and its mean :

$$TSS = \sum_{i=1}^{n}(y_i - \bar{y})^2$$

Generalized R^2 or GRSq is the generalization performance of the model estimated using the MARS algorithm. GRSq can be explained as follows [18].

$$GRS_q = 1 - \frac{GCV}{RSS}$$

GCV is important a statistic for MARS algorithm because it is used to evaluate model subsets in the backward pass.

Bagging (Bootstrap aggregating) MARS algorithm uses bootstrapping among resampling techniques. Bagging models can ensure their own internal estimate of predictive accuracy correlating well with either cross-validation estimates or test set estimates [19]. Bagging method is used as a tool to shape a more stable classifier. Bagging predictor is a method to generate multiple versions of predictors and use them for aggregate predictors [20]. Bagging is used for the purpose of improve the classification accuracy of the MARS method. Thus, this study is expected to obtain better modelling and classification functions through bagging MARS method [21].

To comparatively test the estimate criteria of all the models, the following goodness of fit criteria were determined [22-25]:

1. Pearson correlation coefficient (r) between the observed and predicted dependent variable values.

2. Coefficient of determination

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

3. Adjusted coefficient of determination

$$Adj.R^2 = 1 - \frac{\frac{1}{n-k-1}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

4. Root-mean-square error (RMSE) given by the following formula.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

5. Standard deviation ratio (SD_{ratio})

$$SD_{ratio} = \sqrt{\frac{\frac{1}{n-1}\sum_{i=1}^{n}(\varepsilon_i - \bar{\varepsilon})^2}{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

6. Mean absolute percentage error (MAPE)

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}}{y_i}\right|.100$$

7. Mean absolute deviation (MAD)

$$MAD = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}|$$

8. Akaike Information Criteria (AIC)

$$AIC = nln\left[\sum_{i=1}^{n}\frac{(y_i - \hat{y}_i)^2}{n}\right] + 2k$$

If its standard ratio value is 0.40 or 0.10, then a regression model applied had a good fit or a very good fit was underlined that by Grzesiak and Zaborski [26].

In order to building MARS and Bagging MARS predictive models, the earth package proposed by Milborrow [27,28] in RStudio software was used [25]. Also, the ehaGoF package was used to measure the predictive quality of the evaluated MARS models [25].

Results

Introductory statistics on birth weight, silage consumption and final live weight in Kıvırcık lambs according to birth type are given in *Table 1*.

Table 1. *Descriptive statistics for birth type*

Statistics	BT	BW	SC	FFLW
N	Single	13	13	13
	Twin	27	27	27
$\bar{X}$	Single	4.64	917	37.5
	Twin	4.03	932	36.6
$S\bar{x}$	Single	0.188	107	0.889
	Twin	0.084	72.3	0.478
s	Single	0.678	388	3.21
	Twin	0.438	375	2.48
Min	Single	3.6	479	34.1
	Twin	3.4	320	32.4
Max	Single	6	2049	45.3
	Twin	5	1972	41.3

BT: *Birth type,* ***BW:*** *Birth weight (kg),* ***SC:*** *Silage consumption (g),* ***FFLW:*** *Fattening final live weight (kg)*

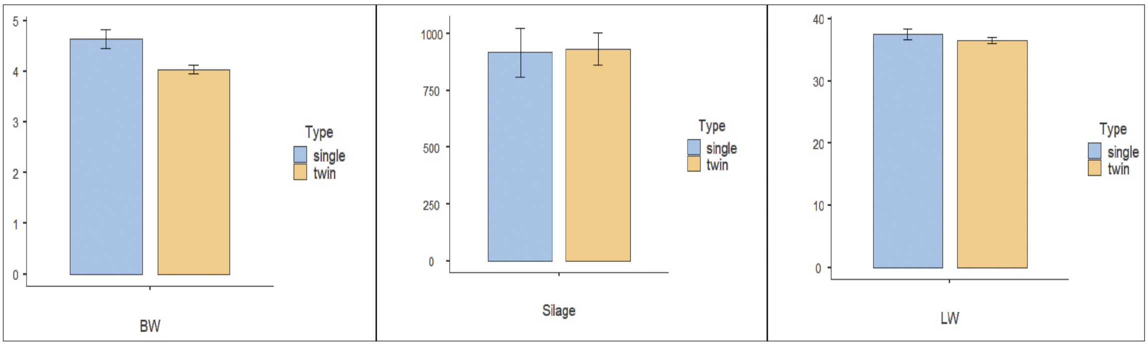

Fig 1. Silage consumption, live weight at birth and fattening final live weight at the end of the fattening period by birth type

As seen in *Table 1*, 13 of the 40 Kıvırcık lambs were born as singles and 27 of them were twins. The mean birth weight of the lambs was 4.64 kg in single and 4.03 kg in twins. While single lambs consumed an average of 917 g of silage per day, twin lambs consumed 932 g of silage. The average live weight at the end of fattening is 37.5 kg in single lambs and 36.6 kg in twin lambs. The values belonging to single and twin lambs is presented in *Fig. 1*.

In *Table 2*, introductory statistics for silage consumption, birth weight and post-fattening live weight are presented according to silage type.

When evaluated according to silage type, lambs fed 50% corn and 50% sunflower and average birth weight (4.56 kg) consumed the most feed. The body weight at the end of fattening was found to be higher at 37.4 kg (feeding with 100% corn, 75% maize + 25% sunflower, 50% maize + 50% sunflower) in the first 3 groups *(Table 2, Fig. 2)*.

Multivariate Adaptive Regression Splines (MARS) and Bagging MARS algorithms, which are data mining methods, were applied in order to examine the effects of factors affecting the end of fattening body weight Kıvırcık lambs.

Fattening body weight (LW) variable is the dependent variable, while delivery type (BT), silage type (ST), birth weight (BW) and daily average silage consumption (SC) variables are also independent variables. Goodness of fit statistics calculated for MARS and Bagging MARS algorithms are given in *Table 3*.

Predictive performances of MARS and Bagging MARS were assessed comparatively in predicting FFLW. Their goodness-of-fit-criteria outcomes are summarized in *Table 3*. The superiority order in the predictive accuracy of the mentioned algorithms was MARS > Bagging MARS according to the estimated model evaluation criteria. Inasmuch as, greater in the first criteria is better, whereas smaller in the remaining criteria is better. The predictive performance of the MARS algorithm was found better than Bagging MARS. Results of the MARS algorithm for Kıvırcık lambs are presented in *Table 4*. The GCV value of the MARS model was 0.0201. For the Kıvırcık lambs,

Table 2. *Descriptive statistics for silage type*

Statistics	Silages	BW	SC	FFLW
N	Corn100	8	8	8
	Corn75-Sunflower25	8	8	8
	Corn50-Sunflower50	8	8	8
	Corn25-Sunflower75	8	8	8
	Sunflower100	8	8	8
$\overline{X}$	Corn100	4.1	763	37.4
	Corn75-Sunflower25	3.96	834	37.4
	Corn50-Sunflower50	4.56	1099	37.4
	Corn25-Sunflower75	4.38	755	35.9
	Sunflower100	4.15	1186	36.3
$S\bar{x}$	Corn100	0.227	87.7	0.808
	Corn75-Sunflower25	0.134	72.6	0.828
	Corn50-Sunflower50	0.239	148	1.35
	Corn25-Sunflower75	0.154	101	0.922
	Sunflower100	0.249	171	0.948
s	Corn100	0.641	248	2.29
	Corn75-Sunflower25	0.378	205	2.34
	Corn50-Sunflower50	0.676	420	3.83
	Corn25-Sunflower75	0.437	286	2.61
	Sunflower100	0.705	485	2.68
Min	Corn100	3.4	484	34.4
	Corn75-Sunflower25	3.4	524	34.1
	Corn50-Sunflower50	3.8	703	34.5
	Corn25-Sunflower75	3.8	320	32.4
	Sunflower100	3.4	751	32.8
Max	Corn100	5	1215	41.3
	Corn75-Sunflower25	4.4	1077	41.1
	Corn50-Sunflower50	6	2049	45.3
	Corn25-Sunflower75	5	1225	40.7
	Sunflower100	5.5	1972	40

BW: *Birth weight (kg),* ***SC:*** *Silage consumption (g),* ***FFLW:*** *Fattening final live weight (kg)*

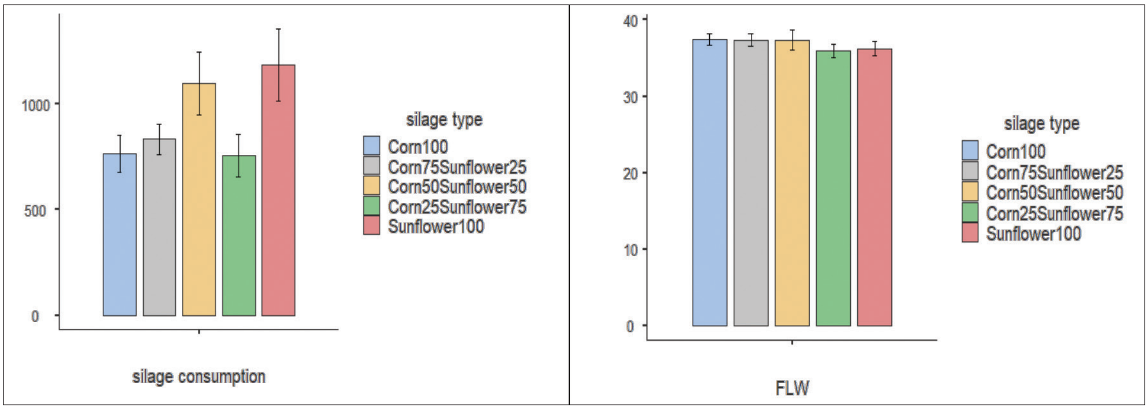

Fig 2. Silage consumption and final live weight according to silage type. Here, the graph of the descriptive statistics of these variables is shown

Table 3. *Predictive performance of MARS and Bagging MARS algorithms*

Methods	r	R^2	Adj. R^2	RMSE	SD Ratio	MAPE	MAD	AIC
MARS	0.9986	0.997	0.977	0.142	0.052	0.239	0.086	-88
Bagging MARS	0.754	0.556	0.453	1.8	0.666	3.960	1.47	115

RMSE: *Root-mean-square error,* ***SD ratio:*** *Standard deviation ratio,* ***MAPE:*** *Mean absolute percentage error,* ***MAD:*** *Mean absolute deviation,* ***AIC:*** *Akaike Information Criteria*

the observed FFLW values of the MARS model with the interaction order of 3 displayed much better fit.

The model equation of the MARS algorithm is as follows.

FFLW = 42.9 - 33 * Typetwin - 2.75 * SilageCorn50Sunflo50 + 8.06 * SilageCorn75Sunflo25 - 4.5 * SilageSunflower100 + 33.5 * max(0, 4.1 - BW) - 26.7 * max(0, BW - 4.1) - 0.0406 * max(0, silage - 745) + 0.034 * max(0, silage - 774) + 0.0647 * max(0, silage - 838) - 0.0875 * max(0, silage - 960) - 0.266 * max(0, 1024 - silage) + 0.0265 * max(0, silage - 1024) - 5.89 * Typetwin * SilageCorn25Sunflo75 -1.27 * Typetwin * SilageCorn50Sunflo50 + 6.13 * Typetwin * BW-0.0204 * SilageCorn75Sunflo25 * silage + 7 * Typetwin * max(0, BW- 4.1) + 0.0243*Typetwin*max(0,1024-silage)-4.38*SilageCorn25Sunflo75 * max(0, 4.1-BW) - 34.7 * SilageCorn25Sunflo75 * max(0, BW - 4.1) + 0.00549 * SilageCorn25Sunflo75 * max(0, 1024 - silage) + 14 * SilageCorn50Sunflo50 * max(0, 4.1 - BW) + 0.000967 * SilageCorn50Sunflo50 * max(0, silage - 1024) + 42.9 * SilageCorn75Sunflo25 * max(0, BW - 4.1) - 0.137 * SilageCorn75Sunflo25*max(0,silage-1024)-41*SilageSunflower100 * max(0, 4.1 - BW) + 0.00515 * SilageSunflower100 * max(0, 1024 - silage) + 0.0598 * BW * max(0, 1024-silage) + 0.0139 * max(0, BW - 4.1) * silage-6.39 * Typetwin * SilageCorn25Sunflo75 * max(0, BW - 4.1) + 0.00468 * Typetwin * SilageCorn75Sunflo25 * max(0, 1024 - silage) + 30.1 * Typetwin * SilageSunflower100 * max(0, 4.1 - BW) + 0.049 * SilageCorn25Sunflo75 * max(0, BW - 4.1) * silage

Among independent variables, the most important and highest positive effects SilageCorn75Sunflo25 * max(0, BW - 4.1), max(0, 4.1 - BW) and Typetwin * SilageSunflower100 * max(0, 4.1 - BW) explained the variability in FFLW in the MARS algorithm, successfully. Likewise, highest negative effects SilageSunflower100 * max(0, 4.1-BW), SilageCorn25Sunflo75 and Typetwin defined the variability in FFLW in the MARS algorithm.

The relative importance of the independent variables is presented in *Table 5*.

As seen in *Table 5*, the greatest importance order was obtained for silage (100%), BW (96.7%), SilageSunflower100 (83%), SilageCorn25Sunflo75 (74.9%), SilageCorn75Sunflo25 (72%), Type twin (67.4%) and SilageCorn50Sunflo50 (67.4%).

The distribution graphs of observed predicted values of FLW was indicated in *Fig. 3*.

In this study, it was observed that there was a bilateral interaction between the variables. The graph representing the three-dimensional surface of the analysis results and the relationship between a pair of predictor variables and the objective variable is presented in *Fig. 4*.

The prediction equation of the Bagging MARS algorithm as below.

FFLW = (32.87505 +17.8484 * max(0, 4-BW) + 13.0234 * max(0, BW-4) - 18.91613 * max(0, BW-4.4) - 0.008153931 * max(0, 1020.86 - silage) + 0.005381609 * max(0, silage - 1020.86) + 3.473147 * Typesingle * max(0, BW-4) + 2.749936 * SilageCorn25Sunflo75 * max(0, BW-4) + 21.03818 * SilageCorn50Sunflo50 * max(0, 4-BW) + 0.01457022 * SilageCorn75Sunflo25 * max(0, 1020.86-silage) - 14.40757 * SilageSunflower100 * max(0, 4-BW) + 50.10852 - 3.484945 * SilageCorn50Sunflo50 - 20.27059 * max(0, BW-3.6) + 19.93425 * max(0, BW-4.2) - 17.32094 * max(0, 4.4-BW) + 8.801585 * SilageCorn50Sunflo50 * max(0, 4.4-BW) - 2.844158 * SilageSunflower100 * max(0, 4.4-BW) + 0.003617947 * max(0, 4.4-BW) * silage + 0.003469904 * max(0, BW-4.4) * silage + 38.08742 - 0.005349635 * max(0, 1024.79-silage) - 0.01436351 * SilageSunflower100 * max(0, 1024.79-silage)/3

Table 4. Results of the MARS algorithm for Kıvırcık lambs

Coefficients	Estimate	Std. Error	T Value	Pr(>|t|)
(Intercept)	4.291e+01	7.772e-01	55.204	2.37e-09 ***
bx[, -1]h(silage-1024.14)	2.648e-02	1.114e-02	2.377	0.055024
bx[, -1]h(1024.14-silage)	-2.659e-01	1.248e-02	-21.311	6.96e-07 ***
bx[, -1]SilageSunflower100	-4.501e+00	6.405e-01	-7.027	0.000415 ***
bx[, -1]h(BW-4.1)	-2.673e+01	1.495e+00	-17.882	1.97e-06 ***
bx[, -1]h(4.1-BW)	3.352e+01	2.053e+00	16.325	3.36e-06 ***
bx[, -1]SilageSunflower100*h(1024.14-silage)	5.145e-03	3.338e-03	1.541	0.174223
bx[, -1]SilageCorn25Sunflo75*h(4.1-BW)	-4.376e+00	1.934e+00	-2.263	0.064282
bx[, -1]SilageCorn75Sunflo25*h(silage-1024.14)	-1.369e-01	1.752e-02	-7.814	0.000232 ***
bx[, -1]Typetwin*h(BW-4.1)	6.999e+00	1.700e+00	4.117	0.006236 **
bx[, -1]SilageCorn75Sunflo25	8.060e+00	1.783e+00	4.521	0.004014 **
bx[, -1]SilageSunflower100*h(4.1-BW)	-4.104e+01	3.085e+00	-13.305	1.11e-05 ***
bx[, -1]SilageCorn25Sunflo75*h(BW-4.1)	-3.467e+01	3.466e+00	-10.003	5.78e-05 ***
bx[, -1]Typetwin*h(1024.14-silage)	2.429e-02	2.127e-03	11.420	2.70e-05 ***
bx[, -1]Typetwin	-3.303e+01	5.659e+00	-5.837	0.001114 **
bx[, -1]BW*h(1024.14-silage)	5.983e-02	2.886e-03	20.732	8.20e-07 ***
bx[, -1]h(BW-4.1)*silage	1.392e-02	9.999e-04	13.924	8.55e-06 ***
bx[, -1]SilageCorn50Sunflo50*h(silage-1024.14)	9.671e-04	1.816e-03	0.533	0.613510
bx[, -1]SilageCorn75Sunflo25*h(BW-4.1)	4.289e+01	3.959e+00	10.833	3.66e-05 ***
bx[, -1]SilageCorn75Sunflo25*silage	-2.045e-02	2.338e-03	-8.745	0.000124 ***
bx[, -1]Typetwin*SilageSunflower100*h(4.1-BW)	3.007e+01	3.119e+00	9.642	7.13e-05 ***
bx[, -1]h(silage-773.857)	3.400e-02	2.408e-02	1.412	0.207629
bx[, -1]Typetwin*SilageCorn25Sunflo75*h(BW-4.1)	-6.394e+00	1.607e+00	-3.980	0.007282 **
bx[, -1]SilageCorn25Sunflo75*h(BW-4.1)*silage	4.903e-02	4.388e-03	11.172	3.07e-05 ***
bx[, -1]SilageCorn50Sunflo50	-2.750e+00	4.438e-01	-6.196	0.000815 ***
bx[, -1]Typetwin*SilageCorn25Sunflo75	-5.889e+00	6.425e-01	-9.166	9.50e-05 ***
bx[, -1]SilageCorn25Sunflo75*h(1024.14-silage)	5.495e-03	1.518e-03	3.619	0.011114 *
bx[, -1]SilageCorn50Sunflo50*h(4.1-BW)	1.401e+01	2.161e+00	6.485	0.000639 ***
bx[, -1]h(silage-744.786)	-4.062e-02	1.642e-02	-2.473	0.048233 *
bx[, -1]Typetwin*SilageCorn50Sunflo50	-1.266e+00	5.582e-01	-2.268	0.063803
bx[, -1]Typetwin*BW	6.127e+00	1.371e+00	4.468	0.004248 **
bx[, -1]h(silage-960)	-8.745e-02	1.890e-02	-4.628	0.003587 **
bx[, -1]h(silage-837.571)	6.474e-02	1.760e-02	3.678	0.010358 *
bx[, -1]Typetwin*SilageCorn75Sunflo25*h(1024.14-silage)	4.683e-03	2.036e-03	2.300	0.061106

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

According to this obtained equation, in the first boot strap, an increase of 13.02 kg in lambs with BW>4, 3.47 kg in singles with BW≤4, 2.75 kg for BW>4 fed 25% corn and 75% sunflower, 21.04 kg in BW≤4 fed 50% corn and 50% sunflower is expected. In the second bootstrap, an increase of 19.93 kg in lambs with BW>4.2, 8.8 kg in those fed with 50% corn and 50% sunflower BW≤4.4 is expected. In the third bootstrap, a small decrease of 0.005 kg in those with slage≤1024.79 and in body weight of 0.014 kg is expected in lambs with slage≤1024.79 g fed 100% sunflower is expected.

The plot between the predicted and observed FFLW values is showed in *Fig. 5* for Bagging MARS algorithm.

In the Bagging MARS model, there is a dual interaction between the variables. The graph showing the three-dimensional surface explaining the relationship between the independent variables and the dependent variable is given in *Fig. 6*.

Table 5. *Relative importance of model independent variables*

Variables	GCV	Number of Subsets
Silage	100.0	33
BW	96.7	32
SilageSunflower100	83	31
SilageCorn25Sunflo75	74.9	28
SilageCorn75Sunflo25	72	27
Type twin	67.4	25
SilageCorn50Sunflo50	67.4	25

BW: *Birth weight,* ***GCV:*** *Generalized cross-validation,* ***Number of Subsets:*** *Variable importance using the "number of subsets" criterion. The number of subsets that include the variable*

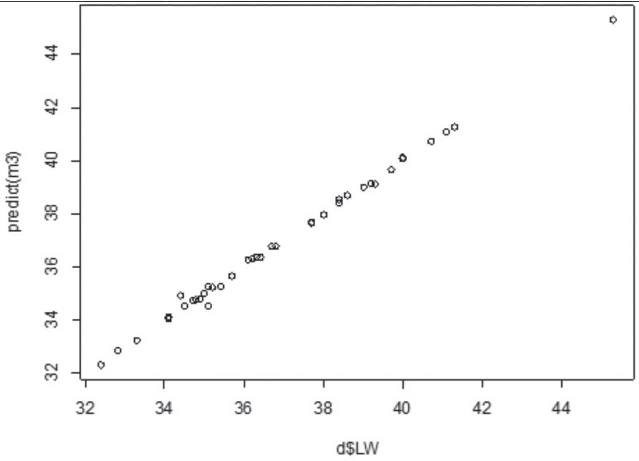

Fig 3. Observed versus predicted values of FFLW (for MARS algorithm)

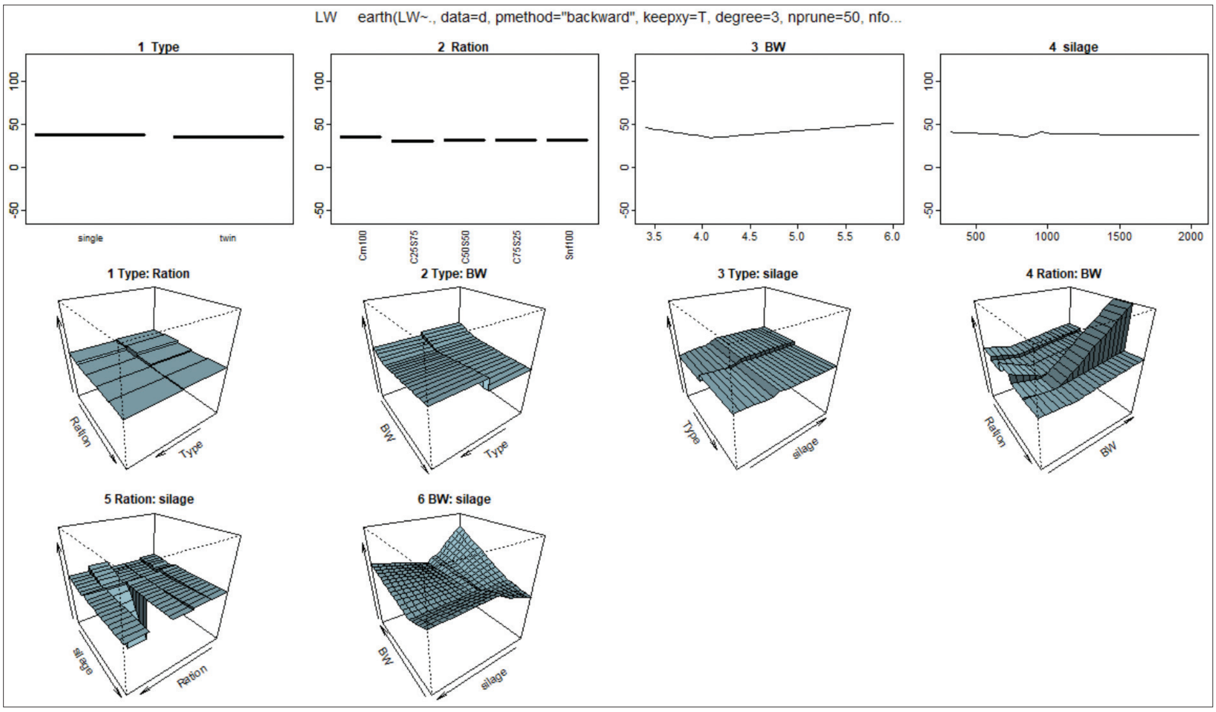

Fig 4. Model surface plots in MARS algorithm

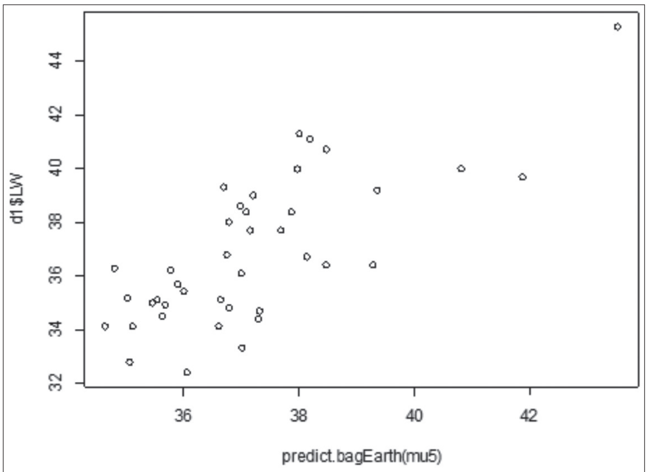

Fig 5. Observed and predicted values of FFLW (for Bagging MARS algorithm)

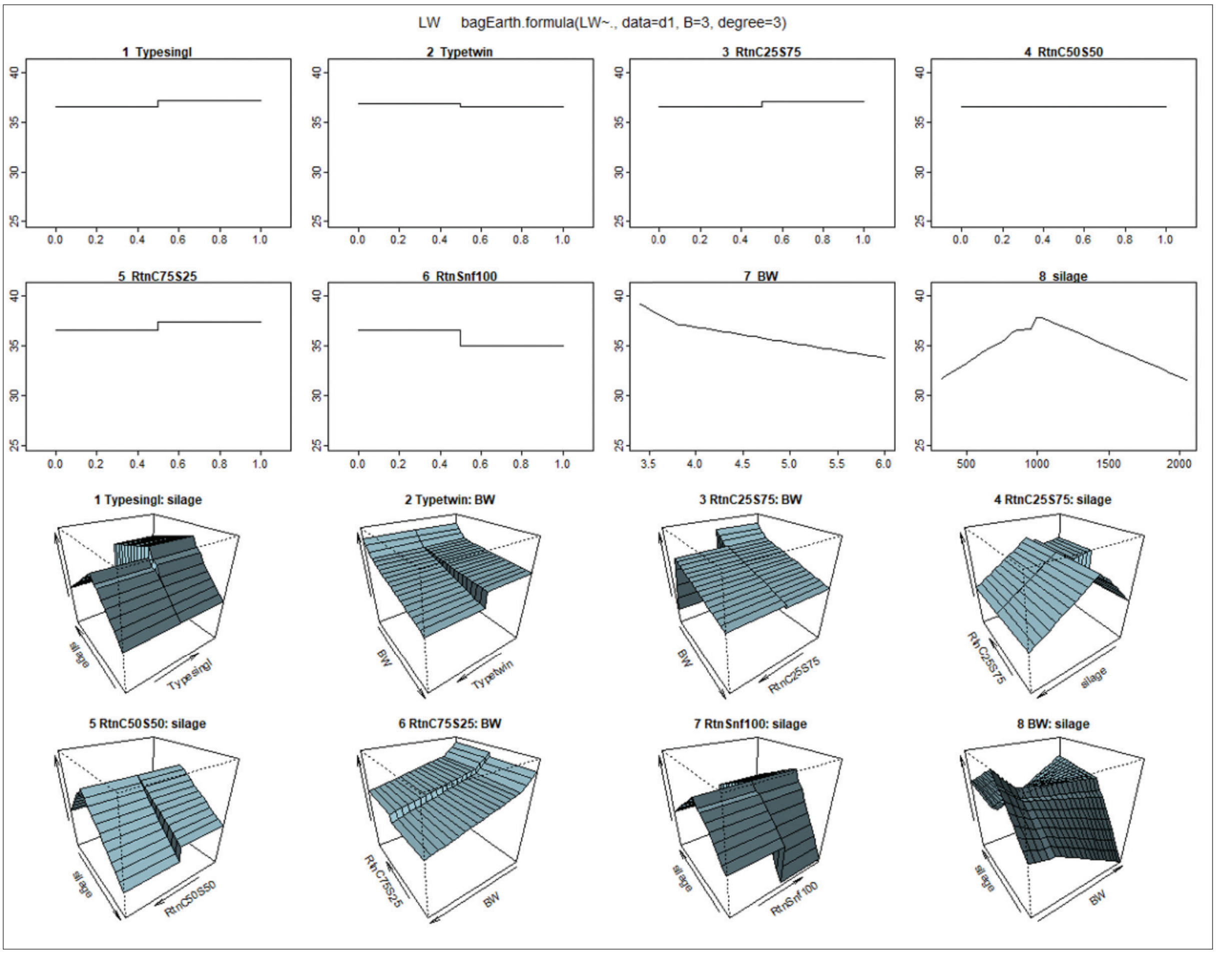

Fig 6. Model surface plots in Bagging MARS algorithm

Discussion

In the present study, two different techniques were used to determine the effect of silage type, silage consumption, birth type and birth weight on live weight in Kıvırcık lambs: MARS algorithm and Bagging MARS algorithm. In different studies, the values obtained regarding the performance of the fattening lambs show significant differences depending on the feeding method, fattening, duration, birth type and birth weight. In general, the results show that birth type and birth weight have an effect on final weight. Similarly, different feeding methods (consumption of concentrate feed, dry roughage and silage) can also have an effect on the final live weight of the lambs.

In the study, the effects of 4 different parameters (silage type, silage consumption, and birth type and birth weight) were found to be significant on the final body weight of lambs. Among these parameters, the most effective ones were determined as silage type, birth weight, silage consumption and birth type, respectively. When evaluated in terms of silage type, it was determined that the final live weight increased significantly due to the increase in sunflower silage in the ration. Altın et al.[29] determined the body weights of Kıvırcık and Karya breeds as 34.70 kg and 29.92 kg, respectively, in their study on live weight. In addition, with the regression analysis, it was determined that the effect of fattening starter live weight on the live weight at the end of the fattening was significant. The body weight values obtained are lower than the findings in this study. In the study of [30], live weights of 180-day-old Kıvırcık lambs were found to be 37.67 kg in singles and 35 kg in twins. The reported findings are in agreement with the results of this study. In addition, the researchers used the linear regression model to determine the effect of birth weight and daily age on body weight. With regression analysis, they found to be significant the effect of birth weight on live weight. In addition, the effect of birth type (single and twin) on birth weight and body weight was found to be significant. The results obtained were similar to the findings of this study. Ekiz et al.[31] found as 26.74 kg the body weight of Kıvırcık lambs at Marmara Animal Breeding Research Institute. The reported values differed from the results in this study. In another study, birth weights were investigated in different genotypes and growth periods. Birth weights in German Black Head x Kıvırcık x Kıvırcık, German Black Head x Merino x Kıvırcık and Kıvırcık genotypes were 4.08, 4.32 and 3.85 kg, respectively, while their 75-day live weight was 19.33, 19.38 and 17.58 kg, respectively [32]. Birth weights were close to the results obtained in this study.

In a study, Kıvırcık lambs housed in cross-ventilated coops were fed with an average of 600 g/lamb concentrate, 100 g/lamb alfalfa grass and 300 g/lamb vetch-wheat mixed grass daily until the post-weaning period (135 days). Birth type significantly affected the birth weight and live weight of lambs [10]. Similarly, the effect of birth type on live weight was found to be significant in this study.

Goodness-of-fit statistics are important in comparing data mining and other statistical methods used to predict any trait in lambs as in all living things.

In a study, artificial neural network, multivariate adaptive regression splines (MARS), support vector regression and fuzzy neural network models were used to predict the serum Immunoglobulin G concentration from gamma-glutamyl transferase enzyme activity, total protein concentration and albumin in lambs. Correlation coefficient (r), root mean square error (RMSE) and mean absolute error (MAE) statistics were used to compare models. It has been observed that the fuzzy neural network is the most successful method for the prediction of Immunoglobulin G value [33]. Although the study in question is similar in terms of using the MARS method and calculating the correlation coefficient and RMSE statistics, it differs in terms of the results obtained with other methods and several different goodness-of-fit statistics used in estimating the dependent variable.

In another study on the use of goodness-of-fit statistics to compare models, different growth models were used for body weight modeling in Romanov lambs. Adjusted determination coefficient (R^2 adj.), mean square error (MSE), Akaike information criteria (AIC) and Durbin-Watson (DW) statistics were used to determine the most appropriate model [34]. Goodness-of-fit statistics (R^2 adj. and AIC) used by the authors in their study were also used in this study.

In the current research, final live weight of Kıvırcık lambs were evaluated to on the basis of Multivariate Adaptive Regression Splines (MARS) and Bagging MARS algorithms showing perfect performance as a robust algorithm without overfitting problem. MARS algorithm gave better results than Bagging MARS algorithm in modeling body weight in lambs. It is expected that good results can be achieved in data mining applications such as MARS and Bagging MARS algorithms in livestock data.

Ethical Statement

This study was carried out with the approval of Bursa Uludağ University Animal Experiments Local Ethics Committee dated 07.01.2020 and numbered 2020-01/02.

Availability of Data and Materials

The authors declare that data supporting the study findings are also available to the corresponding author (Ş. Çelik).

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Competing of Interest

The authors declared no competing interests.

Author Contributions

IA conceived and supervised the study. ÖŞ carried out animal experiments and made measurements. ŞÇ statistical analysis and writing the manuscript. All authors contributed to the critical revision of the manuscript and have read and approved the final version.

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