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Multivariate binary logistic regression spline analysis on the influence of grass and concentrate composition on cattle pregnancy

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Abstract

Introduction: Estimating pregnancy in cattle is a critical aspect of reproductive management in the livestock industry. This study aims to estimate the likelihood of cattle pregnancy by considering variables such as the amount of grass and concentrate consumed, Body Condition Scoring (BCS), and cattle variety.

Objective: In this study, data from one hundred cattle were analyzed, where each animal was recorded for pregnancy status, grass and concentrate consumption, BCS condition, and variety. The data was then analyzed using the Multivariate Adaptive Regression Splines (MARS) method, which allows for the identification of nonlinear relationships and complex interactions between predictor variables and response. From this analysis, four main estimators were identified, with two showing statistical significance as primary predictors of pregnancy, namely grass and concentrate consumption.

Results: It was found that the amount of grass and concentrate consumption has an inverse linear relationship with the likelihood of pregnancy, particularly at consumption points of thirty and fifteen kilograms. MARS analysis also showed that BCS and variety play a role in influencing pregnancy, although in this study they were not as influential as feed consumption. Therefore, body condition scoring and the correct selection of cattle variety should also be considered in cattle reproductive management.

Conclusion: This study highlights the importance of proper selection and management of nutrition as a key factor in increasing the likelihood of cattle pregnancy. Through sophisticated statistical analysis, this research provides important insights into effective ways to increase reproductive efficiency in the livestock industry, thereby helping farmers make data-based decisions for animal nutrition management.

Keywords: Cattle; Concentrate; Food production; Grass; pregnancy; MARS

1. Introduction

The success of cattle breeding is measured by production or reproduction. A key indicator of reproductive success is pregnancy. The success of pregnancy does not occur in isolation from influential factors. These factors include the quality of the male's sperm, the condition of the mother such as BCS and variety, or inseminators if mating does not occur naturally [1]. Another important factor is grass (forage) as a source of carbohydrates for energy. If grass is unavailable, its nutrients are obtained from derivatives [2].

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The nutrient content of grass only meets basic needs so for higher needs such as production and reproduction, additional feed (concentrate) is necessary [3, 4, 5, 6]. One impact on cattle not given concentrate is repeated mating occurrences [7]. In this regard, the estimation of grass and concentrate needs must be considered to achieve a higher chance of pregnancy.

Friedman [8] introduced MARS as a non-parametric and nonlinear regression analysis as a solution to the imbalance between the number of variables and regression functions. MARS data is presented as separate linear pieces (splines). Each spline has a basic function (BF) [9]. The variable that forms the BF has a maximum limit (knot = t) representing the spline part that has a meaningful function. If located to the left of the knot the function is negative, otherwise, it is marked positive if to the right.

2. Material and methods

Data collection included one hundred cattle from various varieties. Each animal was meticulously recorded for various important parameters including pregnancy occurrence, grass and concentrate consumption, Body Condition Score (BCS), and variety. This data was collected to evaluate and understand the factors influencing the level of cattle pregnancy in the environment.

For data analysis, the Multivariate Adaptive Regression Splines (MARS) method was used. This method was chosen for its superior ability to handle nonlinear relationships between response and predictor variables as well as its capability in modeling data that has complex interactions between variables. Pregnancy was designated as the response variable in this analysis, while the amount of grass consumed, concentrate consumption, BCS, and variety were designated as predictor variables.

In the modeling process using MARS, the initial step was the determination of the Basic Function (BF). The BF range tried varied from two to four times the number of existing predictor variables, to see its impact on model accuracy. The model's suitability was then tested by choosing the model with the smallest Generalized Cross-Validation (GCV) value. A low GCV value indicates that the model has a low prediction error on validation data, signifying a more robust and accurate model.

Additionally, checks were also made for the maximum observation (MO) and maximum interaction (MI) possible in the model. This aims to ensure that the developed model can explain the data well without overfitting, considering the complexity of the model proportional to the number of available data.

To implement this model test, MARS version 2 software was used. This software provides a user-friendly interface and efficient algorithms for conducting MARS analysis, allowing researchers to explore data and model more effectively and efficiently.

This method provides new insights into factors significantly affecting cattle pregnancy, which are useful not only for academic purposes but also practical applications in the field. By understanding these factors, farmers can be more directed in managing feed, selecting cattle varieties, and managing the physical condition of cattle to increase pregnancy rates, which will ultimately contribute to increased productivity and sustainability of livestock operations.

3. Results

From the survey of one hundred cattle, 67 were not pregnant and 33 were pregnant. Details of grass and concentrate consumption, BCS, and variety are presented in Table 1. The consumption of grass is significantly higher in non-pregnant cattle compared to pregnant ones ($p < 0.01$). Conversely, the consumption of concentrate is significantly higher in pregnant cattle compared to non-pregnant ones ($p < 0.01$), as shown in Table 1.

Table 1 Consumption of Grass, Concentrate, BCS, and Variety Between Pregnant and Non-Pregnant Cattle

	Grass (kg)	Concentrate (kg)	BCS	Variety
Non-Pregnant	34.93 ± 0.44^{a}	9.93 ± 20.54^{a}	5.06 ± 0.67	2.21 ± 0.67
Pregnant	31.97 ± 4.99^{b}	11.45 ± 20.79^{b}	5.60 ± 0.70	2.18 ± 0.58

Superscripts indicate a significant difference at $p < 0.01$ within the same row.

The best model for the relationship between grass and concentrate consumption, BCS, and variety is presented in Equation (1). This model was achieved at BF= 8, MO =1, MI = 2, or BF= 8, MO =2, MI = 2, or BF=8, MO =3, MI = 3 (Table 2). The variables BCS and variety do not affect the likelihood of pregnancy. The lack of impact of these two variables is indicated by their absence in the model. With variables such as grass and concentrate consumption included in the model, each has an importance score of one hundred. The modeling consists of five BFs: BF1, BF3, BF4, and BF5.

$$f(X) = ln\left[\frac{\pi(X)}{1-\pi(X)}\right] = 0{,}802 + 0{,}278 * \mathrm{BF3} - 0{,}020 * \mathrm{BF4} - 0{,}060 * \mathrm{BF5} \quad \ldots\ldots\ldots\ldots \quad (1)$$

BF1 = max (0, Grass - 30);
BF3 = max (0, Concentrate - 15) * BF1;
BF4 = max (0, 15 - Concentrate) * BF1;
BF5 = max (0, Concentrate - 12) * BF1;

The equation shows an interaction between grass and concentrate (BF3, BF4, and BF5). BF1 = max (0, Grass - 30); is interpreted as a declining linear function from the point of 30 towards the y-axis (y = 0). If not, the function is not meaningful (depicted as a flat line) (Figure 1).

BF*	MI	MO	MSE	GCV	BF**	MI	MO	MSE	GCV	BF***	MI	MO	MSE	GCV
8	1	0	0,154	0,17	12	1	0	0,154	0,17	16	1	0	0,154	0,171
8	1	1	0,155	0,169	12	1	1	0,155	0,170	16	1	1	0,155	0,171
8	1	2	0,157	0,172	12	1	2	0,157	0,17	16	1	2	0,157	0,172
8	1	3	0,156	0,169	12	1	3	0,144	0,18	16	1	3	0,165	0,182
8	2	0	0,146	0,177	12	2	0	0,148	0,18	16	2	0	0,139	0,178
8	2	1	0,141	0,164	12	2	1	0,141	0,17	16	2	1	0,141	0,167
8	2	2	0,145	0,168	12	2	2	0,145	0,17	16	2	2	0,145	0,174
8	2	3	0,141	0,164	12	2	3	0,141	0,17	16	2	3	0,141	0,169
8	3	0	0,148	0,177	12	3	0	0,14	0,18	16	3	0	0,148	0,177
8	3	1	0,141	0,164	12	3	1	0,141	0,17	16	3	1	0,141	0,167
8	3	2	0,145	0,168	12	3	2	0,145	0,17	16	3	2	0,145	0,174
8	3	3	0,141	0,164	12	3	3	0,141	0,17	16	3	3	0,141	0,167

* dua kali variabel bebas
** tiga kali variabel bebas
*** empat kali variabel bebas

Figure 1 Comparative Effectiveness of Statistical Methods Based on MSE and GCV

The downward line means that giving grass as much as or more than 30 kg has an impact, the more the amount of grass given, the further away from the chance of pregnancy. In contrast to giving grass less than 30 kg, it means that giving grass up to less than 30 kg has no impact on the chance of pregnancy.

BF4 = max (0.15 - Concentrate) * BF1, means giving concentrate less than 15 kg while grass is more than 30 kg. If BF4 is one unit, with all BF constant, then the chance of pregnancy increases by 0.020 or two percent in this condition the cow is not pregnant (0.020 <0.5), the same thing also happens in BF5.

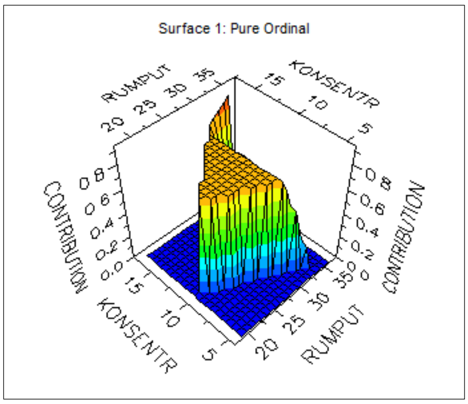

Figure 2 Model of the relationship between grass and concentrate on the occurrence of cow pregnancy. It appears that giving grass up to 30 has a chance of pregnancy of 0.8 and decreases to a chance of pregnancy = 0 when given more than 30 kg

4. Discussion

Of the four variables used as estimators for the occurrence of pregnancy in cattle, only two—grass and concentrate—can be used as estimators. Varieties were not found to be indicators of pregnancy as per the research findings of Ulfah et al. [10]. Similarly, the analysis did not find an influence of BCS on pregnancy occurrence. One indicator to determine the success of livestock management, both in terms of production and reproduction, is BCS. In addition to its advantages, BCS changes reflect the health status of the livestock independent of time or varied interpretations by operators, even for the same subject [11, 12, 13].

The recommended amount of grass for cattle consumption is about 10 percent of body weight, equivalent to thirty to forty kilograms per animal per day [14]. Analysis shows that providing more than thirty kilograms of grass reduces the chances of pregnancy. Grass is a primary source of carbohydrates for cattle. Attention must be given as it varies in nutrient content, and some types contain hepatotoxic saponins [15].

The importance of concentrate is equal to that of grass. This implies the importance of providing concentrate to cattle. Providing concentrate is expected to meet the nutritional needs within the grass that might still be lacking to stimulate bodily activities. The amount of concentrate provided needs to be considered because a certain amount can increase the chances of pregnancy. The protein content in the concentrate stimulates superovulation, the extent of which depends on the type of protein. The larger the concentrate composition relative to grass, the greater the number of corpus lutea produced [16]. The analysis shows that the more concentrate is given, the greater the chance of obtaining pregnant cattle.

5. Conclusion

The success of pregnancy in cattle can be estimated from the amount of feed consumed, both grass and concentrate. It is important to consider the impact as grass or concentrate have threshold points. Providing grass has an impact after thirty kilograms, the more grass given, the lower the chance of pregnancy. The impact of concentrate occurs after fifteen kilograms, increasing the chance of pregnancy, an opposite effect to that of grass, thus the balance between grass and concentrate feeding must also be considered.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

The study was approved by the Faculty of Veterinary Medicine Animal Ethics Committee of Universitas Airlangga. All variables were considered in accordance with the Ethics Committee related to the animal handling to ensure no discomfort or pain was caused to the animals during sampling.

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