Determining the Optimal Ration for Sheep, Using a Mathematical Model

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Abstract: The primary economic sector includes the industry of livestock farming, which is dedicated to the breeding, care, and production of farm animals. The development of information systems is essential for optimizing the variables in livestock production due to rising costs for power, heat, and fuel in recent years, as well as growing technological needs and the need to reduce production costs. One of these factors is feed, which plays a key role in the care of animals and their overall health. There are specific guidelines for the preparation of high-quality animal feed in animal husbandry. This calls for formulating a specific volume of feed combination that contains a specific proportion of ingredients. Following the blending of various amounts in varied ratios, these conditions are satisfied.

Keywords: mathematical model, ration, animal feed.

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1. Introduction

Feeding ruminants can be described as an art, because when preparing a ration, there must be a balance and synchrony between quantity and quality. Some farmers neglect this balance and do not pay attention to quality, do not combine the different feeds properly, which is the reason why the synchrony is broken. [2]

To expect good results, we need to have a balanced diet. This means that the ration we set must be balanced with the more necessary nutrients, namely: crude protein, energy, crude fiber, crude fat, protein digestible in the intestine, micro- and macro elements and vitamins. A large percentage of the above nutrients are neglected, resulting in low productivity and poor health. It should be known that each of the above nutrients has its specific role in animal growth, performance and metabolism. [3]

1. Energy provides the body with the ability to "work," which includes growth, lactation, reproduction, digestion, movement, etc. It is required in the greatest quantities.

2. Protein is the basic building block of the body, which is composed of amino acids. The quality of protein in the ration is important for maintaining growth, milk production and reproduction.

3. Minerals are important for animal growth, bone, reproduction, etc., and their quantity is affected by the type and quality of feed. In most cases they are in insufficient quantities in the feed, necessitating their addition to the ration of the animals.

4. Vitamins are important for growth and reproduction, with attention to vitamin A, D and E. [9]

A proportion of farmers work with nutritionists who work out the best ration for their animals. Another part prepare their own rations and another feeds what is available on the farm. Some of the most common mistakes, which will be looked at individually over the next week, are:

- Improper feed combining;
- Including more than 2 types of protein sources in rations;
- Neglecting feeding norms;

The essence of making a complete ration is a combination of several feeds, minerals and vitamins that are well homogenized so that the animals have no selectivity. In its preparation, the main share is given to roughages (silages, haylage and hay), which take up to 70 %, followed by cereal and protein forages, minerals and vitamins, taking up to 30 %.

In rationing, the aim is to optimise production and achieve economic results. [13]

Increasing prices of electricity, heat and fuel in recent years, together with increased technological requirements and the need to lower the cost of production, require the development of information systems to optimize the parameters in livestock production. One of these parameters is feed, which occupies a significant place in animal husbandry and their general condition.

The objective of the problem is to build a mathematical model to determine the required quantities of the components that make up a minimum cost mixture, while satisfying the composition and quantity requirements of the mixture. [6]

In this work, a model is put forth to determine the ideal feed quantity values, which are represented by a mathematical dependence with the performance requirements in the model's objective function, subject to their established limitations for the problem under consideration. It analyzes information for a sheep farm and determines how much feed to distribute based on the nutritional requirements needed for healthy sheep rearing. On the basis of the findings, solutions are suggested for figuring out how much feed (hay and silage) is required to feed the sheep, thereby figuring out the precise amount of stock not needed for a specific amount of time. This way, feed won't be purchased that won't be used and won't needlessly take up space in the warehouses. Therefore, by purchasing the appropriate quantity of feed, the cost to the cow farm will be decreased.

2. Resources for Food in Animal Husbandry

The concept of proper and balanced nutrition means that livestock should be getting just as much food as they need, not overfeeding them. It is a common and very wrong practice for sheep to have a menu poor in protein, vitamins and minerals and this is quite dangerous for livestock and can lead to a number of problems. For example, ewe lambs will find it quite difficult to breed, which will reduce the birth rate on the farm considerably.

As a consequence of poor nutrition, sheep will gain body mass much more slowly, will need more care, but will also be susceptible to various diseases. They need to get enough energy in the diet, adding carbohydrates to cereal feeds and silages for this purpose. Energy deficiency can lead to a number of problems, such as low fertility, milk yield, reduced growth, low fertilization rate, weight loss and others. [8]

More than a third of the ultimate consumer price is made up of feed expenditures. This article highlights the critical role that feed utilization plays in competitiveness and how it may be improved through improved genetics, feeding practices, and breeding techniques. [18]

Farms engage in marketing initiatives with the goal of maximizing profit and securing the highest market share. The desire to avoid failure or reduce its likelihood exists. [1].

One of the primary goals of food law, as stated in Regulation (EC) No 178/2002 of the European Parliament and of the Council of January 28, 2002 laying down the general principles and requirements of food law, creating the European Food Safety Authority, and establishing procedures in matters of food safety, is to achieve a high level of protection of human and animal health. [17]

In order to ensure optimum animal health, proactive prevention, and enhanced milk supply, it is important to employ both bulky and high-quality compound feeds as well as carefully chosen vitamin-mineral premixes. Any good farmer is aware of this. When creating rations for sheep, the gestation time, the animal's age, and whether it is winter or summer must all be taken into consideration. The meal must be well-balanced and satisfy the ewe's requirements for protein, energy, and other vitamins and minerals. This will enable them to achieve both great performance and a regular metabolism, both of which will be beneficial to their health.

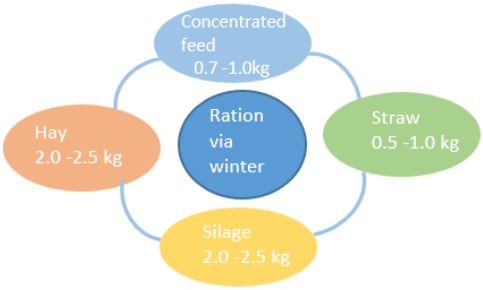

Fig. 1. Sheep ration in winter

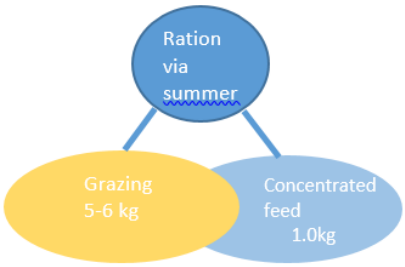

Fig. 2. Sheep ration in summer

Sheep require a varied diet in order to consume a complete diet. The diet might contain grass (grazed pasture), legumes (soya), and fodder with high nutritional value, depending on the farm. According to the season, physical distance, and time of day [5], sheep have distinct preferences for these. Farms implementing free-ranging must take these preferences into

account, as the additional feed encourages animals to milk voluntarily [7. 11]

A really ideal solution for the competitive costs and maximum profitability of industrial livestock production is developed with the aid of special programs that, using the methodology of non-linear forecasting, take into consideration the influence of all aspects. [10] The Exel program and Solver function were utilized in this investigation to solve the puzzle.

The goal is to create a ration that meets certain nutritional standards and is the least expensive. The daily nutritional guidelines are listed in Table 1, along with the number of units of each food that make up one kilogram of it.

It is possible to use the Solver function to optimize some of the agricultural economic issues that are represented by tables made in Microsoft Excel. The created tables reflect a rough, preliminary answer to the issue; they might not be ideal, though. The objective function of the linear problem is described by the quantity that needs to be optimized, which can either be maximized (feed values) or minimized (feed cost per day). [4] The problem's conditions and dependencies are represented in the table as linear relationships. The Solver function menu allows for the addition of additional restrictions. The table's primary parameters are subject to optimization.

In the current project, a model is being created to determine how much hay and silage would be needed to feed 1 sheep every day for the cheapest possible price.

The solution offered in this study is restricted to the creation of an optimization model for feed storage in warehouses, one of the major issues in pig farming. Since feed takes up a lot of space, purchasing the incorrect quantity results in losses.

3. Mathematical Model of the Problem

1. A mathematical representation of the issue.

The amount of the i-th substance in a unit of the j-th component is known to be a_{ij} (gram/kg for the ingredient), and the specific costs of the ingredients are known to be C_j (BGN/kg), while x_i is the amount of the j-th ingredient in the mixture.

Model objective performance:

$$\text{Min } Y=\sum_{j=1}^{s} c_j z_j$$

1.1. In case of restrictions

$$\sum_{j=1}^{s} z_j \geq Q$$

The amount of food consumed every day, month, or year is a relative concept that depends on the product, the animal's weight, and a number of other factors. Typically, the estimate is based on dry concentrates, which need to be the foundation of the diet.

Table1 displays the input parameters for the optimization problem.

Table1. Parameters of the optimisation problem

Nutritional Composition, g / kg	Hay	Silage
Fodder units	0.87	0.32
Calcium	13	1
Phosphorus	2	0.68
Potassium	6.25	1.2
Carotene	0.8	0.4
Protein Digestible In The Gut	53	23
Raw Protein	45	27
Price / BGN	0.16	0.3

The quantity of hay and silage is chosen based on the requirements of the animal. The National Farm Advice Service states that table 2 lists the number of feed dinners required for sheep each day. [14, 15]

Table2. Necessary feed dinners

Nutritional Composition, g / kg	Minimum required quantity
Fodder units	3.25
Calcium	40
Phosphorus	4
Potassium	6.5
Carotene	6
Protein Digestible In The Gut	84
Raw Protein	130

2. Algorithm for solving the task.

The problem's goal is to find the daily mix for the least amount of money.

The model's decision variables are: kg of hay in the daily mix (x1); kg of silage in the daily mix (x2)

The objective is to minimize the total daily cost (in €) of the forage mix - i.e.

$$\text{Min } Z=0.16*x1+0.3*x2$$

The limitations are represented mathematically as follows:
Feed consumed overall (6 kg); [16]
$x1+x2 \geq 6$;
$x1+x2 \leq 10$;

- CEM content of the mixture (≥ 3.25g/day)
$0.87*x1 + 0.32*x2 \geq 16.8$;
- Calcium content of the mixture (≥ 40 g/day)
$13*x1 + 1*x2 \geq 91$;
- Phosphorus content of the mixture (≥ 4g/day)
$2*x1 + 0.68*x2 \geq 28$;
- Regarding the potassium content of the mixture (≥ 6.5 g/day)
$13.25*x1 + 1.2*x2 \geq 48$;
- On the carotene content of the mixture (≥ 6 g/day)
$0.25*x1 + 0.4*x2 \geq 5$;
- Regarding the intestinal digestible protein content of the mixture (≥ 770 g/day)
$73*x1 + 23*x2 \geq 84$;
- For Crude Protein content of the mixture (≥ 1580g/day)
$163*x1 + 27*x2 \geq 130$.

4. Using a Solver, the Issue is Resolved

The Matlab Solver function, shown in Fig. 3, represents the problem's resolution.

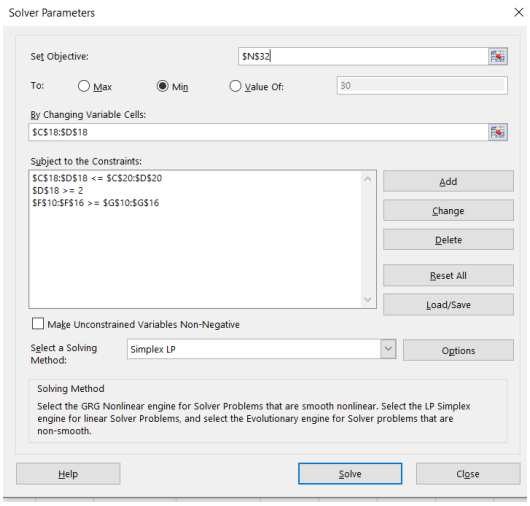

Fig. 3. The problem model in Solver

The Set Objective field is used to enter the objective function, which is the minimum cost of living. [12]

The cells that need to be altered are entered in the By altering Variable Cells field; these are the hay and silage quantities (C18:D18).

Simplex is the approach used to find the best feeding cost.

5. Solving the Problem with Excel

This section of the paper presents the issue's resolution using Solver. Fig.4

	B	C	D	E	F	G
8						
9	**Nutritional Composition, g / kg**	**Hay**	**Silage**		**Calculation**	**Constraints**
10	Fodder units	0.87	0.32		6.295	3.25
11	Calcium	13	1		86.5	40
12	Phosphorus	2	0.68		14.36	4
13	Potassium	3.25	1.2		23.525	6.5
14	Carotene	0.8	0.4		6	6
15	Protein Digestible In The Gut	53	23		390.5	84
16	Raw Protein	45	27		346.5	130
17	Price / BGN	0.16	0.3			
18	z	6.5	2.0			
19						
20	kg per day	7	7			
21						
22	y	1.64				
23						
24	Total amount of feed	8.5				

Fig.4 Representation of the task in a worksheet

To find the solution of the problem with Excel, the objective function Y of the model is calculated in cell C22 by the following formula =SUMPRODUCT(C18:D18,C17:D17).
In cell F10 to cell F16, calculate the amount of different nutrients in the mixture using the formula .

In cell C26 calculate the total amount of feed per day using the formula =SUMPRODUCT(C20:D20)

These rations include the necessary amounts of calcium and phosphorus in addition to adequate amounts of CF, CEM, and PFA. As a result, the meals do not need to be supplemented with additional minerals. This is the exact reason that hay and silage will be used to balance these meals instead of more expensive complex combinations.

Finding silage in the required quantity only is another issue that has been resolved. From the solution, it is clear that, although extremely large (10 kg), the amount of silage does not meet the needs of the necessary nutrients. Both the price and available feed double.

The amount of forage that contains the required amounts of nutrients is 8.5 kg per day per ewe. 6.5 kg is hay and 2 kg is silage. The minimum cost of preparing a feed mixture is y = 0.16 * 6.5 + 0.3 * 2 = £1.64 per sheep per day. Subject to quantity restrictions to be less than or equal to 10.

These rations include the necessary amounts of calcium and phosphorus in addition to having enough dry matter, fodder, and protein that can be digested in the intestine. As a result, the meals do not need to be supplemented with

additional minerals. This is the exact reason that hay and silage will be used to balance these meals instead of more expensive complex combinations.

Finding silage in the required quantity only is another issue that has been resolved. It is clear from the solution (table 3) that while being quite large -10 kg (only for hay – 15 kg), the silage does not provide all of the necessary nutrients. Both the price and the available forage are doubled.

If just silage and only hay are fed to the animals as a sole source of food, the cost of fodder is examined while maintaining the current diet. Table 3 displays the findings for the amounts of nutrients in each decision and associated expenses.

Nutrition Composition, g/kg	Desired value	Optimal	Only Silage	Only Hay
Fodder units	3.25	6.295	3.2	0.87
Calcium	40	86.5	10	13
Phosphorus	4	14.36	6.8	2
Potassium	6.5	23.525	12	3.25
Carotene	6	6	4	0.8
Protein Digestible in The Gut	84	390.5	230	53
Raw Protein	130	346.5	270	45
Quantity/kg		8.5	10	15
Price/BGN		1.64	3	1.6

Table3. Results of various mathematical model decisions

6. Conclusion

Farms' marketing efforts are focused on making the most money possible and capturing the highest market share. The likelihood of failure is being prevented or reduced. On the other hand, ingenious solutions must be developed to lower expenses and improve the organization of farm operations, labor resources, etc. in order to boost the income in sheep farms.

By taking into consideration the limitations on the required amount of feed each day per sheep, the strategy suggested in this study offers a better organization of the storage facilities. The appropriate amount of feed purchased will lower costs and make best use of farm storage. By consuming the required nutrients, the sheep will produce more milk and be healthier, which will lower the cost of medications, veterinarians, and other supplies.

Modern techniques are used by sheep farms to increase their economic efficiency. The best usage of feed is necessary due to its high cost. Because of this, farm management plays a key role in overall profit.

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