

Evaluation on How to Maximize Cattle Diet Revenue While Controlling Carbon Emissions through Linear Programing

Kewei Huang^{1*}, Mingyang Bao², Chenle Han³, Rong Xie⁴, Tingxu Chen⁵

¹Suzhou Dulwich High School, Suzhou, 215127, China, Vivian.Huang23@stu.dulwich.org

²Broward college, 4205 Bonaventure Blvd, Weston, FL33332, 001500, America, 2569721038@qq.com

³Shanghai Pinghe school, Shanghai, 200120, China, hanchenle@shphschool.com

⁴Ningbo Binhai International Cooperative School, Ningbo, 315830, China, rongxie@nbics.com.cn

⁵Wuhan Ulink College of Optics Valley, Wuhan, 430205, China, 1526452932@qq.com

*correspondence author email: Vivian.Huang23@stu.dulwich.org

ABSTRACT

In this work, the goal is to select the appropriate amount of given set of foods that will satisfy a set of cattle daily nutritional requirement at minimum cost. Despite the consideration of financial gain and cost, the concern about environmental protection is recognized in this paper. The optimum diet composition is obtained under the consideration of the controllment of carbon emissions. The problem is formulated as a linear program where the objective is to minimize cost and the constraints are to satisfy the specified nutritional requirements. Equations that help to predict CO₂ and CH₄ production are listed in this study as well. The problem reaches optimum by simplex method. By essentially changing some parameters, the model can be applied to different species and different nutritional conditions.

Keywords: diet studies, cattle, carbon emission, profit maximization and cost minimization

1. INTRODUCTION

The diet problem constraints typically regulate the amount of energy, protein, calcium and phosphorus in the diet. While the mathematical formulation is simple, the solution may not be palatable. Considering that environmental problems cannot be ignored, we regard carbon emissions as one of the limiting conditions, and the maximum output of each food becomes the second limiting condition. How to achieve the optimal balance is the problem we need to solve this time.

To make this work study more convincing, the group looked at recent data, mostly from NASEM and IPCC, which will be explained in more detail later.

First, the work did a background check and explained how to optimize the problem. In particular, the result will cite some empirical estimates that are necessary for our problem formulation. Once this is done, the result presents the data from various sources, categorize and summarize it, which is also presented in table form below. Then, the group chose

Matlab as a tool to calculate the results by plugging in the listed formulas. Finally, the result associate with the animal husbandry related issues, make relevant judgments, and put forward suggestions for the future.

2. BACKGROUND

First, a brief summary of the problem scenario. The scenario consists of three goals and a series of related variables. The work needs to reduce the cost, maximize the nutrient content, and minimize the carbon footprint to achieve the perfect balance. At the same time, it should also be considered that all variables should not exceed the maximum limit and conform to the actual situation.

This model starts with a cattle representative, which is bought at initial weight. The daily cost of which is determined by the market. And The cattle are also believed to have a realistic diet in which it only eats a certain amount of food each day, depending on its weight.

For each type of food, a set of nutrient concentrations was obtained from laboratory and empirical estimates to assess how much nutrients the cattle were getting from the food.

The daily weight gain of a cattle depends on how much food the cow consumes, especially if we assume that the weight gain depends on the total energy intake of the cattle.

Eventually, a cattleman's main source of income is to sell his finished cattle to the meat factory which is an important part the work will consider about.

Then the work imagines governments imposing environmental policies aimed at limiting carbon emissions from cattle. The work assumes that this policy also applies to our cattle, so there is an emission penalty for each unit of carbon emitted (emissions above the emission threshold). The penalty multiplied by excess carbon emissions is the daily cost of emissions.

3. MODELLING

The following part is the process of modelling the issue to find an optimized result. The essential goal of the model is to maximize the profit. Transforming it into mathematical language we got:

$$p \cdot \Delta W - c^T \cdot x - f \cdot \hat{M}$$

However, it is not enough to just recognize the final objective. For the work, it is necessary to scrutinize the whole process of feeding the cattle to determine the components of the so-called profit. Through discussions and investigations, our group decided to consider mainly three components into the calculation of profit.

The first one is the feed cost, which is the money used for consumption of cattle foods. The group supposed that the daily cost to be composed of a matrix where one unit of feed type j cost c_j dollars. Initially, there are twelve types of food, so the total daily cost of feed is:

$$\sum_{j=1}^{12} c_j x_j = c^T x$$

It is obvious that the food taken by the cattle contains different nutrients. For different types of feeds, they have different nutrient compositions. For instance, barely grain, cotton hulls and sugar beets, they have different prices and contribute different functions to the growth of cattle. Therefore, the nutrient matrix is way more complicated than the symbol represents. If the daily cost can be reduced under constrained, the net profit can be improved.

Secondly, to make profit, the work's business must have ways to gain financial capitals. Typically, people raise up cattle to sell them when they grow up. The heavier the cattle, the more valuable they are. Given that the initial weight of the cattle is W . Through a specific equation the change of the weight of the cattle can be

calculated according to their daily nutrient intake. The formula is given by:

$$\Delta W \stackrel{\text{def}}{=} 13.91(C^T x - E_m)W^{-0.6837}$$

Here x is the daily food intake and is defined by:

$$E_m = sW^{0.75}$$

where s is the correlation factor between W and E_m , depends on breed, nutritional state and sex etc.

After calculating the change in weight, the group times it with the sales price, possibly the current price of cattle in the market, and gets the amount of financial capital that will probably be gained from doing such business.

Moreover, the group need to take into consideration the methane emission which is often ignored. It is known that for the stock farming, whenever cattle eat something, there will be methane emitted. Similar to carbon dioxide, methane, as well as other greenhouse gases, will cause the temperature of the Earth surface becomes hotter and hotter which will eventually lead to an unsuitable environment for human beings to live on [1]. Thus, nowadays, the government implemented a policy that there will be a fine for emitting these gases. These are additional costs to our business that may further reduce our net profit. The fine rate is given by a certain rate of the selling price. the group took 20% as a standard level penalty. The amount of methane emission is:

$$\text{emissions} \stackrel{\text{def}}{=} \frac{m \cdot k}{mec} C^T x$$

where m is the methane conversion factor; k is a unit conversion factor and mec is the methane energy constant.

Besides the objectives, limitations are also very essential in solving a linear problem.

Firstly, the nutrient vector x must be positive because it is impossible for us to provide negative food for cattle. Secondly, the weight change of the cattle should be positive, or the group will continuously lose money which is a possible solution but should not be considered in our optimization problem.

4. DATA COLLECTION

Most of the data the work use is from NASEM and IPCC. And the group get the rest of the data from search engine Google and Baidu. At the same time, in order to facilitate the calculation, the work takes some data to take the means of approximate value to facilitate the calculation. In addition, because the carbon penalty varies from region to region, we use California's carbon penalty for our calculations.

All the data and their provenance are listed in the table 1,2 and 3:

Table 1 Data

Known quantity	value	provenance
cost	/	https://hayandforage.com/article-3623-USDA-Hay-Markets-%E2%80%93-August-24-2021.html
A	Listed in sheet one	NASEM [1]
b	Listed in sheet one	NASEM [1]
C	Listed in sheet one	NASEM [1]
p	120\$/kg	https://www.macrotrends.net/futures/cattle [2]
Original weight	300/kg	NASEM [1]
f	Thirty percent of the selling price	https://www.macrotrends.net/futures/cattle
s	0.077	The average value of all the cattles, based on NASEM data
N	44	https://www.ers.usda.gov/topics/animal-products/cattle-beef/sector-at-a-glance/
m	4%	IPCC2020vol.4pp.10.25
mec	56MJ/kg	IPCC2020vol.4pp.10.33
M0	0.1kg	https://www.bp.com/en_us/united-states/home/news/features-and-highlights/bp-aims-for-zero-routine-flaring-in-us-onshore-operations-by-2025.html?gclid=CjwKCAjwmqKJBhAWEiwAMvGt6PjBbBvclRyHdVPTc015TwqEkmV-iUth06CTQHxjbjACp_VwGAMllxoCeOUQAvD_BwE

Table 2 The amount of nutrients contained in different types of food

food	NE	CP	C	P	Cost
Alfalfa fresh	1.4	19	1.3	0.3	170
Barley grain	0	13	0.05	0.35	115
Cotton hulls	0.7	4.5	0.15	0.1	240
Cottonseed meal	1.8	46	0.02	0.02	350
Distiller's grains dried	2	30	0.3	0.8	270

Hay	1.3	19	1.5	0.3	170
Gluten meal	2.1	66	0.08	0.63	723
Oat hulls	0.4	4.5	0.2	0.2	130
Seed	2.3	25	0.18	0.67	390
Straw	0.6	4.5	0.3	0.1	76
Sugar beets	1.8	10	0.7	0.1	130
Wheat midds	1.7	19	0.2	1	230

Table 3 Nutritional requirement

Nutrition	value
Calcium	6.7
Energy	29/100
Protein	11/100
Phosphorus	5/1000

That's all the data that experimental analysis needs.

5. CONCLUSION

In the project, a cattle diet problem is considered with the included component of methane emission. The problem is defined as an optimization problem and is solved by simplex method [3]. Several predictive equations that can adequately predict CH₄ production are created in this study.

Our project has several advantages. In common, these equations could be simple to develop and illuminate for an optimal. Besides, they are sufficient to supply direction for cattle owners for predicting CH₄ emission from a minimum set of inputs. The model is additionally accessible to diverse species and diverse nourishment prerequisites by essentially changing some parameters.

The work's models are simplified in place of assumptions that can be avoided by providing more complex models. First, we believe that the weight picks up of the cattle is constant. Of course, the work's model can provide an evolutionary function in secret time for dynamic design, which can then be extended to dynamic design problems [4]. Second, it is assumed that the same necessities apply to cattle among all age group. In fact, cattle have to intake different food in early years of life and as they grow up. Food requirements constraints therefore depend on the passage of time and should be supplemented by weight increases in the proposed dynamic version of the project. What's more, the

methane emission expense is respected as settled notwithstanding of the sum of over-the-top outflows [5]. However, as in the case of taxation, penalties are usually segmented. For group's problem, this is probably a more complex constraint. In the end, only two foods were recommended in our program because we ignored the importance of digestive issues and a balanced diet. The work assumes that cows absorb all the nutrients that food provides them [6]. However, this cannot happen in reality. Cows may need other assistance to absorb the nutrients of these two specific foods. Future studies of the cattle diet should consider these more complex questions.

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