Animal Feed Optimization under Price Fluctuations using Evolutionary Algorithms

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***Abstract*—In the livestock industry feed cost impacts overall production cost, as the cost of feed amounts to over 60% of the production costs. This makes feed formulation of utmost concern for many breeders. Various challenges including ingredient shortage, and ingredient price fluctuations are encountered during the feed formulation process. In this work, using evolutionary algorithm, the feed formulation problem is modified to include feed cost variation that models feed ingredient price fluctuations, to minimize the feed cost per month. The objective function is modified by generating synthetic ingredient price from real-world price data. A 20% standard deviation is used to generate 12 different costs representing the cost for each month in the year. The proposed method incorporates possible price variations to search for optimal solutions in providing adequate feed materials that minimizes the cost for each month, and can select unique feed materials for each month that fits the animals growth stage and nutritional requirements.**

***Index Terms*—Feed formulation, evolutionary algorithms, price-fluctuation optimization, mathematical modeling, and decision-making.**

I. Introduction

The livestock industry offers many benefits, and products that contributes to the well being of many. Feed formulation plays an essential role in the livestock industry, as it accounts for an estimate of about 60-80% of the production costs [1], [2]. In addition to optimizing the feed formulation problem to derive least-cost rations, challenges such as ingredient price fluctuations is another problem for the breeder to overcome [3]. Conversely, considering the increase and variability of cost could possibly result in the increase of the retail price [4], optimizing these fluctuations or variations in cost could result in effective cost minimization for both producers, and consumers. Providing optimal diet at least cost, while taking into account the possible price fluctuations will incur benefits to the livestock industry. Furthermore, the variability in feed ingredient price and availability, affects several other parts of the industry. For example, in dairy feeding systems where factors such as the availability of feed resources and geographical location impacts the feed ration composition, and production of food products such as milk [5], [6].

Few studies have investigated methods on handling the feed price variations, and availability of feed ingredients. In [7], due to the sudden rise in feed ingredient price, which affected the cost and amount of milk production, they used feed efficiency, and feed costs in describing monthly variations in feed rations, costs, and the effect it has on milk production costs using one growth stage. However, LP models with its rigidity, fails to initiate versatility, and production of optimal solutions in comparison to evolutionary optimization algorithms [8], [9]. In this paper, we modified the feed cost by generating synthetic feed prices for 12 months stochastically using a standard deviation of about 20% to model varying feed prices across different months. The resulting problem is solved by utilizing differential evolution (DE), a type of evolutionary algorithms, with epsilon constraint handling method to handle the constraints in the feed formula. This further relaxes the rigid nutrient requirements in the feed formula to generate an adequate feed formula, that even with some relaxations, does not affect animal's core functions [1], [8].

This paper provides insight in handling variations in cost of feed prices, and how to handle these variations for effective feed management and formulation. The use of mathematical models in solving the feed problem has been existing from as far back as the 1950s and recently, the application of evolutionary optimization based algorithms are gaining more attention in feed optimization. This is because of the non-deterministic polynomial-time hardness (NP-hard) complexity in feed formulation as a result of the presence of linear and non-linear constraints (crude protein, dry matter intake and more). Evolutionary algorithms with its high search capabilities, even in the presence of these constraints that complicates the search problem, presents an optimization method in generating optimal solutions. Therefore in this study, based on the framework proposed in [8], we present an analysis incorporating various feed price fluctuations in an attempt to handle the variability in feed cost. Based on these cost variations, the model selects a set of feed material that varies across different months to generate a least cost ration that takes into account the different cost per month. This information can assist breeders in how they manage their feeds and accumulate much benefits.

The rest of this paper is organized as follows: Section II provides the formulation of the feed optimization problem. Section III provides the framework used and Section IV presents the experimental results from the study, while conclusion and future works were shown in Section V.

II. Problem Formulation

Real-world data used in generating the synthetic data for 12 months were obtained from the Rural Development Administration, Republic of Korea [10]. New costs to represent 12 different feed cost for each month was generated stochastically with a 20% standard deviation, and the overall mean of the results gotten from the 12 months optimization process was computed. Overall, the objective function and constrained optimization problem used in this work is shown mathematically in 1. Additionally, the problem formulation restructured in [8], is shown in Table I, where the inequality constraints with fixed values for each nutritional requirement for dairy cattle, coupled with the respective tolerance parameter (permits constraint relaxation) is described. The notations in Table I can be described as n representing the amount of feed ingredient studied (64), w_i as weight in (kg), and $cost_i$ represents the cost(Won/kg). The letters S, M, O, R, N, and Q depicts Met, MP, Ca, ME, Lys, and P nutritional requirements respectively. Whereas the δ values for each component represents the level of relaxation/satisfaction in p.

$$Cost\ Minimization : \sum_{i=1}^{n} w_i cost_i \tag{1}$$

such that

$$v(x) = \sum_{i=1}^{m} \max(g_i(x), 0) \tag{2}$$

where $g_i(x)$ is the ith inequality constraint and $v(x)$ represents the total constraint violation.

III. Optimization Framework for Ingredient Price Fluctuation

The DE algorithm, a stochastic population-based optimization algorithm was utilized in this study [11]. The algorithm was chosen primarily for its simplicity. Generally, DE begins with a population of members, with each member a possible solution in optimizing the problem at hand. Through operations such as mutation, crossover and selection, the population members evolve over specific number of generations to produce fit or optimal solutions. In evolutionary algorithms application, optimizing a problem with constraints is shown in equation 1. The epsilon constraint handling method was employed to handle the constraints in this problem [12]. In resolving complex optimization problems like the animal feed formulation, effective control of the epsilon parameter is essential. The DE algorithm with the epsilon parameter was used in evolving the initial synthetic prices of 12 months over several generations to generate new solutions with different materials that minimizes the overall cost for each month. In addition, based on these solutions and selected materials, the breeder can manage their purchase appropriately, and make effective decisions.

TABLE I: feed problem formulation

Dairy cattle
$\sum_{i=1}^{n} w_i cost_i \geq 0(3)$
$\|Met - S\| \leq \delta Met * S$
$\|MP - M\| \leq \delta MP * M$
$\|Ca - O\| \leq \delta Ca * O$
$\|ME - R\| \leq \delta ME * R$
$\|Lys - N\| \leq \delta Lys * N$
$\|P - Q\| \leq \delta P * Q$

IV. Experimental setup, simulations, and results

An experimental setup was done using a case of dairy feed formulation consisting of 64 variables according to the nutrient requirement of the Korean dairy cattle. Simulations were done in MATLAB software, with a population size of 200, DE/rand/1 mutation strategy, with a mutation rate of 0.9, binary crossover for crossover strategy, and crossover rate of 10. All simulations were carried out on a 12th Gen. Intel(R) Core(TM) i5-12500 3.00 GHz, with a 64-bit operating system, and 32GB installed RAM. The experimental setup includes a case of dairy cattle at 46 months with a target weight of about 650 kg at one level (Level 1) of nutritional requirement satisfaction as described in [8]. The level used in this work represents a 100% level of satisfaction with delta values of 0.01. The different constraints with their tolerance parameters for the specified level, is seen in [8]. Employing the setup described in [8], simulations were performed and the results for specific materials obtained from the best runs for each month are shown in figures 1, 2, and 3. The figures shows different amount for all ingredients across the 12 months. For example, in figures 1, for the ingredient Calcium salt, the amount selected in the first month differs from the amount selected in the third month. Additionally, for the second, fourth to sixth, and ninth month, little to no amount of that material was selected. Similar scenarios are seen in figures 2 and 3. For each month, the algorithm selected different type of materials, at varying quantity that minimizes the prices per month. The results obtained from this analysis could assist breeders in the decision making process in several ways. For example, based on the predictions, some materials such as calcium salt or hay, can be bought at a lesser price when it is in abundance and stored for when it might be scarce. Furthermore, breeders are informed on which materials to select for each time period early, rather than opting for the same quantity of materials that might not minimize the cost as the prices fluctuate across different months.

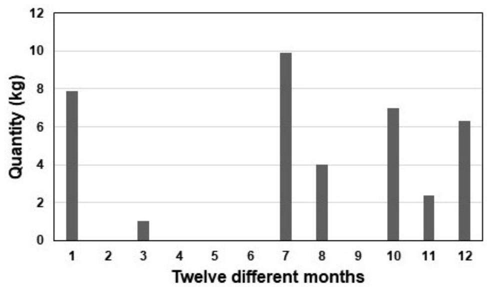

Fig. 1: Selected levels of the same material (Calcium salt) across different time periods

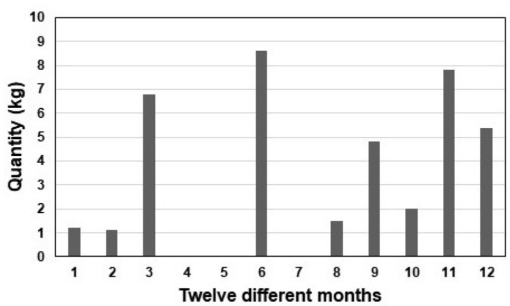

Fig. 2: Selected levels of the same material (Hay) across different time periods

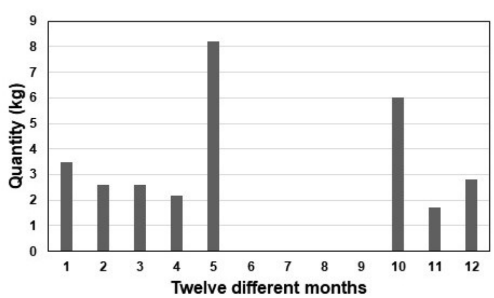

Fig. 3: Selected levels of the same material (Rice bran) across different time periods

V. Conclusion and Future Works

This paper proposes a new approach to animal feed formulations, where varying prices of feed materials are optimized to produce a set of new materials for each month that accounts for the cost variability with attempt at managing the effect of price fluctuations. The generated synthetic data for 12 different months using a 20% standard deviation was used as cost values to generate different feed materials for a particular growth stage of dairy cattle to minimize the cost for each month. Different feed materials that minimizes the cost for each month was selected in the optimization process. This presents a method where breeders, can predict the cost changes, and derive a feasible method or make effective decision in handling the effect of cost variations or price fluctuations by being informed earlier to assist in their decision making.

For future works, we hope to use real-world data of the price variations and also model how these prices affect the feed materials available for each month. Moreover, through this analysis, we plan to optimize the process to minimize the impact of the rise in feed production input by effectively minimizing the overall feed costs. Consequently, this could accrue economical benefits for both breeders, and consumers by preventing the associated rise in overall finished products at the market/supply stage.

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