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Research Article

Cost Optimization of Homemade Diet for Dogs

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ABSTRACT

Nowadays, people raising pet animals in Turkey is increasing daily. The feeding of dogs, which are members of the houses as valuable assets, is at least as necessary as family members. Calculation of dogs' daily nutrient requirements, maintenance, growth, pregnancy, lactating, working, etc. are very variable and require an intense estimate. Feeding pet dogs only with industrially prepared foods can affect the economy of the family and the health of dogs negatively. Mainly, it is continuously questioned by the animal owners whether foods and additives that may harm health are used in industrially prepared foods. Desktop, web, and mobile-based software are used in the animal feeding area. Nevertheless, according to the researches, there is no web-based software that is used for dog diet preparation that can be used by dog owners who can calculate precisely the daily nutrient requirements of dogs and meet these requirements with available ingredients so far. The data used in this study were taken from Selcuk University, Faculty of Veterinary Medicine, Animal Science and Animal Nutrition Department. In this study, a linear programming model is proposed to calculate dog diets that both can meet the nutrient requirements of dogs and can engage cost optimization. User-friendly web-based dog diet preparation software is performed.

1. Introduction

Although commercial dog foods are completed and balanced, many pet owners prefer to prepare their animals' diet at home for reasons such as insecurity and more nutrition for animal food companies [1]. Recipes published by authors and vets are easily accessible by social media (Internet, books and pet magazines). Nutritional imbalances are higher in costly and time-consuming and homemade diets [2, 3]. Another concern is the absence of decisive instructions in more than one recipe that requires animal owners' decisions. It has been concluded that pet owners prefer the same shape as pet owners have in their diet lists. There are trends in vegetables, fruits, and a full-fledged human diet in all developed regions of the world [4]. This set of values led to the emergence of the natural food market of pets. The natural food market of pet animals in the U.S. successfully rose from $ 2.0 billion in 2008 to $ 3.9 billion in 2012 [5]. Unique philosophies have been developed in the definition of food for pets that lead to different food supplement strategies among the natural food developments of pets [5].

Linear Programming (L.P.) techniques have been used in animal feed formulation for more than fifty years. To overcome the disadvantage of the linear approach of the target function for the diet formulation, a mathematical model based on the Nonlinear Programming (NLP) technique has been proposed to measure animal yield in terms of milk yield and weight gain. In the second step, the result of the proposed model is compared with the L.P. model's outcome. The result of the proposed model yielded better results than the L.P. approach. Therefore, the NLP model has been submitted for optimal planning and optimal use of nutrients.

The comparison emphasized that NLP gives better results to maximize animal yield and weight gain and that all variables act simultaneously [6]. [7], a ten-year (2007-2017) food preference database was created to associate food selection in dogs with dietary ingredients by performing the fundamental component analysis (PCA) and applying L.P. between elements. Preferred diets were analysed according to criteria such as sex, breed, age, body weight, and season (hot or cold) of dogs. Thus, it was emphasized that less

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digestible foods such as fiber and dry matter negatively affect dogs' food preferences. According
to the results, they reported that the moisture and fiber content in pet dogs and wild dogs have positive and negative effects, respectively. Finally, in this study, it was emphasized that age and gender changed the preferences of dogs or the impact of preferred diets.

Between March 2011 and December 2013, the veterinary training hospital's clinical nutrition service customers took part in a homemade diet recipe questionnaire formulated by email, mail, and telephone for their dogs. In this study, survey questions; aims to learn the positive and negative aspects of homemade food and current nutrition practices in animal nutrition. 53 (57%) of the 93 dog owners who completed the questionnaire completed the survey in this study. Of the 53 respondents in the survey, 43 (81%) reported that this homemade food is still used to feed their dogs, and this program has been applied to dogs throughout their lives. In this study, the most common motivation for using a homemade formula is the compliance of the patient with special medical needs. Only four (13%) of 30 questionnaires with a complete diet showed that they were fully compatible and suitable for homemade diet recipes (Johnson et al., 2016). In the screened studies, it is seen that the researchers have results and suggestions on the effects of fixed diets and feeding their dogs, examining the content of prepared foods, evaluating preference levels, and creating food raw material datasets.

In this article, unlike studies in the literature, breed, gender, weight, pregnancy, lactating, working conditions of dogs, and linear programming will allow dog owners to prepare the diets they need to feed their dogs with low cost and healthy eating possible. The model will be proposed, and it is aimed to get results with a web-based application.

2. MATERIAL AND METHODS

The database used in this study is obtained from Selçuk University, Faculty of Veterinary Medicine, Department of Animal Nutrition and Nutritional Diseases. The database is set up according to NRC 2006, DTU Fødevareinstituttetv, The Danish Food Composition Databank[8, 9]. In this study, besides improving the daily amount of food, dogs' daily nutrition is also regulated. The amount of food ingredient selected for the type of dog chosen to regulate daily diet at the least cost and the kind of dog, weight, age, and breed is determined. In this study, three type of dogs are selected for comparison and listed as follows (Table 1):

Table 1. Dog types

Dog Features	Dog Type 1	Dog Type 2	Dog Type 3
Breed	Alaskan Malamute	Beagle	Border Collie
Type	Lactating Bitch	Adult	Puppy
Age, years/weeks	3	6	12
Body Weight, kg	35	10	15
No of Puppies	5	N/A	N/A
Stage of Lactation, weeks	3	N/A	N/A
Activity	Inactive	Active	Active

Ingredients are selected to prepare homemade dog diets and also nutrients (Crude protein, g-CP, Energy, kcal-E, Taurine, g-Ta, Fat, g-F, Linoleic acid, g-LA, Calcium, g-Ca, Phosphorus, g-P, Magnesium, mg-Mg, Sodium, mg-Na, Cost,krş, Available amount of ingredients ,kg-Av) of the ingredients are gives as follows (Table 2):

Table 2. Raw materials for homemade dog foods

Ingredients	CP,g	E, kcal	Ta,g	F,g	LA,g	Ca,g	P,g	Mg,mg	Na,mg	Cost,krş	Av.kg
Chicken breast, raw	230.90	1100.00	0.33	12.40	1.70	0.11	1.96	280.00	650.00	6.00	2
Eggshell	44.80	0.00	0.00	2.20	0.00	336.30	0.60	3300.00	500.00	5.00	1
Carrot, raw	10.00	400.00	0.00	3.00	1.61	0.35	0.32	120.00	675.00	2.00	1
Bone meal	81.50	900.00	0.00	33.00	0.00	307.10	128.60	6200.00	3900.00	1.00	1
Magnesium chloride, 6 H2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	119600.00	0.00	0.30	1
Rice, grain	66.10	3580.00	0.00	5.80	1.14	0.03	1.08	230.00	10.00	1.20	2
Sodium chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	393400.00	0.30	1
Sunflower oil	0.00	8840.00	0.00	1000.00	398.00	0.00	0.00	0.00	0.00	20.00	1
Beef, low-fat, raw	180.60	1220.00	0.29	50.20	0.94	0.08	1.78	200.00	680.00	20.00	1
Barley, grain	105.00	3450.00	0.00	22.00	6.95	0.32	2.90	960.00	40.00	0.65	1
Lamb, lean, raw	182.70	1540.00	0.73	90.30	2.60	1.60	3.40	200.00	800.00	20.00	1
Wheat, grain	126.00	3270.00	0.00	15.00	6.00	0.29	2.88	1260.00	20.00	0.60	1
Spinach, raw	28.60	220.00	0.00	3.50	0.20	0.99	0.49	790.00	790.00	1.50	1
Poultry fat	0.00	6290.00	0.00	680.00	132.60	0.70	5.40	600.00	3200.00	17.00	1

Although the concept of optimization has many definitions, it is generally defined as the process of optimizing the object function under certain constraints. George Dantzig proposed the simplex algorithm in 1947, an effective way to solve linear programming problems. Waugh is the first researcher who used mathematical programming methods and after Waugh many researchers has used LP to solve optimization problems in many areas.

In this study, an LP model is proposed to prepare homemade dog food that is able to meet the requirements of animals and has minimum cost. The following indices and decision variables are used in developed model:

n : the number of ingredients j ,

m : the number of nutrients i ,

c_j : the cost of ingredients j ,

x_j : the amount of ingredients j ,

$a_{j,i}$: the quantity of the ingredients j and nutrients i,

av_j : available amounts of ingredients j ,

b_i, d_i : upper and lower bounds of nutrients i,

Mathematical model of LP is as follows,

$$\text{Min Z} = \sum_{j=1}^{n} c_j x_j \quad (1)$$

Subject to :

$$\sum_{j=1}^{n} a_{j,i} x_j \leq b_i \quad i = 1,2,\dots,m \quad (2)$$

$$\sum_{j=1}^{n} a_{j,i} x_j \geq d_i \quad i = 1,2,\dots,m \quad (3)$$

$$x_j \leq av_j \quad j = 1,2,\dots,n \quad (4)$$

$$x_j \geq 0 \quad j = 1,2,\dots,n \quad (5)$$

Eq. 1 is the objective function. Constraint set (2) and (3) provides the requirements of dogs is met. Constraint set (4) limits the amounts of the raw materials to be used. Constraint set (5) is used for all continuous decision variables to be positive.

3. EXPERIMENTAL RESULTS

In this study, three types of dogs and some ingredients are selected to use for homemade dog diets to show the effectiveness of the LP model. The requirements of dogs are calculated according to type, age, live weight, number of offspring, mobility status, and so forth. Ingredients' data are chosen from database and listed. By using these data and LP model exact solution is obtained. To compare the results that is obtained by LP, experts who can prepare homemade foods for dogs by using MS excel software are made a decision for amounts of ingredients that is satisfied with the dogs' requirements. Dog features, ingredients to be used and quantities of ingredients are decided by experts and obtained by LP are listed for each dog types in Table 3 to 5.

Table 3. Obtained ingredients amounts for dog type 1

Ingredients	Amounts by expert, kg	Amount by LP, kg
Chicken breast, raw	1.50	1.15874717
Eggshell	0.006	-
Carrot, raw	0.30	-
Bone meal	0.05	0.05974931
Magnesium chloride, 6 H_2O	0.005	0.00049932
Rice, grain	1.50	1.97693963
Sodium chloride	0.007	0.00768953
Sunflower oil	0.15	0.14351356
Total	**3.518**	**3.347**

Table 4. Obtained ingredients amounts for dog type 2

Ingredients	Amounts by expert, kg	Amount by LP, kg
Beef, low-fat, raw	**0.10**	-
Eggshell	**0.003**	0.00203773
Barley, grain	**0.18**	0.20222503
Carrot, raw	**0.1**	-
Sodium chloride	**0.0005**	0.00035781
Sunflower oil	**0.01**	0.00584657
Total	**0.393**	**0.210**

Table 5. Obtained ingredients amounts for dog type 3

Ingredients	Amounts by expert, kg	Amount by LP, kg
Lamb, lean, raw	0.35	0.3413613
Wheat, grain	0.3	0.23043207
Spinach, raw	0.2	-
Bone meal	0.015	0.01492853
Sodium chloride	0.0009	0.00098579
Poultry fat	0.025	0.04924405
Total	**0.891**	**0.637**

When the results are examined in Table 3 to 5, obtained results by LP shows that less ingredients are included to homemade dog foods. For instance, in Table 3 , 8 ingredients are listed and used by experts to prepare for homemade dog foods but the LP model is used 6 ingredients.

Table 6. Obtained nutrient requirements amounts for dog type1

Nutrient	Min Req.	Max Req.	Obtained Manuel	Obtained LP
CrudeProtein,g	403.10	1007.74	452.8438	403.1
Energy,kcal	8062.09	9674.50	8511	9674.5
Calcium,g	16.12	19.34	17.6863	18.53578
Phosphorus,g	10.08	12.09	11.0896	12.09
Magnesium,mg	1209.31	3627.93	1728.8	1209.31
Sodium,mg	4031.04	4434.14	4144.3	4031.038
Taurine,g	0	1	0.495	0.382387
Fat,g	171.32	342.64	179.8632	171.32
Linoleic Acid,g	26.20	65.5	64.443	61.34198
Cost, TL			**14,48**	**12,26**

Dog nutrient requirements vary from one dog to another, so the minimum and maximum requirements listed below are calculated for each dogs' separately. Obtained nutrients quantities of Manuel and LP solutions are given and nutrient values whose cannot be met are marked as bold in Table 6-8.

Table 7. Obtained nutrient requirements amounts for dog type2

Nutrient	Min Req.	Max Req.	Obtained Manuel	Obtained LP
Crude Protein,g	18.73	46.82	38.09	21.32492
Energy,kcal	749.36	899.23	871.40	749.36
Calcium,g	0.75	0.90	1.11	0.750001
Phosphorus,g	0.56	0.67	0.73	0.587675
Magnesium,mg	89.92	269.76	214.70	200.8605
Sodium,mg	149.87	164.85	163.87	149.8703
Taurine,g	0	1	0.03	0
Fat,g	10.3	20.6	19.29	10.3
Linoleic Acid,g	2.06	5.15	5.49	3.732399
Cost, TL			**2.53**	**0.26**

Table 8. Obtained nutrient requirements amounts for dog type3

Nutrient	Min Req.	Max Req.	Obtained Manuel	Obtained LP
Crude Protein,g	70.18	175.45	108.6875	92.61783
Energy,kcal	1602.39	1922.86	1734.75	1602.39
Calcium,g	4.81	5.77	5.469	5.232026
Phosphorus,g	4.01	4.81	4.216	4.01
Magnesium,mg	160.24	480.72	714	480.72
Sodium,mg	881.31	969.44	936.56	881.3097
Taurine,g	0	1	0.2555	0.249194
Fat,g	34.13	68.26	54.3	68.26
Linoleic Acid,g	5.29	13.22	6.065	8.799893
Cost, TL			**7.92**	**7.82**

Results show that in contrast to manual solutions LP solutions are met with all nutrients. Furthermore, thanks to the LP model, homemade dog foods' total costs and used ingredients numbers are decreased (Figure 1, Figure 2).

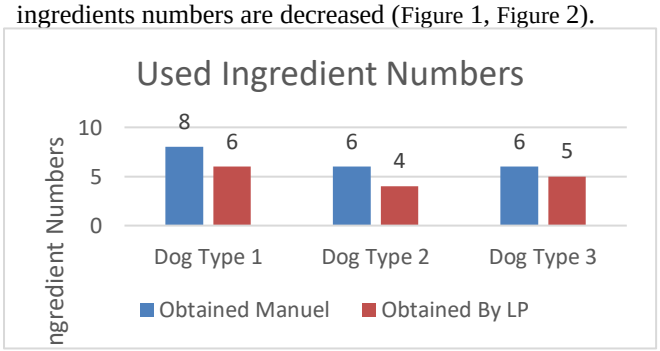

Figure 1. Graph of used ingredient numbers

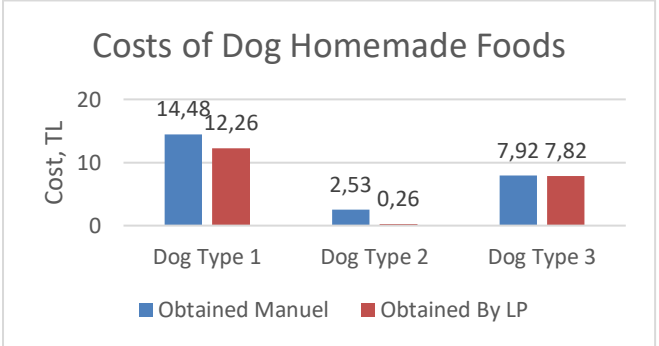

Figure 2. Graph of homemade foods costs

4. DIET FORMULATION SOFTWARE

In this study, it is aimed to calculate the cost-effective home cooking for dogs and make it available for those who feed animals in our country. A web-based application was also implemented to allow users to use the proposed work easily. When performing a web-based application, Laravel is used for MVC, mySql for database and JSLPsolver as LP solver.

In the first part of the program, a mixture of dogs is created to be used next to solve the dog homemade diet in the application (Figure 3, Figure 4).

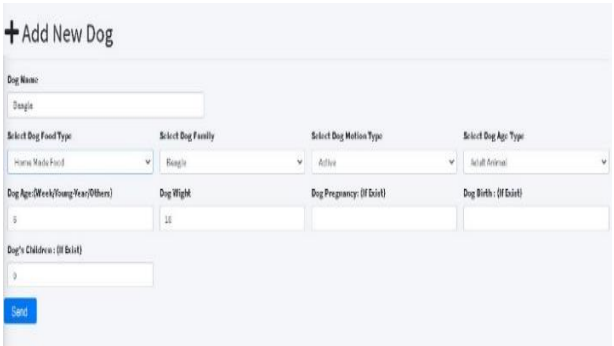

Figure 3. Add new dog interface

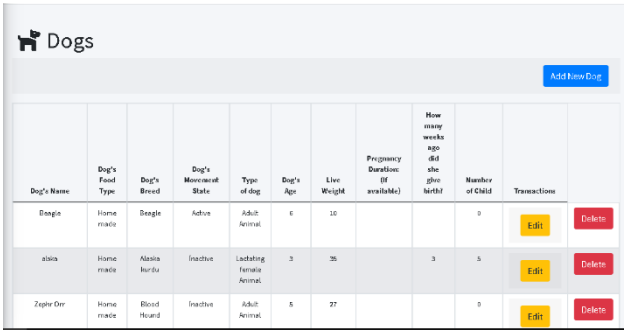

Figure 4. Saved dog's features interface

Decision makers can find the food formulation using this program by selecting ingredients in the database within the constraints that are identified. In the first part of the program, new food is created for the program, adding values from those that make up the food, adding the name of the food, and defining its group. Also, the food can be modified after adding it (Figure 5, Figure 6).

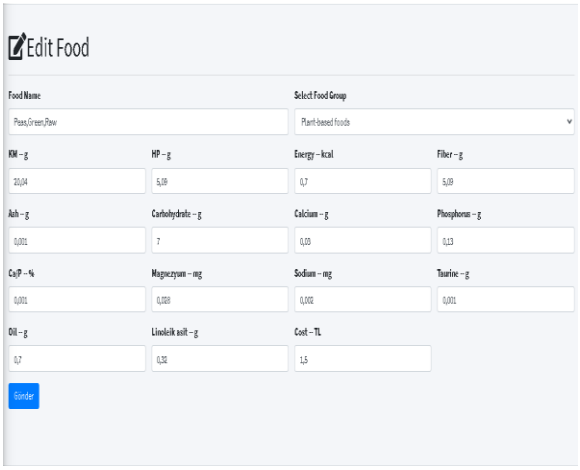

Figure 5. Add new ingredient interface

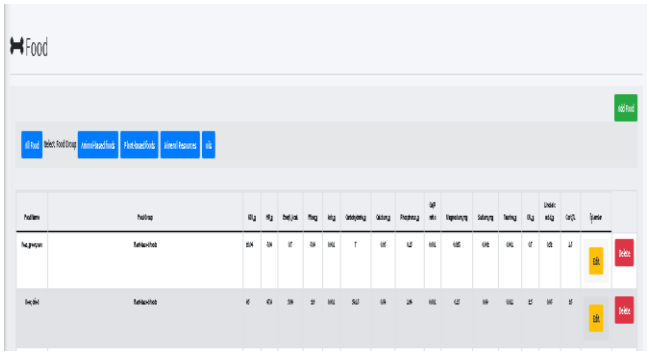

Figure 6. Saved ingredients's features interface

Before using LP solver in the application, it is determined by which dog, as well as choosing ingredients that previously added to database, after which a feasible solution is found through the program to organize dog's daily homemade diet (Figure 7)

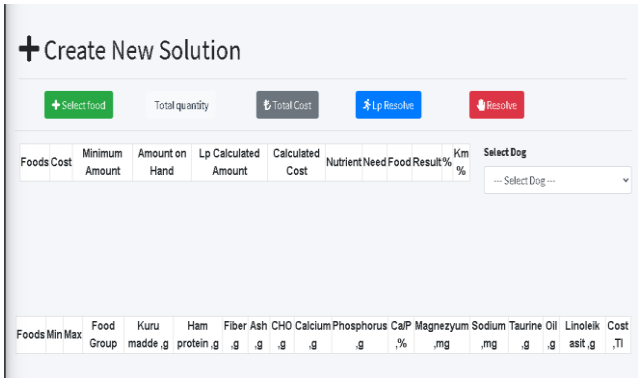

Figure 7. Create new LP solution interface

Likewise, the results obtained by hand or LP solver can be shown in the form of different formats for printing, for example, pdf, excel, directly printing, or copying the results instantly (Figure 8).

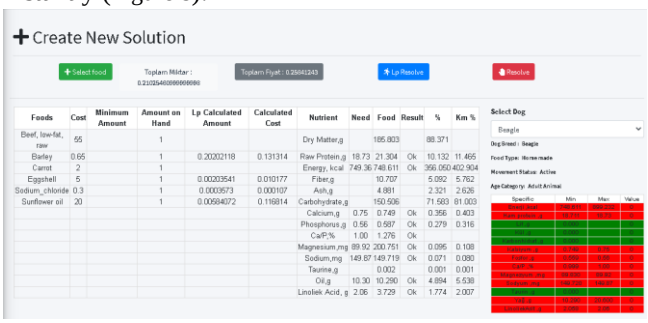

Figure 8. Obtained results by LP interface

5. Conclusions

There are lots of application was conducted for dog food preparation. Despite the fact that these applications which are not considered dog's age, gender, activity status and etc. are being used by dog owners, these applications are not met the real needs of dogs. In this study, a web based application has been developed. With this application, users are able to add their food raw materials and dog features. This application has been utilized linear programming solver so as to meet dogs' needs according to available food sources. The effectiveness of this web application has been compared with three different dog types and food sources which have been selected by experts. The proposed web-based application has been met dogs need totally and decreased the homemade dog foods' cost.

Author's Note

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