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Modeling the Optimal Diet Problem for Renal Patients with Fuzzy Analysis of Nutrients

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Abstract: This research is intended to analyze optimum nutrition of renal patients in fuzzy environment. One of the important factors in optimized nutrition of renal patients is the daily amount of received nutritious materials. High consumption of proteins, phosphor, salt and potassium enhances the disability of kidneys in these patients. There are several factors for which the accurate determination of nutritious materials present in different foods is impossible. Our purpose in this paper is to present a proper diet model for renal patients in the fuzzy environment. In most studies the daily nutrient intake decisions were made based on crisp data. By prescribing a diet based on crisp data, some of realities are neglected. For the same reason, we dealt with renal patient's diet problem through fuzzy approach. we have provided diet problem as multi-objective fuzzy linear programming problem in which minimization of Protein, Phosphor, Sodium, Potassium are considered as our objectives. Results indicated uncertainty about amount of nutrients and their intake affects diet quality making it more realistic. This research consists of two parts. In the first part, multi-objective fuzzy linear programming problem was investigated and in the second part, practical example of multi-objective fuzzy linear programming problem in relation to optimized diet of human will be presented and solved.

Keywords: Optimal Diet Problem, Renal Patients, Multi-Objective Fuzzy Linear Programming, Fuzzy Analysis of Nutrients

1. Introduction

Obeying an appropriate diet is to some extent difficult and challenging for renal patients because most of present foods in a healthy diet includes potassium, phosphor, protein and sodium which are harmful for renal patients. Therefore, adjusting one diet in which reception of potassium, phosphor, protein and sodium is minimum, is essential and required. But a problem exists regarding the inaccurate values of nutrients in foods because the amounts of nutrients available in a certain food are normally known but there is always a question of their exact amounts. If presence of a certain nutrient is doubted, it will be assumed that its amount is negligible which makes the problem of inaccurate near-zero amounts appears again. There are numerous evidences which prove that the amount of nutritious materials existing in a food is never a specific and definite number. This number should be considered as a fuzzy number. For example the amount of carbohydrates in an apple is a function of apple type and level of maturation. Even besides checking maturation level and type of apple, other variations associated with soil and growth conditions are present. Accordingly, necessity of incorporating fuzzy concept is further appreciated for expressing the respective values. Some studies have been conducted concerning application of fuzzy logic in nutrition; please refer to research Wirsam et al [Wirsam, Hahn, Uthus, and Leitzmann, 1997]. They are demonstrated that a nutrient intake can be described in a differentiated way and can be evaluated by employing fuzzy decision making. In addition, the important factor in people's nutrition is the amounts of macro and micro nutrients contained in any unit of consumed foods, which are undoubtedly uncertain values. For example, according to studies and researched performed in the Agriculture Department of United States, there is 2 grams of sugar per 100 grams of lettuce. For several reasons these numbers cannot be considered as the basis of decision makings. If the lettuce implanted in area with plenty of water, then due to increased water amount in the unit volume of this plant, the density of sugar available in 100 grams will be less than density of sugar available in 100 grams of the same lettuce samples cultivated in an area with less water. Therefore, the number related to sugar in 100 grams of lettuce should be considered as fuzzy number. On the other hand, it is not possible to determine a definite boundary for people's maximal and minimal daily usage of micronutrients and macronutrients because factors such as geographical region, gender, age, etc. because fluctuation and obscurity in the usage amount of nutrients. For example, when it is said the maximal permissible daily usage amount of sodium is 2300 mg, this value must be considered as fuzzy number. In summary the reason for dealing with nutrition problem from fuzzy standpoint in this paper is great significance of applying suitable diet for specific patients including renal disease, because the daily required amount of these people to fats, carbohydrates, proteins, etc are dependent on patient's physical state. For this reason, one is not able to properly acquire an optimal nutrition combination using the classical approach. According to what mentioned above, risk will exist even if we follow nutritional instructions prescribed based on classic method. For example, if a renal disease patient is allowed to eat 60 grams of low-fat yogurt per day, both the term "low-fat "and previously mentioned issues are sufficient to look at optimal nutrition of these patients as a fuzzy concept. Fuzzy logic was first proposed by Zadeh in 1965. Fuzzy set theory has been applied to many disciplines such as control theory and management sciences, mathematical modeling and industrial applications. Let X denotes a universal set. A fuzzy subset $\tilde{A}$ of X is defined as a set of ordered pairs of element x and grade $\mu_{\tilde{A}}(x)$ and is written$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)): x \in X\}$. $\mu_{\tilde{A}}(x)$ Is now called the membership function or grade of membership of the x in the fuzzy set $\tilde{A}$ [Zimmermann, 2001]. The membership function can vary between 0 and 1. The value 0 represents the worst status possible, death. The value 1 represents the absolute optimum. All values between 0 and 1 can be described verbally. The concept of fuzzy linear programming (FLP) on general level was first proposed by Tanaka et al [Tanaka, Okuda, and Asai, 1974]. Fuzzy linear programming (FLP) is a very useful and practical model for many real world problems. Concept of decision analysis in fuzzy environment was first proposed by Bellman and Zadeh [Bellman and Zadeh, 1970]. B. Jana and T. Kumar Roy [Jana and Kumar Roy, 2005] examine the transportation model in fuzzy environment. Coefficients of target, supply, demand and capacity transfer functions were expressed as fuzzy numbers in their model. Multi-objective Fuzzy linear programming problem with other applications as well. For example in traveling salesman problem by A. Chaudhuri and K. De [Chaudhuri and De, 2011] and its application in optimized human diet problem based on the minimum cost of food by H.eghbali et al [H. Eghbali, M. Eghbali and vahidian, 2012].

In this paper, we discussed about optimizing diet problem for Renal disease in fuzzy environment and it formulates the research problem as a linear multi-objective fuzzy programming problem (MOFLPP) with mixed constraints in which right hand side of constraints are fuzzy numbers and presents a suitable solution for it. In the respective nutrition model which is at the form of a multi-objective fuzzy linear program, we attained good results for presenting an optimum diet through minimizing final Protein, Phosphor, Sodium and Potassium. In fuzzy approach by considering the parameters in their real values (through taking into account all possible states) would result in enhancement of nutritional quality. This causes the decisions to be more realistic in this regard.

2. Preliminaries

Definition 2.1 Let F (R) be a set of all triangular fuzzy number in a real line R . A triangular fuzzy number $\widetilde{A}$ (∈F (R)) represented with three points $\widetilde{A} = (a_1, a_2, a_3)$ .This representation is interpreted as membership functions. (Fig - 1)[Jana and Kumar Roy, 2005].

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1} & a_1 \le x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & a_2 \le x \le a_3 \\ 0 \text{ elsewhere} \end{cases}$$

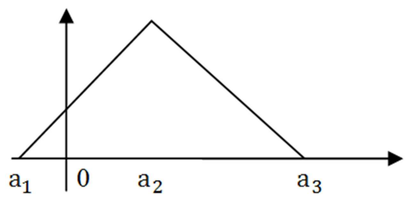

Fig. 1. *TFN* $\tilde{A} = (a_1, a_2, a_3)$

Remark 2.1 we consider $\tilde{0}$= (0, 0, 0) as the zero triangular fuzzy number.

Definition 2.2 The left TFN $\tilde{A} = (a_1, a_2, a_2)$ is suitable to represent positive large or words with similar meaning. Provided that $a_2 > a_1$ it is represented by the following membership functions [Jana and Kumar Roy, 2005]:

$$\mu_{\tilde{A}}(x) = \begin{cases} 1 \; x \ge a_2 \\ \dfrac{x - a_1}{a_2 - a_1} \; a_1 \le x \le a_2 \\ 0 \; x \le a_1 \end{cases}$$

Definition 2.3 The right TFN $\tilde{A} = (a_2, a_2, a_3)$ is suitable to represent positive small or words with similar meaning. Provided that $a_3 > a_2$. It is represented by the following membership functions [Jana and Kumar Roy, 2005]:

$$\mu_{\tilde{A}}(x) = \begin{cases} 1 \; x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} \; a_2 \le x \le a_3 \\ 0 \; x \ge a_3 \end{cases}$$

2.1. Multi-Objective Linear Programming Problems (MOLPP)

The General Multi-Objective Linear Programming Problem (GMOLPP) with mixed constraints may be written as follows:

$$\text{Minimize } Z = [Z^1, Z^2, Z^3, \dots, Z^K] \tag{2.1}$$

Subject to $\sum_{j=1}^{n} a_{ij}x_j \geq b_i \; i = 1,2,3, \dots, s_1$

$$\sum_{j=1}^{n} a_{ij}x_j \leq b_i \; i = s_1 + 1, s_1 + 2, \dots, s_2$$

$$\sum_{j=1}^{n} a_{ij}x_j = b_i \; i = s_2 + 1, s_2 + 2, \dots, s$$

$$x_j \geq 0 \,, j = 1,2,3, \dots, n$$

Where $Z^k = \sum_{j=1}^{n} c_j{}^k x_j \;, k = 1,2,3, \dots, K$

2.2. Multi-objective Fuzzy Linear Programming Problems (MOFLPP)

In generality when the objective function's coefficients, technological coefficients and also right hand side of constraints are fuzzy numbers then (2.1) becomes [Jana and Kumar Roy, 2005]:

$$\text{Minimize } \tilde{Z} = [\tilde{Z}^1, \tilde{Z}^2, \tilde{Z}^3, \dots, \tilde{Z}^K] \quad (2.2)$$

Subject to $\sum_{j=1}^{n} \tilde{a}_{ij}x_j \geq \tilde{b}_i \; i = 1,2,3, \dots, m_1$

$$\sum_{j=1}^{n} \tilde{a}_{ij}x_j \leq \tilde{b}_i \; i = m_1 + 1, m_1 + 2, \dots, m_2$$

$$\sum_{j=1}^{n} \tilde{a}_{ij}x_j = \tilde{b}_i \; i = m_2 + 1, m_2 + 2, \dots, m$$

$$x_j \geq 0 \; j = 1,2,3, \dots, n$$

Where $\tilde{Z}^k = \sum_{j=1}^{n} \tilde{c}_j{}^k x_j \;\; k = 1,2,3, \dots, K$

Assumption: Fuzzy objective and constraints coefficients are considered as the following positive TFN's [Jana and Kumar Roy, 2005]:

Right TFN $\tilde{c}_j{}^k = (c_j{}^k, c_j{}^k, c_j{}^k + p_j{}^k)$ with tolerance $p_j{}^k > 0$ for objective function

$$\sum_{j=1}^{n} \tilde{c}_j{}^k x_j \text{ For } k = 1,2,3, \dots, K$$

Left TFN $\tilde{a}_{ij} = (a_{ij} - d_{ij}{}^0, a_{ij}, a_{ij})$ with tolerance $d_{ij}{}^0 < a_{ij}$ and $\tilde{b}_i = (b_i - b_i{}^0, b_i, b_i)$

With tolerance $b_i{}^0 < b_i$ for $\sum_{j=1}^{n} \tilde{a}_{ij}x_j \geq \tilde{b}_i \; i = 1,2,3, \dots, m_1$

Right TFN $\tilde{a}_{ij} = (a_{ij}, a_{ij}, a_{ij} + d_{ij}{}^0)$ with tolerance $d_{ij}{}^0 > 0$ and $\tilde{b}_i = (b_i, b_i, b_i + b_i{}^0)$

With tolerance $b_i{}^0 > 0$ for $\sum_{j=1}^{n} \tilde{a}_{ij}x_j \leq \tilde{b}_i \; i = m_1 + 1, m_1 + 2, \dots m_2$

TFN $\tilde{a}_{ij} = (a_{ij} - d_{ij}{}^l, a_{ij}, a_{ij} + d_{ij}{}^r)$ with tolerance $d_{ij}{}^l < a_{ij}$, $d_{ij}{}^r > 0$ and $\tilde{b}_i = (b_i - b_i{}^l, b_i, b_i + b_i{}^r)$ With tolerance $b_i{}^l < b_i \,, b_i{}^r > 0$ for $\sum_{j=1}^{n} \tilde{a}_{ij}x_j = \tilde{b}_i \; i = m_2 + 1, m_2 + 2, \dots, m$

In continue we use the Fuzzy Programming Technique [Jana and Kumar Roy, 2005] for solution problem (2.2).at last by using the max-min operator [Chaudhuri and De, 2011]. The problem (2.2) formulated as follow that it's a crisp linear programming problem.

$$\text{Maximize } \lambda \quad (2.3)$$

Subject to $\sum_{j=1}^{n} (c_j{}^k + \lambda p_j{}^k)x_j + \lambda(U_k - L_k) \leq U_k \; k = 1,2,3, \dots, K$

$$\sum_{j=1}^{n} (a_{ij} - \lambda d_{ij}{}^0)x_j - \lambda b_i{}^0 \geq b_i \; i = 1,2,3, \dots, m_1$$

$$\sum_{j=1}^{n} (a_{ij} + \lambda d_{ij}{}^0)x_j + \lambda b_i{}^0 \leq b_i \; i = m_1 + 1, m_1 + 2, \dots, m_2$$

$$\sum_{j=1}^{n} (a_{ij} - (1 - \lambda)d_{ij}{}^l)x_j + \lambda b_i{}^r \leq b_i + b_i{}^r \; i = m_2 + 1, m_2 + 2, \dots, m$$

$$\sum_{j=1}^{n} (a_{ij} + (1 - \lambda)d_{ij}{}^r)x_j - \lambda b_i{}^l \geq b_i - b_i{}^l \; i = m_2 + 1, m_2 + 2, \dots, m$$

$$0 \leq \lambda \leq 1 \,, x_j \geq 0 \; j = 1,2,3, \dots, n$$

Let L_k and U_k be the lower and upper bound for the k-th objective [Jana and Kumar Roy, 2005], where L_k= aspired level of achievement for the k-th objective function, and U_k= highest acceptable level of achivement for the k-th objective function. The problem (2.3) may be solved by fuzzy decisive set method [Sakawa and Yano, 1985].

3. Diet for Renal Patients (Chronic Renal Failure) in Fuzzy Environment

Main bases of an appropriate diet for renal patients are: limiting reception of sodium when initial indications of renal injury are observed and then limiting the consumption of protein, potassium and phosphor parallel to development of renal injury [Zimmermann, 1987]. Salt or sodium is the main factor for development of chronic renal patients, high blood pressure and heart disease [Zimmermann, 1987]. Therefore, its daily consumption must be limited. One low sodium diet is the first defensive action of body when the operation of renal starts to decrease [Sakawa and Yano, 1985]. Potassium is the main intercellular action of body and it is low in outside of cell but accumulation of potassium outside of cell according to heart lesions is the most dangerous poison in renal failure. In the beginning of renal failure, the level of phosphor in blood may increase which makes the calcium unbalance [Sakawa and Yano, 1985]. This forces the body to get calcium from bones. Controlling the level of phosphor is essential because high amount of phosphor causes renal failure, bone disease and hearth problems. The most important action is low consumption of protein. One diet including low amount of protein is effective in prevention of worsening of renal disease in persons suffering abnormal operation of renal. Kidneys of patient may have problem for separation of protein from useless materials of blood. Therefore, some doctors want their patients to reduce the amount of protein they eat by which the kidneys work less. Now one diet must be scheduled so that in addition to providing the daily needs of patient for nutritious materials minimizes four factors of protein, potassium, sodium and phosphor. For this purpose, food schedule is modeled in the form of one four-purpose linear scheduling question. According to previously presented explanations, all the coefficients are considered as triangular fuzzy numbers. The minimum and maximum amounts of reception of nutritious materials are limitations of model. A general Multi-Objective nutrition model with mixed constraints, written as follows:

$$\text{Minimize } \tilde{Z}^1 = \sum_{j=1}^{n} \tilde{c}_j^{\,1} x_j \qquad (3.1)$$

$$\text{Minimize } \tilde{Z}^2 = \sum_{j=1}^{n} \tilde{c}_j^{\,2} x_j$$

$$\text{Minimize } \tilde{Z}^3 = \sum_{j=1}^{n} \tilde{c}_j^{\,3} x_j$$

$$\text{Minimize } \tilde{Z}^4 = \sum_{j=1}^{n} \tilde{c}_j^{\,4} x_j$$

Subject to

$$\sum_{j=1}^{n} \tilde{a}_{ij} x_j \geq \tilde{b}_i \quad i = 1,2,3,\ldots,m$$

$$\sum_{j=1}^{n} \tilde{a}_{ij} x_j \leq \tilde{d}_i \quad i = 1,2,3,\ldots,m$$

$$x_j \geq 0, j = 1,2,\ldots,n$$

Where:

x_j: 100 g of food j eaten per day.

$\tilde{c}_j^{\,1}$: approximate amount of potassium in 100 g of food j.

$\tilde{c}_j^{\,2}$: approximate amount of phosphor in 100 g of food j.

$\tilde{c}_j^{\,3}$: approximate amount of sodium in 100 g of food j.

$\tilde{c}_j^{\,4}$: approximate amount of protein in 100 g of food j.

$\tilde{a}_{ij}$: The amount of nutrient i in 100 g of food j.

$\tilde{b}_i$: The required daily amount of nutrient i.

$\tilde{d}_i$: The maximum daily amount of nutrient i.

M: The number of nutrients.

N: The number of foods.

4. Numerical Example

In the following example 20 useful food are considered for the renal disease patients including a variety of fruits, low fat dairy products, meat, protein and useful vegetables. These foods are:

Pomegranate, Apple, Tangerines, Watermelon, Lemon, Carrots, Fungus, Tomatoes, spinach, Bread,

Soya, Walnut, Olive oil, Pumpkin seeds, Honey, Chicken, Fish, Low-fat cheese, Low-fat yogurt, Low-fat milk. Suppose one 45 years old patient with weight of 82 kg and BMI=27.72 kg/m^2. The amount of daily energy need of this person is 2050 Kcal (25 Kcal/kg in per day). 50-60% of this energy must be supplied by carbohydrates and 20-30% of this energy must be supplied by fats and 0.8 to 1 gram of protein per kg weight [Ikizler, 2004]. Also approximately 20-30 g of fiber must be consumed. Every gram of protein per gram of carbohydrate produces 4 kcal of energy. Also per gram of fat can produce about 9 kcal of energy [Ikizler, 2004]. Table 1 shows the minimum, maximum and actual nutrient requirements. The limitation related to amount of nutrient intake which is undefined in table 1 will be disregarded.

Table 1. *Approximate amount of micronutrient and celery requirement per day (Renal patient, 45 years old, BMI 27.72 kg/m^2).*

Nutrient	Min	Max	Nutrient	Min	Max
Energy(kcal/d)	2050	N.D	Niacin(mg/d)	14	35
Carbohydrate(g/d)	130	307.5	Foliate (μg/d)	400	1000
Total Fiber(g/d)	20	30	Vitamin B12(μg/d)	2.4	N.D
Sugar(g/d)	N.D	124	Calcium(mg/d)	1000	2500
Fat(g/d)	N.D	153.75	Iron(mg/d)	16	45
Protein(g/d)	65.6	82	Magnesium(mg/d)	320	370
Vitamin A(IU)	2333	10000	Phosphorus(mg/d)	300	2000
Vitamin C(mg/d)	75	2000	Potassium(mg/d)	2300	N.D
Thiamin(mg/d)	1.1	N.D	Sodium(mg/d)	1600	2000
Riboflavin(mg/d)	1.1	N.D			

Approximate amount of nutrients and Energy requirement per day that shown in Table 1 is given by crisp numbers. Decision variables, the same amount of food consumed daily (in terms of 100 grams) and minimal and maximal permissible daily amounts for using vitamins and minerals are included as the constraints. In order to create Triangular fuzzy number by using crisp data, one needs sampling and evaluating fluctuation level which in turn requires research and laboratory work, not performed by any researcher in the literature as of today. Nonetheless, we are forced to accept the related raw data gathered by nutrition authorities and alimental industries with slight deviation due to variations in amount nutrients in foods as well as lack of certain boundaries about maximal and minimal amount of daily intake of nutrients varieties for individuals.

$$\text{Minimize } \tilde{Z}^1 = \sum_{j=1}^{20} \tilde{c}_j{}^1 x_j \quad (4.1)$$

$$\text{Minimize } \tilde{Z}^2 = \sum_{j=1}^{20} \tilde{c}_j{}^2 x_j$$

$$\text{Minimize } \tilde{Z}^3 = \sum_{j=1}^{20} \tilde{c}_j{}^3 x_j$$

$$\text{Minimize } \tilde{Z}^4 = \sum_{j=1}^{20} \tilde{c}_j{}^4 x_j$$

Subject to

$$\sum_{j=1}^{n} \tilde{a}_{ij} x_j \geq \tilde{b}_i \; i = 1,2,3,\dots,17$$

$$\sum_{j=1}^{n} \tilde{a}_{ij} x_j \leq \tilde{d}_i \; i = 1,2,3,\dots,15$$

$$x_j \geq 0, j = 1,2,\dots,20$$

Where all Coefficients in this MOFLPP are given as Appendix.by using the previous method the optimal solution of the above Fuzzy Nutrition problem shown in table 2.

Table 2. *The amount of optimal solution parameters of Fuzzy.*

x_1 =0	x_7 =0.17117	x_{13} =1.34036	x_{19} =2.97283
x_2 = 0	x_8 =0.0053	x_{14} =0	x_{20} =0
x_3 =0.12983	x_9 =1.02432	x_{15} =1.06012	
x_4 =0	x_{10} =2.18958	x_{16} =0	and aspiration Level
x_5 =0.86543	x_{11} =0.33743	x_{17} =0.41164	is :λ =0.0116103
x_6 =0	x_{12} =0	x_{18} =0	

Since x_j is a 100 g of food j eaten per day, we have:

Table 3. *the amount of foods(In terms of gram) in fuzzy solution.*

Food	in fuzzy solution	Food	in fuzzy solution
Pomegranate	0	Soya	33.743
Apple	0	Walnut	0
Tangerines	12.983	Olive oil	13.4036
Watermelon	0	Pumpkin seeds	0
Lemon	86.543	Honey	106.012
Carrots	0	Chicken	0
Fungus	17.117	Fish	41.164
Tomatoes	0.53	Low-fat cheese	0
Spinach	102.432	Low-fat yogurt	297.283
Bread	218.958	Low-fat milk	0

Table 3 shows the amount of foods in fuzzy solution. the main objectives of research that are to optimize the potassium, phosphor, sodium and protein have been achieved. while table 4 Shows the intake of the nutrients by using the optimal renal diet in fuzzy solution. Implementation of renal diet problem in fuzzy environment is not suggestive of total violation of its classic state; however, fuzzy approach –by considering the parameters in their real values (through taking into account all possible states) - would result in enhancement of nutritional quality. This causes the decisions to be more realistic in this regard.

Table 4. *Intake the nutrients by using the optimal human diet.*

Nutrient	Amount in fuzzy solution	Nutrient	Amount in fuzzy solution
Energy(kcal/d)	2530.4	Niacin(mg/d)	14.75
Carbohydrate(g/d)	226.463	Float (μg/d)	428.493
Total Fiber(g/d)	29.986	Vitamin B12(μg/d)	2.401
Sugar(g/d)	123.984	Calcium(mg/d)	1000
Fat(g/d)	153.736	Iron(mg/d)	16.012
Protein(g/d)	81.988	Magnesium(mg/d)	369.941
Vitamin A(IU)	10000	Phosphorus(mg/d)	1295.2
Vitamin C(mg/d)	75.035	Potassium(mg/d)	2300.6
Thiamin(mg/d)	1.1	Sodium(mg/d)	1698.7
Riboflavin(mg/d)	1.45		

5. Conclusion

As you see, the numbers which have been applied in the optimized nutrition model for renal patients are considered as fuzzy numbers, which covered the uncertainty problem in previous inputs and determined the nutrition problem with a real-view. Fuzzy logic believes that ambiguity is in nature of science in contrary to others who believe that approximations should be made more accurate to increase efficiency. Fuzzy logic is trying to produce models in which ambiguity is one part of system. There are some sentences in fuzzy logic that are to some extent correct and to some extent incorrect. When the classic rules are related to realities, they are not sure and when they are sure, they cannot reflect realities. Implementation of renal diseases diet problem in fuzzy environment is not suggestive of total violation of its classic state; however, fuzzy approach by considering the parameters in their real values (through taking into account all possible states) would result in enhancement of nutritional quality. This causes the decisions to be more realistic in this regard. Comparison of the results of the previous models and the proposed model proposed using the multi-objectives fuzzy programming problem in this study, the effectiveness of the proposed model is clearly evident. As observed before, numbers used in the optimal nutrition model of renal diseases diet problem in the fuzzy environment as fuzzy numbers based on which the subject of uncertainty in the previous dada were covered and considered with a real aspect of nutrition issue. Anyway, the methods of this study are the new models for determination of diet for certain patients with pre-arranged aims which considered one of the fuzzy mathematical applications in medical science.

Appendix

$$\tilde{C}^1 = \left\{\begin{array}{c} (236,236,239)(107,107,109)(166,166,166)(112,112,115)(124,124,124)(320,320,322)(754,754,754) \\ (237,237,237)(558,558,558)(247,247,249)(81,81,81)(441,441,444)(1,1,1)(919,919,921)(52,52,52) \\ (358,358,358)\ (358,358,358)\ (86,86,88)\ (234,234,234)\ (150,150,155) \end{array}\right\}$$

$$\tilde{C}^2 = \left\{\begin{array}{c} (36,36,37)(11,11,11)(20,20,22)(11,11,11)(6,6,6)(35,35,36)(184,184,184)(24,24,25)(49,49,49)(202,202,202) \\ (776,776,776)(346,346,347)(0,0,0)(92,92,92)(4,4,4)(319,319,320)(168,168,170)(134,134,134) \\ (144,144,144)\ (94,94,94) \end{array}\right\}$$

$$\tilde{C}^3 = \left\{\begin{array}{c} (3,3,4)(1,1,1)(2,2,2)(1,1,1)(1,1,1)(69,69,70)(35,35,35)(5,5,5)(79,79,79)(472,472,472)(1005,1005,1005) \\ (2,2,2.1)\ (2,2,2)\ (18,18,18)\ (4,4,4)\ (104,104,105)\ (56,56,58)\ (406,406,406)\ (70,70,70)\ (41,41,41) \end{array}\right\}$$

$$\tilde{C}^4 = \left\{\begin{array}{c} (1.7,1.7,2)(.3,.3,.3)(.8,.8,.8)(.6,.6,.7)(.4,.4,.4)(.9,.9,1)(9.2,9.2,9.2)(.9,.9,.9)(2.9,2.9,2.9)(13,13,13) \\ (80.7,80.7,80.7)(15.2,15.2,15.5)(0,0,0)(18.5,18.5,19)(.3,.3,.3)(43.4,43.4,44)(13.4,13.4,13.4)(12.4,12.4,13) \\ (5.2,5.2,5.2)\ (3.3,3.3,3.4) \end{array}\right\}$$

Hear $\tilde{c}_1{}^1 = (236,236,239)$, $\tilde{c}_1{}^2 = (107,107,109)$,$\tilde{c}_2{}^1 = (36,36,37)$, $\tilde{c}_2{}^2 = (11,11,11)$

And similar representation for other elements and in continues, resources or the
Maximum and minimum values of required daily amounts of nutrients are given as follows:

$$\tilde{b} = \left\{\begin{array}{c} (2000,2050,2050)(125,130,130)(18,20,20)(63.6,65.6,65.6)(2320,2333,2333)(72,75,75)(1.1,1.1,1.1) \\ (1,1.1,1.1)(12,14,14)(398,400,400)(2.3,2.4,2.4)(998,1000,1000)(15,16,16)(318,320,320)(298,300,300) \\ (2250,2300,2300)\ (1590,1600,1600) \end{array}\right\}$$

$$\tilde{d} = \left\{\begin{array}{c} (307.5,309,309)(30,30,31)(124,124,125)(153.75,153.75,155)(82,82,83)(1000,1000,1002) \\ (2500,2500,2550)\ (45,45,46)\ (370,370,375)\ (2000,2000,2010)\ (2000,2000,2010) \end{array}\right\}$$

Hear $\tilde{b}_1 =$ (2000,2050,2050), $\tilde{b}_2 = (125,130,130))$, $\tilde{d}_1 = (307.5,309,309)$, $\tilde{d}_2 = (30,30,31)$ and similar representation for other elements and in continue , fuzzy coefficients in constraints are given.

Note: The crisp data related amount of nutrients in 100 gram of foods was provided by USDA1 SR-21(see [11]). Because of the uncertainty in this numbers , their fuzzy form is assumed as following:

The Columns of the constraints matrix associated with the inequality " ≥ ", is as follows:

Columns 1 through 10

(82,83,83)	(50,52,52)	(52,53,53)	(27,30,30)	(24,25,25)	(40,41,41)	(281,284,284)	(16,18,18)	(18,23,23)	(245,247,247)
(18.4,18.7,18.7)	(13.6,13.8,13.8)	(13.1,13.3,13.3)	(7,7.5,7.5)	(8.6,8.6,8.6)	(9.2,9.6,9.6)	(72,73,73)	(3.8,3.9,3.9)	(3.6,3.6,3.6)	(41.3,41.3,41.3)
(4,4,4)	(2.4,2.4,2.4)	(1.8,1.8,1.8)	(.4,.4,.4)	(.4,.4,.4)	(2.8,2.8,2.8)	(70.1,70.1,70.1)	(1.2,1.2,1.2)	(.4,.4,.4)	(6.7,6.8,6.8)
(1.4,1.7,1.7)	(.3,.3,.3)	(.8,.8,.8)	(.5,.6,.6)	(.4,.4,.4)	(.8,.9,.9)	(9.2,9.2,9.2)	(.9,.9,.9)	(2.9,2.9,2.9)	(13,13,13)
(0,0,0)	(54,54,54)	(681,681,681)	(569,569,569)	(20,20,20)	(16695,16705,1)	(0,0,0)	(831,833,833)	(9376,9376,937)	(3,3,3)
(10,10.2,10.2)	(4.5,4.6,4.6)	(26.4,26.7,26.7)	(8,8.1,8.1)	(46,46,46)	(5.8,5.9,5.9)	(0,0,0)	(12.7,12.7,12.)	(28.1,28.1,28.1)	(0,0,0)
(.1,.1,.1)	(0,0,0)	(.1,.1,.1)	(0,0,0)	(0,0,0)	(.1,.1,.1)	(0,0,0)	(0,0,0)	(.1,.1,.1)	(.4,.4,.4)
(.05,.1,.1)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(.05,.1,.1)	(.7,.8,.8)	(0,0,0)	(.2,.2,.2)	(.2,.2,.2)
(.2,.3,.3)	(.1,.1,.1)	(.3,.4,.4)	(.2,.2,.2)	(.1,.1,.1)	(.9,.1,.1)	(6.1,6.3,6.3)	(.5,.6,.6)	(.7,.7,.7)	(4.7,4.7,4.7)
(36,38,38)	(3,3,3)	(15,16,16)	(3,3,3)	(12,13,13)	(18,19,19)	(36,38,38)	(14,15,15)	(193,194,194)	(48,50,50)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(10,10,10)	(6,6,6)	(37,37,37)	(7,7,7)	(7,7,7)	(31,33,33)	(159,159,159)	(10,10,10)	(99,99,99)	(107,107,107)
(.2,.3,.3)	(.1,.1,.1)	(.2,.2,.2)	(.2,.2,.2)	(0,0,0)	(.3,.3,.3)	(5.9,5.9,5.9)	(.3,.3,.3)	(2.7,2.7,2.7)	(2.4,2.4,2.4)
(10,12,12)	(4,5,5)	(12,12,12)	(9,10,10)	(6,6,6)	(11,12,12)	(83,83,83)	(11,11,11)	(79,79,79)	(82,82,82)
(35,36,36)	(11,11,11)	(18,20,20)	(11,11,11)	(6,6,6)	(34,35,35)	(184,184,184)	(23,24,24)	(49,49,49)	(202,202,202)
(233,236,236)	(105,107,107)	(166,166,166)	(109,112,112)	(124,124,124)	(318,320,320)	(754,754,754)	(237,237,237)	(558,558,558)	(248,248,248)
(2,3,3)	(1,1,1)	(2,2,2)	(1,1,1)	(1,1,1)	(68,69,69)	(35,35,35)	(5,5,5)	(79,79,79)	(472,472,472)

Columns 11 through 20

(335,338,338)	(653,654,654)	(882,884,884)	(442,446,446)	(302,304,304)	(228,231,231)	(194,195,195)	(70,72,72)	(62,63,63)	(46,50,50)
(7.3,7.4,7.4)	(13.7,13.7,13.7)	(0,0,0)	(53.4,53.7,53.7)	(82.3,82.4,82.4)	(0,0,0)	(0,0,0)	(2.7,2.7,2.7)	(7,7,7)	(5.1,5.1,5.1)
(5.6,5.6,5.6)	(6.6,6.7,6.7)	(0,0,0)	(0,0,0)	(.2,.2,.2)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(80.7,80.7,80.7)	(14.9,15.2,15.2)	(0,0,0)	(18,18.5,18.5)	(.3,.3,.3)	(42.8,43.4,43.4)	(13.4,13.4,13.4)	(11.8,12.4,12.4)	(5.2,5.2,5.2)	(3.2,3.3,3.3)
(0,0,0)	(19,20,20)	(0,0,0)	(60,62,62)	(0,0,0)	(27,29,29)	(310,310,310)	(38,41,41)	(51,51,51)	(187,189,189)

1 : United States Department of Agriculture

(0,0,0)	(1.2,1.3,1.3)	(0,0,0)	(.3,.3,.3)	(.5,.5,.5)	(0,0,0)	(0,0,0)	(0,0,0)	(.8,.8,.8)	(.2,.2,.2)
(.2,.2,.2)	(.2,.3,.3)	(0,0,0)	(0,0,0)	(0,0,0)	(.1,.1,.1)	(.1,.1,.1)	(0,0,0)	(0,0,0)	(0,0,0)
(.1,.1,.1)	(.2,.2,.2)	(0,0,0)	(.1,.1,.1)	(0,0,0)	(.15,.2,.2)	(.1,.1,.1)	(.2,.2,.2)	(.2,.2,.2)	(.2,.2,.2)
(1.4,1.4,1.4)	(1.1,1.1,1.1)	(0,0,0)	(.25,.3,.3)	(.1,.1,.1)	(18.9,19.2,19.2)	(3.9,4,4)	(.1,.1,.1)	(.1,.1,.1)	(.1,.1,.1)
(175,176,176)	(96,98,98)	(0,0,0)	(8,9,9)	(1,2,2)	(3.6,5.6,5.6)	(14,15,15)	(10,12,12)	(10,11,11)	(4,5,5)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(.4,.5,.5)	(1.5,1.5,1.5)	(.6,.6,.6)	(.6,.6,.6)	(.5,.5,.5)
(178,178,178)	(96,98,98)	(1,1,1)	(53,55,55)	(6,6,6)	(20,21,21)	(35,35,35)	(59,61,61)	(183,183,183)	(114,117,117)
(14.5,14.5,14.5)	(2.9,2.9,2.9)	(.6,.6,.6)	(3.3,3.3,3.3)	(.4,.4,.4)	(1.4,1.5,1.5)	(1.3,1.3,1.3)	(.1,.1,.1)	(.1,.1,.1)	(0,0,0)
(39,39,39)	(156,156,158)	(0,0,0)	(259,262,262)	(2,2,2)	(39.2,40.6,40.6)	(55,55,55)	(5,5,5)	(17,17,17)	(10,11,11)
(776,776,776)	(345,346,346)	(0,0,0)	(92,92,92)	(4,4,4)	(318,319,319)	(166,168,168)	(134,134,134)	(144,144,144)	(94,94,94)
(81,81,81)	(438,441,441)	(1,1,1)	(917,919,919)	(52,52,52)	(358,358,358)	(358,358,358)	(84,86,86)	(234,234,234)	(145,150,150)
(1005,1005,100)	(1.9,2,2)	(2,2,2)	(18,18,18)	(4,4,4)	(103,104,104)	(54,56,56)	(406,406,406)	(70,70,70)	(41,41,41)

The Columns of the constraints matrix associated with the inequality " ≤ ", is as follows:

Columns 1 through 10

(18.7,18.7,19)	(13.8,13.8,14)	(13.3,13.3,13.5)	(7.5,7.5,8)	(8.6,8.6,8.6)	(9.6,9.6,10)	(73,73,74)	(3.9,3.9,4)	(3.6,3.6,3.6)	(41.3,41.3,41.3)
(4,4,4)	(2.4,2.4,2.4)	(1.8,1.8,1.8)	(.4,.4,.4)	(.4,.4,.4)	(2.8,2.8,2.8)	(70.1,70.1,70.1)	(1.2,1.2,1.2)	(.4,.4,.4)	(6.8,6.8,6.9)
(13.7,13.7,14)	(10.4,10.4,10.5)	(10.6,10.6,11)	(6.2,6.2,6.5)	(2.4,2.4,2.4)	(4.7,4.7,4.7)	(0,0,0)	(2.6,2.6,2.7)	(.4,.4,.4)	(5.6,5.6,5.7)
(1.2,1.2,1.3)	(.2,.2,.2)	(.3,.3,.35)	(.2,.2,.2)	(0,0,0)	(.2,.2,.2)	(.7,.7,.7)	(.2,.2,.2)	(.4,.4,.4)	(3.3,3.3,3.3)
(1.7,1.7,2)	(.3,.3,.3)	(.8,.8,.8)	(.6,.6,.7)	(.4,.4,.4)	(.9,.9,1)	(9.2,9.2,9.2)	(.9,.9,.9)	(2.9,2.9,2.9)	(13,13,13)
(0,0,0)	(54,54,54)	(681,681,681)	(569,569,569)	(20,20,20)	(16705,16705,1)	(0,0,0)	(833,833,835)	(9376,9376,937)	(3,3,3)
(10.2,10.2,10.4)	(4.6,4.6,4.7)	(26.7,26.7,27)	(8.1,8.1,8.2)	(46,46,46)	(5.9,5.9,6)	(0,0,0)	(12.7,12.7,12.7)	(28.1,28.1,28.1)	(0,0,0)
(.3,.3,.4)	(.1,.1,.1)	(.4,.4,.5)	(.2,.2,.2)	(.1,.1,.1)	(.1,.1,.9)	(6.3,6.3,6.5)	(.6,.6,.7)	(.7,.7,.7)	(4.7,4.7,4.7)
(38,38,40)	(3,3,3)	(16,16,17)	(3,3,3)	(13,13.14)	(19,19,20)	(38,38,40)	(15,15,16)	(194,194,195)	(50,50,52)
(10,10,10)	(6,6,6)	(37,37,37)	(7,7,7)	(7,7,7)	(33,33,35)	(159,159,159)	(10,10,10)	(99,99,99)	(107,107,107)
(.3,.3,.4)	(.1,.1,.1)	(.2,.2,.2)	(.2,.2,.2)	(0,0,0)	(.3,.3,.3)	(5.9,5.9,5.9)	(.3,.3,.3)	(2.7,2.7,2.7)	(2.4,2.4,2.4)
(12,12,14)	(5,5,6)	(12,12,12)	(10,10,11)	(6,6,6)	(12,12,13)	(83,83,83)	(11,11,11)	(79,79,79)	(82,82,82)
(36,36,37)	(11,11,11)	(20,20,22)	(11,11,11)	(6,6,6)	(35,35,36)	(184,184,184)	(24,24,25)	(49,49,49)	(202,202,202)
(3,3,4)	(1,1,1)	(2,2,2)	(1,1,1)	(1,1,1)	(69,69,70)	(35,35,35)	(5,5,5)	(79,79,79)	(472,472,472)

Columns 11 through 20

(7.4,7.4,7.5)	(13.7,13.7,13.7)	(0,0,0)	(53.7,53.7,54)	(82.4,82.4,82.5)	(0,0,0)	(0,0,0)	(2.7,2.7,2.7)	(7,7,7)	(5.1,5.1,5.1)
(5.6,5.6,5.6)	(6.7,6.7,6.8)	(0,0,0)	(0,0,0)	(.2,.2,.2)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(2.6,2.6,2.7)	(0,0,0)	(0,0,0)	(82.1,82.1,82.2)	(0,0,0)	(0,0,0)	(2.7,2.7,2.8)	(7,7,7)	(5.1,5.1,5.4)
(3.4,3.4,3.4)	(65.2,65.2,65.2)	(100,100,100)	(9.4,9.4,9.5)	(0,0,0)	(5,5,5)	(15.3,15.3,15.3)	(1,1,1)	(1.5,1.5,1.5)	(2,2,2.1)
(80.7,80.7,80.7)	(15.2,15.2,15.5)	(0,0,0)	(18.5,18.5,19)	(.3,.3,.3)	(43.4,43.4,44)	(13.4,13.4,13.4)	(12.4,12.4,13)	(5.2,5.2,5.2)	(3.3,3.3,3.4)
(0,0,0)	(20,20,21)	(0,0,0)	(62,62,64)	(0,0,0)	(29,29,31)	(310,310,310)	(41,41,44)	(51,51,51)	(189,189,191)
(0,0,0)	(1.3,1.3,1.4)	(0,0,0)	(.3,.3,.3)	(.5,.5,.5)	(0,0,0)	(0,0,0)	(0,0,0)	(.8,.8,.8)	(.2,.2,.2)
(1.4,1.4,1.4)	(1.1,1.1,1.1)	(0,0,0)	(.3,.3,.35)	(.1,.1,.1)	(19.2,19.2,19.5)	(4,4,4.1)	(.1,.1,.1)	(.1,.1,.1)	(.1,.1,.1)
(176,176,177)	(98,98,100)	(0,0,0)	(9,9,10)	(2,2,3)	(5.6,5.6,7.6)	(15,15,16)	(12,12,14)	(11,11,12)	(5,5,6)
(178,178,178)	(98,98,100)	(1,1,1)	(55,55,57)	(6,6,6)	(21,21,22)	(35,35,35)	(61,61,63)	(183,183,183)	(117,117,120)
(14.5,14.5,14.5)	(2.9,2.9,2.9)	(.6,.6,.6)	(3.3,3.3,3.3)	(.4,.4,.4)	(1.5,1.5,1.6)	(1.3,1.3,1.3)	(.1,.1,.1)	(.1,.1,.1)	(0,0,0)
(39,39,39)	(158,158,200)	(0,0,0)	(262,262,265)	(2,2,2)	(40.6,40.6,42)	(55,55,55)	(5,5,5)	(17,17,17)	(11,11,12)
(776,776,776)	(346,346,347)	(0,0,0)	(92,92,92)	(4,4,4)	(319,319,320)	(168,168,170)	(134,134,134)	(144,144,144)	(94,94,94)
(1005,1005,100)	(2,2,2.1)	(2,2,2)	(18,18,18)	(4,4,4)	(104,104,105)	(56,56,58)	(406,406,406)	(70,70,70)	(41,41,41)

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