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RESEARCH ARTICLE

A Mathematical Model for Green Leaves Diet Using Ranking of Tridecagonal Fuzzy Numbers

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Abstract This study presents a new way of ranking transportation options using tridecagonal fuzzy numbers. This approach takes into account factors such as demand, supply, and transportation costs, and aims to provide a more optimized solution for these fuzzy environments. With the rising importance of healthy eating habits, particularly emphasizing green leafy vegetables, devising an effective dietary plan becomes imperative. Traditional approaches often overlook the inherent uncertainty and fuzziness in dietary preferences and nutritional requirements. In this context, tridecagonal fuzzy numbers offer a robust framework to represent and analyze uncertain dietary preferences. Our ultimate goal is to promote a green leaf diet that is both affordable and widely available, while also improving the overall health and well-being of the general public. This research contributes to the advancement of mathematical modelling in nutrition science, offering a valuable tool for promoting healthier dietary choices and lifestyle habits.

Keywords: Fuzzy transportation problem, tridecagonal fuzzy number, ranking function, human balanced diet for green leaves.

Introduction

Background and Motivation

Fuzzy numbers play a crucial role in real life. Ranking fuzzy numbers is an essential aspect of scaling up fuzzy data for optimization [1]. The necessary combination of studies in the ranking of generalized tridecagonal fuzzy numbers in transportation gives the value of cost in the generalized nonagon fuzzy portion ([4], [5], and [7]). The ranking of normal fuzzy numbers was first suggested by Jain [13] and Yager [42]. Bass and Kwakernaak [2], Bovtolan and Degani [3], Chen S.-M. And Chen J.-H. [6], Jose Parvin Praveena, Sagaya Nathan Stalin, and Rajkumar [14] proposed different ranking methods based on fuzzy numbers and fuzzy subsets ([8], [15], [19], [22], and [23]).

Green leafy vegetables are recognized as nutritional powerhouses, rich in vitamins, minerals, and antioxidants essential for maintaining good health and preventing various chronic diseases ([17], [24], [25], and [9]). Green leaves also contain pectin, which helps with digestion and supports the structure of our body. A balanced diet can be divided into three physiological stages - high cost, moderate cost, and low cost. The components of a balanced diet vary depending on one's financial situation and Indians tend to prefer more vegetarian diet [33]. In recent years, fuzzy logic has emerged as a powerful tool for modelling and decision-making in uncertain and imprecise environments. Tridecagonal fuzzy numbers, in particular, offer a flexible and expressive framework for representing and reasoning with uncertainty, enabling more realistic modelling of complex dietary preferences.

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The motivation for this study stems from the need to develop a comprehensive mathematical model that can effectively optimize green leafy vegetable diets while accommodating the inherent uncertainty and variability in cost and nutritional requirements. By leveraging the ranking of tridecagonal fuzzy numbers, this study aims to address this gap in the literature and provide a novel approach to personalized dietary recommendation systems.

In this research paper, we are focusing on estimating the cost of purchasing green leaves that are rich in carbohydrates, proteins, vitamins, calcium, minerals, and iron. We have identified Amaranth leaves, Basella leaves, beet greens, fenugreek leaves, and gongura leaves as the green leaves that are appropriate for our diet. To better estimate the cost of buying these green leaves, we are using the ranking of tridecagonal fuzzy numbers summarized by Vogel's approximation method (VAM) ([27], [30], [31], [32], [34], [38]). By promoting the consumption of green leafy vegetables through optimized dietary plans, this research contributes to the broader goal of improving public health and well-being.

Literature Review

Green leafy vegetables play an important role in the absorption, consumption, and utilization of a balanced diet. Eating green leafy vegetables daily can improve overall health and reduce the risk of illness. They provide both health benefits and illness prevention. The risk of cardiovascular disease is significantly reduced by consuming green leafy foods, especially cruciferous vegetables ([26], [29]). According to [17], [24], and [25], green leaves are rich in iron, vitamins, and minerals.

The green leaves that people use most frequently across the nation include amaranth, basella, beetroot greens, fenugreek and gongura leaves. Green leaves are highly nutritious, containing proteins, carbohydrates, calcium, iron, vitamins, and minerals. They are also a great source of vitamin C and vitamin A, which are both important for maintaining a healthy diet. One of the best sources of carbohydrates is amaranth leaves, which are rich in energy. Additionally, amaranth leaves contain potassium, an essential nutrient for maintaining a healthy heart and a high vitamin C content that facilitates easy digestion ([Krishnendu, J. R. [16] and Govender et al. [12]). Gongura leaves are known to provide numerous health benefits such as clear skin, rich nutrients, and prevention of various ailments. With low calorie content, Gongura is a healthy food choice. The antioxidants present in Gongura help boost immunity and prevent the risk of cancer. (Mennem et al. [21] and Misra et al. [20]). Basella leaves are a rich source of vitamin A and β-carotene and aid in digestion. They are high in fibre and support a healthy digestive tract. (Smith et al., [36]). Consuming fenugreek leaves is an effortless way to enhance fibre absorption. Fenugreek leaves are enriched with minerals and nutrients such as potassium and copper, which are vital for the body's immunological development. These leaves also aid in digestion and weight loss. Furthermore, fenugreek leaves contain iron, a crucial component of haemoglobin. On the other hand, beet greens act like an oxygen mask and help to prevent heart disease. According to Goldman et al. [10] and Ramu and Sakthi [28], beetroot greens are rich in vitamins and have a high nutrient content that shields us from a variety of illnesses.

Paper Organization

In this workThe structure of the remaining of the paper is as follows: Section 2 presents the background information required for the study. Section 3 presents the architecture of the proposed mathematical model. Section 4 discuss the results of this study in detail. Section 5 summarises the conclusion of this study.

Preliminaries

In order to understand fuzzy sets, it is necessary to comprehend the fundamental concept of classical set theory in mathematics. The classical set A in the Universal Set X, A⊂X is normally characterized by the function $\mu_A(x)$which takes the value 1 and 0, indicating whether or not x∈X is a member of A, $\mu_A(x) = \begin{cases} 0 & for\ x \epsilon A \\ 1 for\ x \notin A \end{cases}$. Here $\mu_A(x)$∈{0,1}. The function $\mu_A(x)$ takes only the values 1 or 0. Now, assumed that the function $\mu_A(x)$ may take values in the interval [0, 1]. In this way, the idea of membership is no longer clear-cut but rather fuzzy, representing partial belonging or a degree of membership.

Definition: 1(Fuzzy set)

If X is a universe of disclosure and x is any particular element of X, then a fuzzy set defined on X may be written as a collection of ordered pairs where each pair is called a singleton. A fuzzy set is denoted by

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x))/x \in U, \mu_{\tilde{A}}(x) \in [0,1]\}$$

When X is countable then the fuzzy set $\tilde{A}$ on X is expressed as

$$\tilde{A} = \sum_{x \in X}^{\cdot} \mu(x)/x$$

When X is infinite and uncountable set, a fuzzy set $\tilde{A}$ on X is expressed as $\tilde{A} = \int \mu(x)/x$.

Definition: 2 (Membership function)

The membership function values are not always described by discrete values. Sometimes, they are described by a continuous function. The most commonly used range of values for membership functions is [0, 1]. In this case, each membership function maps elements of a given universal set X (crisp set) into real numbers in [0, 1].The membership function of a fuzzy A is expressed by the symbol μ, i.e., $\mu_1 : X \rightarrow [0,1]$

Definition: 3

A Fuzzy number must satisfy the following conditions:

- μ is piece wise continuous
- There exist at least one with μ = 1
- must be normal and convex
- It must be a fuzzy set on the real line R

Definition: 4 Triangular fuzzy number

Triangular Fuzzy Number is defined as $A = (a, b, c)$, where all a, b, c are real numbers and its membership function is given below.

$$A(x) = \begin{cases} (x-a)(b-a) \text{for } a \leq x \leq b \\ (c-x)\ (c-b) \text{for } b \leq x \leq c \\ 0\ otherwise \end{cases}$$

Definition: 5 Trapezoidal fuzzy number

A fuzzy set $A = (a, b, c, d)$ is said to trapezoidal fuzzy number if its membership function is given by where $a \leq b \leq c \leq d$

$$A(x) = \begin{cases} 0 & \text{for } x < a \\ (x-a)\ (b-a) & \text{for } a \leq x \leq b \\ 1 & \text{for } b \leq x \leq c \\ (d-x)(d-c) & \text{for } c \leq x \leq d \\ 0 & \text{for } x > d \end{cases}$$

Definition 6: Tridecagonal fuzzy Number

A fuzzy number $\tilde{G}_T$ is a tridecagonal fuzzy number denoted by

$\tilde{G}_T = (g_1, g_2, g_3, g_4, g_5, g_6, g_7, g_8, g_9, g_{10}, g_{11}, g_{12}, g_{13})$, Where g_1, g_2, g_3, g_4, g_5, g_6, g_7, g_8, g_9, g_{10}, g_{11}, g_{12}, and g_{13} are real values and their membership functions are given below:

$$\mu_{\tilde{G}_T}(x) = \begin{cases} \frac{1}{6}\frac{(x-g_1)}{(g_2-g_1)}, & for\ g_1 \le x \le g_2 \\ \frac{1}{6}+\frac{1}{6}\frac{(x-g_2)}{(g_3-g_2)}, & for\ g_2 \le x \le g_3 \\ \frac{2}{6}+\frac{1}{6}\frac{(x-g_3)}{(g_4-g_3)}, & for\ g_3 \le x \le g_4 \\ \frac{3}{6}+\frac{1}{6}\frac{(x-g_4)}{(g_5-g_4)}, & for\ g_4 \le x \le g_5 \\ \frac{4}{6}+\frac{1}{6}\frac{(x-g_5)}{(g_6-g_5)}, & for\ g_5 \le x \le g_6 \\ \frac{5}{6}+\frac{1}{6}\frac{(x-g_6)}{(g_7-g_6)}, & for\ g_6 \le x \le g_7 \\ 1-\frac{1}{6}\frac{(x-g_7)}{(g_8-g_7)}, & for\ g_7 \le x \le g_8 \\ \frac{5}{6}-\frac{1}{6}\frac{(x-g_8)}{(g_9-g_8)}, & for\ g_8 \le x \le g_9 \\ \frac{4}{6}-\frac{1}{6}\frac{(x-g_9)}{(g_{10}-g_9)}, & for\ g_9 \le x \le g_{10} \\ \frac{3}{6}-\frac{1}{6}\frac{(x-g_{10})}{(g_{11}-g_{10})}, & for\ g_{10} \le x \le g_{11} \\ \frac{2}{6}-\frac{1}{6}\frac{(x-g_{11})}{(g_{12}-g_{11})}, & for\ g_{11} \le x \le g_{12} \\ \frac{1}{6}\frac{(g_{13}-x)}{(g_{13}-g_{12})}, & for\ g_{12} \le x \le g_{13} \end{cases}$$

Definition 5: Ranking of the Tridecagonal Fuzzy Number

The real line is mapped directly by a fuzzy number based on the ranking method. Let $\tilde{G}_T$ be a generalized tridecagonal fuzzy number. The ranking of $\tilde{G}_T$ is denoted by R ($\tilde{G}_T$) and is calculated as follows:

$$R(\tilde{G}_T) = \left[\frac{g_1 + 3g_2 + 2g_3 + 4g_4 + 6g_5 + g_6 + g_7 + g_8 + 6g_9 + 4g_{10} + 2g_{11} + 3g_{12} + g_{13}}{35}\right]$$

Architecture of Proposed Mathematical Model

This study included a well-balanced green leafy diet that satisfied the public's nutritional requirements. The main aim of this paper is to offer a precise cost estimate for buying green leaves. A mathematical model has been summarized to calculate the minimum cost, which involves ranking the tridecagonal fuzzy number associated with Vogel's approximation method. This model estimates the minimum cost by using the tridecagonal fuzzy number connected with Vogel's approximation approach.

The architecture of the proposed mathematical model starts with the selection of edible nutrition rich green leafy vegetables such as amaranth leaves, basella leaves, beet greens, fenugreek leaves, and gongura leaves, which are abundant in terms of protein, fat, total fiber, carbohydrates, and calcium. Real data were collected and the amounts of nutritional feed in the green leaves were listed, from the Nutritive Value of Indian Foods provided by the National Institute of Nutrition [11], and Indian Food Composition Tables [18]. The next step is to calculate the current cost of the materials discussed above. The cost of edible portion of foodstuff per 100 gm of nutrient green leaves is taken as the supply and the cost of nutrition per 100 gm of nutrient green leaves is taken as the demand. Amaranth, basella, beetroot greens, fenugreek, and gongura leaves are among the most often used green leaves in India because of their high protein, carbohydrate, calcium, iron, and vitamin and mineral contents. This step is followed by ranking of tridecagonal fuzzy numbers is determined using a systematic approach. The lowest, essential, and highest fulfilled amounts of protein, fats, total fiber, carbohydrates, and calcium, respectively in every green leaf were treated as tridecagonal fuzzy numbers. By employing Vogel's approximation method, an optimal solution is derived to enhance the efficiency of the nutrient distribution. This calculation uses the same format of lower fuzzy numbers like triangular fuzzy number and trapezoidal fuzzy number [37]. Subsequently, defuzzification is applied to convert the fuzzy number rankings into crisp values, facilitating a clearer interpretation of the data [39]. This systematic process enables a robust analysis of nutrient content, leveraging both fuzzy logic and optimization techniques to derive meaningful insights from the complex information inherent in green leaf nutrient profiles. After those process minimum total cost is obtained for the green leaves. As the final step of this study optimal daily green leaves diet plan for 3000 calories a day suggested.

Results and Discussion

Table 1 shows the details of the nutrient content of the green leaves. Following this, the ranking of tridecagonal fuzzy numbers is determined using a systematic approach. By employing Vogel's approximation method, an optimal solution is derived.Subsequently, defuzzification is applied to convert the fuzzy number rankings into crisp values. The subject of this study was the diet of green leaves, which are rich in calcium, lipids, protein, total fiber, and carbohydrates. Examples of these leaves are amaranth, basella, beet, and fenugreek. Based on the Indian Food Composition tables [18] and the Nutritive Value of Indian foods provided by the National Institute of Nutrition [11], actual data were gathered and the nutritional content of the green leaves was indicated. Tridecagonal fuzzy numbers are used to represent the lowest, most necessary, and most fulfilled amounts of protein, lipids, total fiber, carbohydrates, and calcium in each green leaf, respectively. The mathematical formulation for given green leaves used to solve the fuzzy transportation problem ([31] [34] [35]) is described below by using Table 1:

Min Z = R (1.27, 1.31, 1.35, 1.39, 1.43, 1.47, 1.51, 1.55, 1.59, 1.63, 1.67, 1.71, 1.75)
+R (0.41, 0.42, 0.43, 0.44, 0.45, 0.46, 0.47, 0.48, 0.49, 0.50, 0.51, 0.52, 0.53)
+R (2.00, 2.02, 2.04, 2.06, 2.08, 2.10, 2.12, 2.14, 2.16, 2.18, 2.20, 2.22, 2.24)
+R (11.56, 11.61, 11.66, 11.71, 11.76, 11.81, 11.86, 11.91, 11.96, 12.01, 12.06, 12.11, 12.16)
+R (0.63, 0.65, 0.67, 0.69, 0.71, 0.73, 0.75, 0.77, 0.79, 0.81, 0.83, 0.85, 0.87)
+R (0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30)
+R (1.21, 1.23, 1.25, 1.27, 1.29, 1.31, 1.33, 1.35, 1.37, 1.39, 1.41, 1.43, 1.45)
+R (12.63, 12.73, 12.83, 12.93, 13.03, 13.13, 13.23, 13.33, 13.43, 13.53, 13.63, 13.73, 13.83)
+R (1.35, 1.37, 139, 1.41, 1.43, 1.45, 1.47, 1.49, 1.51, 1.53, 1.55, 157, 1.59)
+R (0.29, 0.30, 0.31, 0.32, 0.33, 0.34, 0.35, 0.36, 0.37, 0.38, 0.39, 0.40, 0.41)
+R (8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60, 8.61, 8.62, 8.63, 8.64, 8.65, 8.66)
+R (4.80, 4.86, 4.92, 4.98, 5.04, 5.10, 5.16, 5.22, 5.28, 5.34, 5.40, 5.46, 5.52)
+R (0.43, 0.45, 0.47, 0.49, 0.51, 0.53, 0.55, 0.57, 0.59, 0.61, 0.63, 0.65, 0.67)
+R (0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14)
+ R (3.34, 3.36, 3.38, 3.40, 3.42, 3.44, 3.46, 3.48, 3.50, 3.52, 3.54, 3.56, 3.58)
+R (8.27, 8.46, 8.65, 8.84, 9.03, 9.22, 9.41, 9.60, 9.79, 9.98, 10.17, 10.36, 10.55)
+ R (0.51, 0.53, 0.55, 0.57, 0.59, 0.61, 0.63, 0.65, 0.67, 0.69, 0.71, 0.73, 0.75)
+R (0.24, 0.27, 0.30, 0.33, 0.36, 0.39, 0.42, 0.45, 0.48, 0.51, 0.54, 0.57, 0.60)
+R (1.71, 1.77, 1.83, 1.89, 1.95, 2.01, 2.07, 2.13, 2.19, 2.25, 2.31, 2.37, 2.43)
+R (10.63, 10.88, 11.13, 11.38, 11.63, 11.88, 12.13, 12.38, 12.63, 12.88, 13.13,
13.38, 13.63

Table 1. Nutritional content of green leaves

Foods	Protein	Fat	Total Fiber	Carbohydrates	Supply (cost of Edible portion of food stuff per 100 gm)
AMARANTH LEAVES	1.27, 1.31, 1.35,1.39, 1.43, 1.47, 1.51,1.55, 1.59, 1.63, 1.67,1.71,1.75	0.41, 0.42, 0.43,0.44, 0.45, 0.46, 0.47,0.48, 0.49, 0.50, 0.51,0.52, 0.53	2.00, 2.02, 2.04, 2.06,2.08, 2.10, 2.12, 2.14,2.16, 2.18, 2.20, 2.22, 2.24	11.56, 11.61, 11.66, 11.7, 11.76,11.81, 11.86,11.91, 11.96,12.01, 12.06,12.11,12.16	1.22, 1.23, 1.24, 1.25, 1.26, 1.27, 1.28, 1.29, 1.30, 1.31, 1.32, 1.33, 1.34
BASELLA LEAVES	0.63, 0.65, 0.67,0.69, 0.71, 0.73, 0.75,0.77, 0.79, 0.81, 0.83, 0.85, 0.87	0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30, 0.30	1.21, 1.23, 1.25, 1.27, 1.29, 1.31, 1.33, 1.35, 1.37, 1.39, 1.41, 1.43, 1.45	12.63, 12.73, 12.83, 12.93, 13.03, 13.13, 13.23, 13.33, 13.43, 13.53, 13.63, 13.73, 13.83	0.89, 0.90, 0.90,0.91, 0.92, 0.93,0.94, 0.95, 0.95, 0.96, 0.97, 0.98, 0.99
BEET GREENS	1.35, 1.37, 139, 1.41, 1.43, 1.45, 1.47, 1.49, 1.51, 1.53, 1.55, 157, 1.59	0.29, 0.30, 0.31, 0.32, 0.33, 0.34, 0.35, 0.36, 0.37, 0.38, 0.39, 0.40, 0.41	8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60, 8.61, 8.62, 8.63, 8.64, 8.65, 8.66	4.80, 4.86, 4.92,4.98,5.04, 5.10,5.16, 5.22, 5.28, 5.34, 5.40,5.46,5.52	0.60, 0.60, 0.61, 0.61, 0.62, 0.62, 0.62, 0.63, 0.63, 0.63, 0.64, 0.64, 0.65
FENUGREEK LEAVES	0.43, 0.45, 0.47, 0.49, 0.51, 0.53, 0.55, 0.57, 0.59, 0.61, 0.63, 0.65, 0.67	0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14, 0.14	3.34, 3.36, 3.38, 3.40, 3.42, 3.44, 3.46, 3.48, 3.50, 3.52, 3.54, 3.56, 3.58	8.27, 8.46, 8.65,8.84,9.03, 9.22, 9.41, 9.60,9.79, 9.98, 10.17,10.36,10.55	0.85, 0.87, 0.89, 0.90, 0.92, 0.93, 0.95, 0.97, 0.98, 1.00, 1.01, 1.03, 1.05
GONGURA LEAVES	0.51, 0.53, 0.55, 0.57, 0.59, 0.61, 0.63, 0.65, 0.67, 0.69, 0.71, 0.73, 0.75	0.24, 0.27, 0.30, 0.33, 0.36, 0.39, 0.42, 0.45, 0.48, 0.51, 0.54, 0.57, 0.60	1.71, 1.77, 1.83, 1.89, 1.95, 2.01, 2.07, 2.13, 2.19, 2.25, 2.31, 2.37, 2.43	10.63, 10.88, 11.13, 11.38, 11.63, 11.88, 12.13, 12.38, 12.63, 12.88, 13.13, 13.38, 13.63	1.18, 1.21, 1.24, 1.28, 1.31, 1.34, 1.37, 1.41, 1.44, 1.47, 1.50, 1.54, 1.57
Demand (cost of nutrition per 100 gm)	0.27, 0.28, 0.29, 0.29, 0.30, 0.31, 0.32, 0.33, 0.34, 0.35, 0.35, 0.36, 0.37	0.09, 0.10, 0.10, 0.11, 0.11, 0.11, 0.12, 0.12, 0.13, 0.13, 0.13, 0.14, 0.14	0.96, 0.97, 0.98, 0.99, 1.00, 1.01, 1.02, 1.03, 1.04, 1.05, 1.06, 1.07, 1.08	3.41, 3.46, 3.51, 3.55, 3.60, 3.65, 3.70, 3.75, 3.80, 3.84, 3.89, 3.94, 3.99	

Let $\tilde{G}_T$ be a generalized tridecagonal fuzzy number. The ranking of $\tilde{G}_T$ is denoted by R ($\tilde{G}_T$) and is calculated as follows:

$$R(\tilde{G}_T) = \left[\frac{g_1+3g_2+2g_3+4g_4+6g_5+g_6+g_7+g_8+6g_9+4g_{10}+2g_{11}+3g_{12}+g_{13}}{35}\right].$$

By using this formula we estimate the following Table 2.

Table 2. Fuzzy transportation problem after applying the ranking technique

Foods	Protein	Fat	Total Fiber	Carbohydrates	Supply
AMARANTH LEAVES	$R(\tilde{G}_T) = \frac{1}{35}[52.85]$ = 1.51	$R(\tilde{G}_T) = \frac{1}{35}[16.45]$ = 0.47	$R(\tilde{G}_T) = \frac{1}{35}[74.20]$ = 2.12	$R(\tilde{G}_T) = \frac{1}{35}[415.10]$ = 11.86	$R(\tilde{G}_T) = \frac{1}{35}[44.80]$ = 1.28
BASELLA LEAVES	$R(\tilde{G}_T) = \frac{1}{35}[26.25]$ = 0.75	$R(G_T) = \frac{1}{35}[10.50]$ = 0.30	$R(\tilde{G}_T) = \frac{1}{35}[46.55]$ = 1.33	$R(\tilde{G}_T) = \frac{1}{35}[463.05]$ = 13.23	$R(\tilde{G}_T) = \frac{1}{35}[32.90]$ = 0.94
BEET GREENS	$R(\tilde{G}_T) = \frac{1}{35}[51.45]$ = 1.47	$R(\tilde{G}_T) = \frac{1}{35}[12.25]$ = 0.35	$R(\tilde{G}_T) = \frac{1}{35}[301]$ = 8.60	$R(\tilde{G}_T) = \frac{1}{35}[180.60]$ = 5.16	$R(\tilde{G}_T) = \frac{1}{35}[21.70]$ = 0.62
FENUGREEK LEAVES	$R(\tilde{G}_T) = \frac{1}{35}[19.25]$ = 0.55	$R(\tilde{G}_T) = \frac{1}{35}[4.90]$ = 0.14	$R(\tilde{G}_T) = \frac{1}{35}[121.10]$ = 3.46	$R(\tilde{G}_T) = \frac{1}{35}[329.35]$ = 9.41	$R(\tilde{G}_T) = \frac{1}{35}[33.25]$ = 0.95
GONGURA LEAVES	$R(\tilde{G}_T) = \frac{1}{35}[22.05]$ = 0.63	$R(\tilde{G}_T) = \frac{1}{35}[14.70]$ = 0.42	$R(\tilde{G}_T) = \frac{1}{35}[72.45]$ = 2.07	$R(\tilde{G}_T) = \frac{1}{35}[424.55]$ = 12.13	$R(\tilde{G}_T) = \frac{1}{35}[47.95]$ = 1.37
Demand	$R(\tilde{G}_T) = \frac{1}{35}[11.20]$ = 0.32	$R(\tilde{G}_T) = \frac{1}{35}[4.20]$ = 0.12	$R(\tilde{G}_T) = \frac{1}{35}[35.70]$ = 1.02	$R(\tilde{G}_T) = \frac{1}{35}[129.50]$ = 3.70	**5.16**

To determine the optimum solution for the distribution of Amaranth leaves, Basella leaves, Beet greens, Fenugreek leaves, and Gongura leaves, Vogel's approximation method (VAM) was used. VAM is a mathematical approach utilized in transportation and linear programming problems to efficiently allocate resources. In this context, the supply and demand for each type of leaf play a crucial role in determining the optimal distribution. The supply refers to the quantity of each leaf available, while demand signifies the requirements for these leaves in various locations or markets. By applying VAM, one can systematically analyze the costs associated with transporting these leaves from suppliers to consumers, considering the discrepancies in both supply and demand. This method aims to minimize transportation costs and maximize the overall efficiency of the distribution network, ensuring that each type of leaf reaches its intended destination in the most economical manner. In summary, the Vogel's approximation method facilitates the creation of an optimal distribution plan for Amaranth leaves, Basella leaves, Beet greens, Fenugreek leaves, and Gongura leaves based on their respective supply and demand dynamics.

Table 3. Optimum the minimum total cost for green leaves is solution obtained by Vogel's approximation method

Foods	Protein	Fat	Total Fiber	Carbohydrates	Supply
AMARANTH LEAVES	**0.32** 1.51	**0.12** 0.47	**0.08** 2.12	**0.76** 11.86	1.28
BASELLA LEAVES	0.75	0.30	**0.94** 1.33	13.23	0.94
BEET GREENS	1.47	0.35	8.60	**0.62** 5.16	0.62
FENUGREEK LEAVES	0.55	0.14	3.46	**0.95** 9.41	0.95
GONGURA LEAVES	0.63	0.42	2.07	**1.37** 12.13	1.37
Demand	0.32	0.12	1.02	3.70	5.16

Min Z = (1.51) (0.32) + (0.47) (0.12) + (2.12) (0.08) + (11.86) (0.76) + (1.33)(0.94) + (5.16) (0.62) + (9.41) (0.95) + (12.13) (1.37)

Min Z = Rs. 39.73

Table 4. Optimal daily green leaf diet plan for 3000 calories a day

Green leaves	Daily serving sizes in grams	Cost of serving in rupees
AMARANTH LEAVES	15.96	9.72
BASELLA LEAVES	1.33	1.25
BEET GREENS	5.16	3.20
FENUGREEK LEAVES	9.41	8.94
GONGURA LEAVES	12.13	16.62
Optimal daily Green Leaves diet cost	-	39.73

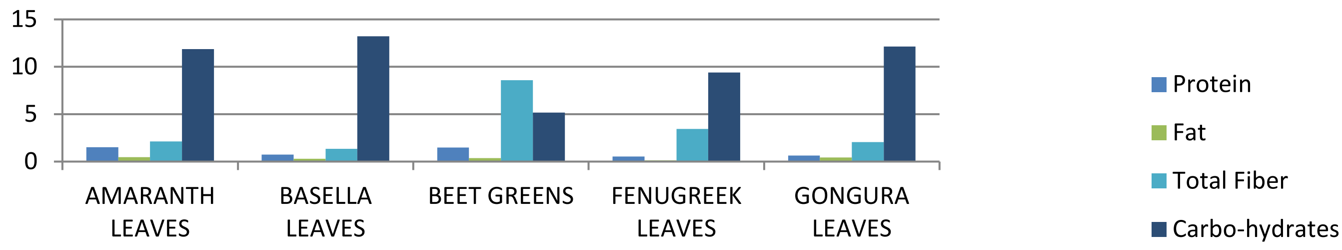

Figure 1. Nutrient content of green leaves

Figure 1 shows the nutrient contents of amaranth leaves, basella leaves, beet greens, fenugreek leaves, and gongura leaves, which are characterized by protein, fat, total fiber, and carbohydrates, which are visually represented through a bar chart. This graphical representation serves as a comprehensive tool for comparing and contrasting the nutritional composition of these green leaves. The bar chart vividly illustrates the variations in protein, fat, fiber, and carbohydrate content among the different types of leaves, providing a clear and accessible means for viewers to comprehend the nutritional profile of each. This approach not only facilitates a quick and intuitive understanding of the data but also allows for easy identification of trends or disparities in the nutrient composition of the selected green leaves. Through the visual aid of the bar chart, one can glean valuable insights into the relative nutritional strengths of amaranth leaves, basella leaves, beet greens, fenugreek leaves, and gongura leaves, aiding in informed dietary choices or scientific analysis.

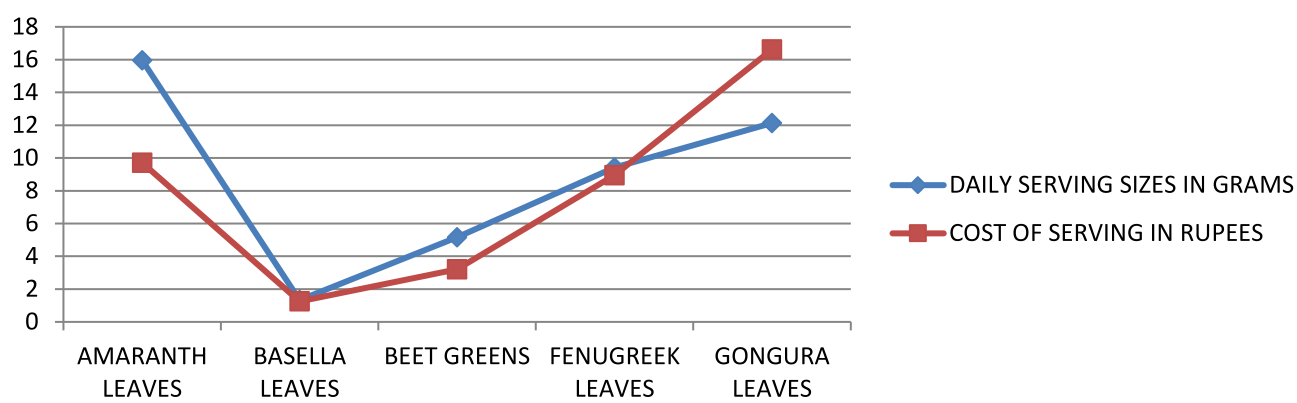

Figure 2 Optimal daily green leaf diet plan for 3000 calories a day

Table 4 and Figure 2 represent the optimal daily green leaf diet plan tailored to achieve a caloric intake of 3000 calories. The table outlines the recommended daily serving sizes, measured in grams, and the corresponding cost in rupees for five types of green leaves: amaranth leaves, basella leaves, beet greens, fenugreek leaves, and gongura leaves. For amaranth leaves, the optimal daily serving size is 15.96 grams with a cost of 9.72 rupees. Basella leaves have a suggested serving size of 1.33 grams, incurring a cost of 1.25 rupees. Beet greens reach 5.16 grams with a cost of 3.20 rupees, while fenugreek leaves recommend 9.41 grams at a cost of 8.94 rupees. Gongura leaves, with an optimal serving size of 12.13 grams, have a corresponding cost of 16.62 rupees. The total cost of the optimal daily green leaf diet was 39.73 rupees. This comprehensive breakdown provides a detailed guide for individuals aiming to achieve a balanced diet while adhering to a 3000-calorie daily intake, considering both nutritional requirements and economic considerations

Conclusions

It is often believed that a diet centred on green leafy vegetables can be expensive and is not widely accepted among Indian individuals. This notion is primarily based on several studies conducted on the typical Indian diet. However, taking a supplement can be costly and may not be entirely natural. Therefore, in this research paper, we employ a generalized tridecagonal fuzzy number to determine the minimum cost of a well-rounded diet that includes green leafy vegetables, which are a crucial source of nutrients such as proteins, vitamins, minerals, calcium, and iron. We have established the ideal quantity of green leafy vegetables in the diet by employing a fuzzy transportation approach, resulting in a well-balanced meal plan. Our findings also have implications for promoting awareness about the significance of green leafy vegetables in our diet and encouraging individuals to incorporate them into their meals on a regular basis.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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