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Recommendation of Diet to Jaundice Patient on the Basis of Nutrients Using AHP and Fuzzy AHP Technique

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Abstract: Jaundice is a disease caused due to alarmingly high level of bilirubin. This prevails in places with low level of sanitation and inability to access nutrient enriched diet. In the Indian perspective, jaundice is a severe menace affecting many people including infants, ladies and men. To cure jaundice, the bilirubin levels need to be lowered which can be done by a proper diet incorporating multiple critical nutrients in right proportion along with medication. This makes it an incredibly complex process. The proposed paper recommends diet to jaundice patient by using Analytic Hierarchy Process (AHP). This technique for diet recommendation has not been used before and it provides a new perspective which is different from conventional techniques. In AHP, critically important nutrients are taken as factors and alternative diet plans are evaluated on the basis of these factors in order to select the best option. The result is the diet plan which includes meals to be consumed by a jaundice patient at breakfast, lunch and dinner. The results obtained by AHP are further validated using Fuzzy Analytic Hierarchy Process (FAHP). FAHP provided the same results as obtained from AHP.

Keywords: Jaundice, Diet, AHP, Fuzzy AHP, Nutrients.

1. Introduction

Jaundice also known as icterus, is a liver disease in which discoloration of the skin to yellow occurs which may be caused due to high bilirubin levels. Increase in bilirubin levels may be due to many reasons- high RBC breakdown results in more bilirubin, which becomes difficult for liver cells to process. RBC breakdown may be due to some genetic disease like sickle cell anaemia or thalassemia. Another reason can be when liver cells are not able to take up bilirubin well, this leads to increase in their levels and due to this the bilirubin spread in the bloodstream and cause jaundice. Liver cells can be affected by diseases such as cirrhosis, or Gilbert's Syndrome. Third reason can be damage of tiny bile ducts in the liver which restrict the flow of bile. Another reason can be blockage of the bile duct. Blockage of bile duct can be due to gallstones, cancer or pancreatitis [1].

Jaundice is most common in newborns and infants because their body has more bilirubin then their body can excrete. This is because while they are in the womb, extra bilirubin is removed through placenta but after birth the body has to remove it on its own. To cure jaundice in newborns proper medical treatment is necessary as diet cannot be recommended to them [2]. A pregnant woman can also be the patient of jaundice due to acute fatty liver of pregnancy or intrahepatic cholestasis of pregnancy. It becomes inevitable to cure it otherwise it may affect the health of the baby as well as the mother. So a pregnant woman needs a proper diet along with medication [3]. Jaundice is a disease which can happen to any person with poor liver and poor condition or functioning of liver can be caused by any of the reasons stated above resulting in rise of bilirubin levels.

Jaundice can be diagnosed by symptoms like yellowing of white area of the eyes and also the skin. The person may suffer itchiness or pruritus, abdominal pain due to blockage of bile duct. He may also suffer some weight loss and may feel vomiting and fever. He may also notice dark urine

and paler stools than usual [4]. Jaundice is a serious health disease which can cause the rapid deterioration of a person's health. It can also induce many other serious illnesses and diseases. Such is the impact of it, that jaundice needs to be cured effectively and early. If not, permanent damages to health may occur which may be fatal. However all is not lost as long as a proper and healthy diet containing all essential nutrients is being provided to the patient.

The previous work done so far has been cited in section 2. All these work revolve around the factors such as likeliness, climatic change or prakriti. None have shown the work for diet with nutrients which are required the most. So, this paper focuses strictly on the diet required for jaundice patient containing all the important nutrients. This paper outlines its uniqueness as there has been no previous work in this field. To propose a diet based on suggested nutrients AHP technique is used here as it focuses only on the critically important factors to be present in the diet. This technique compares all the factors with each other and rates their importance accordingly. Secondly, using AHP the exact diet can be recommended to the patient with all the nutrients present in their right proportion. This technique provides the result with the best diet to be suggested for better cure and recovery from jaundice. Thirdly, AHP checks for the consistency of the data.

The paper is organized in following way: In section 2 previous works on diet recommendations is explained. In section 3, research methodology used is explained, that is, AHP and Fuzzy AHP stating their background and steps to be followed for obtaining the results. In section 4, experimental work using AHP is shown with all the calculations and results. Section 5 deals with the validation of the results obtained from experimental work of AHP. The results obtained in section 4 and 5 are discussed in section 6. Finally, section 7 includes the conclusions and future work that can be carried on this research work.

2. Literature review

Previous work in the field of diet recommendation has been done using varieties of techniques. Diet recommendation for diabetes is done by type 2 fuzzy ontology to recommend a personal diet plan based on eating habits and preferences. Factors like, diet, obesity and physical activity have major influence on type-2 diabetes. For people with diabetes it is important to follow a proper meal plan. Like it is necessary to include fruits vegetables, grains etc. in the diet of diabetic patient [5]. Here, the nutrients required in the diet are suggested like, proteins, fat, carbohydrates, but the food which contains these nutrients is not mentioned. Based on recipe ontology diet recommendation was made which defines various food nutrients necessary to cure some common diseases. Some people may continue on low fat diet to lose weight which results in lack of other nutrients required by the body to complete its needs. This is where diet recommendation is necessary. Fuzzy methods were used there for diet journaling and planning [6]. Fuzzy expert system was designed for a nutritional guidance application based on expert knowledge to treat obesity and diabetes. The information about the nutrition people intake in their food are recorded and then compared to the nutritional value which they must consume. This will help maintain their nutritional level and have a balanced diet [7]. A drawback here is that food rich in nutrients is not recommended rather an analysis is done on intake of nutrients. Seasonal changes also causes imbalance in energies which can result in illness and different diseases. For good health and to prevent diseases, diet is the best medicine in Ayurveda. If the diet is given in right proportion there is no need of even medicines. Every person is born with their own prakriti or energy. These energies are needed to maintain the physical and mental state of the human being. A well planned diet helps to maintain that [8]. It focuses on the diet based only on prakriti and seasons, it lacks other factors like already borne illness or deficiency. Also fuzzy logic was used for diet therapy to control blood pressure and hypertension. Blood pressure and hypertension are common diseases affecting majority of people. Only about half of people have their blood pressure under control, rests are facing serious issues which are even causing deaths. So nutrition based diet was recommended for prevention and control of hypertension. The fuzzy logic was used for planning and managing the cost in social nourishment along with the nutritive composition of meals. The main idea is to maintain the daily energy and nutrient needs. The nourishment was planned based on nutrient offer, age of the person, gender and also the profession to know about their physical activity level [9]. This paper outlines an estimate of daily nutrition intake but does not outline the food to cover this nutritional need.

To reduce diseases, healthy diet is required. Unhealthy diet can lead to diseases like peptic ulcer, diabetes mellitus and gastro enteritis. The diet was planned to provide all the correct nutritional information based on recipe ontology. The main

purpose of the diet plan was to provide good health in daily lives to carry out daily activities effectively [10]. In this paper, nutrient based recipe is recommended but it does not tell when a person can consume a particular recipe, that is, at breakfast, lunch or dinner, because some food items are required to be taken at a particular time of the day. Development of healthy dietary pattern using fuzzy algorithms was done so that all the micronutrients needed by the body to reduce the risk of chronic diseases are consumed daily. Food groups like fruits, vegetables, grains, meats, milk, oils and fats are considered and their average nutrient content is determined which was further based on sex and the age group of people [11]. The value of food groups for intake is suggested here which does not clear about the exact diet to be taken belonging to a particular food group.

In this paper diet for jaundice patient is proposed on the basis of nutrients that must be present in his diet. Since the best diet among all the available diet alternatives must be chosen keeping in mind the critical nutrients and their relative importance, Analytic hierarchy process (AHP) has been chosen to recommend the best suitable diet [12]. The work is validated by Fuzzy AHP [13].

3. Research methodology

3.1 Multi criteria decision making

MCDM is used where multiple criterion decision making problems are faced to make wise decisions. Usually, there is no final unique solution for these types of problems, so the preferences are used to decide the solutions. The MCDM approach used here is Analytic Hierarchy Process (AHP) which deals with such type of problems by applying the use of preferences.

3.2 Analytic hierarchy process

Analytic Hierarchy Process (AHP) was developed by Thomas L Saaty in 1970's and is refined since then. It is a technique of decision making where different criteria are considered and different alternatives are defined based on all the criteria selected. A hierarchy is built which is the result of decomposition of the decision problem so that it could be well understood and analyzed independently. The elements of the hierarchy are then evaluated by comparing them with each other with respect to the impact they have on the above element in that hierarchy. [14]

Table 1. Sample data

	Criteria 1	Criteria 2	Criteria 3	Criteria 4
Criteria 1	1	7	5	2
Criteria 2	1/7	1	4	2
Criteria 3	1/5	¼	1	6
Criteria 4	½	½	1/6	1

Steps to be followed in AHP:

Step1: On the basis of the questionnaire and survey conducted these elements are weighted on the scale of 0-9.

A sample table is shown in Table 1.The weight of each criterion if filled as compared to their importance with other criterions. For example: weight 7 shows that criteria 1 is highly important as compared to criteria 2 and vice versa.

Step 2: The tables then created are used for calculating the n^{th} root of the product and their sum. Calculate by multiplying the complete row and then taking the n^{th} root, where n= no. of elements in the matrix.

Step 3: Eigen vector ω is then calculated by dividing the n^{th} root product by their sum.

Step 4: Next stage is to calculate λ_{max} so as to calculate Consistency Index (C.I) and Consistency Ratio (C.R). A_w is calculated by summation of product of each element of row to eigen vector.

$$\lambda max = {Aw}/{\omega} \quad (1)$$

where, λ_{max} is eigen value and ω is the eigen vector.

Step 5: Consistency Index is then calculated as

$$C.I = {(\lambda max - n)}/{(n-1)} \quad (2)$$

Step 6: Finally the Consistency Ratio is calculated as

$$C.R = \frac{C.I}{R.I} \quad (3)$$

Where, R.I represents the average of consistency index.

According to Saaty, C.R < 0.1 means that the judgements made are trustworthy and if C.R > 0.1 that means the judgements made is not consistent.

Table 2. Saaty fundamental scale

Scale Rating	Definition
1	Equally Important
3	Moderately Important
5	Very important
7	Highly Important
9	Strongly Important
2,4,6,8	Intermediate values between two adjacent judgements

Table 3. Diet based on selected factors

S.No.	Diet
Diet 1	**Breakfast:** Pear, whole wheat bread with little butter and pear juice. **Lunch:** Apple juice, raw vegetable salad, scrambled eggs. **Dinner:** Palak soup and scrambled eggs.
Diet 2	**Breakfast:** Apple juice, dalia, orange juice. **Lunch:** Coconut water, Steamed spinach, moong dal khichdi, sugarcane juice. **Dinner:** Hot skimmed milk with honey, steamed spinach, mixed vegetable juice.
Diet 3	**Breakfast:** Mango, egg white, apple juice. **Lunch:** Buttermilk, sweet potatoes. **Dinner:** Salad, lime water

The AHP hierarchy has three major levels/ layers [15]:
Layer 1: The goal or objective of the problem is defined.
Layer 2: All the critical factors/ criteria are defined.
Layer 3: Alternatives for these criteria are defined.
Below is the Table 2 which shows the clear definition of all the scale rating in Saaty fundamental scale.

4. Experimental work using AHP

4.1 Determination of critical factors

In this paper four critical factors are selected which are highly recommended to cure jaundice. The explanation of their criticality or why they are chosen as important factors is given below.

Proteins (C1) - They are good for repairing body cells and also make new ones. It is a 'macronutrient' which means that the body needs it in large amounts. Proteins provide energy to the body, helps in producing enzymes and hormones. They are good source of amino acids which aids in liver regeneration.

Carbohydrates (C2) - These are required to provide energy to the body. Carbohydrate rich food can hasten jaundice recovery as they are good for liver. Carbohydrate intake should be limited but not restricted. The foods containing low glycemic index are not harmful to liver and do not contribute to liver fat.

Dietary Fiber (C3) - These are needed to lower the causes (such as gallstones) that are affecting bile duct which can lead to severity of jaundice. Without these liver cannot function properly. Dietary fibers absorb all the extra fat and sugar in the body which were affecting the liver. They regulate the progression of bile in the liver, allow regular bowels movement, controls cholesterol levels and also the sugar levels, and prevent unwanted fat to grow. Fiber in one's diet is a necessary source of energy too and they also help in improving their immune system. A fiber rich diet decreases the accumulation of toxins and fats in the body which ultimately leads to the proper functioning of the liver.

Vitamins (C4) - Vitamins like A, B, C, D and E are essential as they all contribute in maintaining the health of liver. Vitamin B-12 is beneficial for formation of red blood cells and also to improve the color of the skin. B - Complex vitamins promote the breakdown of fats, carbohydrates and proteins in the liver. Vitamin E is known as best antioxidant and it promotes healthy liver. Vitamin E helps to low down the oxidative stress which may include stress from alcohol, drugs and other factors which may directly affects the liver conditions and makes it difficult for the liver to function properly. Vitamin C boosts your immune system and is another good antioxidant which turns to be a good source for healthy liver. Vitamin D also promotes liver health as its deficiency can cause cirrhosis which may result in increasing levels of bile which directly links to the health of liver. Vitamin A can also be considered a good source in diet as it builds up immune system.

Based on these factors different diets are proposed which were suggested by the doctors who have vast experience in treating jaundice. All the diets suggested include all the factors proposed above, that is, proteins, carbohydrates, dietary fibers and vitamins. Also the diets are selected with the view of their easy availability and affordability to the common man. Diets selected are divided into three meals- breakfast, lunch and dinner. This is done so that the patient can have variety of food at

different times of the day and also all the nutrients are consumed as per the requirements by the patient body. Table 3 below shows the diet selected based on the above four factors.

4.2 Proposed diet plan model

The paper shows the best diet to be selected which can be recommended to jaundice patient. Here, three diets are considered – diet 1, diet 2 and diet 3 on the basis of these four critical factors.

4.3 Calculations for factors and criterions

Based on the factors discussed above, now create judgement matrix of each alternative in regard to each factor. Table 4 here shows Saaty consistency index for random judgement. Table 5 shows the comparison of factors on the basis of Saaty fundamental scale.

From equations 1, 2 and 3,

$\lambda_{max} = 4.069$

C.I = (4.069 -4)/ (4-1)

= 0.023

Random Index for 4 factors from Saaty's table is 0.90

C.R = C.I/0.90

C.R = 2.5%

Table 6 shows the scale rating of each diet related to the factor/ criteria, proteins. From Eqs.(1), (2), and (3),

$\lambda_{max} = 3.025$

C.I = (3.025-3)/ (3-1)

= 0.0125

Random Index for 3 factors from Saaty's table is 0.58

C.R = C.I/0.58

C.R for Proteins = 2.6%

Table 7 shows the scale rating of each diet related to the factor/ criteria, carbohydrates. From Eqs.(1), (2), and (3),

$\lambda_{max} = 3.039$

C.I = 0.0195

Random Index for 3 factors from Saaty's table is 0.58

C.R = C.I/0.58

C.R for Carbohydrates = 4%

Similarly, Consistency Index (C.I) and Consistency Ratio (C.R) for other remaining factors can also be calculated.

C.I for Dietary Fiber = 0.037

C.R for Dietary Fiber = 7.7%

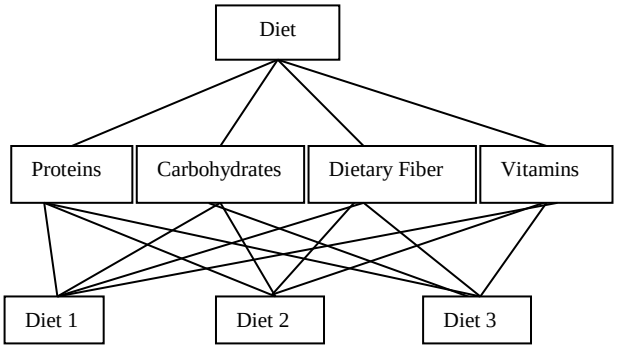

Figure.1 Proposed hierarchical diet model

Table 4. Saaty's index for consistency for random judgement

1-2	3	4	5	6	7	8	9
0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Table 5. Weight of the factors

	C1	**C2**	**C3**	**C4**	**4th root of product of values**	**Eigen Vector**
C1	1	1	1/5	1/7	0.410	0.073
C2	1	1	1/3	1/5	0.508	0.090
C3	5	3	1	1/3	1.495	0.266
C4	7	5	3	1	3.201	0.570

Table 6. Eigen vector for proteins

	Diet 1	**Diet 2**	**Diet 3**	**3rd root of product of values**	**Eigen Vector**
Diet 1	1	1/2	4	1.259	0.332
Diet 2	2	1	5	2.154	0.569
Diet 3	¼	1/5	1	0.368	0.097

Table 7. Eigen vector for carbohydrates

	Diet 1	**Diet 2**	**Diet 3**	**3rd root of product of values**	**Eigen Vector**
Diet 1	1	1/3	3	1	0.258
Diet 2	3	1	5	2.466	0.637
Diet 3	1/3	1/5	1	0.405	0.104

Table 8. Eigen vectors for all diets

	C1	**C2**	**C3**	**C4**
Diet 1	0.332	0.258	0.166	0.193
Diet 2	0.569	0.637	0.761	0.743
Diet 3	0.097	0.104	0.072	0.063

C.I for Vitamins = 0.0355

C.R for Vitamins = 7.4%

Table 9. Reliability index

Diet	Result	Rank
Diet 1	0.201	2
Diet2	**0.723**	**1**
Diet3	0.07	3

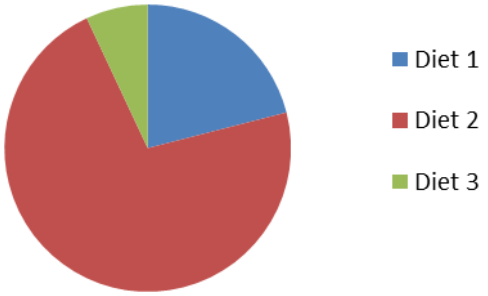

Figure.2 Representation of diets

Table 10. Fuzzy values used for producing qualitative assessments [13]

Fuzzy Values	Triangular Membership Function
1	(1, 1, 3)
x	(x-2, x, x+2) for x=3,5,7
9	(7, 9, 11)

Eigen vectors calculated for all the factors above are shown in Table 8. The Reliability Index for diets is calculated in Table 9. The calculations here show that diet 2 is the best recommended diet for the patient to recover from jaundice as it contains all the meal items which have all the above stated nutrients that is proteins, carbohydrates, dietary fiber and vitamins in the right proportion. This diet will help the patient to gain his health back soon. In other techniques proper diet was not targeted. But here, diet 2 considered as the best diet contains all the meals – breakfast, lunch and dinner containing all the required nutrients to cure jaundice patient.

5. Validation of experimental work

Validation of the above work is done by fuzzy AHP. Fuzzy AHP was designed by Hepu Deng [13]. Now its calculations will verify the above result about diet 2 to be the best diet among the three diets. Weights assigned to the factors are same as assigned in AHP.

Triangular fuzzy numbers are used in the pairwise comparison matrices shown in Table10.

Step 1: First create the decision matrix R for the selection problem. This is determined by using fuzzy arithmetic [16].

Consider the data from Table 6 and Table 7 for proteins and carbohydrates and similarly for dietary fiber and vitamins.

$$a_{ls} = \begin{cases} 1,3,5,7,9, & l < s \\ 1, & l = s \\ \frac{1}{asl}, & l > s \end{cases} \quad (4)$$

$$R_{ij} \text{ or } W_j = \sum_{s=1}^{k} als \,/\, \sum_{l=1}^{k} \sum_{s=1}^{k} als \quad (5)$$

Decision matrix R is calculated using equations 4 and 5 below,
R1 is calculated for proteins:

$$\left[\frac{1+\frac{1}{2}+4}{1+\frac{1}{2}+4+2+1+5+\frac{1}{4}+\frac{1}{5}+1}\right]$$

$$R1 = \left[\frac{2+1+5}{1+\frac{1}{2}+4+2+1+5+\frac{1}{4}+\frac{1}{5}+1}\right]$$

$$\left[\frac{\frac{1}{4}+\frac{1}{5}+1}{1+\frac{1}{2}+4+2+1+5+\frac{1}{4}+\frac{1}{5}+1}\right]$$

Now, R2 is calculated for carbohydrates:

$$\left[\frac{1+1/3+3}{1+\frac{1}{3}+3+3+1+5+\frac{1}{3}+\frac{1}{5}+1}\right]$$

$$R2 = \left[\frac{3+1+5}{1+\frac{1}{3}+3+3+1+5+\frac{1}{3}+\frac{1}{5}+1}\right]$$

$$\left[\frac{\frac{1}{3}+\frac{1}{5}+1}{1+\frac{1}{3}+3+3+1+5+\frac{1}{3}+\frac{1}{5}+1}\right]$$

R3 is calculated for dietary fiber:

$$\left[\frac{1+\frac{1}{6}+3}{1+\frac{1}{6}+3+6+1+8+\frac{1}{3}+\frac{1}{8}+1}\right]$$

$$R3 = \left[\frac{6+1+8}{1+\frac{1}{6}+3+6+1+8+\frac{1}{3}+\frac{1}{8}+1}\right]$$

$$\left[\frac{\frac{1}{3}+\frac{1}{8}+1}{1+\frac{1}{6}+3+6+1+8+\frac{1}{3}+\frac{1}{8}+1}\right]$$

Similarly, R4 for vitamins is calculated:

$$\left[\frac{1+\frac{1}{5}+4}{1+\frac{1}{5}+4+5+1+9+\frac{1}{4}+\frac{1}{9}+1}\right]$$

$$R4 = \left[\frac{5+1+9}{1+\frac{1}{5}+4+5+1+9+\frac{1}{4}+\frac{1}{9}+1}\right]$$

Table 11. Decision matrix

	R1	R2	R3	R4
Diet 1	(0.116, 0.367, 1.047)	(0.077, 0.291, 1.053)	(0.063, 0.202, 0.571)	(0.092, 0.241, 0.606)
Diet 2	(0.179, 0.535, 1.465)	(0.176, 0.605, 1.756)	(0.329, 0.727, 1.455)	(0.323, 0.695, 1.364)
Diet 3	(0.046, 0.096, 0.401)	(0.054, 0.102, 0.507)	(0.038, 0.071, 0.288)	(0.038, 0.063, 0.236)

Table 12. Fuzzy performance matrix

	Z1	Z2	Z3	Z4
Diet 1	(0.0047, 0.028, 0.344)	(0.003, 0.024, 0.389)	(0.006, 0.062, 0.461)	(0.017, 0.127, 0.734)
Diet 2	(0.007, 0.041, 0.481)	(0.007, 0.05, 0.649)	(0.031, 0.223, 1.175)	(0.059, 0.367, 1.653)
Diet 3	(0.001, 0.007, 0.131)	(0.002, 0.008, 0.187)	(0.003, 0.021, 0.232)	(0.007, 0.033, 0.286)

$$\left[\frac{\frac{1}{4}+\frac{1}{9}+1}{1+\frac{1}{5}+4+5+1+9+\frac{1}{4}+\frac{1}{9}+1}\right]$$

Table 11 shows the decision matrix.

Step 2: Criteria weights are to be calculated based on fuzzy arithmetic [16]. Using weights of the factors from Table 5, and then calculating weighting vector using Eqs.(4) and (5),

$$W1 = \left[\frac{1+1+\frac{1}{5}+\frac{1}{7}}{1+1+\frac{1}{5}+\frac{1}{7}+1+1+\frac{1}{3}+\frac{1}{5}+5+3+1+\frac{1}{3}+7+5+3+1}\right]$$

$$W2 = \left[\frac{1+1+\frac{1}{3}+\frac{1}{5}}{1+1+\frac{1}{5}+\frac{1}{7}+1+1+\frac{1}{3}+\frac{1}{5}+5+3+1+\frac{1}{3}+7+5+3+1}\right]$$

$$W3 = \left[\frac{5+3+1+\frac{1}{3}}{1+1+\frac{1}{5}+\frac{1}{7}+1+1+\frac{1}{3}+\frac{1}{5}+5+3+1+\frac{1}{3}+7+5+3+1}\right]$$

$$W4 = \left[\frac{7+5+3+1}{1+1+\frac{1}{5}+\frac{1}{7}+1+1+\frac{1}{3}+\frac{1}{5}+5+3+1+\frac{1}{3}+7+5+3+1}\right]$$

W_1 = (0.041, 0.077, 0.329)
W_2 = (0.043, 0.083, 0.370)
W_3 = (0.096, 0.308, 0.808)
W_4 = (0.185, 0.529, 1.212)

Step 3: Obtain the fuzzy performance matrix Z by taking the product of decision matrix R and weighting vector W as shown in Table 12.

Table 13. Interval performance matrix

	$Z_{\alpha 1}$	$Z_{\alpha 2}$	$Z_{\alpha 3}$	$Z_{\alpha 4}$
Diet 1	(0.016, 0.186)	(0.0135, 0.2065)	(0.034, 0.2615)	(0.072, 0.4305)
Diet 2	(0.024, 0.261)	(0.0285, 0.3495)	(0.127, 0.699)	(0.213, 1.01)
Diet 3	(0.004, 0.069)	(0.005, 0.0975)	(0.012, 0.1265)	(0.02, 0.1595)

Table 14. Overall crisp performance matrix

	$Z_\alpha^{\lambda'}{}_1$	$Z_\alpha^{\lambda'}{}_2$	$Z_\alpha^{\lambda'}{}_3$	$Z_\alpha^{\lambda'}{}_4$
Diet 1	0.101	0.110	0.147	0.251
Diet 2	0.142	0.188	0.413	0.611
Diet 3	0.036	0.051	0.069	0.089

Table 15. Normalized performance matrix

	$Z_\alpha^{\lambda}{}_1$	$Z_\alpha^{\lambda}{}_2$	$Z_\alpha^{\lambda}{}_3$	$Z_\alpha^{\lambda}{}_4$
Diet 1	0.57	0.493	0.332	0.377
Diet 2	0.802	0.843	0.932	0.917
Diet 3	0.203	0.228	0.156	0.134

Table 16. Positive and negative ideal solution

$A_\alpha^{\lambda+}$	0.802	0.843	0.932	0.917
$A_\alpha^{\lambda-}$	0.203	0.228	0.156	0.134

Step 4: Now calculate interval performance matrix Z_α by applying α-cut operation on fuzzy performance matrix Z and it is shown in Table 13. For α = 0.5.

Step 5: Overall crisp performance matrix $\mathbf{Z}_\alpha^{\lambda'}$ is calculated using equation (6). The matrix is represented by Table 14.

$$\mathbf{Z}_{ij\alpha}^{\lambda'} = \lambda Z^{\alpha}_{ijr} + (1-\lambda)\, Z^{\alpha}_{ijl},\ \lambda \in [0,1] \tag{6}$$

For λ = 0.5

Step 6: Now, normalized performance matrix $\mathbf{Z}_\alpha^{\lambda}$ is calculated using equation 7 and it is depicted in Table 15.

$$Z_{ij\alpha}^{\lambda} = Z_{ij\alpha}^{\lambda'} / \sqrt{\sum_{i=1}^{n} (Z\, ij\alpha\lambda')^2} \tag{7}$$

Step 7: Calculation of Positive Ideal Solution and Negative Ideal Solution is done using equations 8 and 9. It is shown in Table 16.

$$A^{\lambda+}{}_\alpha = (Z^{\lambda+}{}_{1\alpha}, Z^{\lambda+}{}_{2\alpha}, \ldots.. Z^{\lambda+}{}_{m\alpha})$$

$$A^{\lambda-}{}_\alpha = (Z^{\lambda-}{}_{1\alpha}, Z^{\lambda-}{}_{2\alpha}, \ldots\ldots Z^{\lambda-}{}_{m\alpha}) \tag{8}$$

$$Z_\alpha^{\lambda+} = \max (Z^{\lambda}_{1j\alpha}, Z^{\lambda}_{2j\alpha, \ldots\ldots} Z^{\lambda}_{nj\alpha})$$

$$Z_\alpha^{\lambda-} = \min (Z^{\lambda}_{1j\alpha}, Z^{\lambda}_{2j\alpha, \ldots\ldots} Z^{\lambda}_{nj\alpha}) \tag{9}$$

Table 17: Performance Index and Ranking

	Performance Index	Ranking
Diet 1	0.399	2
Diet 2	**0.798**	**1**
Diet 3	0.078	3

Step 8: Obtain the similarity degree for every alternative and positive ideal solution and also for every alternative and negative ideal solution using equations 10 and 11. Then, calculate the performance index and its corresponding ranking using equation 12.

$$S^{\lambda+}_{i\alpha} = A^{\lambda}_{i\alpha}\, A^{\lambda+}_{i\alpha} / \max\left(A^{\lambda}_{i\alpha}\, A^{\lambda}_{i\alpha}, A^{\lambda+}_{i\alpha}\, A^{\lambda+}_{i\alpha}\right) \quad (10)$$

$$S^{\lambda-}_{i\alpha} = A^{\lambda}_{i\alpha}\, A^{\lambda-}_{i\alpha} / \max\left(A^{\lambda}_{i\alpha}\, A^{\lambda}_{i\alpha}, A^{\lambda-}_{i\alpha}\, A^{\lambda-}_{i\alpha}\right) \quad (11)$$

$$P^{\lambda}_{\alpha} = S^{\lambda+}_{i\alpha} / \left(S^{\lambda+}_{i\alpha} + S^{\lambda-}_{i\alpha}\right) \quad (12)$$

Table 17 shows the performance index and ranking of alternatives. The results obtained shows that diet 2 is the best ranked diet among all the proposed diet alternatives. The results obtained from Fuzzy AHP are same as results obtained from AHP.

6. Results and discussions

The results obtained in section 4.3 above using AHP shows that diet 2 is the best diet among all three diets stated. This diet contains proteins, carbohydrates, dietary fiber and vitamins in the right proportion and all the recommended meal items are best sources of these nutrients, which means that if the person suffering from jaundice takes the recommended diet 2 he may recover fast as compared to other diets taken. To make sure about diet 2 as the best alternative, the result obtained from AHP is further validated in section 5 using Fuzzy AHP. Again, after all the calculations and work, it shows diet 2 as the best alternative to cure jaundice. So this confirms that diet 2 is the best diet which will help the person return to his health and function normally.

7. Conclusions

As the development grow so does the health issues. Not every time a person can rely on medicines, a proper diet is also a necessity. In this paper it is shown that for a jaundice patient, a proper diet containing all the essential nutrients required for recovery is necessary. The nutrients being important for jaundice are found to be proteins, carbohydrates, dietary fiber and vitamins. If the patient follows the above prescribed diet he/ she will be able to boost up their recovery level. And for the selection of such diet AHP and Fuzzy AHP techniques are used which compare all the factors of all diets and provide the best alternative. In future, more different methods or techniques can be used to evaluate the same and enhance the obtained results by taking into consideration some more criteria to make results more specific. Further nutrient value needed can also be specified in every meal.

Another scope can be the development of a diet recommendation application for jaundice as well as other diseases which may consider several factors like age, sex, physical condition or any other medical condition, so that it becomes easy for people to know about what all can be beneficial for them to consume while suffering from a particular type of disease. And this will further contribute in savings from the medical expenses.

References

[1] https://patient.info/in/health/jaundice-leaflet (accessed on 09.03.2017).

[2] http://www.webmd.com/parenting/baby/tc/jaundice-in-newborns-hyperbilirubinemia-topic-overview#1 (accessed on 09.03.2017).

[3] https://patient.info/in/doctor/jaundice-in-pregnancy (accessed on 10.03.2017)

[4] http://www.medicalnewstoday.com/articles/165749.php (accessed on 12.03.2017)

[5] C. Lee, M. Wang and H. Hagras, "A Type-2 Fuzzy Ontology and Its Application to Personal Diabetic-Diet Recommendation", *IEEE Transactions on Fuzzy Systems*, Vol. 18, No. 2, pp. 374-395, 2010.

[6] J. Krbez and A. Shaout, "Fuzzy Nutrition System", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 1, No. 7, pp. 1360- 1371, 2013.

[7] P. Heinonen, M. Mannelin, and H. Iskala, "Development of a Fuzzy Expert System for a Nutritional Guidance Application", In: *Proc of IFSA/EUSFLAT Conf.*, pp. 1685-1690, 2009.

[8] S. Chavan and S. Sambare, "Study of Diet Recommendation System based on Fuzzy Logic and Ontology", *International Journal of Computer Applications*, Vol. 132, No. 12, pp. 20-24, 2015.

[9] J. G. Kljusuric, I. Rumora, and Z. Kurtanjek, "Application of Fuzzy Logic in Diet Therapy - Advantages of Application", *Fuzzy Logic - Emerging Technologies and Applications*, pp. 42-63, 2012.

[10] Y. Ting, Q. Zhao, and R. Chen, "Dietary Recommendation Based on Recipe Ontology", In: *Proc. Of 6th Conference on Awareness Science and Technology (iCAST)*, pp. 1-6, 2014.
[11] G. Asghari, H. Ejtahed, M. Sarsharzadeh, P. Nazeri, and P. Mirmiran, "Designing fuzzy algorithms to develop healthy dietary pattern", *International Journal of Endocrinology and Metabolism*, Vol.11, No. 3, pp.154-161, 2013.
[12] T. Saaty, "Decision making with dependence and feedback: the analytic hierarchy process", *Mathematical and Computer Modelling: An International Journal*, Vol. 46, No. 7-8, pp. 1041-1053, 1996.
[13] H. Deng, "Multicriteria analysis with fuzzy pairwise comparison", *International Journal of Approximate Reasoning*, Vol 21, pp. 215-231, 1999.
[14] T. Saaty, "The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation", *Mcgraw- Hill, Texas*, 1980.
[15] C. Juang and D. Lee, "A Fuzzy Scale for Measuring Criteria Weights in Hierarchical Structures", In: *Proc. Of International Fuzzy Engineering Symposium*, pp. 415-421, 1992.
[16] A. Kaufmann and M. Gupta, "Introduction to Fuzzy Arithmetic Theory and Application", *Van Nostrand Reinhold*, New York, 1985.