

# Recommending Food Replacement Shakes along with Ice Cream for Diabetic Patients using AHP and TOPSIS to control Blood Glucose Level

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## Abstract

Currently diabetic is affecting almost all human races and the numbers of effected people are increasing. It has four major categories, type-1 type2, gestational and pre- diabetes. However, medication, physical exercise (life style) and meal plan are the controlling mechanisms. From thus meal plan is better than others in time, cost, and no side effect and easy to apply. This study is specifically focus on recommendation of food replacement shakes and ice cream by considering the diabetic patients' blood glucose level. For these AHP and TOPSIS are implemented.

**Keywords:** AHP, TOPSIS, Blood Glucose level, Food replacement shakes, Ice cream, Diabetes, Macronutrients

## I. INTRODUCTION

Diabetic is one of chronically disease today throughout the world affecting every human being when insulin is not produced or malfunction. According to WHO prediction in 2030 the number of patients will be 552 million. And different associations and charities are opening and doing many researches on the cause, treatment mechanisms, prevention and curing method even. However, the number of diabetes patients prevalence also increasing.

The causes of diabetes are the food we eat (obesity), sedentary life style, vascular diseases, having family back ground, history of gestational diabetes, and high cholesterol. This means when human eat food the digestion or the breakdown of the food starts from mouth to intestine. After some processes it changed into glucose and enters into the blood stream. Then our body cells get energy. The problem is when insulin is not working or not produced at pancreas. If insulin is malfunctioning is called diabetic type-2 and if not produced is called type-1 diabetic. This insulin is nothing but hormone use to maintain blood glucose. So in both causes if the blood glucose is above normal that means the diabetes happed.

Diagnosing mechanisms are fasting blood sugar, two-hour post prandial blood sugar, random blood sugar and oral glucose tolerance test. If the people not diagnose the diabetes in early he/she increase the expose of other diseases. Since diabetes affects the blood of human it exposed to other diseases, which are diabetic complications such as heart problem, stroke, eye problem, amputations, nerve. So controlling diabetes is controlling other diseases and being healthy.

Fortunately, physical exercise (life style) and eating low carb are better way of controlling diabetic person's blood glucose level than insulin injection and other medicine. Since physical exercise and low carb are natural prevention methods they do not have side effect.

**Side effects of medicines on diabetic patients :** low blood sugar, upset stomach, skin rash or itching, weight gain, sickness with alcohol, kidney complications, tiredness or dizziness, metal taste, gas, bloating and diarrhea, risk of liver disease, anemia risk and swelling of legs or ankles. So, controlling while eating food is good than these complications.

In this study five different ice creams and four different food replacement shakes with their six macronutrients are considered. Macronutrients are source of energy for human cells while causes diabetes if it's out of required amount. The major aim of the study is solving this by using AHP and TOPSIS.

Organization of the paper is section 1 introduction, section 2 literature review, section 3 proposed solution, section 4 result analysis, section 5 recommendation, section six future work and section seven references.

## II. LITERATURE REVIEW

Here under let see the researches worked on ice cream recommendation for diabetic patient, diet recommendation, the methodology AHP in different fields, other methodologies as follows.

Suhas G, Preeti M. and Rahul J. recommend ice cream to diabetic patient by calculated the weight, consistency index and ratio to rank it and mapped with particular diabetic patients' blood glucose level. They used AHP and MATLAB to verify the recommendation of low sugar content ice cream for high blood glucose level diabetic person. [1]. Sugar was their major criterion from macronutrients and this study the major criterion is dietary fiber and other also considered according to their impact factor on the increasing of blood glucose level. Unlike this in the new proposed study all macronutrients are considered and combination of food replacement shakes and ice cream also considered according to the patients' blood glucose level.

Ibrahim A. (2015) develops an intelligent medical expert system for diabetes type-2 daily meal recommendation mainly for Sudanise. He has done food-court pyramid according to Sudan's food menu and recommend by considering BMI, activity and other disease incase suffering any of heart, liver, blood pressure, bitter, typhoid, sugary\_exited of the patients. Since, it's difficult for experts to reach for early treatment this daily meal planner is very important and done to reduce risk factors because the system balance the serving amount of starch, vegetables, fruits, protein, milk, sugar and fat at breakfast, lunch, snack and dinner meal time. The difference of this new study is parameters he used Sudan's food menu differently this new study focused on food replacement shakes and ice cream together recommend for diabetic person depend on his or her blood glucose level. Because, shakes and ice creams are ready for diabetic person and even need another mapping for the best diabetes controlling and other risks.[2]

Ibrahim A. and Abeer M. (2014) they developed a rule based expert system for diabetic patients to recommend daily meal by considering patients IBM, activity, and weight and health status. This recommendation is almost similar to his previous study. Using IBM is not good than considering the blood sugar level because BMI is dependent on weight and height to recommend diabetic patients. In addition, his scope of working area is Sudanese diet only [3].

Ludovic-Alexandre V, Franck M. and Jean-Claude B. (2010) they used AHP to measure the project complexity and consider multiple criteria. They implemented AHP to overcome the problems such as reliability, intuitive and user friendly, globally independent of project module and rank the projects. That is why in this study also AHP is preferred. In addition, in 2010 they developed refining framework of Delphi methodology and use AHP to rank the projects [4].

Audrey M., Joel D. and Kulani M. develop prototype of an expert system in diabetic patients, which asks

questions from users and after this system get enough information output diabetic advice and descriptions. The methodology they used was the iterative system development methodology [5].

Suhas G., Dr.Preeti M. and Rahul J (2015) developed system dynamics modeling for analyzing recovery rate of diabetic patients by mapping of sugar content in ice cream and sugar intake per day[8]

In conclusion this study is different from others which done similarly by inputs, impactful macronutrients, and alternatives. When we say alternatives here considered combined alternatives (drinks and ice cream). And will see how the mapping done and the recommendation of the best drink and ice cream according to diabetes patient blood glucose level.

### **III. PROPOSED SOLUTION**

Diabetes is the abnormality of blood glucose level and blood glucose again will increases by the food human being eats. These foods contain macronutrients, minerals, water, which is very necessary for human body cells when the function of insulin is balancing the amount of calorie intakes with cells calorie needs amount. This means when the food injected it broke down into glucose directly or with some process and goes into blood stream. If not that is called diabetes happened and diabetic complications. Insulin is nothing but hormone use to regulate blood level in human body. Food contains calorie, protein, vitamins, fats, fatty acids, and minerals. Each of them have their own role in human body and life as well if not balanced amount can cause disease such as diabetes. This is why this recommendation of appropriate amount of calorie required since until no medication to cure diabetes.

The impact of macronutrient is sugar is greater than cholesterol is greater than carbohydrate is greater than fat is greater than protein on the patient blood glucose level increasing through metabolism. On the other hand, dietary fiber has no effect on the increasing of blood glucose level rather able to control. These weigh impact of macronutrients on blood glucose level will be verified by AHP. After that TOPSIS rank the food replacement shakes and ice cream depending on the nutritional contents.

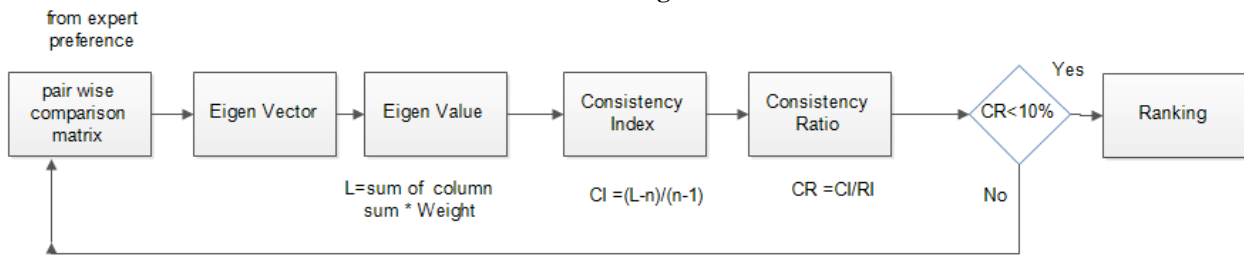
#### **A. Introduction about AHP**

AHP is multi-criteria decision making method which is structured, easy mathematical and psychological, consistence and robust method. Currently in every field whenever multi-criteria decision is there AHP is applicable such as Engineering, Social, Health, Political and Marketing. TOPSIS also a multi-criteria decision making method applying in every multi-criteria decision area.

Since AHP structure gives hierarchy for the problem i.e. the goal, criteria, sub criteria and alternatives here

below shows in figure (2).

Figure I AHP Flow Chart



Step1, the first step is experts plot the hierarchy of the problem; goal, criteria, sub criteria and alternatives.

values of relative importance of criteria or alternative are as per the developer of AHP (Pro. Saaty 1980) given at table below. Diagonal of the pair wise matrix is 1. Because in i and j has the same criteria or alternative.

Step2, the second step is constructing a pairwise comparison matrix of criteria with respect to the goal.

This means constructing nXm matrix i.e. comparing how much each the criteria affecting the goal. The

Table I AHP Relative Preference Numbers

Intensity of importance	Definition	Explanation
1	Equally important	Two criteria or alternative has equal importance to the goal
3	Weak importance of one over another	The importance of one criteria or alternative is slightly favor over another
5	strong importance of one over another	The importance of one criteria or alternative is strongly favor over another
7	Very strong importance of one over another	The importance of one criteria or alternative is very strongly favor over another
9	Extremely strong importance of one over another	The importance of one criteria or alternative is extremely strong favor over another
2,4,6,8	Intermediate value between two adjacent judgments	When compromise is needed
Reciprocal of above nonzero	If criteria or alternative I has one of the above nonzero numbers assigned to it when compared with criteria or alternative j, then j has the reciprocal value when compared with i.	

- a. Then to rank the criteria with respect to the goal flow some steps and realization of the pair wise matrix consistency also. Calculating Eigenvector e, Eigenvalue ( $\lambda_{max}$ ), Consistency Index (CI), Consistency Ratio(CR) and verifying CR weather its acceptable or not.
- b. Calculating Eigenvector
  - i. Sum each column of criteria or alternative
  - ii. Divide each row by above sum(i)
  - iii. Sum row wise and divide by number of criteria or alternative. This result is Eigenvector it is used to calculate Eigenvalue.
- c. Calculating Eigenvalue
  - i. Multiply each column sum of pairwise matrix by each row Eigenvector and sum. This value denoted by  $\lambda_{max}$  and used to drive CI. And the value is approximately number of criteria or alternative.

Calculating CI

$$CI = (\lambda_{max} - n) / (n-1)$$

Calculating CR

$$CR = CI/RI$$

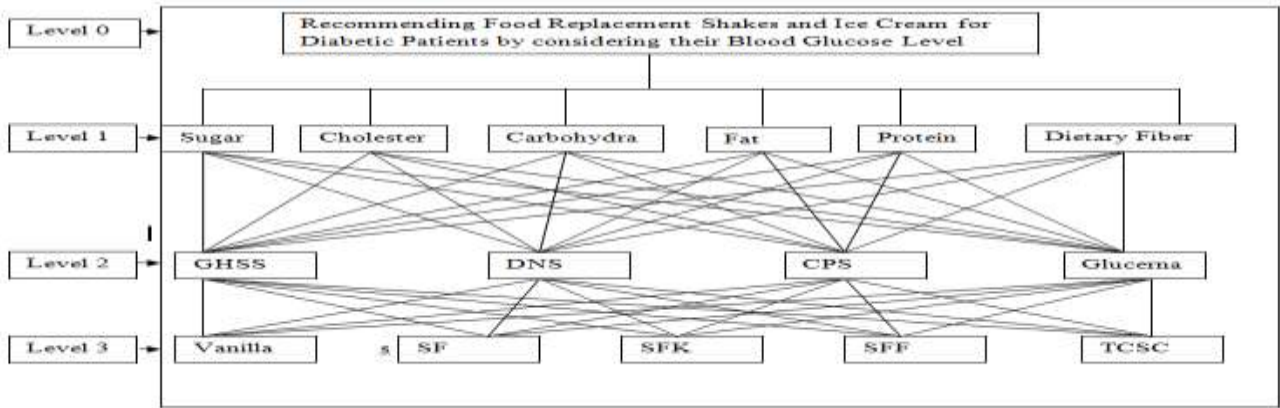
(Note: RI is Random consistency index i.e in table 1) If CR > 0.1 the above work is perfect and rank the criteria or alternative from largest to smallest. If not go to pair wise matrix and reconstruct.

These are the steps to do AHP for analysis of the best criteria or alternative for ranking and selection.

Table II Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
R	0	0	0.5	0.	1.1	1.2	1.3	1.4	1.4	1.4
I			8	9	2	4	2	1	5	9

In the figure 2 the AHP of proposed solution has 4 levels: level-0 is the goal that is recommending food



replacement shakes and Ice cream to the diabetes patients depending on their blood glucose level. Level-1 is criteria with respect to the goal and alternatives. Level-2 food replacement shakes with respect to the criteria and ice cream. Level-3 ice cream with respect to the criteria and food replacement shakes. In the following sections will see how much criteria affect the goal and alternatives are affected by them. Finally, the mapping of the best food

replacement shakes and ice cream for diabetes patients according to their blood glucose level.

Figure II AHP Model

Chart I Food Replacement Shakes Macronutrients in gram

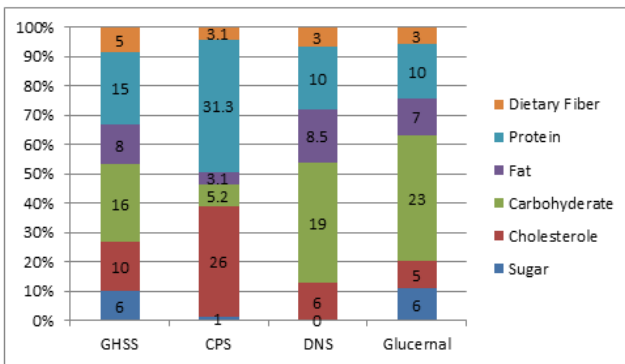


Chart II Ice Creams Macronutrients in gram



**B. AHP analysis of criteria with respect to the goal**

These charts depict the inputs macronutrients amounts in each food replacement shakes and ice cream bars [15 - 20].

Table III Pairwise Matrix of Criteria with Respect to the Goal

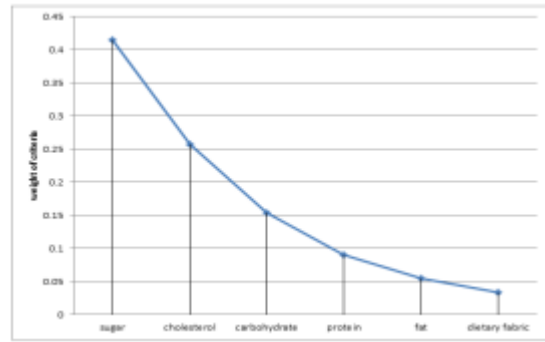
Criteria	sugar	Cholesterol	Carbohydrate	Fat	Protein	Dietary fabric
Sugar	1	2	3	5	7	9
Cholesterol	0.5	1	2	3	5	7
Carbohydrate	0.3333	0.5	1	2	3	5
Fat	0.2	0.3333	0.5	1	2	3
Protein	0.1428	0.2	0.3333	0.5	1	2
dietary fabric	0.1111	0.1428	0.2	0.3333	0.5	1

This matrix is the pairwise comparisons of criteria wise respect to the goal i.e. recommend food replacement shakes and ice cream for diabetic patient according to their blood glucose level. Criteria are sugar, carbohydrate, cholesterol, fat, protein, and dietary fiber. And the values are according to the effect of these criteria on the goal as in table 2. Then this matrix is used to calculate the weight. Then can

calculate Eigenvector, Eigen value, CI, CR as the following.

- Eigenvector is calculated by equation in step2 (b) and Sugar, cholesterol, carbohydrate, protein, fat, dietary fabric 0.414798, 0.25694, 0.153231, 0.089635, 0.054032 and 0.03361 respectively.
- Eigenvalue which is used to drive CI calculated as the following by equation step2(c)
 
$$\lambda_{\max} = 6.0578130368 \cong \text{number of criteria}$$
 and verify the pairwise comparison matrix is best.
- Consistency index of criteria with respect to the goal calculated by equation given by step2(d) :CI= (6.0578130368 – 6)/(6-1) ; CI =0.01156260736
- Consistency ratio of criteria with respect to the goal can be calculated by equation give at step2 (e). CR = CI /RI; CR =0.01156260736; CR =0.009324 < 0.1 acceptable value.

Then the priority vector shows how much the macronutrient is affecting the blood glucose level.



**C. Technique for Order Preference by Similarity to the Ideal Solution**

TOPSIS is one of the multi-criteria decisions making methods and first developed by Hwang & Yoon in 1981. That is the MCDM methods use to selection of the best, from a set of alternatives, each of which evaluated against multiple criteria according to the distance of separation from shortest of positive solutions and farthest of negative solutions [20]. Solutions are the options, which are to be, evaluated the selection of the best from them. These solutions evaluated according to the attributes (criteria) decided by the decision maker or the expert. The weights of criteria scaled by the experts or decision makers depend on the importance preference of that criterion against the solution.

Figure III TOPSIS Flow Chat

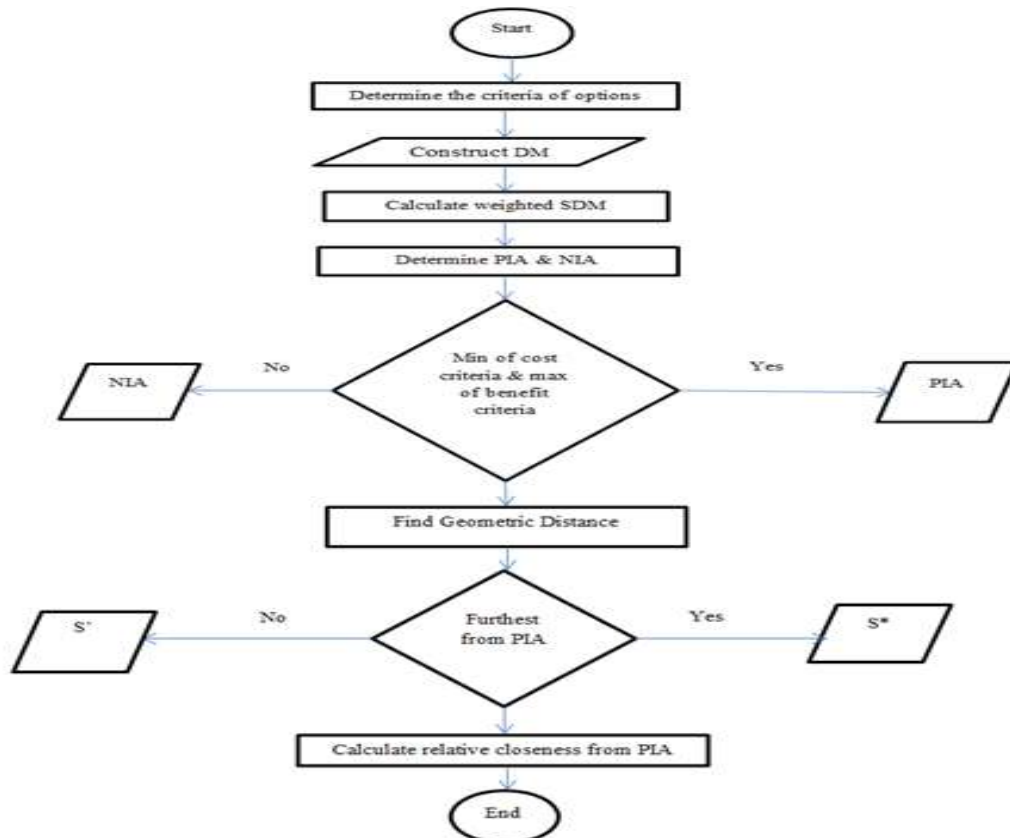


Chart III Criteria Weight with Respect to the Goal

In TOPSIS, the criteria also categorized into two beneficiary and cost criteria. Beneficiary criteria have positive impact on the goal. For instance, this this study dietary fiber is beneficial criterion for the goal



reducing blood glucose level and other diabetic complications also. Cost criteria have negative influence on the goal if it increases achieving the goal is less. Similar example to recommend food for diabetic patient if amount of sugar is more the stability of blood glucose level is less. Therefore, beneficiary criterion is dietary fiber and the cost criteria are sugar, cholesterol, carbohydrate, fat and protein.

There are two artificial alternatives (solutions) hypothesized:

Positive Ideal alternative (PIA): one which has the best attribute values (i.e. maximum of the beneficial attributes and a minimum of the cost attributes)

Negative Ideal alternative (NIA): one which has the worst attributes values (i.e. minimum of the beneficial attributes and maximum of the cost attributes)

Therefore, when decision has made the solution should be closest to the PIA and farthest from NIA. To do this the following procedure are there:

Determine the criteria of options depend on different parameters the decision maker chooses the criteria those can compare the solution such as time, performance, cost, speed, etc.

Construct a decision matrix (nXm) this is the squared matrix of criteria against solution.

Standardize the decision matrix (normalizing)

$$A_i = \sum_i^n \sqrt{C_i^2} \text{ -----} \tag{1}$$

$$SDM = C_i / A_i \text{ -----} \tag{2}$$

a. Construct weighted SDM  
WSDM =  $w_i$  X SDM -----

(3) b. Determine PIS and NIS  
 $A^* = \{ \max(\text{each PIS}) \& \min(\text{each NIS}) \}$  ----

(4)  $A' = \{ \min(\text{each PIS}) \& \max(\text{each NIS}) \}$  ----  
(5)

c. Determine separation from PIS and NIS  
 $S^* = \sum_i^n ((A_i - A^*_i)^2)^{1/2}$  -----  
(6)

$$S' = \sum_i^n ((A_i - A'_i)^2)^{1/2} \text{ -----} \tag{7}$$

d. Determine relative closeness of PIS  
 $C'_i = S'_i / (S^*_i + S'_i)$  -----  
(8)

e. Max of  $C'_i$  is the best solution

**Decision matrix of food replacement shakes**

This matrix is constructed by looking the nutritional fact of food replacement shakes and ice creams as depicted on chart 1 and chart 2 by gram unit measurement. These values are the actual values and so helpful for the effective decision.

**Table IV Nutritional Fact of Food Replacement Shakes**

	Sugar	Cholesterol	Carbohydrate	Fat	Protein	Dietary Fiber
GHSS	6	10	16	8	15	5
CPS	1	26	5.2	3.1	31.3	3.1
DNS	0	6	19	8.5	10	3
Glucerna	6	5	23	7	10	3

**Standardize the decision matrix**

Transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. For standardizing, each column of decision matrix is divided by root of sum of square of the respective columns.

**Table V Standardized Decision Matrix of food replacement shakes**

	Sugar	Cholesterol	Carbohydrate	Fat	Protein	Dietary Fiber
GHSS	0.4932	0.1195	0.2183	0.3284	0.1602	0.4752
CPS	0.0137	0.8076	0.0231	0.0494	0.6974	0.1826
DNS	0	0.0431	0.3078	0.3708	0.0712	0.1711
Glucerna	0.4932	0.0298	0.4510	0.2514	0.0712	0.1711

**Weighted standardize decision matrix of food replacement shakes based on the equation (3)**

**Table VI Weighted Standardized Decision Matrix of Food Replacement Shakes**

	Sugar	Cholesterol	Carbohydrate	Fat	Protein	Dietary Fiber
GHSS	0.0148	0.0108	0.0110	0.0492	0.0416	0.1948
CPS	0.0005	0.0726	0.0012	0.0074	0.1814	0.0749
DNS	0	0.0039	0.0154	0.0557	0.0185	0.0702
Glucerna	0.0148	0.0026	0.0225	0.0378	0.0185	0.0702

Weight of sugar, cholesterol, carbohydrate, fat, protein and dietary fiber with respect to the food replacement shakes are 0.41, 0.26, 0.15, 0.05, 0.09 and 0.03 respectively.

**Determine PIA and NIA of food replacement shakes**

$A^*$  By applying equation (4)  
 $A'$  by applying equation (5) then the results are the following:

$A^*$ , {0, 0.00288172, 0.001152256, 0.007397619, 0.018509422, 0.1948299} and  
 $A'$ , {0.014794521, 0.072688172, 0.01352895, 0.04926614, 0.181334956, 0.0701388}

**Determine separation from PIS and NIS of food replacement shakes**

$S^*$  By applying equation (6)  
 $S'$  By applying equation (7) the results are  
 $S^*$  = {0.0516175, 0.2139398, 0.1344492, 0.1309351} and

$S^* = \{0.573526, 0.270892, 0.504625, 0.50338\}$

**Determine relative closeness of PIA of food replacement shakes**

$C'_i$  by applying equation (8) relative closeness GHSS, CPS, DNS and Glucerna are 0.08256895, 0.44126630, 0.21038121 and 0.206419555 respectively.

**Max of  $C'_i$  is the best alternative form food replacement shakes**

CPS is better than DNS is better than Glucerna and is better than GHSS

**TOPSIS of ice creams**

**Construct a decision matrix ( $n \times m$ ) of ice creams:** from chart (2) the nutritional fact of ice cream in grams can construct the matrix as the following:

**Table VII Decision Matrix of Ice Creams**

	Sugar	Cholesterol	Carbohydrate	Fat	Protein	Dietary Fiber
SF	2	5	10	5	2	2
SFK	2	5	10	6	2	2
TCSC	3	10	17	3.5	3	2
Vanilla	4	10	14	4	2	4
SFF	7	0	17	0.5	4	6

**Standardize the decision matrix of ice cream:**  $A_i$  by equation (1) and  $SDM$  by equation (2)

**Table VIII Standardize Decision Matrix of Ice Creams**

	Sugar	Cholesterol	Carbohydrate	Fat	Protein	Dietary Fiber
SF	0.00	0.01	0.01	0.02	0.02	0.21
SFK	0.00	0.01	0.01	0.03	0.02	0.21
TCSC	0.00	0.01	0.02	0.01	0.02	0.21
Vanilla	0.00	0.01	0.01	0.02	0.02	0.43
SFF	0.01	0.00	0.00	0.00	0.03	0.64

Then calculating  $WSDM$  by using equation (3)

**Table VIII Weighted Standardized Decision Matrix of Ice Creams**

	Sugar	Cholesterol	Carbohydrate	Fat	Protein	Dietary Fiber
SF	0.22	0.32	0.32	0.53	0.33	0.25
SFK	0.22	0.32	0.32	0.63	0.33	0.25
TCSC	0.33	0.63	0.54	0.37	0.49	0.25
Vanilla	0.44	0.63	0.45	0.42	0.33	0.50
SFF	0.77	0.00	0.54	0.05	0.66	0.75

**Determine PIA and NIA of ice creams**

$A^*$  By equation (4) and  $A'$  by equation (5) the results are

$A^* = \{0.00221, 0.00000, 0.00961, 0.00211, 0.01644, 0.63750\}$  and  $A' = \{0.00773, 0.01265, 0.01634, 0.02537, 0.03288, 0.21250\}$  respectively.

**Determine separation from PIA and NIA of ice creams**

$S^*$  by equation (6) and  $S'$  equation (7) the results are  $S^* = \{0.425473, 0.425683, 0.425512, 0.213436, 0.018602\}$  and

$S' = \{0.020098, 0.019648, 0.014101, 0.213348, 0.425824\}$  respectively.

**Determine relative closeness of PIA of ice creams**

$C'_i$  Calculated by equation (8) and PIA relative closeness of Ice Cream SF, SFK, TCSC, Vanilla and SFF are 0.045105598, 0.044119311, 0.032076013, 0.499896501 and 0.958142713 respectively.

**Max of  $C'_i$  is the best alternative form ice cream**

SFF is better than Vanilla is better than SFK is better than and SF is better than TCSC.

**IV. RESULT ANALYSIS**

AHP result has some inconsistency on priority vector results such as ice cream with respect to sugar SF and SFK have the same priority vector results, ice cream with respect to cholesterol vanilla and TCSC, SF and SFK have the same results, ice cream with respect to carbohydrate TCSC and SFF, Sf and SFF have the same results, ice cream with respect to dietary fiber SF and TCSC have the same results.

In food replacement shakes: with sugar GHSS and Glucerna have the same results, with protein DNS and Glucerna have the same results and with dietary fiber DNS and Glucerna have the same results.

This inconsistency is acceptable because the entire CR indexes are less than 0.1. However, in TOPSIS there is no such inconsistency even. So, in this study the aim achieved by this second method TOPSIS. When it has been done AHP the relative importance of two adjacent criteria or alternatives decided by experts, but in TOPSIS the measured nutritional fact has been taken.

**V. RECOMMENDATION**

We have seen the results and its consistency, so preferred methodology is TOPSIS and uses its result to recommend food replacement and ice cream for particular diabetic patient according to his or her blood glucose level as given at the input section above charts. So, the person who have blood glucose level 220mg/dl can have SFF and CPS, 200mg/dl can have vanilla and GHSS, 150mg/dl can have SF and Glucerna and 126mg/dl can have SFK or TCSC and DNS to control their glucose level.

**VI. FUTURE WORK**

As explained above and done the recommendation is based on the macronutrients and blood glucose level. Form the macronutrients dietary fiber is having ability to reduce the blood glucose level. So, in future will analysis the recovery rate of patients’ blood glucose level.

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Acronyms	Definition
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order Preference by Similarity to the Ideal Solution
WSM	Weighted Score Method
SF	Sweet Freedom
SFK	Sweet Freedom Krunch Lites
TCSC	Triple chocolate slow churned
SFF	Sweet Freedom Fudge Lites
GHSS	Glucerna Hanger Smart Shake
CPS	Chocolate protein shakes
DNS	Diabetics Nutritional shakes
CI	Consistency Index
CR	Consistency Ratio
λmax	EigenValue
RI	Random Consistency Index
N	Number of Criteria or Alternatives
Food replacement shakes	Food Replacement Shakes
S.W.R.G	Sugar with respect to the Goal
C.W.R.G	Cholesterol with respect to the Goal
Ca.W.R.G	Carbohydrate with respect to the Goal
F.W.R.G	Fat with respect to the Goal
P.W.R.G	Protein with respect to the Goal
D.F.W.R.G	Dietary Fiber with respect to the Goal
MCDM	Multi Criteria Decision Making
PIA	Positive Ideal Alternative
NIA	Negative Ideal Alternative
Ai	Squared matrix of decision matrix
Ci	Each cell of the matrix
SDM	Standardized decision matrix



WSDM	Weighted standardized decision matrix
W <sub>i</sub>	Wight if criteria or alternatives
A*	Set of PIA
A'	Set of NIA
S*	Set of PIS separation
S'	Set of NIA separation
C <sub>i</sub>	Relative closeness to the PIA
DM	Decision matrix