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SUCCESS OF DIETARY AMINO ACIDS, ANTIOXIDANTS, VITAMINS AND MINERALS IN PREVENTION AND CONTROL OF DIABETES

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ABSTRACT

Diabetes Mellitus is a menace for people worldwide. In a search for prevention and arrest of the disease, investigation has been carried on to see how the dietary amino acids , antioxidants, vitamins and minerals could play important roles towards achievement of the goal. The above antidiabetic elements from a vegetarian diet proposed earlier indicate that they can successfully prevent and sometimes arrest diabetes of both type1 and type 2 if consumed regularly. Here, thirtyfive antidiabetic elements have been estimated from the concerned vegetarian diet by evaluating their amount amount in each item of the diet and added up to get the final result.The net amount of antidiabetic elements in comparison to the medicinal doses is found to be nearly equal to the ratio of daily intake amount and the medicinal doses. Sometimes the ratios from the proposed diet is larger than the daily intake amount ratio signifying that the antidiabetic elements from the proposed diet could successfully prevent diabetes, as well as control the same.

Key Words: Diabetes Mellitus, Amino Acids, Antioxidants, Vitamins, Minerals, Antidiabetic and Dietary.

Introduction

Diabetes is a menace of the day for people worldwide. From Indian perspective it is quite alarming.

According to IDF(International Diabetic Federation) , presently about 11.8% population of India are suffering from diabetes and in 2030 it will double. The IDF report[1] says that 2 in 3 people with diabetes live in urban areas and 3 in 4 people with the disease live in low and middle income countries.

So we are worried and searching for remedy of the disease. Actually, the disease cannot be cured and the reason is our food habit and daily activity. Diabetes is a serious, chronic condition . ADA(American Diabetes Association) says that the above condition is the seventh leading cause of death in U.S.A.

While, diabetes itself is manageable, its complications can severely impact on daily living and some can be fatal if not taken care immediately[2]. As for the food habits , over the past two generations , middle and upper class Indians have jumped from a primarily cereal based traditional diet to highly processed food , most of which are unhealthy.

As the consumption of unhealthy foods has increased so have obesity and noncommunicable diseases like heart disease and diabetes. Indians today eat more salt , refined carbohydrates , fat and sugar . In addition, many regularly consume sugary, high-calorie drinks. This eating pattern is deficient in fiber, a critical dietary component for preventing or managing diabetes[3]. The present day need for Indians is to get them educated about the importance of proper nutrition and regular physical exercises to prevent and manage diabetes.

A nutrition based diet in this regard has been proposed earlier[4], which has been found to contain high vitamins, micronutrients and macronutrients.

The above diet plays satisfactory role in the prevention of diabetes[5].

After the success of the dietary model in so many aspects , it would now be tempting to investigate, in detail , the model as preventor and controller against diabetes.

The daily routine for physical activity could not be changed abruptly , because they are need based. So , Srimat Swami Sibananda Saraswati advised[6] some exercises in addition to the daily activity. Purposeful exercises advised for diabetic patients are :

- a) ' Vromon Pranayam'
- b) 'Yogamudra'
- c) 'Paschimottasana'

- d) 'Sahajagnisar'
- e) 'Biparit Karani Mudra' and
- f) 'Pabanmuktasana'

An elaborate discussion of the excercises could be made elsewhere.

In this article, amino acids, antioxidants, vitamins and minerals from the proposed diet have been investigated in detail to examine their antidiabetic effects.

The amino acids from the diet of interest are :Methionine, Lysine, Histidine, Arginine, Alanine, Glutamic acid, Glycine, Serine and Leucine.

The antioxidants from the diet which play important role as antidiabetic agents are: Vit A, Vit C, Vit D, Vit E , Vit K, Alphalipoic Acid, Co-enzyme Q10, N-Acetyl Cysteine and Betaine. Similarly the vitamins of interest are : Thiamine, Niacin, Pyridoxin, Biotin, Inositol, Folic Acid and Vit B12.

Finally the antidiabetic effects of the minerals from the diet are:

Calcium, Magnesium, Zinc, Iron, Vanadium, Chromium, Manganese, Potassium, Selenium and Iodine.

Thus, in all, thirtyfive elements from the diet have been studied in detail as to their antidiabetic effects.

Materials and Methods

The proposed diet involves a variety of food items containing legume, vegetables etc. Evaluation of the above antidiabetic elements from each item of the food has been done and added up to get the net result. The result obtained acts as preventive doses and sometimes medicinal doses against diabetes .

Results and Discussions

We are now in a position to present the amount of antidiabetic elements obtained from the proposed diet.

But before that it may be relevant to discuss how the above elements take part to act as antidiabetic agents. Table-1 below summarises the function of the amino acids, antioxidants, vitamins and minerals in relation to diabetes.

Table 1

The antidiabetic elements and their functions towards prevention and arrest of diabetes.

| Antidiabetic Elements(A) | Corresponding antidiabetic functions(B) |
|--------------------------|---|
| 1. Methionine | Dietary methionine restriction (MR) is known to reduce body weight by increasing energy expenditure(EE) and insulin sensitivity. An elevated concentration of circulating fibroblast growth factor 21 (FGF21) has been implicated as the potential underlying mechanism[7]. |

| Antidiabetic Elements(A) | Corresponding Antidiabetic Functions(B) |
|--------------------------|---|
| 2. Lysine | <p>Human body is unable to produce lysine itself, consequently it must be supplied from external sources –primarily food.</p> <p>A pilot study on diabetic patients found that oral supplementation with lysine may decrease blood glucose level and improve insulin sensitivity[8].</p> <p>In addition, a study on healthy subjects shows that lysine may decrease blood glucose levels while increasing glucagon and insulin levels[9].</p> |
| 3. Histidine | <p>Dietary histidine is associated with lower blood pressure, It reduces oxidative stress. It is observed that histidine supplementation decreases insulin resistance, lowers fasting blood glucose levels and increases insulin</p> |

| (A) | (B) |
|-------------|---|
| | sensitivity[10,11]. |
| 4. Arginine | <p>Research shows that [12] amino acid arginine proves just as useful as established type 2 diabetes drugs at metabolizing glucose in mice. The same effect may be observed in human patient with type2 diabetes with appropriate dose of arginine. Clinical trials on people found that L-Arginine supplementation can help decrease oxidative stress in type2 diabetic patients by producing nitric oxide and activating antioxidant enzymes , which may help prevent diabetic complications[13].</p> |

| (A) | (B) |
|------------|--|
| 5. Alanine | <p>Alanine is used to manage blood sugar levels in people with diabetes, since it plays a role in helping the body use glucose and preventing low blood sugar. The liver absorbs it and convert it into pyruvate. This process is important for regulating the use of glucose and blood sugar management[14].</p> <p>A study showed in 2002, that there is an interrelationship between L-Alanine and secretion of insulin by the pancreas. When allowed to react with glucose , it leads to an increased production and excretion of insulin thereby positively influencing diabetes[15].</p> |

| (A) | (B) |
|------------------|---|
| 6. Glutamic Acid | <p>Glutamic Acid plays important role in the treatment of diabetes.</p> <p>Actually, Glutamic Acid Decarboxylase (GAD) is the enzyme that catalyzes the formation of gamma-aminobutyric acid (GABA) from Glutamic Acid[16].</p> <p>It exists in two isoforms viz GAD67 and GAD65.</p> <p>Both of them are targets of autoantibodies in people who later develop type1 diabetes or autoimmune diabetes.</p> <p>GAD65 prevents type1 diabetes and preserves insulin production[17].</p> |

| (A) | (B) |
|------------|---|
| 7. Glycine | <p>Glycine helps to regulate blood sugar by converting glucose into energy. So it is used to improve blood sugar levels of patients with type2 diabetes[18,19].</p> <p>Type2 diabetes may lead to low levels of glycine. Since glycine has been shown to increase insulin response in people , without diabetes , it is suggested that glycine supplements may improve impaired insulin response in people with type2 diabetes[20].</p> |

| (A) | (B) |
|-----------|---|
| 8. Serine | <p>Evidence suggests a role of L-Serine in the development of diabetes and its complications: L-Serine metabolism is altered in type1 , type2 and gestational diabetes, and its supplementations improve glucose homeostasis and mitochondrial function which reduce neuronal death. L-Serine lowers the incidence of autoimmune diabetes. Dietary supplementations are generally regarded as safe. So, it is believed that L-serine may be considered as an emerging therapeutic option in diabetes[21].</p> |

| (A) | (B) |
|------------|---|
| 9. Leucine | Leucine plays a very important role in regulating blood sugar levels. Studies have shown that increases in dietary leucine can reduce diet induced obesity ,hyperglycemia and cholesterol levels. So, this amino acid may have a role to play in preventing diabetes[22]. |

From the above table it is found that amino acids play important role in the prevention and arrest of diabetes. However, all of the above do not act in the same fashion. Methionine, Lysine and Histidine , for example, increase insulin sensitivity.

Arginine, Alanine and Leucine help glucose metabolism and maintain proper glucose level. Same is the action of Glycine.

Glutamic Acid, on the other hand , deals with insulin secretion. Serine plays a negative role in diabetes as it helps the development of diabetes

and its complications. However, dietary serine helps diabetic patients by lowering the disease.

Having presented the functions of amino acids in regard to diabetes , it may now be interesting to discuss the functions of the antioxidant in that respect. Table1 continues to represent them.

Table-1 ,continued

| Antidiabetic elements(A) | Corresponding antidiabetic functions(B) |
|--------------------------|---|
| 10. Vitamin A | Vitamin A has important role in the pancreas development and islet regulation. In animal model decreased pancreatic vitamin A causes increased Alpha-cell to Beta-cell mass ratio , hyperglycemia and hyperglucagonamia which are restored by reintroducing dietary Vitamin A. Intake of Alpha and Beta carotene and lycopene has shown to improve glucose metabolism in subjects with high risk of type2 diabetes[23]. |

| (A) | (B) |
|---------------|---|
| 11. Vitamin C | Vit C participates in multiple reactions, acting as a potent antioxidant. The main cause of increased requirement of Vitamin C in type2 diabetes is the high levels of oxidative stress caused by hyperglycemia. Vitamin C has been shown to reduce anxiety levels in diabetes[24]. |

| (A) | (B) |
|----------------------|--|
| <p>12. Vitamin D</p> | <p>Lower levels of Vitamin D is reported in patients with type1 diabetes in their early stage of effect compared to age and sex match nondiabetic people. A greater prevalence of Vitamin D insufficiency and deficiency has been observed in prediabetic children. Maternal Vitamin D insufficiency during pregnancy influences the risk of type1 diabetes in offspring. It is reported that prevalence of type2 diabetes is associated with low levels of Vitamin D. In healthy people , Vitamin D sufficiency is positively correlated with insulin sensitivity and adequate pancreatic beta-cell function.</p> |

| | |
|--|---|
| | <p>On the other hand Vitamin D deficiency might affect glucose homeostasis and cause impaired glucose tolerance and insulin resistance[25].</p> |
|--|---|

| (A) | (B) |
|----------------------|---|
| <p>13. Vitamin E</p> | <p>Oxidative stress contributes to the progression on type2 diabetes and causes damage to many organs. VitaminE supplementation could mitigate the role of oxidative damage in the occurrence of diabetes complications. Subgroup analysis indicated that Vitamin E could enhance insulin action and glucose disposal in type2 diabetic patients. It is found that in normal weight or over weight other than obese patients with type2 diabetes is significantly improved by supplementation with Vitamin E. However, there is no evidence to support that Vitamin E</p> |

| | |
|--|--|
| | <p>supplementation have utility in the management of type2 diabetes[26].</p> |
|--|--|

| (A) | (B) |
|-----------------------------|--|
| <p>14. Vitamin K</p> | <p>Several studies have reported the beneficial effects of Vitamin K on insulin sensitivity, metabolic syndrome and glucose homeostasis reducing the risk of diabetes[27]. Studies suggest that Vitamin K dependant protein mediate the beneficial function of Vitamin K in insulin sensitivity and glucose tolerance[28].</p> |
| <p>15. Alphalipoic Acid</p> | <p>Blood glucose concentration is the surest evidence of diabetes. The effect of high dose lipoic acid on glucose utilization has been examined in patient with type2 diabetes leading to positive result[29].</p> |

| | |
|--|---|
| | <p>There is strong evidence that alphasalipoic acid supplements help patients with type2 diabetes. It can improve insulin resistance[30].</p> |
|--|---|

| (A) | (B) |
|--------------------------|---|
| <p>16. Co-enzyme Q10</p> | <p>Diabetes is a condition of increased oxidative stress and impaired energy metabolism. Plasma concentration of reduced Co-enzyme Q10 has been found to be lower in diabetic patients than healthy people. The pathogenesis of type2 diabetes involves the early onset of glucose intolerance and hyperinsulinemia with progressive loss of tissue responsiveness to insulin. Insulin resistance is connected to a decrease in Co-enzyme Q10 expression. IT is observed that supplementation with this</p> |

| | |
|--|---|
| | <p>antioxidant could restore insulin sensitivity.</p> <p>Thus Co-enzyme Q10 supplementation is believed to be a more useful tool for the primary prevention of type2 diabetes rather than its management[31].</p> |
|--|---|

| (A) | (B) |
|-----------------------------|---|
| <p>17. N-AcetylCysteine</p> | <p>N-acetylcysteine may aid in the prevention and management of diabetes as suggested by a 2016 studies[32].</p> <p>N-acetylcysteine may provide better control of diabetes by increasing sensitivity to insulin. On the flip side, by increasing glucose tolerance this antioxidant may prevent people with prediabetics from progressing to diabetes[33].</p> |

| (A) | (B) |
|--------------------|--|
| <p>18. Betaine</p> | <p>Betaine acts as an important osmoprotectant as well as oxidative metabolite of choline and is suggested to have beneficial actions in human diseases like diabetes[34]. In 2016, plasma betaine levels were shown to be reduced in insulin-resistant human and correlated closely with insulin sensitivity[35].</p> |

In the antioxidant group, we have included Vitamins A , C, D , E, and K because their antioxidant properties were more prominent. The antioxidants discussed here help in the reduction of diabetes, some in T1D and others in T2D.

Vitamin C reduces oxidative stress and anxiety levels of patients with T2D. Vitamin D deficiency causes impaired glucose tolerance and insulin resistance. Vitamin E supplementation helps in the improvement and management of T2D. Vitamin K reduces

the risk of diabetes. Thus it acts as a preventor of diabetes. Alphalipoic acid supplementation of diabetic patients help in the glucose tolerance and insulin resistance. Co-enzyme Q10 has the primary role of prevention of T2D, than management of the disease.

N-acetylcysteine , on the other hand helps in the prevention, as well as, management of diabetes. Little is known about the role of betaine on diabetic patients, but is conjectured to have beneficial role in human diabetes.

The third group of elements acting as antidiabetic is the vitamins. Their actions will be discussed in brief as per their antidiabetic effects in the Table1 continued further.

Table1 continued further

| (A) Antidiabetic elements | (B)Corresponding antidiabetic functions |
|---------------------------|---|
| 19. Thiamine | Thiamine(VitaminB1) is an essential cofactor in carbohydrate metabolism which may have an impact on glucose homeostasis. Studies have shown that reduced blood levels of thiamine occur in people with diabetes. Thiamine supplementations demonstrate positive effects on blood glucose. Daily intake of thiamine is positively correlated with the circulating level of endothelial |

| | |
|--|--|
| | <p>progenitor cells and vascular endothelial function in patients with type2 diabetes[36].</p> |
|--|--|

| (A) | (B) |
|-------------------|---|
| <p>20. Niacin</p> | <p>Taking VitaminB3(as niacin or niacinamide) might prevent or limit the severity of type1 diabetes. High doses niacin are sometimes recommended to lower high triglyceride and cholesterol levels in people with T1D[37].</p> <p>Dietary niacin is important for healthy management of cholesterol and triglycerides , however, high dose supplementation with niacin could worsen glycemic control in people with type2 diabetes. The potential benefits of micro- encapsulated niacin in</p> |

T2D are yet to be investigated[38].

| (A) | (B) |
|-----------------------------------|--|
| <p>21. Pyridoxine(Vitamin B6)</p> | <p>Pyridoxine acts as a coenzyme for glucose phosphorylase which is necessary for the utilization of glycogen in liver and muscle, thus have an important role in glucose metabolism.</p> <p>Patients with type2 diabetes were found to have lower PLP , the active form of B6 in comparison to healthy people. People with diabetes may have an increased need for pyridoxine.</p> <p>Supplementation with this vitamin may help maintain</p> |

| | |
|--|-------------------------------------|
| | normal levels and prevent T1D [39]. |
|--|-------------------------------------|

| (A) | (B) |
|-------------------------|--|
| 22. Biotin (Vitamin B7) | <p>Biotin may improve glucose levels for type 1 diabetes while it may improve glucose and triglyceride levels in people with type 2 diabetes.</p> <p>High doses of biotin have been suggested to reverse some of the negative effects of chronic low insulin levels on glucose metabolism.</p> <p>Biotin may reduce pain from diabetic nerve damage.</p> <p>People with T2D are found to have lower Biotin levels compared to healthy people</p> |

| | |
|--|---|
| | <p>without diabetes. Supplementation with various doses of Biotin may lead to : Normalization of glucose levels , reductions in high triglyceride levels, but no effect on glucose or insulin levels for people with T2D[40].</p> |
|--|---|

| (A) | (B) |
|---------------------|--|
| <p>23. Inositol</p> | <p>Inositol may improve diabetic neuropathy. Inositol in the form of myo- and D-chiro inositol has many functions in the body , including assisting in normal cellular responsiveness to insulin. A gene alteration that affects inositol metabolism may be associated with risk of T1D. People with type1 and type2 diabetes have been found to lose more myo-inositol in their urine compared to those without</p> |

| | |
|--|---|
| | <p>diabetes. Inositol has shown improvement in glucose metabolism and insulin sensitivity in women with polycystic ovarian syndrome and a preliminary evidence suggests it may lower HbA1c in people with T2D. Disturbances in inositol metabolism are thought to be an underlying factor in insulin resistance and T2D[41].</p> |
|--|---|

| (A) | (B) |
|-----------------------------------|---|
| <p>24. Folic Acid(Vitamin-B9)</p> | <p>Folic Acid supplementation may improve blood glucose control and insulin sensitivity in people with T2D. Folic acid also lowers homocysteine levels and and preliminary evidence suggests it may help to prevent and treat diabetes complications[42].</p> |
| <p>25. Vitamin B12</p> | <p>Supplementation with vitamin B12 or cobalamin may improve symptoms of diabetic</p> |

| | |
|--|--|
| | <p>neuropathy. People with T1D have risk of disorders that can affect their B12 status. Proper dose of B12 for a period of time has been found to reduce symptoms and disability due to diabetic nerve damage. B12 deficiency is found in people being treated medically for T2D. Supplementation can restore healthy levels and prevent dangerous long-time</p> |
|--|--|

| | |
|-----|-------------------------------------|
| (A) | (B) |
| | consequences of B12 deficiency[43]. |

In this group of elements, thiamine has no direct effect on diabetes, but its supplementation helps in some functions of the diabetic patients , while niacin prevents or limits of severity of type1 diabetes. The beneficial role of niacin in type2 diabetes is yet to be confirmed.

People with diabetes need pyridoxine. Supplementation with pyridoxine may help in the maintenance of normal levels and prevention of type1 diabetic complications.

Biotin may be helpful for both type1 and type2 diabetes.

Inositol metabolism alteration is associated with risk of type1 diabetes.

People with type1 and type2 diabetes are found to lose more myo-inositol in their urine than those without diabetes.

Supplementation with inositol is necessary, as it improves glucose metabolism and insulin sensitivity in women with polycystic ovarian syndrome.

Folic acid, the widely available vitamin, may improve blood glucose control and insulin sensitivity of type2 diabetes. It helps prevention and treatment of diabetic complications.

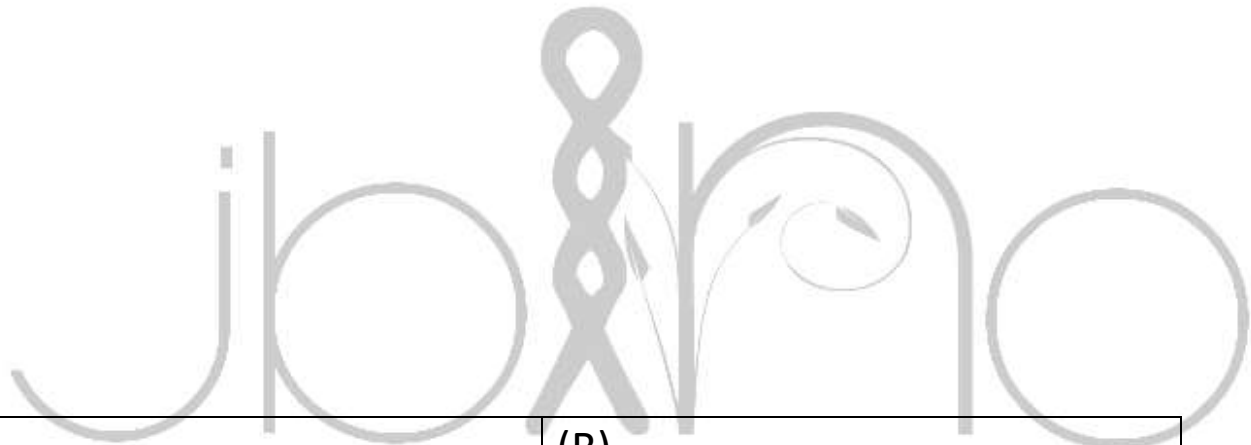
Vitamin B12 reduces the symptoms and disability due to diabetic nerve damage.

Now we are in a position to discuss the antidiabetic effects of the minerals obtainable from the proposed diet .

They are presented in Table-1 continued:

| Antidiabetic Elements(A) | Corresponding antidiabetic Functions(B) |
|--------------------------|---|
| 26. Calcium | Calcium appears to reduce the risk of type2 diabetes . A large scale study found that those supplemented daily with a calcium supplement has lower rates of diabetic development than those without supplement[44]. The potential benefit of dietary calcium is that it |

benefits the prediabetics. However, any alteration in calcium flux can have adverse effects on beta-cell secretory function and may interfere with normal insulin release [45]. So, a balance in calcium supplementation is necessary which may vary on the person concerned.



| (A) | (B) |
|----------------------|--|
| <p>27. Magnesium</p> | <p>Magnesium is an essential ion involved in multiple levels in insulin secretion its binding and activity. Magnesium plays important role to improve insulin resistance[45]. Recent studies found that higher magnesium intake were associated with a lowering risk</p> |

of type2 diabetes. Further more , insulin resistance, has been linked to inadequate magnesium status. It is thought that pancreatic beta-cells , which secrete insulin, becomes less responsive to changes in insulin sensitivity in magnesium deficient people[46].



| (A) | (B) |
|----------|---|
| 28. Zinc | Zinc plays an important role in glucose metabolism. It is believed that zinc is involved in the regulation of insulin receptor initiated signal transadation mechanism and insulin receptor synthesis[45]. Poor glycemic control and frequent urination by diabetic |

patients may lead to urinary loss of zinc, i.e. zinc deficiency. Dietary supplementation of zinc is necessary for patients with T2D, hence such patients should ensure that their diet provide enough zinc to cover their needs, especially , if their blood glucose is poorly controlled[47].



| (A) | (B) |
|----------|--|
| 29. Iron | Iron is an important element for human activities. However, the balance of iron stores in body is very much critical. Elevated iron stores may induce diabetes through a variety of mechanisms, including oxidative damage to pancreatic beta-cells, |

impairment of hepatic insulin extraction by the liver, and interference with insulin's ability to suppress hepatic glucose production[45]. Again, iron deficiency anemia, elevates HBA1C levels in diabetic individuals with plasma glucose levels. Hence, it plays an important role in the treatment regimen for diabetes[48].



| (A) | (B) |
|--------------|---|
| 30. Vanadium | Use of oral vanadium supplements in diabetes, specially on T2D is thought to be valuable, although animal studies show that it has potential benefit in T1D. In T2D patients vanadium increases insulin sensitivity. It |

may increase glucose oxidation and glycogen synthesis and suppress hepatic glucose output. In T1D, vanadium may not affect insulin sensitivity but it lowers daily insulin doses. Pharmacological doses appear to have a mild effect on insulin sensitivity and glucose utilization in T2D[49].



| (A) | (B) |
|--------------|---|
| 31. Chromium | Chromium, required for normal carbohydrate metabolism and a critical cofactor for insulin action, is a component of the glucose tolerance factor which plays a role in glucose homeostasis. |

Chromium concentrations are reduced in blood of type2 diabetic patients but urinary levels of this element is found to be higher[45].
 Research undertaken in China indicated that chromium supplementation might be beneficial in the treatment of type2 diabetes. However, large scale RCT of chromium are needed to see if chromium is effective in the treatment of T2D[50].



| (A) | (B) |
|---------------|--|
| 32. Manganese | Manganese, specially the enzymes activated with manganese play important roles in the metabolism of carbohydrates , amino acids and cholesterol. It helps in |

glucose metabolism and is required for normal synthesis and secretion of insulin. The level of manganese is lower in type2 diabetes , the mean manganese is significantly low in blood and scaphair samples of diabetics[45].



| (A) | (B) |
|---------------|--|
| 33. Potassium | Potassium is important for insulin secretion from the pancreatic cells. Low potassium intake or blood potassium levels are |

associated with an increased risk for insulin resistance and diabetes.

Potassium depletion studies show that low serum potassium decreases glucose tolerance associated with reduced insulin secretion and leads to alterations in glucose metabolism.

It is found that potassium supplementation prevents the progression of prediabetes to diabetes by improving glucose metabolism[51].

| (A) | (B) |
|--------------|--|
| 34. Selenium | Selenium, for its antioxidant properties, might prevent the development of diabetes. It also prevents the development of complications in diabetic |

patients.
 However, from various studies it is inferred that higher selenium concentrations is associated with a higher prevalence of diabetes. It is found that the mean selenium concentrations in type2 diabetic patients with or without complications are significantly lower than those in healthy controls[45,52].



| (A) | (B) |
|------------|--|
| 35. Iodine | Iodine is an essential micronutrient needed for the production of thyroid hormones. Naturally, iodine insufficient and excessive |

intakes are associated with thyroid disorders. There is a close relationship between thyroid function and the risk of diabetes[53] which may be extrapolated to the relationship between iodine intake and diabetes[54].



- Calcium reduces the risk of type2 diabetes , it reduces the development of diabetes and benefits the prediabetics , but the main point in this mineral is to find the proper dose, otherwise there could be many complications of the patient.
- Magnesium, on the other hand , is beneficial for type2 diabetes. It also helps insulin secretion implying that it may help type1 diabetics.

- Zinc is necessary for type2 diabetics, so such patients should ensure enough dietary zinc to safeguard against poorly controlled blood glucose.
- Iron, eventhough essential for human activity, its store in the body is critical, because higher store may lead to diabetes.
- From human and animal studies, it may be concluded that vanadium is useful for diabetic patients of both type1 and type2.
- Chromium supplementation may be useful in the treatment of T2D, but awaits further investigation. Diabetic patients have lower concentration of chromium, which indicates that such patients should be supplemented with chromium.
- Manganese helps in glucose metabolism which is necessary for normal synthesis and secretion of insulin implying its help for diabetic patients.
- Potassium plays important roles for diabetic patients, since low potassium levels are associated with increased risk of diabetes. It also helps the slower progression of prediabetes to diabetes.
- Selenium, for its antioxidant properties might prevent the development of diabetes. However, higher concentration of selenium is associated with prevalence of diabetes.
- There is a close relationship between thyroid function and risk of diabetes. Since paucity and higher intake of iodine lead to thyroid disorder , intake of iodine should be blanced to check diabetes.

Table-2 : The amount of antidiabetic elements from the proposed diet

| Antidiabetic Elements(a) | Minimum amount in mgm/day(b) | Maximum amount in mgm/day(c) |
|--------------------------|------------------------------|------------------------------|
| 1. Methionine | 868 | 1628 |

| | | |
|-----------------------|-----------|-----------|
| 2. Lysine | 2238 | 4538 |
| 3. Histidine | 1304 | 2231 |
| 4. Arginine | 2564 | 3739 |
| 5. Alanine | 2059 | 3866 |
| 6. Glutamic Acid | 14680 | 16278 |
| 7. Glycine | 1863 | 4014 |
| 8. Serine | 3885 | 5421 |
| 9. Leucine | 3924 | 6517 |
| 10. Vitamin A | 0.45 | 0.77 |
| 11. Vitamin C | 48 | 297 |
| 12. Vitamin D | 0.0054245 | 0.0054245 |
| 13. Vitamin E | 1.17 | 8.77 |
| 14. Vitamin K | 0.16 | 0.16 |
| 15. Alpha-lipoic Acid | 90 | 96 |

| (a) | (b) | (c) |
|----------------------|------|------|
| 16. Co-enzyme Q10 | 2.90 | 5.05 |
| 17. N-AcetylCysteine | 631 | 1036 |

| | | | |
|-----|------------------------|--------|---------|
| 18. | Betaine | 170 | 318 |
| 19. | Thiamine | 1.62 | 3.85 |
| 20. | Niacin | 20.33 | 29.37 |
| 21. | Pyridoxine(Vitamin B6) | 2.91 | 3.5 |
| 22. | Biotin(Vitamin B7) | 0.037 | 0.04686 |
| 23. | Inositol | 570 | 1240 |
| 24. | Folic Acid(Vitamin B9) | 0.656 | 1.038 |
| 25. | Vitamin B12 | 0.0018 | 0.0024 |
| 26. | Calcium | 844.36 | 1087.9 |
| 27. | Magnesium | 382.56 | 570.34 |
| 28. | Zinc | 2.22 | 5.41 |
| 29. | Iron | 17.33 | 26.21 |
| 30. | Vanadium | 0.02 | 0.02 |

| | | |
|-----------|-------|------|
| (a) | (b) | (c) |
| 31. Chro- | 0.102 | 0.12 |

| | | |
|--------------------|---------|--------|
| mium | | |
| 32. Man- ganese | 8.1022 | 9.644 |
| 33. Po- tassium | 2198.38 | 4259.1 |
| 34. Selenium | 0.140 | 0.152 |
| 35. Iodine | 0.15 | 0.15 |

We would now check, how the data from Table2 compare with the daily intake amount for the elements and their medicinal doses in connection with diabetes. In order to do that we shall present the amount of mean values of the elements from the proposed diet, the daily intake amount and the medicinal doses in Table3.

Table-3: The mean values of the amount of elements from the proposed diet per day, daily intake amount and the medicinal doses

| Antidiabetic Elements(a') | Mean values of the amount from the proposed diet in mg/day(b') | Mean values of the intake amount in mg/day(c') | Medicinal doses in mg/day(d') |
|---------------------------|--|--|-------------------------------|
| 1. Methionine | 1248 | 1330 | 8000-10000 |
| 2. Lysine | 3388 | 2660 | 1000-3000 |
| 3. Histidine | 1767.5 | 980 | 4000 |
| 4. Arginine | 3151.5 | 2500 | 9000 |
| 5. Alanine | 2962.5 | 4000 | 20000-40000 |
| 6. Glutamic Acid | 15479 | 8500 | - |
| 7. Glycine | 2938.5 | 1000 | 5000 |
| 8. Serine | 4654.5 | 2100 | 30000 |
| 9. Leucine | 5220.5 | 3010 | 7500 |
| 10. Vitamin A | 0.61 | 0.68 | 12.5 |
| 11. Vitamin C | 172.5 | 65 | 800 |
| 12. Vitamin D | 0.0054245 | 0.017 | 0.5 |
| 13. Vitamin E | 4.97 | 9 | 363.6 |

| (a') | (b') | (c') | (d') |
|------|------|------|------|
|------|------|------|------|

| | | | |
|---------------------------|---------|--------|---------------------------------|
| 14. Vitami n-K | 0.16 | 0.105 | 0.5 |
| 15. Alphali- poic Acid | 93 | 75 | 600 |
| 16. Co-enzyme Q10 | 3.975 | 65 | 150 |
| 17. N-acetyl- cysteine | 833.5 | 900 | 1200 |
| 18. Betaine | 244 | 150 | 4100 |
| 19. Thiamine | 2.735 | 1.45 | 300 |
| 20. Niacin | 24.85 | 20.5 | 3000 |
| 21. Pyridoxine(VitB6) | 3.205 | 1.7 | 1800 |
| 22. Biotin(Vit B7) | 0.04193 | 0.0325 | 2-4 for type1 9-15 for type2 |
| 23. Inositol | 905 | 1500 | 500 for type1 |
| 24. Folic Acid(Vit B9) | 0.847 | 0.5 | 5 |

| | | | |
|------|------|------|------|
| (a') | (b') | (c') | (d') |
|------|------|------|------|

| | | | |
|-----------------|---------|--------|--|
| 25. Vitamin B12 | 0.0021 | 0.0025 | 0.5 |
| 26. Calcium | 966.13 | 900 | 1250 |
| 27. Magnesium | 461.45 | 600 | 400 |
| 28. Zinc | 3.815 | 10 | 30 |
| 29. Iron | 21.77 | 19 | - |
| 30. Vanadium | 0.02 | 0.02 | 125 |
| 31. Chromium | 0.111 | 0.3375 | 0.35 |
| 32. Manganese | 9.5522 | 3.5 | 3-5 for type1 diabetes 1.8-2.6 for type2 diabetes |
| 33. Potassium | 3228.74 | 4100 | 2700 |
| 34. Selenium | 0.146 | 0.0625 | 0.2 |
| 35. Iodine | 0.15 | 0.09 | 50 |

From Table3 it is clear that the amount of antidiabetic elements from the proposed diet compete successfully with the daily intake amount , however they are nowhere near to

medicinal doses with the exception of lysine, leucine, N-acetylcysteine, Calcium, Magnesium, Potassium and selenium.

So, the antidiabetic elements which have comparable amounts from the proposed diet to the medicinal doses may act as preventors as well as arrestor of the disease while the others can only act as preventor.

In case of lysine, histidine, arginine, glutamic acid, glycine, serine, leucine, vitamin c, vitamin k, betaine, thiamine, pyridoxine, folic acid, chromium, manganese, selenium and iodine, the contributions from the proposed diet are higher than the daily intake amount.

Thus lysine, histidine, glutamic acid, arginine, glycine, leucine, vitamin c, vitamin k, betaine, thiamine, pyridoxine, folic acid, manganese and selenium from the proposed diet act more positively towards prevention of diabetes.

The role of serine, chromium and iodine is questionable and needs further investigation.

The amount of lysine, leucine, N-acetylcysteine, calcium, magnesium, potassium and selenium from the diet under consideration are comparable to the medicinal doses, so they are capable of arresting the diabetes.

It is very difficult to infer about the iron activity towards diabetes because any amount over and below the balance amount may lead to negative result.

Graphical understanding of the roles of the thirtyfive elements towards diabetes may be interesting and quick to check. In order to do that rational values of the amounts from the diet and medicinal doses versus the ratios of daily intake amount to medicinal doses for the elements need to be shown. The rational values for the elements are shown in Table4.

Table 4: Rational values of the elements

| <u>Antidiabetic Elements(a')</u> | <u>Rational values of amount from proposed diet and medicinal doses</u> $x=b'/d'$ | <u>Rational values of daily intake amount and medicinal doses</u> $y=c'/d'$ |
|----------------------------------|--|--|
| 1. Methionine | 0.1387 | 0.1478 |
| 2. lysine | 1.694 | 1.33 |
| 3. Histidine | 0.442 | 0.245 |
| 4. Arginine | 0.350 | 0.278 |
| 5. Alanine | 0.0988 | 0.133 |
| 6. Glutamic Acid | - | - |
| 7. Glycine | 0.588 | 0.20 |
| 8. Serine | 0.155 | 0.07 |
| 9. Leucine | 0.696 | 0.401 |
| 10. Vitamin A | 0.0488 | 0.0544 |
| 11. Vitamin C | 0.216 | 0.0813 |
| 12. Vitamin D | 0.0108 | 0.034 |
| 13. Vitamin E | 0.0137 | 0.025 |
| 14. Vitamin K | 0.32 | 0.21 |
| 15. Alpha-liopoic acid | 0.155 | 0.125 |

| a' | x | Y |
|-----------------------|---------------------------------|----------------------------------|
| 16. Co-enzyme Q10 | 0.0265 | 0.433 |
| 17. N-acetyl cisteine | 0.695 | 0.75 |
| 18. Betaine | 0.0595 | 0.0366 |
| 19. Thiamine | 0.0091 | 0.0048 |
| 20. Niacin | 0.0083 | 0.0068 |
| 21. Pyridoxine | 0.0018 | 0.00094 |
| 22. Biotin | 0.014 for T1D 0.0035 for T2D | 0.0108 for T1D 0.0027 for T2D |
| 23. Inositol | 1.81 | 3 |
| 24. Folic acid | 0.169 | 0.1 |
| 25. Vitamin B12 | 0.0042 | 0.005 |
| 26. Calcium | 0.773 | 0.72 |
| 27. Magnesium | 1.154 | 1.5 |
| 28. Zinc | 0.127 | 0.383 |
| 29. <u>Iron</u> | = | = |
| 30. Vanadium | 0.00016 | 0.00016 |

| (a') | (x) | (y) |
|---------------|--------------------------------|--------------------------------|
| 31. Chromium | 0.317 | 0.096 |
| 32. Manganese | 2.388 for T1D 4.342 for T2D | 0.875 for T1D 1.591 for T2D |
| 33. Potassium | 1.196 | 1.519 |
| 34. Selenium | 0.73 | 0.313 |
| 35. Iodine | 0.003 | 0.0018 |

From Table4, it is found that x and y have one to one correspondence , i.e, while x have small values, so have y and when x have large values, y also have large values.

It is clear from the above table that the values of x and y matches reasonably with each other, which implies that the antidiabetic elements from proposed diet give good support in the prevention of diabetes as does the daily intake amount.

The result x and y in Table4 have been shown graphically in Fig1 and Fig2.

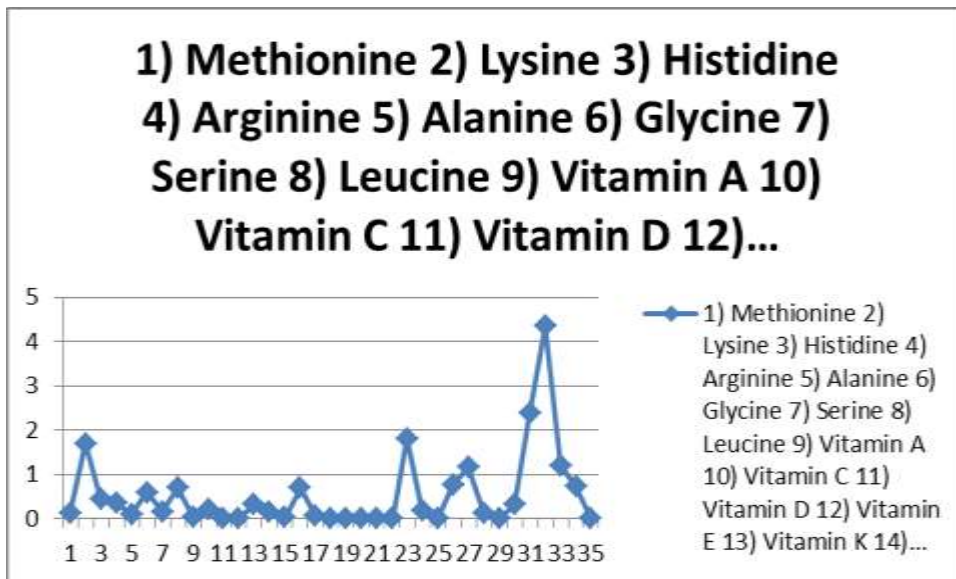
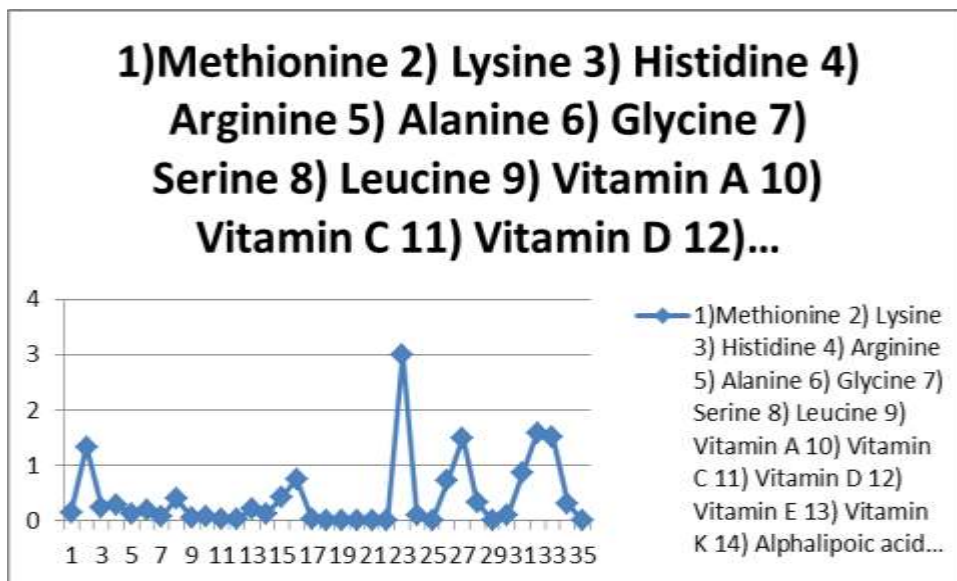


Fig-1

Fig-1 represent the ratio x of the amount of antidiabetic elements from the propose diet and the medicinal doses of the corresponding element.



The nature of the two curves are same. So, it is very clear from Fig-1 and Fig-2 that the proposed diet finds its excellent performance in prevention of diabetes.

The other interesting features which follow from Table4 are:

1. $\text{Sum}(x)$ for T1D=14.41 and $\text{Sum}(y)$ for T1D=13.91.
So, $\text{Sum}(x)$ for T1D \geq $\text{Sum}(y)$ for T1D
2. $\text{Sum}(x)$ for T2D=16.36 and $\text{Sum}(y)$ for T2D=14.61.
Here again $\text{Sum}(x)$ for T2D \geq $\text{Sum}(y)$ for T2D.

Both the above results signify the importance of the proposed diet in prevention and arrest of diabetes of type1 and type2 over the daily intake amount.

Conclusion

Diabetes is threatening the present human world for its dangerous consequences. The disease is not curable because in the process of curing the side complications may prove fatal. So, wise decision is to search for prevention and arrest of the disease. Scientists are incessantly searching for the same. Detail investigation for a vegetarian diet proposed earlier gave some clue to the success of the same in prevention of diabetes.

In the present article further studies indicate that the diet under consideration contains nine amino acids, nine antioxidants, seven vitamins and ten minerals which have antidiabetic effects and help in the prevention and arrest of the disease. The amount of the above in the diet is quite comparable and sometimes larger than the daily intake amount, so it may be concluded that the vegetarian diet could be a successful preventor, as well as, an arrestor of the disease.

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