Original Article

Diabetics of Northeast India are at risk of dietary Zinc and Manganese deficiency: Possible improvement through consumption of some traditional edibles or edibles of limited popularity

Rahul Chakraborty, Sudip Dey, Paul S. Dkhar, Clarice R. Thabah, Wandondor Rynjah

Sophisticated Analytical Instrument Facility, North Eastern Hill University, Permanent Campus, Mawlai, Shillong 793022, Meghalaya, India

Background: Restricted diets of Northeast India were found to be low in both zinc and manganese. **Aim:** To explore the possibilities of compensating for the low zinc and manganese content in restricted diet by supplementing with traditional edibles and edibles of limited popularity. **Materials and Method:** Concentration of these two elements in a number of edibles from Northeast India was assessed along with some traditional edibles and edibles of limited popularity. **Results:** Relatively high concentration of zinc and manganese were recorded in some traditional edibles and edibles of limited popularity, which when added to diabetic diet could elevate the concentration of zinc and manganese, and bring the level of these two elements close to the recommended level. **Conclusion:** It is suggested that, the deficiency of essential elements in the restricted diet of diabetics in Northeast India should be monitored and appropriate supplementation may be tried, preferably through some traditional edibles and edibles of limited popularity.

KEY WORDS: Diabetics, diet, selenium, traditional food

DOI: 10.4103/0973-3930.70860

Introduction

Several reports indicate that diabetes mellitus is increasing at a rapid rate throughout the developing and developed world.[1] In 1995, the estimated global burden of diabetic individuals was nearly 135 million individuals, which was projected to reach more than 300 million by the year 2025.[2] It is anticipated that much of this increase in prevalence rate will occur in developing countries, especially in Indian sub-continent.[3] The same is true for Northeast India, even though no concrete data are available for the same.[4]

The diet for diabetics is generally restricted in carbohydrate intake, as blood glucose tends to increase because of carbohydrate rich diet, due to nonutilization of glucose by the body.[5] However, recently diabetic patients were advised and recommended by the diabetic associations that 60–70% of the calories in a diabetic diet should be in the form of complex polysaccharides, i.e., starch and non-starch polysaccharides, i.e., dietary fiber.[6] Diet modification plays an important role in the management of diabetes mellitus, and several scientific studies provide evidence in support of the same.[7-11] However in general practice, care has been taken to reduce the carbohydrate content in the diet of the diabetics. Many common food items are restricted for consumption by the diabetic patients. It is generally recommended that some of the carbohydrate-rich food such as rice and wheat should be consumed in a low amount and some vegetables, usually the underground roots and shoots such as carrot, turnip, and potato and vegetables like sweet-gourd, sweet-potato, brinjals (or egg-plants), ladies-finger, etc. should be avoided totally or taken in a minimum quantity by the diabetics. Most of the fruits (especially sweet ones) are also restricted for the diabetics. However, it is certain that the food items omitted from the diet of diabetics contain several essential elements, whose omission should be compensated otherwise, for proper physiological functioning. One possible nutritional problem likely

Correspondence to: **Dr. Rahul Chakraborty**, Electron Microscope Division, Sophisticated Analytical Instrument Facility, North Eastern Hill University, Bijni Complex, Laitumkhrah, Shillong 793 003, Meghalaya, India. E-mail: rahulshillongsem@yahoo.in

Manuscript received: 12.05.2009; Revision accepted: 12.08.2010

to be experienced by the diabetics due to omission of these food items from their diet is the possible dietary deficiency of essential trace elements.

Usually, ecological and geo-climatic conditions of a particular region greatly influence the concentration of certain trace elements in vegetations and edibles growing in this region. Therefore, it is quite possible that the food items restricted to diabetics may contain higher amount of certain essential elements as compared to those permitted to them. This study was undertaken to know the status of zinc and manganese in the recommended diet of diabetic patients of Northeast India, since the ecological and geo-climatic conditions of this region are quite different from the rest of the country, the relevancy of this study lies in the fact that the soil of Northeast India is acidic and rich in iron, the conditions which are known to influence the uptake of several elements by the vegetation from soil.[12,13]

A preliminary survey on some diabetic patients of the cities of Shillong and Guwahati, the state capitals of Meghalaya and Assam, in Northeastern province of India revealed some interesting facts. Increase in diabetes mellitus along with complications associated with the disease such as retinopathy, nephropathy, and several types of cardiovascular complications are increasing at an alarming rate.[4] Among the complications that are observed along with diabetes is untimely aging, hypertension, several cardiovascular disorders, formation of cataract, and kidney dysfunction. The survey further revealed that these complications are not universal to all the diabetics, rather they do not exist at all in some of the patients, whose diet invariably contain some traditional food items or some edibles of limited popularity, suggesting that in northeastern region of India, the diabetes and complications associated with diabetes are likely to be influenced by the diet, or to be precise some micronutrients of the diet.

Experimental and clinical studies indicate that zinc deficiency may pre-dispose to glucose intolerance; diabetes mellitus, insulin resistance, along with atherosclerosis and coronary artery disease.[14,15] Lower dietary zinc intake and lower concentration of serum zinc were found to be associated with higher prevalence of diabetes and glucose intolerance in rural and urban Indian men and women, along with coronary artery disease.[16] Central obesity, hypertension, hypertriglyceridemia and low high density lipoprotein cholesterol were also found to be more prevalent among urban Indian subjects consuming a diet low in zinc.[16] In the case of human beings, studies showed some protective effect of zinc supplementation for the development of diabetic retinopathy, which is associated with increase in superoxide dismutase.[17]

Reduction of manganese concentration was observed in blood and scalp-hair samples of diabetic patients as compared to control human subjects.[18] In the case of neural oxidative defense against hyperglycemic injury, manganese superoxide dismutase activity is thought to be an important cellular modifier.[19] Elevated manganese superoxide dismutase provides extensive protection to diabetic mitochondria and provides overall protection to the diabetic heart.[20,21] Synthetic manganese porphyrins can be used as potent therapeutic agents in diabetics.[22] It was also thought that manganese superoxide dismutase gene polymorphism might be associated with the development of type 2 diabetes.[23,24]

Keeping these in view, a detailed survey on a large number of edibles namely, cereals and pulses, vegetables, fruits and fish, meats were undertaken to estimate two important essential elements namely, zinc and manganese. Few traditional food items or food items of limited popularity namely, Indian pennywort, mint leaves, neem leaves, and arum shoot were also examined to assess the quantity of zinc and manganese.

Materials and Methods

The samples were oven dried to remove moisture, and were crushed with the help of a mortar and a pestle to a fine powdery form. One gram each of the samples was treated with a few drops of hydrogen peroxide and was kept overnight, and later evaporated to dryness. One milliliter of perchloric acid was then added to the sample, heated to dryness, and the process was repeated two or three times. Hydrochloric acid, 4 or 5 mL, was then added to the sample and the solution was diluted with double distilled water to 50 mL. The elemental analysis was carried out using an atomic absorption spectrophotometer. The model used in the analysis was 'Perkin Elmer' 3110 Atomic Absorption Spectrophotometer.

The sample preparation procedure was followed as described by Dey *et al*.[25] Standard deviations (SD) were calculated using Microsoft Excel.

Ten replicates of each sample were used to confirm the quantitative estimation of the element selenium. Each replicates were further analyzed five times.

Results

A total of 60 samples were selected for this study. Out of these, 3 were cereals, 4 were pulses, 22 samples were vegetables, 8 samples were fruits, 6 were fish, 2 were meat, 3 were eggs, and 12 samples of traditional edibles or edibles of limited popularity (vegetables) were selected taking care that these traditional edibles are allowed to a diabetic.

Concentrations of zinc and manganese in different edibles collected from various municipal markets of two major cities of Northeast India namely, Shillong and Guwahati are shown in Table 1. It is noteworthy that several edibles which are restricted to the diabetics, exhibit high concentrations of both the elements. As for example, ladies-finger, red-beet, and carrot showed high concentration of zinc (105.75 μg, 141.47 μg and 75.04 μg per kg dry weight, respectively). At the same time, high concentration of manganese was also recorded in carrot and red-beet (33.15 μg and 23.26 μg per kg dry weight, respectively). Kala-dal or red-bean dal, which is again restricted for the diabetics, recorded

Table 1: Zinc and manganese content of some common edibles estimated this study

Samples	Zinc (μg) per kg dry wt.	Manganese (μg) per kg dry wt.
Cereals		
Joha-rice (*Oriza sativa*)	26.38 (±10.38)	13.64 (±5.29)
Primal-rice (*Oriza sativa*)	33.04 (±6.34)	27.27 (±12.23)
Wheat-flour (*Triticum aestivum*)	14.03 (±3.58)	9.50 (±0.70)
Pulses		
Pigeon-pea or arhar dal (*Cajanus cajan*)	50.63 (±8.74)	11.11 (3.30)
Lentils or musur dal (*Lens culinaris*)	58.05 (±13.37)	9.91 (±0.21)
Chick-peas or channa dal (*Cicer arietinum*)	58.03 (±17.34)	12.11 (±4.19)
Red-bean or kala dal (*Phaseolus radiatus*)[a]	66.46 (±14.85)	13.33 (±7.51)
Vegetables		
Tomato (*Lycopersicum esculentum*)	76.81 (±43.59)	13.19 (5.08)
Garden peas (*Pisum sativum*)	93.44 (±16.64)	15.68 (±5.14)
Capsicum (*Capsicum longifolia*)	47.84 (±9.44)	22.66 (±12.60)
French-bean (*Phaseolus vulgaris*)	95.52 (±35.26)	30.19 (±10.46)
Pointed-gourd (*Trichosenthes dioicai*)	68.76 (±14.17)	10.93 (5.35)
Brinjal or egg-plant (*Solanum melongena*)[a]	54.21 (±22.22)	9.80 (±0.50)
Cucumber (*Cucumis sativus*)	103.83 (±35.78)	13.72 (±4.54)
Sweet-gourd (*Cucurbita maxima*)[a]	40.25 (±9.12)	10.15 (±0.39)
Ladies-finger (*Abelmoschus esculentus*)[a]	105.74 (±36.87)	17.80 (±4.49)
Papaya (*Carica papaya*)	31.14 (±11.57)	9.96 (±0.05)
Flat-bean (*Dolichos lablab*)	59.38 (±37.36)	12.56 (±4.64)
Potato (*Solanum tuberosum*)[a]	33.23 (±7.49)	9.21 (±1.05)
Sweet-potato (*Ipomoea batatus*)[a]	10.12 (±0.90)	2.90 (±0.90)
Red-beet (*Beta vulgaris*)[a]	141.47 (±74.06)	23.26 (±14.50)
Carrot (*Daucus Corota*)[a]	75.04 (±25.88)	33.15 (±7.16)
Turnip (*Brassica rapa*)[a]	85.67 (±26.20)	17.24 (±4.98)
Cauliflower (*Brassica oleracea*)	48.23 (±3.82)	13.51 (±5.97)
Cabbage (*Brassica capitata*)	130.69 (±46.71)	9.43 (±0.74)
Spinach (*Spinaca oleracea*)	128.56 (±32.11)	36.57 (±5.42)
Celery leaf (*Apium graveolens*)	77.40 (±10.53)	11.89 (±2.86)
Onion (*Allium cepa*)	68.62 (±20.41)	12.57 (±4.77)
Garlic (*Allium sativum*)	40.12 (±19.91)	12.09 (±4.47)
Fruits		
Banana (*Musa paradisiaca*)[a]	34.97 (±15.14)	28.90 (±6.01)
Mango (*Mangifera indica*)[a]	62.25 (±29.41)	50.00 (±2.80)
Guava (*Psidium guajava*)	7.66 (±0.73)	9.82 (±2.12)
Pear (*Pyrus commusis*)	10.47 (±3.99)	ND
Pineapple (*Ananas comosus*)[a]	18.86 (±2.96)	7.50 (±1.49)
Grapes (*Vitus vinifera*)[a]	16.41 (±3.45)	0.63 (±0.39)
Groundnut (*Arachis hypogaea*)[a]	38.64 (±6.01)	10.10 (±1.02)
Coconut (*Cocos nucifera*)[a]	8.69 (±1.06)	2.02 (±1.20)
Fish		
Ompok bimaculatus	132.58 (±11.52)	82.10 (±33.47)
Puntius sophpre	152.77 (±6.05)	83.15 (±22.26)
Puntius ticto	78.37 (±8.35)	162.56 (±29.23)
Clarius batrachus	55.80 (±3.43)	51.61 (±7.71)
Labeo rohita	14.50 (±1.85)	2.85 (±0.80)
Catla catla	26.61 (±1.32)	3.16 (±0.41)
Meat		
Goat muscle or mutton (*Capra hircus*)[a]	84.90 (±27.63)	ND
Chicken muscle (*Gallus gallus*)	51.91 (±12.02)	ND
Egg		
Local chicken egg	36.60 (±5.07)	ND
Farm chicken egg	25.13 (±0.63)	0.30 (±0.21)
Duck egg	27.40 (±6.13)	1.05 (±0.44)

All values are in μg per kg dry weight; ND = not detected; values in parenthesis are standard deviation (SD); [a]Edibles usually avoided by diabetics.

considerable amount of both the elements (66.46 μg per kg dry weight of zinc and 13.33 μg per kg dry weight of manganese). Most of the fruits on the other hand, which are restricted for the diabetics, recorded considerable amount of zinc and manganese. As for example, banana and mangoes recorded 34.97 μg and 62.25 μg per kg dry weight of zinc, respectively, where their manganese concentrations were 28.90 μg and 50.00 μg per kg dry weight, respectively. Both meat and eggs when examined recorded various concentrations of zinc in them, but in the case of manganese, the element was found to be below detectable limit, or present in very low concentration [Table 1]. All the small fishes, such as *Ompok*, *Puntius,* and *Clarius*, recorded relatively high concentrations of both the elements, where bigger fishes like *Labeo* or *Catla* recorded relatively lower concentrations of the elements [Table 1].

Table 2 represents the concentrations of zinc and manganese in 12 numbers of traditional edibles, or edibles of limited popularity, which are usually not restricted for the diabetics. Quite high concentrations of both the elements were recorded in several of them. As for example, Indian pennywort, mint leaves, coriander, and soya recorded a high concentration of zinc (144.20 μg, 205.59 μg, 208.55 μg, and 171.74 μg per kg dry weight, respectively). High concentration of manganese was also recorded in neem leaves, coriander, mint leaves, arum stem, etc. (297.57 μg, 155.36 μg, 122.22 μg, and 140.39 μg per kg dry weight, respectively) [Table 2].

Diabetics who are strict vegetarian and do not consume traditional edibles (Group 1) can obtain about 136.80 μg of zinc and 38.10 μg of manganese daily from this type of diet [Table 3]. The values are considered after calculating a maximum of three meals per day. On the other hand, the groups of diabetics who are non-vegetarian (considering their meal contains fish, meat, and eggs) but do not consume traditional edibles (Group 2) can obtain about 241.05 μg of zinc and 63.70 μg of manganese per day [Table 4].

The diabetics, who are non-vegetarian and at the same time consume traditional edibles (Group 3), can get about 301.65 μg of zinc and 169.02 μg of manganese from their daily diet [Table 3]. It should be noted that the amount of edibles considered for consumption for all the diabetic groups is taken on a higher side, where in practice much less may be consumed by the population in general and the diabetic groups considered here in particular.

Discussion

This study clearly shows that the restricted diets of diabetics are low in both zinc and manganese. It is, therefore, also possible that this food habit can cause dietary deficiency of both zinc and manganese for the strict vegetarian diabetics of Northeastern region of India. The estimation of daily dietary intake of both the elements was based on a number of edibles, including fish meat and eggs on an average of three meals per day. Therefore, it is quite possible that the values of zinc and manganese intake per day by the diabetic patients, as presented in our data [Tables 3-5] are on the maximum side. Many diabetics may not always take all the vegetables, fish, and meat at the same time on a daily basis, especially the poorer section of the population. From this study, it can also be safely predicted that the diabetics following strict vegetarian diet are at the maximum risk of having both zinc and manganese deficiency. Only if they continue to consume

Table 2: Zinc and manganese content of some traditional or edibles of limited popularity estimated in this study

Samples (edibles of limited popularity)	Zinc (μg) per kg dry wt.	Manganese (μg) per kg dry wt.
Indian pennywort (*Centella asiatica*)	144.20 (±11.80)	9.80 (±0.50)
Mint leaves (*Mentha arvensis*)	205.59 (±61.65)	122.22 (±32.15)
Salad leaves (*Lactuca sativa*)	144.29 (±5.58)	24.07 (±9.01)
Neem leaves (*Azadirachta indica*)	144.30 (±5.30)	297.57 (±70.91)
Fenugreek leaves (*Trigonella foenum-gracum*)	81.39 (±1.18)	15.27 (±2.45)
Arum stem (*Colocasia esculenta*)	238.03 (±47.21)	140.39 (±77.15)
Soya (*Glycene max*)	171.74 (±49.59)	13.52 (±5.71)
Chebulic (*Terminalia chebula*)	92.13 (±16.63)	79.52 (±31.39)
Bamboo shoot (*Dandrocalamus strictus*)	30.17 (±4.10)	36.59 (±1.32)
Sweet-gourd leaves and shoots (*Cucurbita maxima*)	58.57 (±1.25)	4.36 (±0.40)
Ginger flower (*Zingiber officinale*)	63.11 (±15.63)	12.29 (±6.90)
Coriander (*Coriendrum sativum*)	208.55 (±86.99)	155.36 (±28.80)

All values are in μg/kg dry weight, ND = not detected; Figures in parentheses are the standard deviation (SD).

Table 3: Approximate maximum daily dietary intake of zinc and manganese by diabetic patients (Group 1, who are strictly vegetarian but, *do not* consume nonconventional edibles) from their restricted diet in a single meal[a]

Edibles	Amount (gram)	Zn intake (μg) (Approx.)	Mn intake (μg) (Approx.)
Primal—rice (*Oriza sativa*)	100	3.30	2.72
Pigeon-pea or arhar dal (*Cajanus cajan*)	100	5.06	1.11
Tomato (*Lycopersicum esculentum*)	50	3.85	0.60
Garden peas (*Pisum sativum*)	50	4.70	0.65
French-bean (*Phaseolus vulgaris*)	50	4.80	1.51
Pointed-gourd (*Trichosenthes dioica*i)	50	3.45	0.55
Flat-bean (*Dolichos lablab*)	50	3.45	0.65
Papaya (*Carica papaya*)	50	1.56	0.50
Cauliflower (*Brassica oleracea*)	50	2.42	0.70
Cabbage (*Brassica capitata*)	50	6.55	1.85
Spinach (*Spinaca oleracea*)	50	6.45	1.85
Approx. Zn and Mn intake in a single meal		45.60	12.70
Approx. Zn and Mn intake per day (in three meals)		45.60 × 3 = 136.80	12.70 × 3 = 38.10

[a]Maximum possible intake of edibles has been taken, though in practice much less may be consumed by the general population.

Table 4: Approximate maximum daily dietary intake of zinc and manganese by diabetic patients (Group 2, who are non-vegetarian but, *do not* consume traditional edibles or edibles of limited popularity) from their restricted diet[a]

Edibles	Amount (gram)	Zn intake (μg) (Approx.)	Mn intake (μg) (Approx.)
Diabetics consuming non-vegetarian diet and not consuming edibles of limited popularity			
Primal—rice (*Oriza sativa*)	100	3.30	2.72
Arhar dal (*Cajanus cajan*)	100	5.06	1.11
Tomato (*Lycopersicum esculentum*)	50	3.85	0.60
Garden peas (*Pisum sativum*)	50	4.70	0.65
French-bean (*Phaseolus vulgaris*)	50	4.80	1.51
Pointed-gourd (*Trichosenthes dioica*i)	50	3.45	0.55
Flat-bean (*Dolichos lablab*)	50	3.45	0.65
Papaya (*Carica papaya*)	50	1.56	0.50
Cauliflower (*Brassica oleracea*)	50	2.42	0.70
Cabbage (*Brassica capitata*)	50	6.55	1.85
Spinach (*Spinaca oleracea*)	50	6.45	1.85
Fish-*Puntius sophore*	100	15.30	8.21
Meat-Mutton	100	8.49	Nil
Egg-local chicken egg	50	1.85	Nil
Approx. Zn and Mn intake in a single meal		71.35	20.90
Approx. Zn and Mn intake per day (in three meals)		71.35 × 3 = 241.05	20.90 × 3 = 62.70

[a]Maximum possible intake of edibles has been taken, though in practice much less may be consumed by the general population.

some vegetables (containing high amount of zinc and manganese) namely, cucumber, garden-peas, and tomato on a daily basis, their chances of having zinc and manganese deficiency reduce marginally. As most of the edibles permitted to diabetics for consumption do not contain high concentration of both the elements examined here, the diabetic groups, especially the ones following strict vegetarian diet are at serious risk of developing deficiency of both zinc and manganese. Our data also show that the group of diabetics who are non-vegetarian and the same time consume sufficient quantities of vegetables (Group 2) on a daily basis may stand at a less risky position, because they can get substantial amount of the elements from fish, meat, etc. It is worthwhile to mention here that the non-vegetarians diabetic who consume small fish rather than bigger fish are in a better position in terms of essential element intake compared to those preferring bigger fish, such as *Labeo* or *Catla*.

It is, however, quite evident from our study that the restricted diet for both the vegetarian and non-vegetarian diabetics of Northeastern region of India contain significantly low amount of both zinc and

Table 5: Approximate maximum daily dietary intake of zinc and manganese by diabetic patients (Group 3, who are non-vegetarian and, *consume* non-conventional edibles or edibles of limited popularity) from their restricted diet[a]

Edibles	Amount (g)	Zn intake (μg) (Approx.)	Mn intake (μg) (Approx.)
Diabetics consuming non-vegetarian diet and consuming edibles of limited popularity			
Primal-rice (*Oriza sativa*)	100	3.30	2.72
Arhar dal (*Cajanus cajan*)	100	5.06	1.11
Tomato (*Lycopersicum esculentum*)	50	3.85	0.60
Garden peas (*Pisum sativum*)	50	4.70	0.65
French-bean (*Phaseolus vulgaris*)	50	4.80	1.51
Cauliflower (*Brassica oleracea*)	50	2.42	0.70
Cabbage (*Brassica capitata*)	50	6.55	1.85
Spinach (*Spinaca oleracea*)	50	6.45	1.85
Indian pennywort (*Centella asiatica*)	50	7.21	0.50
Mint leaves (*Mentha arvensis*)	50	10.30	6.15
Neem leaves (*Azadirachta indica*)	50	7.21	14.87
Arum stem (*Colocasia esculenta*)	50	11.90	7.02
Coriander (*Coriendrum sativum*)	50	10.43	7.80
Fenugreek leaves (*Trigonella foenum-gracum*)	50	4.07	0.80
Fish—*Puntius sophore*	100	15.30	8.21
Approx. Zn and Mn intake in a single meal		103.55	56.34
Approx. Zn and Mn intake per day (in three meals)		103.55 × 3 = 301.65	56.34 × 3 = 169.02

[a]Maximum possible intake of edibles has been taken, though in practice much less may be consumed by the general population.

manganese, and therefore putting them at the risk of having deficiencies of both the elements. For vegetarians, at best they can obtain ~137 μg of zinc and ~38 μg of manganese, where the non-vegetarians can get ~240 μg of zinc and ~64 μg of manganese. In both cases, the values are much below the recommended daily dietary allowances of these two elements. The recommended daily dietary intake of zinc is 15 mg per day while that of manganese is 2.5 mg per day.[26]

Inclusion of some traditional edibles or edibles of limited popularity (namely Indian pennywort, mint leaves, salad leaves, neem leaves, coriander, and arum stem) in the daily diets of diabetics of Northeast India, on the other hand, can improve the situation considerably [Table 5], where the daily dietary intake of both zinc and manganese can rise substantially (~302 μg of zinc and ~170 μg of manganese). Another important factor can be considered in this case is that all these traditional edibles are not at all costly, and therefore will not be a burden to the poor. Under these circumstances, Indian pennywort, mint leaves, salad leaves, neem leaves, arum stem, and coriander can be recommended as a daily dietary component for the diabetics because of their high zinc and manganese content as well as low price.

There are several studies establishing the importance of both zinc and manganese in maintaining proper health. Recent studies showed that zinc along with metallothionein protects cells against the redox stress that occurs in diabetes and contributes to its progression toward diabetic complications, including heart disease.[27] Zinc complexes were also found to attenuate both hyperglycemia and hyperinsulinemia in laboratory mice by decreasing serum insulin,[28] and in the case of maternal zinc deficiency, the progenies were found to have impaired immunity development in laboratory animals.[29] Dietary manganese deficiency, which may enhance susceptibility to elliptical functions in brain, appears to affect manganese homeostasis, probably followed by alteration of neural activity. On the other hand, Mn also acts as a toxicant in the brain because this metal has pro-oxidant activity.[30] Reduced consumption of Mn along with copper, zinc, and selenium was found to be closely associated with retarded fetal development.[31] Mercury which is a non-essential element renders inhibitory effect on many physiological activities of plants and animal even at low concentration. Plants absorb Hg from soil through its root system, and Mn has been found to counter the inhibitory effect mostly by preventing its uptake from soil.[32]

In the light of our findings, it can be suggested that, while formulating diets for diabetics of Northeast India, care should be taken to ensure adequate intake of essential trace minerals, especially zinc and manganese, because deficiencies of these elements can result in several complications associated with diabetes. In this study, we also observed that the diabetics of this region have a very limited knowledge regarding the importance of trace minerals, and their primary concern remains limitation of carbohydrates in their daily diet. Concerned authorities and health officials must address this issue in a priority basis and appropriate measures should be undertaken as early as possible. From our study, it is also evident that inclusion of few food items of limited popularity, which were found to contain high amount of zinc and manganese, in the daily diet of diabetics, can increase both zinc and manganese intake.

Acknowledgments

The authors are thankful to the Head, Sophisticated Analytical Instrument Facility, North Eastern Hill University, Shillong, Meghalaya, for infrastructural and analytical facilities.

References

1. Adachi Y, Yoshikawa Y, Sakurai H. Antidiabetic zinc (II)-N-acetyl-L-cystine complex: Evaluations of *in vitro* insulinomimetic and *in vivo* blood glucose-lowering activities. Biofactors 2007;29:213-23.
2. Anderson JW, Randles KM, Kendall CW, Jenkins DJ. Carbohydrate and fiber recommendations for individuals with diabetes: A quantitative assessment and meta analysis of the evidence. Am J Coll Nutr 2004;23:5-17.
3. Benov L, Batinic-Haberle I. A manganese porphyrin suppresses oxidative stress and extend the life span of streptozotocin-diabetic rats. Free Redic Res 2005;39:81-8.
4. Bowen HG. Trace Elements in Biochemistry. London: Academic Press; 1966.
5. Dey S, Stafford R, Debroy MK, Bhattacharjee CR, Khating DT, Bhattacharjee PC, *et al*. Metal toxicity and trace element deficiency in some wild animals from Northeast India, as revealed by cellular, bio-inorganic and behavioral studies. Curr Sci 1999;77:276-80.
6. Dkhar PS. Spectroscopic study of the trace elements on rice *Oriza sativa* Linn. In Meghalaya. Ph.D. Thesis. Shillong. Meghalaya. India: North Eastern Hill University; 1996
7. Faure P, Ben Hamou P, Perard A, Halimi S, Roussel A. Lipid peroxidation in insulin dependent diabetic patients with early retinal degenerative lesions: Effects of an oral Zn supplementation. Eur J Clin Nutri 1995;49:282-8.
8. Gopalan C. Nutrition Research in Southeast Asia. The Emerging Agenda of the Future. World Health Organization. India: AITBS Publishers and Distributors; 1996
9. Kaput J, Rodriguez RL. Nutritional genomics: The next frontier in the post genomic era. Physiol Genomics 2004;16:166-77.
10. Kazi TG, Afridi HI, Kazi N, Jamali MK, Arain MB, Lalbani N, *et al*. Copper, chromium, manganese, iron, nickel, and zinc levels im biological samples of diabetes mellitus patients. Biol Trace Elem Res 2008;122:1-18.
11. Khongsdier R. Increasing Urbanisation in Tribal States of Northeast India: Implications for the Prevalence of Chronic Diseases. Health and Nutritional Problems of Indigenous Populations. Tribes Tribals 2008;2:25-33.
12. King H, Aubert RE, Herman WH. Global burden of diabetes, 1995 - 2025: Prevalence, numerical estimates and projections. Diab Care 1998;21:1414-31.
13. Liu S. Intake of refined carbohydrates and whole grain foods in relation to risk of type 2 diabetes mellitus and coronary artery disease. J Am Coll Nutr 2002;21:298-306.
14. Maret W, Sandstead HH. Possible roles of zinc nutriture in the fetal origins of disease. Exp Gerontol 2008;43:379-81.
15. Maret W. A role of metallothionein in the pathogenesis of diabetes and its cardiovascular complications. Mol Genet Metab 2008;94:1-3.
16. Metzger BE. The global increase in diabetes: Unique issues for mothers and children. Int J Diab Dev Count 2006;26:57-62.
17. Nakanishi S, Yamane K, Ohishi W, Nakashima R, Yoneda M, Nojima H, *et al*. manganese superoxide dismutase Ala16Val polymorphism is associated with the development of type 2 diabetes in Japanese-Americans. Diab Res Clin Pract 2008;81:381-5.
18. Nongkynrih P, Dakhar PS, Khating DT. Micronutrient elements in acid alfisoil of Meghalaya on the rice cultivation. J Ind Soc Soil Sci 1996;44:455-7.
19. Osada H, Watanabe Y, Nishimura Y, Yukawa M, Seki K, Sakiya S. Profile of trace element concentration in the feto-placental unit in relation to fetal growth. Acta Obstat Gynecol Scand 2002;81:931-7.
20. Petrovic MG, Cilensek I, Petrovic D. manganese superoxide dismutase gene polymorphism (V16A) is associated with diabetic retinopathy in Slovene (Caucasians) type 2 diabetes patients. Dis Markers 2008;24:59-64.
21. Raghuram TC. Diet and diabetes mellitus. In: Bamji MB, Rao PN, Reddy V, editors. Text Book of Human Nutrition. New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd.; 1996. p. 333-45.
22. Roy SB, Bera AK. Amelioration of mercurial toxicity by manganese: I. A case study in mung been seedling. J Environ Biol 2002;23:321-3.
23. Roth H, Kirchgessner M. Zinc and insulin metabolism. Biol. Trace Elem Res 1991;3:13-32.
24. Sheard NF, Clark NG, Brand-Miller JC, Franz MJ, Pi-Sunyer FX, Mayer-Davis E. *et al*. Dietary carbohydrate (amount and type) in the prevalence and management of diabetes. Diab Care 2004;27:2266-71.
25. Shen X, Zheng S, Metreveli NS, Epstein PN. Protection of cardiac mitochondria by overexpression of MnSOD reduces diabetic cardiomyopathy. Diabetes 2006;55:798-805.
26. Singh RB, Gupta UC, Mittal N, Ghosh S, Rastogi V. Epidemiological study of trace elements and magnesium and risk of coronary artery disease in the rural and urban Indian population. Am J Coll Nutri 1997;16:62-7
27. Subramanium G, Vijaya J. Trace elements in cardiovascular disease. Tirupati, India: SV Medical College; 1997. p. 15-66.
28. Takeda A. Manganese action in brain function. Brain Rev Brain Res Rev 2003;41:79-87.
29. Vincent AM, Russel JW, Sullivan KA, Backus C, Hayes JM, McLean LL, *et al*. SOD2 protects neurons from injury in cell culture and animal models of diabetic neuropathy. Exp Neurol 2007;208:216-27.
30. Viswanathan V. Type 2 diabetes and diabetic nephropathy I in India – magnitude of the problem. Nephrol Diab Transplant 1999;14:2805-7.
31. Willett W, Manson J, Liu S. Glycemic index, glycemic load and risk of type 2 diabetes. Am J Clin Nutr 2002;76:274S-80.
32. Xia Z, Gua Z, Nagareddy PR, Yuen V, Yeung E, McNeill JL. Antioxidant N-acetylcysteine restores myocardial Mn-SOD activity and attenuates myocardial dysfunction in diabetic rats. Eur J Pharmacol 2006;544:118-25.

Source of Support: Nil, **Conflict of Interest:** None declared