Health Implications of the Glycemic Index, Glycemic Load and Elemental Constituents of a Commonly Consumed Mixed Food in Nigeria

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Abstract

Background*: The work involves the determination of the glycemic index, glycemic load and mineral constituents of a commonly consumed mixed diet that are significant in diabetic and good health management.* ***Objectives****: Literature is scarce on the glycemic index, glycemic load and the mineral elements of the popular mixed diet of 'garri' and tilapia fish commonly consumed in Nigeria. The paper therefore aims to fill this gap.* ***Methods:*** *Twenty healthy individuals were subjected to overnight fast for a minimum of 12 hours (10 control and 10 test subjects).The glycemic index was determined by making use of the mean of 10 healthy individuals who were fed with 50g carbohydrate equivalent of the test food and their postprandial responses were measured with a standardized glucometer. The 10 controls were treated as the test subjects but were fed with 50g of powered glucose. The glycemic index and glycemic load for test food were calculated by making use of standard methods. The proximate analysis of the test food was also determined by standard methods. The elemental constituents of the test food were determined with an Inductively Coupled Plasma Mass Spectrophotometer. The results were analyzed by using ANOVA and expressed as mean ±SEM of duplicate determinations.* ***Results:*** *The results indicate that the GI and GL of the test food were 62 and 35 respectively, the proximate analysis showed that the nutrient compositions ranged between 1.21±0.0 (fiber) and 55.74±5.73% (carbohydrate), and the elemental constituent concentrations ranged between 0.17±0.02mg/kg (cadmium) and 5990.26±119.19mg/kg (calcium) respectively.* ***Conclusion:*** *The mixed food has a medium glycemic index and a high glycemic load and could be consumed by non-diabetics and diabetics. In additionthe 20 elements detected are needed in the daily dietas they play significant roles in human physiology and metabolism.*

Keywords

Glycemic Index, glycemic load, proximate analysis, carbohydrate, elements.

I. INTRODUCTION

Glycemic index (GI) is a relative scale for classifying foods according to the blood sugar response that they cause.[1]The Low GI carbohydrate (CHO) food is classified as being digested and absorbed slowly and highGI CHO food as being rapidly digested and absorbed[2] resulting in different glycemic responses[3]. The concept of glycemic index (GI) was developed to help diabetic patients with blood glucose control when it was evident that high-GI food consumption was associated with an increased risk of type 2 diabetes mellitus (type 2 DM)[4] obesity, cardiovascular diseases, and some cancers[3, 5, 6].

Cassava ***(****Manihotesculentacrantz)* grows well in a tropical climate and is an important root crop in Pacific Island countries, Latin America, Africa and regions of Asia. Cassava is grown for its enlarged starch-filled roots, which contains about 30% starch and very little protein. A wide variety of foods are produced from cassava by fermentation, viz*garri, fufu,lafun, attieke, farinha de rnadioca*, to mention a few[7]. 'Garri,' fermented gelatinous granular flour, is a major source of dietary energy for most consumers in many parts of tropical Africa, including major urban areas and is regarded as one of the slowly digested and absorbed carbohydrates[8]. 'Garri' is a granulated white or yellowish product, depending on production methods, and it is a dehydrated, staple food, consumed raw or cooked [9].

Tilapia fish *(Oreochromisniloticus*) is a very important source of animal protein in the diets of man.Tilapia can be found in lakes, wetlands, marine habitats, water courses, estuaries, and marine environments. Several methods are used for the preservation of fish in order to extend its shelf-life. The methods include drying, salting and smoking.[10] Smoked or dried fish is a traditional part of the diet of a large section of the world's population.[11] The nutritional constituents of dried tilapia fish and its

parts are beneficial to man as regards weight loss, bone health, prevention of prostate cancer, heart health and brain health. The iodine in fish prevents goiter or enlargement of thyroid glands. The hormone thyroxin produced from dietary iodine regulates several body processes.

Recently, the research into the GI and GL of single foods started in Nigeria with less attention on mixed-foods or diets. Additionally, minerals play significant roles in the body for construction and maintenance of bones and normal function of nerves and muscles. Though minerals do not contribute energy to the body, they are essential in physiological processes which are important to life.[12] There is limited information on the elemental contents in mixed foods like garri and tilapia fish that is commonly consumed in Nigeria. It has been well documented that minerals play significant rolesin health and diseases states of man and domestic animals. Twenty-one elements were assayed for in the mixed food. The results indicate that the elements were in varied concentrations. This paper is therefore designed to provide the GI, GL and the elemental constituents of a mixed-food that is commonly consumed in Nigeria and relate the results and findings to its health implications in humans.

II. METHODOLOGY

A. Sample Collection

The raw samples - cassava and tilapia fish - used for this study were purchased from a popular market called New Benin Market inBenin City, Edo state, Nigeria.

B. Preparation of Powdered Cassava ('garri')

The cassava tubers were peeled and grated after washing and rinsed with deionized water. The grated cassava was tied in a porous bags and the liquid portion was drained out by the application of pressure. Theprocess of pressure application was stopped when the water stopped draining out of the bag that contained the grated cassava. The partially dried and grated cassava was sieved and roasted in an aluminum shallow basin by the application of heat to powdered cassava ('garri'). After roasting the powdered 'garri' was allowed to cool in a dry tray.

C. Preparation of smoked tilapia fish

Fresh tilapia fish was washed and dried on wire gauze on a fireplace with semi wet fire wood underneath it for two days and was dried partially in the form in which they are sold and eaten. This product is called "smokedfish" in Nigeria. Thereafter, the smoked fish was wrapped with aluminum foil to prevent the absorption of moisture.

D. Preparation of mixed food

The mixed food was prepared by weighing the 'fried garri' and the smoked tilapia fish in a ratio of 1:1 to yield a total of 50g.

E. Proximate Analysis of themixed food

The methods described by the Association of Official Analytical Chemists (AOAC)[13] were adopted for the determinations of the moisture, lipid, ash, crude protein, crude fiber, and the carbohydrate contents of the mixed food.

F. Elemental Analysis of the mixed food

The elemental constituents of the mixed food were analyzed for with an inductively Coupled Plasma Mass Spectrophotometer as described bySahan et al[14,15].

G. Determination of blood glucose

Twenty (20) university undergraduates from whom informed consent had been obtained were the subjects. After an overnight fast of 12 hours the 10testsubjects were served the quantity of the mixed food that gave 50g of carbohydrate equivalent when consumed. The 10 control subjects were served 50g of pure glucose. These meals were served along with demineralizedwater to aid swallowing and rinsing of the mouth into the stomach in order that the weighed diet was totally administered.Thereafter, their blood samples were collected by pricking the finger with a lancet and the blood sample was placed on a test strip and inserted into a calibrated glucometer which gave direct reading after some seconds. The fasting blood sugar (FBGS) levels(0minute) were determined before the feeding commenced and the postprandial blood sugar levels of the subjects were taken at 30minute intervals, that is, 30, 60, 90,120 and 150 minutes.

H. GI and GL Calculations

The blood glucose values were used in the construction of curves for the individual control subjects and the test subjects. The trapezoidal rule described byJenkins et al[16] was used in the calculation of the incremental area under the blood glucose response curve(IAUC) for 50g carbohydrate of the test food and control food (glucose). The calculation of the GI was done by the method of Jenkins et al[16].The GI and GL were calculated with the formulae below:

GI = AUC for 50g carbohydrate from test food x 100

AUC for 50g carbohydrate from glucose

(AUC: area under the curve)

GL = Carbohydrate content per serving of food x GI

100

I. Statistical Analysis

The data collected were analyzed using ANOVA and all results are expressed as mean ±SEM of duplicate determinations.

III. RESULTS

The results of the proximate analysis,the elemental constituents, GI and GL of the mixed food are presented in Tables 1-3.

Table 1: Proximate analysis of the mixed food ('garri' and smoked tilapia fish)

Parameters determined	Mixed food of 'Garri' and Tilapia Fish (Mean)
Moisture (%)	13.20±2.69
Lipid (%)	11.59±1.04
Ash (%)	11.66 ±4.59
Protein (%)	19.80±4.80
Fiber (%)	1.21±0.01
Carbohydrate (%)	55.74±5.73

The proximate analysis results (Table 1)revealed that the mixed food contains moisture, lipid, fiber, ash, protein and carbohydrate in varied concentrations. The nutrient concentrations ranged from 55.74±5.73% (carbohydrate 1.21±0.01% (fiber).Additionally, the result showed that major nutrients required in a balanced diet are present in the mixed food. Besides, high concentrations of carbohydrates, proteins, fats and ash were detected in the mixed food.

Table 2: Elemental constituents of the mixed food

Elements Determined	Mean
Na (mg/kg)	3927.01±44.04
K (mg/kg)	5540.44±268.43
Pb (mg/kg)	0.52± 0.05
Cd (mg/kg)	0.17± 0.02
As (mg/kg)	29.60±11.02
Hg (mg/kg)	0.19±0.01
Co (mg/kg)	0.22±0.00
Ni(mg/kg)	6.74 ±0.85
Ba (mg/kg)	12.34±0.07
Fe (mg/kg)	385.74±9.08
Zn (mg/kg)	70.40 ±7.09
Cu (mg/kg)	3.18±0.21
P (mg/kg)	2327.48±173.36
Cr (mg/kg)	2.34±0.77
Sn (mg/kg)	1686.84±172.37
V (mg/kg)	49.20±2.82
Mg (mg/kg)	748.53±173.96
Ca (mg/kg)	5990.26±119.19
Al (mg/kg)	110.75±8.19
Se (mg/kg)	ND
Mn (mg/kg)	8.16±1.10

The minerals result of the mixed food (Table 2) revealed that 20 elements were detectable out of the 21 elements assayed for. The detected elements were in varied concentrations.Calcium had the highestconcentration(5990.26±119.19mg/kg) while the least concentration was in cadmium (0.17± 0.02mg/kg).Selenium was the only element that was not detectable in the mixed food.Overall, the elements detected have a role to play in human health as discussed hereunder.

The glycemic index and load of the individual subjects are as presented in Table 3. Additionally, the average glycemic index and glycemic load of ten test subjects and ten controls are also shown on the same Table 3, being 62 and 35 respectively.

Table 3: Glycemic Index and Glycemic Load of the Mixed Food

	Glycemic Index	Glycemic Load
Mean	62	35

Figures 1-10 show the postprandial responses of the test subjects and the controls

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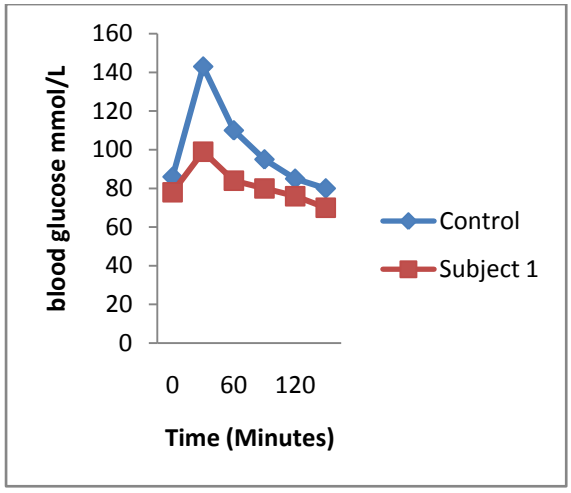

Fig.1: Postprandial response of mixed food for Subject 1 and the Control

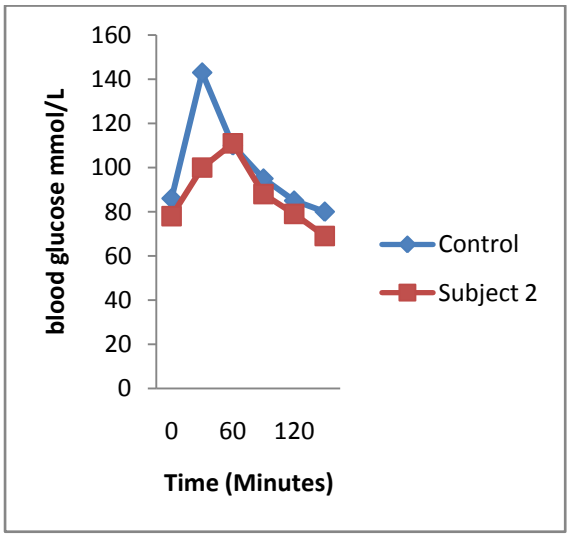

Fig.2 : Postprandial response from mixed food for Subject 2 and the Control

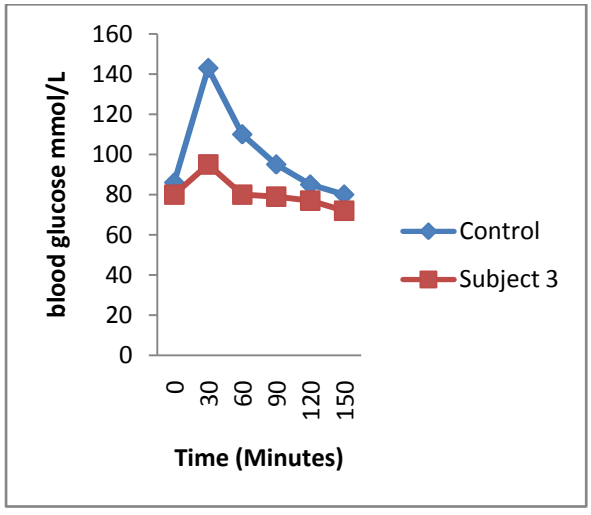

Fig.3: Postprandial response of mixed food for Subject 3 and the Control

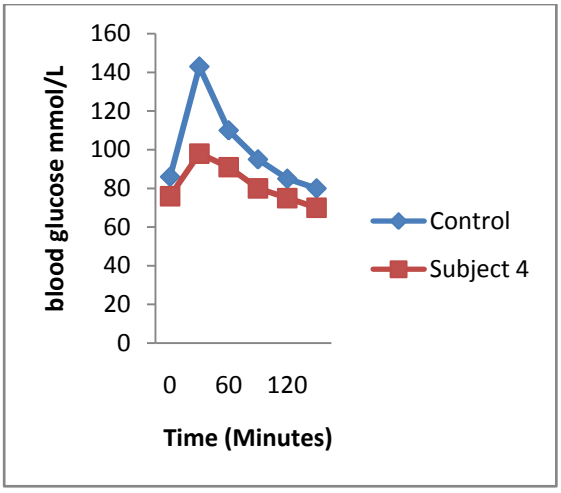

Fig.4:Postprandial response of mixed food for Subject 4 and the Control

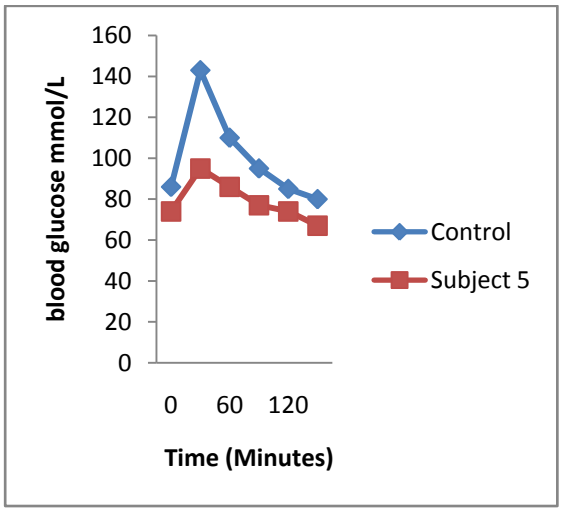

Fig. 5:postprandialresponse of mixed food for Subject 5 and the Control

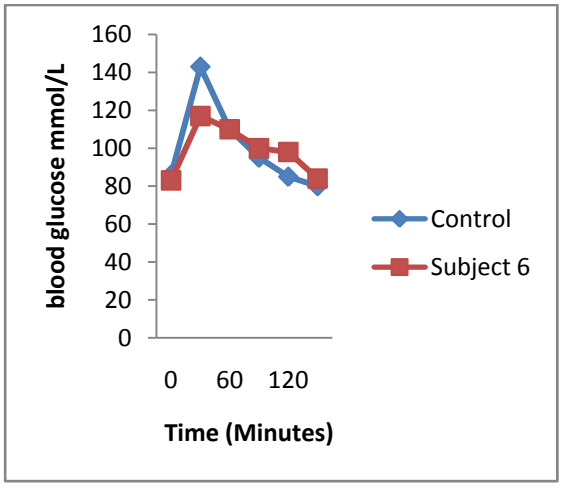

Fig. 6: postprandialresponse from mixed food for Subject 6 and the Control

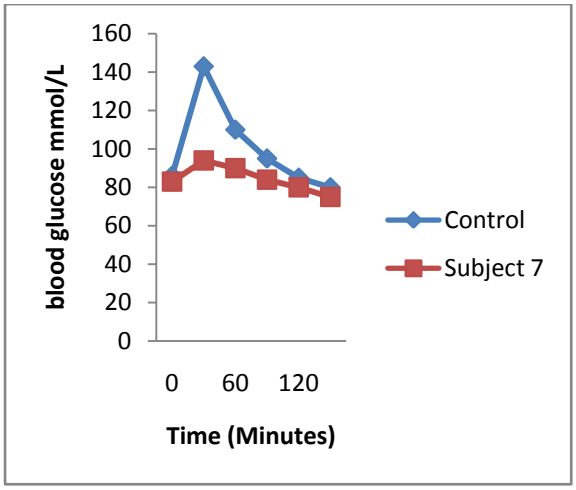

Fig.7: Postprandialresponse of mixed food for Subject 7 and the Control

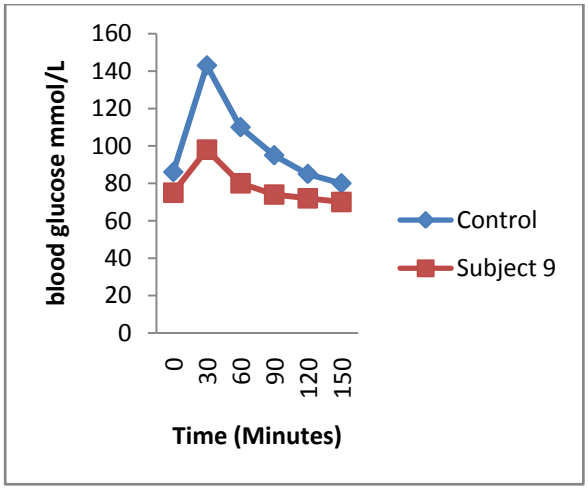

Fig. 9: Postprandialresponse of mixed food for Subject 9 and the Control

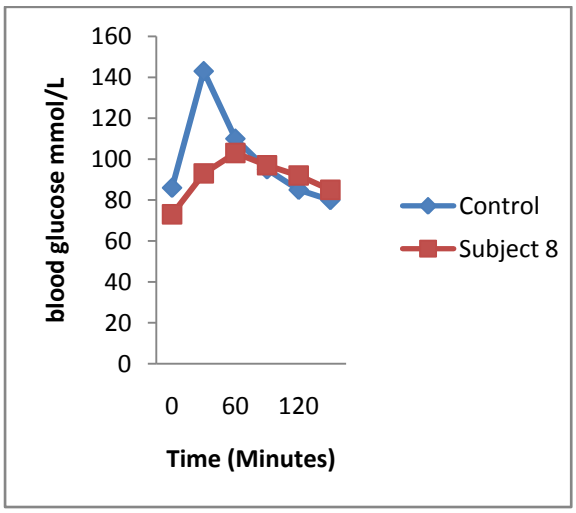

Fig. 8: Postprandialresponse from mixed food for Subject 8 and the Control

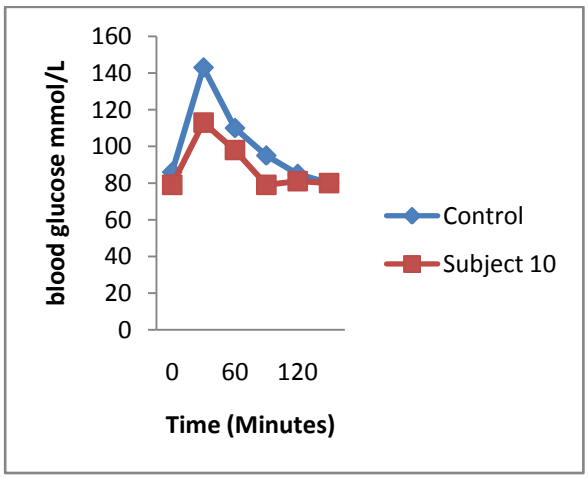

Fig. 10: Postprandialresponse of mixed food for Subject 10 and the Control

IV. DISCUSSION

The results can be linked to the factors that influence the glycemic index and glycemic load of foods. These factors include the physical form of the food, methods of preparationandthe duration and intensity of heatand moisture applied[17]. Additionally, the other factors include the type of starch present in the food, theco-ingested protein, fiber and fat[18,19].

During the administration of the test food ('garri' and "smoked" tilapia fish) they were chewed by the subjectsfollowed by the drinking and rinsing of the mouth with 300ml of demineralized water(in order not to increase the mineral contents of the mixed food that were also analyzed). The chewing obviously assisted in the reduction of theirparticle sizes and increased their surface area of exposure, thus facilitating the speedy action of the salivary amylase in the mouth that started the digestion of the available carbohydrates[20].Themoderate absorptionof the carbohydratereached its peak within 30minutes of consumption as shown in the figures. Thereafter, the effects of the other components in the mixed diet like fats, proteins, fiberetc. caused the drop in the postprandial response as shown in all the figures.

In a high glycemic index single diet the absorption is always rapid and high[21]. The rate of entry of glucose into the blood stream and duration of the elevation of the glucose could cause several hormonal and metabolic changes that could affect human health and consequently the disease parameters [22].

The mean results for the GI and GL were 62 and 35 respectively. The G1 of this mixed food by the standard rating is of mediumvalue [23].Arising from the increasing rate of diabetes the application of dietary management has become significant in its therapy. The management of this disorder has thus gone

beyond the traditional departure from carbohydrate foods with simple sugars (mono and disaccharides) and the increased consumption of complex carbohydrates and fibre.[24] In the management of this disease condition, with the knowledge of the glycemic index of a single diet like 'garri' which is rated medium or high depending on the processing and preparation methods,[25]it could now be consumed in combination with a high protein and fat food like the tilapia fish as shown in this study. 'Garri' is known to contain minute amounts of protein[26]with high carbohydrate and fiber constituents and hence diabetics have been advised not to consume it.The benefits of Chromium, one the essential micro-elements detected in the mixed food had been reported as capable of playing very important roles in the maintaining and regulating proper levels of carbohydrate, lipid metabolism and enhancing insulin signaling[27,28]. One the roles of this element as stated above should have played a contributory role to the postprandial response reported in this work.

The other elements detected and reported hereunder should thus not be regarded as reviews of these elements but rather as a pointer to their contributory roles to human physiological activities whenever this mixed food is consumed. The concentrations of the elements detected were within the permissible levels for the daily dietary intake.

A. Iron

Iron plays a key roles in many biological reactions. It is present in several enzymes responsible for electron transport (cytochromes), for activation of oxygen and oxygen transport (hemoglobin, myoglobin). It is also an essential cofactor in the synthesis of neurotransmitters such as dopamine, norepinephrine and serotonin.The deficiency of iron results in a disease knownas anemia .Additionally, iron plays significant role in the triacarboxylic acid cycle (TCA), as the 24 enzymes in the cycle use iron either at their active sites or as cofactor.[29,30]

B. Zinc

Though zinc is essential in the diet of humans, too little zinc intake can cause health problems, just as too much intake is harmful. Hypogonadism, growth failure, impaired wound healing and decreased taste and smell acuity are part of the deficiency disease of zinc[29].

C. Copper

In human cells, copper is involved in a number of biochemical reactions. Wilson's disease is a genetic disorder in which the body cannot rid itself of copper, thus resulting in deposition in organs and serious consequences, such as liver failure and neurological damage. Copper is necessary for the hematologic and neurologic system. In human nutrition, copper is required for cellular respiration, bone formation, proper cardiac function etc.Deficiency of copper could cause anaemia andMenke's disorder[31].

D. Calcium

Calcium, like phosphorus forms the major part of the mineral content of bone. Calcium is very abundant in the human body. Non-skeletal calcium plays important roles in a wide variety of essential functions in body metabolism[29]. Calcium exists in two forms that have quite different functions. Most of the calcium in the body is found as calcium phosphate crystals in the bones and teeth, forming the cement that contributes to the physical strength of these structures. Calcium is also found in an unbound ionic form (Ca^{2+}) that performs critical functions in muscle concentration, nerve impulse transmission, ion transport, and transmission of signals across membranes [32]. Reduction in the extracellular blood calcium increases the irritability of nerve tissue and very low levels may cause spontaneous discharges of convulsions.[33]

E. Magnesium

Magnesium has many diverse physiological functions. It is essential for the integrity of bones and teeth. It is the second most plentiful cation after potassium. Magnesium is an active components of several enzymes systems in which thiamine pyrophosphate (TPP) is a cofactor[32]. It also plays a significant role as an activator of enzymes [29]. Additionally, magnesium plays active roles in protein synthesis and in neuromuscular transmission. Toxicity diseases in humans include depressed deep tendon reflexes and respiration [31].

F. Manganese

It has been reported that if some minor elements like manganese occur above certain limits, they become hazardous to health or impact sensory effect to water and thus makes it objectionable to the consumer. Additionally, manganese toxicity in humans is associated with several psychiatric disorders (LocuraMarganica) resembling Schizophrenia, followed by a permanently crippling neurological disorder clinically similar to Parkinson's disease [32]. The element can function both as an enzyme activator and as a constituent of metalloenzymes, like other essential trace elements.

G. Phosphorus

This element is found in every cell of the body and is involved in every metabolic process in man e.g. buffers in the body [34]. The deficiency syndrome includes rickets and hyperparathyroidism. Increase in serum phosphorus is associated with chronic nephritis and hypoparathyroidism. Toxicity results in low serum Ca^{++}: P ratio and perhaps bone loss[32, 35] etc.

H. Sodium

Sodiumhas been documented as the principal cation in the extracellular fluid. It functions in the regulation of plasma volume and acid-base balance, osmotic pressure of the body fluids, etc.[32]. Excessive levels of sodium is called hypernatremia and is positively associated with Cushing's disease, etc.[35]. Decreased levels of sodium in the serum is hyponatremia and is associated with Addison's disease, vomiting, diarrhea, nephrosis, severe burns and intestinal obstruction.[35]. Individuals that are susceptible may be hypertensive at toxicity levels of sodium.

I. Potassium

Like sodium, K functions in the regulation of osmotic pressure but it is the principal cation in intracellular fluid and is also involved in the acid-base balance. Potassium functions in several pathways particularly in nerve impulse transmission, muscle contractions, cell membrane function and Na^+/K^+ - ATPase etc. An Increased level of K is hyperkalemia and is associated with Addison's disease, advanced chronic renal failure, etc. Deficiency symptoms are evident in functional and structural abnormalities, muscle weakness, paralysis, and mental confusion[34].

J. Cobalt

It is a constituent of vitamin B_{12} and serves as a cofactor in enzymes associated with DNA biosynthesis and amino acid metabolism[36]. It is readily absorbed in the bloodstream and excreted in the urine primarily. The toxicity symptoms in humans include vitamin B_{12} deficiency, goiter, hypothyroidism and heart failure[32].

K. Selenium

It is associated with glutathione peroxidase, being a constituent [32]. It is also involved as a constituent element of the entire defense system that protects the living organism from the harmful action of free radicals. Selenium and vitamin E work as antioxidants in the body system.It protects from oxidative damage to cell membranes bydestroying H_2O_2. Selenium is involved in the metabolic role of glutathione.

L. Nickel

Authors have reported that the dietary intake from food could be enough to meet the recommended daily dietary allowances for nickel since it is needed in minute quantities [37].

M. Vanadium

It has been shown that this element positively affects the metabolism of glucose and lipids[38,39].The element has roles in biological activities like effects on ribonuclease, alkaline phosphatase, adenyl cyclase, NADH oxidase and phosphofructokinase[40].

N. Cadmium

This element accumulates in the human body and especially in the kidneys, thus resulting in the dysfunction of the kidneys with impaired reabsorption of, for instance proteins, glucose, and amino acids.Skeletal damage(osteoporosis)arising from long termtoxicity has also been reported. Disturbances in metabolism, hypercalciuria and formation of renal stones have been positively linked to long-termcadmium exposure.In addition, the role of diet in absorption and toxicity of oral cadmium have been reported. **[41]**

O. Lead

The toxicology effects of lead are well reported in literature and lead is most intensively studied as a toxicant. Numerous effects of lead on humans have been documented and include studies in neurotoxicity/developmental effects [33].

V. CONCLUSION

In conclusion, the findings suggest that the mixed food could be consumed by both nondiabetic and diabetic individuals. Additionally, the result agrees with earlier findings that the addition of fats and proteins to carbohydrate foods reduces the postprandial responses. These effects have a number of possible implications for human nutrition such as supporting the roles of high protein and fat diets for the management of diabetes. The elements detected play significant roles in the human body either as structural components of organs and tissues or they are involved in biochemical reactions (metabolism) in humans, serving numerous functions as cofactors in enzymes, and in the regulation of acid-base balance in body fluids. Besides, each of the elements detected in the mixed food are required in specific amounts to meet the recommended dietary intakes in man for healthy living.

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