LEGUMES AS A DIETARY APPROACH IN COMBATING HYPERGLYCEMIA: A REVIEW.

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Abstract: Diabetes mellitus, a global public health problem, is now emerging as an epidemic over the world. Nigeria is the leading country in Africa in terms of the number of people with diabetes, 3.9 million had diabetes with 105,091 diabetes‑related deaths in 2013 which is estimated to increase annually by 125,000 between 2010 and 2030 and in addition, there are still about 1.8 million Nigerians with undiagnosed diabetes in 2013. Oxidative damages in people suffering from diabetes can be reduced by intake of antioxidants, but butylated hydroxyanisol (BHA) and butylated hydroxytoluene (BHT) could have adverse side effect in human because they are synthetic compounds. Since most people are skeptical about the likely adverse effects of prolonged consumption of synthetic antioxidants, natural antioxidant of plant origin is becoming very popular. The use of low-glycemic index (GI) diets (comprising of legumes) in the management of diabetes has been recommended around the world. Physical exercise, along with diet, has forms an effective combination for the prevention of DM. Legumes form an important part of our diet on account of their nutritive value. Several studies implicate legumes in the prevention and treatment of DM. Hence, this paper reviews different legume grains that have been shown to possess anti-diabetics properties.

Key words: Diabetes mellitus, Nigeria, Glycemic index, Lifestyle, Diet and Legumes,

INTRODUCTION

Diabetes mellitus (DM) was first recognized as a disease around 3000 years ago by the ancient Egyptians and Indians, illustrating some clinical features very similar to what we now know as diabetes (Frank, 1957) DM is a combination of two words, “diabetes” Greek word derivative, means siphon - to pass through and the Latin word “mellitus” means honeyed or sweet. In 1776, excess sugar in blood and urine was first confirmed in Great Britain. (Reece and Hanko, 1998; Ahmed, 2002) with the passage of time, a widespread knowledge of diabetes along with detailed etiology and pathogenesis has been achieved. Diabetes mellitus, a global public health problem, is now emerging as an epidemic over the world. According to a widely accepted estimation, the prevalence of diabetes for all age groups was 2.8% in 2000, and the number of patients with diabetes is expected to reach 4.4%, i.e., 366 million by the year 2030 (Wild *et al.,* 2004). Currently, Sub‑Saharan Africa is estimated to have 20 million people with diabetes, about 62% are not diagnosed and the number is expected to reach 41.4 million by 2035 or an increase of 109.1%. Nigeria has the highest number of people with diabetes with an estimated 3.9 million people (or an extrapolated prevalence of 4.99%) of the adult population aged 20–79‑year‑old (World Health Assembly, 2013). Further, in terms of morbidity, diabetes contributes to the development of heart disease, renal disease, pneumonia, bacteremia, and tuberculosis (TB) (Saydahosti, 2002; Thomson *et al.,* 2004; Thomson *et al.,* 2005; Kornum *et al.,* 2008; Jeon and Murry, 2008; Hall *et al.,* 2011) It is known that people with diabetes are 3 times more likely to develop tuberculosis and approximately 15% of TB globally is thought to have background diabetes as a predisposing factor. This situation of the double burden of disease particularly in developing countries put diabetes to compete for resources as well as political commitment (Jeon and Murry, 2008). Studies conducted in Nigeria indicated that the prevalence of diabetes ranged from low level of 0.8% among adults in rural highland dwellers to over 7% in urban Lagos with an average of 2.2% nationally (Olatunbosun *et al.,* 1998).

Atlas, shows that Nigeria is the leading country in Africa in terms of the number of people with diabetes, 3.9 million had diabetes with 105,091 diabetes‑related deaths in 2013 which is estimated to increase annually by 125,000 between 2010 and 2030 even though the prevalence of 4.99% is far less than that of Reunion (15.38%), Seychelles (12.11%), Gabon (10.71%), Zimbabwe (9.73%), and South Africa (9.27%); in addition, there are still about 1.8 million Nigerians with undiagnosed diabetes in 2013 (International Diabetes Federation, 2013). DM can be of three major types, based on etiology and clinical features. These are DM type 1 (T1DM), DM type 2 (T2DM), and gestational DM (GDM). In T1DM, there is absolute insulin deficiency due to the destruction of β cells in the pancreas by a cellular mediated autoimmune process. In T2DM, there is insulin resistance and relative insulin deficiency. GDM is any degree of glucose intolerance that is recognized during pregnancy. DM can arise from other diseases or due to drugs such as genetic syndromes, surgery, malnutrition, infections, and corticosteroids intake. (Narayan *et al.,* 2006; Whiting *et al.,* 2011).T2DM factors which can be irreversible such as age, genetic, race, and ethnicity or revisable such as diet, physical activity and smoking (Shaw, 2010). Globally, T2DM is at present one of the most common diseases and its levels are progressively on the rise. It has been evaluated that around 366 million people worldwide or 8.3% in the age group of 20-79 years had T2DM in 2011.This increased oxidative stress is accompanied by a decreased antioxidant capacity. During the development of Type 2 diabetic mellitus, abnormalities in lipid and carbohydrate metabolism lead to increased oxidative stress which gives rise to high blood sugar level (Palanisamy *et al.,* 2011). Breaking down of starch by pancreatic α-amylase and absorption of glucose by intestinal α-glucosidase lead to risen blood glucose level that causes Type 2 diabetes. Increase in lipids or lipoprotein leads to hyperlipidemia and could lead to oxidative stress (Rotimi *et al.,* 2013). It has been documented that hyperlipidemia and hyperglycemia exist together in people suffering from diabetes (Rotimi *et al.,* 2013). Oxidative damages in people suffering from diabetes can be reduced by intake of antioxidants (Edziri 2012), but butylated hydroxyanisol (BHA) and butylated hydroxytoluene (BHT) could have adverse side effect in human because they are synthetic compounds. Since most people are skeptical about the likely adverse effects of prolonged consumption of synthetic antioxidants, natural antioxidant of plant origin is becoming very popular (El-Mawla and Husam 2011).

Diabetes Prevention Program Research Group 2002 remind us that nutrition and lifestyle approaches can be more effective in delaying the onset of this disease. Dietary therapy especially has a bright future in the management of T2DM. Currently, the American Diabetes Association (ADA) recommends the use of diabetes food pyramid for T2DM patients. The use of low-glycemic index (GI) diets (comprising whole-grain cereals and legumes) in the management of diabetes has been recommended around the world (Wolever *et al.,* 1992; Brand-Miller *et al.,* 2003; Canadian Diabetes Association, 2008). Physical exercise, along with diet, forms an effective combination for the prevention of DM (Eriksson and Lindgiirde 1991). Since diet forms the mainstay in the management of DM, there is an urgent need to exploit plant food materials possessing hypoglycemic activity for a possible beneficial use. Legumes form an important part of our diet on account of their nutritive value. Several studies implicate legumes in the prevention and treatment of DM. Hence, with this background, this paper reviews different legume grains that have been shown to possess anti-diabetics properties.

1.1 RELATION BETWEEN DIET AND HYPERGLYCEMIA

The role of diet in the etiology of T2DM was proposed by Indians as mentioned earlier, who observed that the disease was almost confined to rich people who consumed oil, flour, and sugar in excessive amounts (Seidell, 1998). During the First and Second World Wars, declines in the diabetes mortality rates were documented due to food shortage and famines in the involved countries such as Germany and other European countries. In Berlin, diabetes mortality rate declined from (Parimala *et al.,* 2015) 1/100,000 in 1914 to 10.9 in 1919. In contrast, there was no change in diabetes mortality rate in other countries with no shortage of food at the same time period such as Japan and North American countries.(Lumey *et al.,* 1944) Whereas few studies have found strong association of T2DM with high intake of carbohydrates and fats. Many studies have reported a positive association between high intake of sugars and development of T2DM (Khatib *et al.,* 2014). In a study, Ludwig (Ludwig *et al.,* 2001) investigated more than 500 ethnically diverse schoolchildren for 19 months. It was found that for each additional serving of carbonated drinks consumed, frequency of obesity increased, after adjusting for different parameters such as dietary, demographic, anthropometric, and lifestyle. A study was conducted which included the diabetic patients with differing degrees of Glycemic control. There were no differences in the mean daily plasma glucose levels or diurnal glucose profiles. As with carbohydrates, the association between dietary fats and T2DM was also inconsistent. (Peterson *et al.,* 2001) many of prospective studies have found relations between fat intake and subsequent risk of developing T2DM. It was also stated by (Assy *et al.,* 2008) that diet soft drinks contain glycated chemicals that markedly augment insulin resistance. Food intake has been strongly linked with obesity, not only related to the volume of food but also in terms of the composition and quality of diet (Amin *et al.,* 2008). High intake of red meat, sweets and fried foods, contribute to the increased the risk of insulin resistance and T2DM (Panagiotakos *et al.,* 2005). In contrast, an inverse correlation was observed between intake of vegetables and T2DM. Consumption of fruits and vegetables may protect the development of T2DM, as they are rich in nutrients, fiber and antioxidants which are considered as protective barrier against the diseases (Villegas *et al.,* 2008). Recently, in Japanese women, a report revealed that elevated intake of white rice was associated with an increased risk of T2DM (Nanri *et al.,* 2010). This demands an urgent need for changing lifestyle among general population and further increase the awareness of healthy diet patterns in all groups.

1.2 Hyperglycemia; Physical Activity and Lifestyle

The existing evidence suggests a number of possible biological pathways for the protective effect of physical activity on the development of T2DM. First, it has been suggested that physical activity increases sensitivity to insulin. In a comprehensive report published by Health and Human Services, USA, 2015 reported that physical activity enormously improved abnormal glucose tolerance when caused by insulin resistance primarily than when it was caused by deficient amounts of circulating insulin. (Charokopou *et al.,* 2015) Second, physical activity is likely to be most beneficial in preventing the progression of T2DM during the initial stages, before insulin therapy is required. The protective mechanism of physical activity appears to have a synergistic effect with insulin. During a single prolonged session of physical activity, contracting skeletal muscle enhances glucose uptake into the cells. This effect increases blood flow in the muscle and enhances glucose transport into the muscle cell. (Tucker and Palmer, 2011) third, physical activity has also been found to reduce intra-abdominal fat, which is a known risk factor for insulin resistance. In certain other studies, physical activity has been inversely associated with intra-abdominal fat distribution and can reduce body fat stores. (Cole *et al.,* 1998) Lifestyle and environmental factors are reported to be the main causes of extreme increase in the incidence of T2DM. (Danaei *et al.,* 2011)

2.0 Dietary Therapy for DM Management

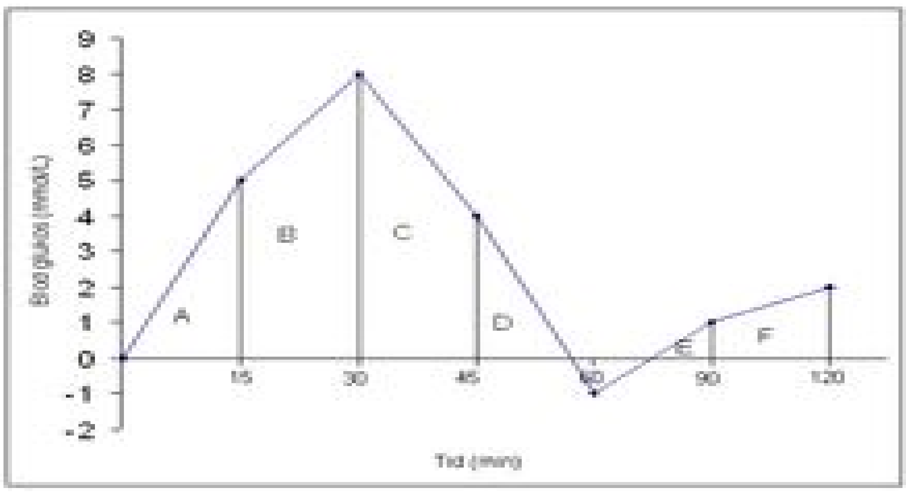
Dietary therapy especially has a bright future in the management of T2DM. Currently, the American Diabetes Association (ADA) recommends the use of diabetes food pyramid for T2DM patients. The use of low-glycemic index (GI) diets (comprising whole-grain cereals and legumes) in the management of diabetes has been recommended around the world (Wolever *et al.,* 1992; Brand-Miller *et al.,* 2003; Canadian Diabetes Association, 2008). Physical exercise, along with diet, forms an effective combination for the prevention of DM (Eriksson and Lindgiirde 1991). Since diet forms the mainstay in the management of DM, there is an urgent need to exploit plant food materials possessing hypoglycemic activity for a possible beneficial use. Legumes form an important part of our diet on account of their nutritive value. Several studies implicate legumes in the prevention and treatment of DM This paper reviews different legume grains that have been shown to possess anti-diabetics properties.

2.1 Glycemic Index

The glycemic index (GI) (Zeevi *et al.,* 2015) is a number from 0 to 100 assigned to a food, with pure glucose arbitrarily given the value of 100, which represents the relative rise in the blood glucose level two hours after consuming that food (Zeevi *et al.,* 2015). The GI of a specific food depends primarily on the quantity and type of carbohydrate it contains; but also is affected by the amount of entrapment of the carbohydrate molecules within the food, the fat and protein content of the food, the amount of organic acids (or their salts) in the food, and whether it is cooked and if so how it is cooked. A food is considered to have a low GI if it is 55 or less; high GI if 70 or more; and mid-range GI if 56 to 69. It takes into account only the available carbohydrate (total carbohydrate minus fiber) in a food. Glycemic index does not predict an individual's glycemic response to a food, but can be used as a tool to assess the insulin response burden of a food, averaged across a studied population. Individual responses vary greatly (Brown *et al.,* 2015). The glycemic index is usually applied in the context of the quantity of the food and the amount of carbohydrate in the food that is actually consumed. A related measure, the glycemic load (GL), (Scheiner and Gary, 2013) factors this in by multiplying the glycemic index of the food in question by the carbohydrate content of the actual serving. A practical limitation of the glycemic index is that it does not measure insulin production due to rises in blood sugar. As a result, two foods could have the same glycemic index, but produce different amounts of insulin. Likewise, two foods could have the same glycemic load, but cause different insulin responses.

- **Measurement**

The glycemic index of a food is defined as the incremental area under the two-hour blood glucose response curve (AUC) following a 12-hour fast and ingestion of a food with a certain quantity of available carbohydrate (usually 50 g). The AUC of the test food is divided by the AUC of the standard (either glucose or white bread, giving two different definitions) and multiplied by 100. The average GI value is calculated from data collected in 10 human subjects. Both the standard and test food must contain an equal amount of available carbohydrate. The result gives a relative ranking for each tested food (Brown *et al.,* 2005). Foods with carbohydrates that break down quickly during digestion and release glucose rapidly into the bloodstream tend to have a high GI; foods with carbohydrates that break down more slowly, releasing glucose more gradually into the bloodstream, tend to have a low GI.



Graph describing blood sugar change after a meal.

A lower glycemic index suggests slower rates of digestion and absorption of the foods' carbohydrates and can also indicate greater extraction from the liver and periphery of the products of carbohydrate digestion. The current validated methods use glucose as the reference food, giving it a glycemic index value of 100 by definition. This has the advantages of being universal and producing maximum GI values of approximately 100. White bread can also be used as a reference food, giving a different set of GI values (if white bread = 100, then glucose ≈ 140). For people whose staple carbohydrate source is white bread, this has the advantage of conveying directly whether replacement of the dietary staple with a different food would result in faster or slower blood glucose response. A disadvantage with this system is that the reference food is not well-defined, because there is no universal standard for the carbohydrate content of white bread.

- **Accuracy**

Glycemic index charts often give only one value per food, but variations are possible due to

- **Ripeness** - riper fruits contain more sugars, increasing GI
- **Cooking methods** - the more cooked, or over cooked, a food, the more its cellular structure is broken, with a tendency for it to digest quickly and raise blood glucose more
- **Processing** - e.g. , flour has a higher GI than the whole grain from which it is ground as grinding breaks the grain's protective layers) and the length of storage. Potatoes are a notable example, ranging from moderate to very high GI even within the same variety. (Freeman and Janine, 2005)

More importantly, the glycemic response is different from one person to another, and also in the same person from day to day, depending on blood glucose levels, insulin resistance, and other factors. (Freeman and Janine, 2005)

❖ **GROUPING**

GI values can be interpreted intuitively as percentages on an absolute scale and are commonly interpreted as follows:

- Low 55 or less fructose ; beans (black, pinto , kidney , lentil, peanut , chickpea); small seeds (sunflower , flax, pumpkin , poppy, sesame , hemp); walnuts , cashews , most whole intact grains (durum/ spelt / kamut wheat, millet , oat , rye , rice , barley); most vegetables , most sweet fruits (peaches, strawberries, mangos); tagatose ; mushrooms ; chilis
- Medium 56–69 white sugar or sucrose , not intact whole wheat or enriched wheat , pita bread , basmati rice , unpeeled boiled potato, grape juice , raisins , prunes, pumpernickel bread , cranberry juice , regular ice cream , banana , sweet potato (Foster *et al.,* 2002)
- High 70 and above glucose (dextrose, grape sugar), high fructose corn syrup , white bread (only wheat endosperm), most white rice (only rice endosperm), corn flakes , extruded breakfast cereals , maltose , maltodextrins , white potato (Atkison *et al.,* 2008)

A low-GI food will cause blood glucose levels to increase more slowly and steadily, which leads to lower postprandial (after meal) blood glucose readings. A high-GI food causes a more rapid rise in blood glucose level and is suitable for energy recovery after exercise or for a person experiencing hypoglycemia. The glycemic effect of foods depends on a number of factors, such as the type of starch (amylose versus amylopectin), physical entrapment of the starch molecules within the food, fat and protein content of the food and organic acids or their salts in the meal – adding vinegar, for example, will lower the GI (Kirpitich and Maryuink, 2011). The presence of fat or soluble dietary fiber can slow the gastric emptying rate, thus lowering the GI. In general, coarse, grainy breads with higher amounts of fiber have a lower GI value than white breads (Atkison *et al.,* 2008). However, most bread made with 100% whole wheat or whole meal flour have a GI not very different from endosperm only (white) bread. (Atkison *et al.,* 2008) Many brown breads are treated with enzymes to soften the crust, which makes the starch more accessible (high GI). While adding fat or protein will lower the glycemic response to a meal, the differences remain. That is, with or without additions, there is still a higher blood glucose curve after a high-GI bread than after a low-GI bread such as pumpernickel.

3.0 LEGUMES AS ANTI-DIABETIC AGENTS

Legumes- the poor man's meat, are important sources of food proteins consumed all over the world (Duranti and Gius 1997). They are generally good sources of complex carbohydrates (namely dietary fibers) and are rich in proteins (18–25%), soybean being the exception, containing about35–43% proteins. They are also good sources of vitamin C, riboflavin, and niacin, especially the germinated legumes (Tharanathan and Mahadevamma, 2003). General information on legumes regarding their scientific name, common names, and major nutrients has been given in Table 1.Legumes are normally consumed after processing, which not only improves their palatability but also increases the bioavailability of nutrients, by inactivating phytic acid, trypsin inhibitors, and hemaglutinins, although resulting in some loss of water-soluble nutrients (Tharanathan and Mahadevamma,2003). Several reports claim that the inclusion of legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases.

3.1 Bioactive Components and Nutraceuticals of Legumes

In the past, legumes were consumed as the main staple foods in traditional dietary patterns; they are valuable sources of essential micronutrients and some important nutraceuticals.

Legumes are rich in high-biological value proteins, bioactive peptides and essential amino acids (Madar and Stark, 2002).Non-digestible carbohydrates and slowly digestible starch including dietary fiber, resistance starches and oligosaccharides (α-galactosides) are the most of carbohydrates of legumes (Tovar, 2000). Dietary fiber content of leguminous seeds was reported ranging from 8-27.5%(soluble fiber ranges 3.3-18.3%) of dry weight (Guillion and Champ, 2002).Other bioactive compounds such as functional fatty acids(linoleic acid, α-linoleic acid), isoflavones (daidzein,genistein, glycitein), phenolic acids, saponins, and phytic acid; some polyphenols including pelargonidin, cyanidin.

3.2 Potential Properties of Legumes in Glycemic Control

Legumes are considered a component of a healthy diet and there is much evidence showing that regular consumption of legumes has protective effects against obesity, type 2 diabetes, and cardiovascular diseases (Venn and Mann, 2004; Durenti, 2006).Various aspects of nutritional properties of legumes have been highlighted in the literatures; digestibility of main nutrients, colonic fermentation of oligosaccharides and resistance starch, as well as postprandial glycemic and insulinemic responses and effects of legumes on lipid and lipoprotein metabolism are the main of them (Madar and Stark, 2002; Guillion and Champ, 2002).Studies showed that a substantial replacement of rapidly digested dietary carbohydrate with legumes could improve glycemic control. A three-month dietary intervention in type2 diabetic patients showed that the low-glycemic index legume diet compared to the high wheat fiber diet had greater effect on reduction of HbA1c levels (-0.2%, 95% CI= -0.3%to -0.1%, $P<0.001$). A significant greater reduction in coronary heart disease risk score was also observed in the low-GI legume diet compared to the high wheat fiber diet (Jenkin *et al.,* 2012)).The α-amylase inhibitory peptides are one of the bioactive compounds in legumes and beans that reduce digestion and absorption of dietary carbohydrates, and modulate postprandial glycemic response; other bioactive peptides of grain legumes including the 7S globulin α´ chain and conglutin γ have unique properties to regulate lipid metabolism and normalize lipid and lipoprotein levels (Lopoz *et al.,* 2006). It is suggested insoluble fiber in legumes could attenuate the rate of digestion and absorption of carbohydrates, and subsequently reduce postprandial glycemia; intestinal production of short chain fatty acids through fermentation of resistance starch and indigestible carbohydrates is another potential mechanism could be explained anti-hypoglycemic effect of legumes (Higgins, 2012).

Table 1: General information on legumes

Macronutrients Scientific name	Common name	CHO (%)	Protein (%)	Fat (%)	Fiber (%)	Reference
Vigna unguiculata (Linn) Walp variety 'drum'.		64.87	19.63	2.97	2.22	(Olapoda *et al.,* 2017)
Cajanus cajan	Pigeon pea, Red gram	62.7	19.3	2.0	6.4	(Singh and Singh, 1992)
Lens culinaris	Lentils	56.4	20.6	2.15	6.83	(Almeida Costa *et al.,* 2006)
Pisum sativum	Garden pea	52.5	21.9	2.34	10.4	(Almeida Costa *et al.,* 2006)
Phaseolus lunatus	Lima bean	22.5	3.35	4.46		(Adeparusi, 2001)
Phaseolus vulgaris	Kidney bean	52.5	20.9	2.49	8.55	(Almeida Costa *et al.,* 2006)
Vicia faba	Broad bean	58	26	1–2	25	(US of Agriculture, 2001)
Glycine max	Soybean	35	36	19	17	(Mateos-Aparicio *et al.,* 2008)

3.3 Hyperglycemia Potential of Commonly Consumed Legumes

Currently, the role of legumes as therapeutic agents in the diets of persons suffering from metabolic disorders is gaining interest (Simpson *et al.,* 1981; Shehata *et al.,* 1988; Jang *et al.,* 2001). According to a recent report, these can be considered as Nutraceutical products with an immense potential to prevent metabolic disorders (Duranti, 2006). It is in this context that an attempt has been made to review the various food legumes which have been investigated in human and animal trials for their anti-diabetic potential and the mechanism of their action.

- ***Cajanus cajan:*** ***Pigeon Pea***

Pigeon pea (*Cajanus cajan*) is a woody perennial legume. This crop is important because of its diverse uses as food, medicine, and fuel. It is widely cultivated in India and Eastern and Southern Africa. Pigeon peas are an important staple in India, East Africa, and the Caribbean. About 90% of the world's supply is produced in the Indian subcontinent (Amarteifio et al.,2002). It contributes immensely to African diets because of its high protein content (20–28%) and palatability (Obizoba, 1991).

- ***Glycine max*: Soybean**

Soybean is a singular food because of its rich nutrient content. Soybean foods represent an excellent source of high-quality protein, are low in saturated fat, and are cholesterol-free, and contain oligosaccharides, dietary fibers, phytochemicals (especially isoflavones), and minerals (Mateos-Aparicio *et al.,* 2008). In October 1999, the US Food and Drug Administration (FDA) approved a health claim that allowed food label claims for reduced risk of heart disease on foods that contain ≥6.25 g of soybean protein per serving. In particular, a daily soybean protein intake of 25 g was considered beneficial, based on a number of previous clinical observations (Duranti, 2006). There are numerous studies and clinical trials indicating soybean as an ideal vegetable protein in the prevention of diabetes, cardiovascular disease, cancer, etc.

- ***Phaseolus lunatus*: *Lima Bean***

Lima bean has desirable agronomic and nutritional characteristics. It is widely available and thrives in lowland tropical in forest areas and on poor soils where most crops cannot grow well. However, like other tropical legumes, lima bean seed contains some anti-nutritional factors such as phytins and tannins, hydrogen cyanide, and trypsin inhibitors that get destroyed upon cooking (Akinmutimi and Ezea, 2006).

- ***Phaseolus vulgaris*: *Kidney Bean***

Kidney bean (*Phaseolus vulgaris* L.) is the most widely producedand consumed food legume in Africa, India, Latin America and Mexico (Food and Agriculture Organization, 1993). It is an excellent source of proteins (20–25%) and carbohydrates (50–60%) and a fairly good source of minerals and vitamins. However, its wide acceptability is adversely affected by the presence of tannins, saponins, and other antinutritional substances, but the destruction of these antinutritional substances in cooked forms increases its consumption as well (Rehman *et al.,* 2001).Consumption of the bean in the normal Guatemala diet has been associated with a low glycemic response, low serum cholesterol levels, and a decrease of colon cancer risk factors (Serrano and Goi, 2004).

- ***Pisum sativum*: *Garden Pea***

Peas are important food legumes, with a world production exceeded only by soybeans, peanuts, and dry beans. For both humans and animals, dry pea seeds are a potentially rich source of protein and carbohydrates (Adsule *et al.,* 1989).

4.0 CONCLUSION

With increasing development and affluence, the changes in lifestyle and dietary habits have resulted in increasing incidences of lifestyle diseases such as T2DM, especially in the developing countries. The disease has an enormous burden in terms of diagnosis and treatment costs, and lifestyle approaches, including appropriate diet and exercise programs, are effective in managing this disease. Dietary intervention with a diet rich in legumes seems to be a natural, cost-effective, and free from side effects solution for the prevention and treatment of T2DM. It is concluded that the above-discussed legumes, which form a part of diet all over the world, possess anti-diabetic properties and help in lowering blood glucose levels and in maintaining blood cholesterol by increasing bile salt excretion.

REFERENCES

Almeida Costa, G.E, Queiroz-Monici K.D.S, Reis, S.M. and Oliveira A.C. (2006).Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. *Food Chemistry.* 94(3):327–330.

Amarteifio J.O, Munthali D.C, Karikari S.K. and Morake T.K. (2002). The composition of pigeon peas (*Cajanus cajan* (L.) Millsp.) grown in Botswana.*Plant Foods Human. Nutrition.*57:173–177.

Amin T.T, Al-Sultan A.I, Ali A. (2008). Overweight and obesity and their association with dietary habits, and sociodemographic characteristics among male primary school children in Al Hassa, Kingdom of Saudi Arabia. Indian Journal Community Medicine; 33:172-81

Assy N, Nasser G, Kamayse I, Nseir W, Beniashvili Z, Djibre A. (2008). Soft drink consumption linked with fatty liver in the absence of traditional risk factors. Canada Journal Gastroenterol ; 22:811-6.

Atkinson F.S, Foster-Powell K, Brand-Miller J.C (December 2008). "International tables of glycemic index and glycemic load values: 2008".

Brand J.C, Snow, B.J, Nabhan, G.P. and Truswell, A. S. (1990). Plasmaglucose and insulin responses to traditional Pima Indian meals. *Am. Journal. Clinical Nutrition.* 5(I):416–420.

Brand-Miller J, Hayne S, Petocz, P. and Colagiuri, S. (2003). Low–glycemic index diets in the management of diabetes a meta-analysis of randomized controlled trials. *Diabetes Care.* 26(8):2261–2267.

Canadian Diabetes Association. (2008). Available from http://www.diabetes.ca/files/Diabetes GL FINAL2 CPG03.pdf (accessed April 8, 2009).

Charokopou M, Sabater F, Townsend R, Roudaut M, McEwan P, Verheggen B. (2013). Methods appliedin cost-effectiveness models for treatment strategies in Type 2 diabetes mellitus and their use in health technology assessments: A systematic review of the literature from 2008 to 2013. Current Medical Res Opin 2015; 32:1-12.

Danaei G, Finucane MM, Lu Y, Singh GM, Cowan MJ, Paciorek CJ (2011)*et al*. National, regional, and global trends in fasting plasma glucose and diabetes prevalence since 1980: Systematic analysis of health examination surveys and epidemiological studies with 370 country-years and 2·7 million participants. Lancet 2011; 378:31-40.

Diabetes Prevention Program Research Group. (2002). Reduction in the incidenceof Type 2 diabetes with lifestyle intervention or metformin. *N Engl. J.Med.* 346:393–403.

Duane, W.C. (1997). Effects of legume consumption on serum cholesterol,biliary lipids, and sterol metabolism in humans. *J. Zipid Hps.* 38:1120–1128.

Duranti, M. (2006). Grain legume proteins and nutraceutical properties. *Fitoterapia.*77 (2):67–82.

Duranti, M. and Gius, C. (1997). Legume seeds: Protein content and nutritional value. *Field Crops Res.* 53:31–45.

Foster-Powell K, Holt SH, Brand-Miller JC (July 2002). "International table of glycemic index and glycemic load values: 2002". Am. J. Clin. Nutr. 76 (1): 5–56. doi: 10.1093/ajcn/76.1.5 .PMID 12081815

Frank L.L (1957). Diabetes mellitus in the texts of old Hindu medicine (Charaka, Susruta, Vagbhata). Am Gastroenterol; 27:76-95.

Freeman, Janine (September 2005). "The Glycemic Index debate: Does the type of carbohydrate really matter? Diabetes Forecast. Archived from the original on February 14, 2007.

Hall V, Thomsen RW, Henriksen O, Lohse N. Diabetes in sub Saharan Africa 1999‑2011: Epidemiology and public health implications. A systematic review. BMC Public Health 2011;11:564.

International Diabetes Federation. Diabetes Atlas. 6th ed. Brussels: International Diabetes Federation; 2013. Available from: https://www.idf.org/sites/default/files/EN_6E_Atlas_Full_0. pdf. [Last accessed on 2014 Jan 23].

Jang,Y, Lee J.H, Kim O.Y, Park H.Y and Lee S.Y (2001).Consumption of whole grain and legume powder reduces insulin demand, lipid peroxidation and plasma homocysteine concentrations in patients with coronary artery disease. *Arterioscler. Thromb. Vasc. Biol.* 21:2065.

Jenkins, D.J.A, Wolever, T.M.S, Taylor, R.H, Barker, H, Fielden H, Baldwin, J.M, Bowling A.C, Newman, H.C, Jenkins, A.L and Goff, D.V (2012). Glycemic index of foods: A physiological basis for carbohydrate exchange. *Am. J. Clin. Nutr.* 34:362–366.

Jeon C.Y, Murray M.B. Diabetes mellitus increases the risk of active tuberculosis: A systematic review of 13 observational studies. PLoS Med 2008;5:e152.

Khatib O. (2004). Non-communicable diseases: Risk factors and regional strategies for prevention and care. East Mediterr Health Journal; 10:778-88.

Kirpitch, A.R, Maryniuk, M.D. (2011). "The 3 R's of Glycemic Index: Recommendations, Research, and the Real World". Clinical Diabetes. 29(4):155–59.doi: 10.2337/diaclin.29.4.155 .ISSN 0891-8929.

Kornum JB, Thomsen RW, Riis A, Lervang HH, Schønheyder HC, Sørensen HT. Diabetes, glycemic control, and risk of hospitalization with pneumonia: A population‑based case control study. Diabetes Care 2008;31:1541‑5.

Ludwig DS, Peterson KE, Gortmaker SL. (2005).Relation between consumption of sugar sweetened drinks and childhood obesity: dietary habits, blood glucose and insulin levels among people without cardiovascular disease and Type 2 diabetes; the ATTICA study. Rev Diabet Stud; 2:208-15.

Madar, Z. and Stark, A. H. (2002). New legume sources as therapeutic agents.*Br. J. Nutr*. 88(3):S287–S292.

Mateos-Aparicio, I., Cuenca, A. R., Villanueva-Su´arez, M. J. and Zapata-Revilla, M. A. (2008) Soybean, a promising health source. *Nutrition. Hospital* .23(4):305–312.

Nanri A, Mizoue T, Noda M, Takahashi Y, Kato M, Inoue M (2010). Rice intake and Type 2 diabetes in Japanese men and women: The Japan public health center-based prospective study. Am Journal Clinical Nutrition; 92:1468-77.

Narayan KV, Zhang P, Kanaya AM, Williams DE, Engelgau MM, Imperatore G,(2006). Diabetes: The Pandemic and Potential Solutions. Washington, DC: World Bank; 2006.

Olatunbosun S.T, Ojo P.O, Fineberg N.S, Bella A.F. Prevalence of diabetes mellitus and impaired glucose tolerance in a group of urban adults in Nigeria. J Natl Med Assoc 1998;90:293 301.

Peterson D.B, Lambert J, Gerring S, Darling P, Carter RD, Jelfs R,(1986). Sucrose in the diet of diabetic patients--just another carbohydrate? Diabetologia; 29:216-20.

Reece E.A, Homko C.J. (1998). Diabetes mellitus in pregnancy. What are the best treatment options? Drug Saf; 18:209-20.

Saydah S.H, Eberhardt MS, Loria C.M, Brancati F.L. Age and the burden of death attributable to diabetes in the United States. Am J Epidemiol 2002;156:714‑9.

Scheiner, Gary (2013). Until There is a Cure: The Latest and Greatest in Diabetes Self-Care . Spry Publishing LLC. ISBN 978-1-938170-13-3.

Seidell J.C. Dietary fat and obesity: An epidemiologic perspective. Am J Clin Nutr 1998;67 3 Suppl:546S-50.

Serrano, J. and Go˜ni, I. (2004). Role of black bean *Phaseolus vulgaris* onthe nutritional status of Guatemalan population. *Arch. Latinoam Nutr.* 54(1):36–44.

Shaw J.E, Sicree R.A, Zimmet P.Z. Global estimates of the prevalence of diabetes for 2010 and 2030. Diabetes Res Clin Pract 2010; 87:4-14.

Shehata, N. A., Darwish, N., Nahr, F. E. and Razek, F. A. A. (1988). Supplementation of wheat flour with some local legumes. *Die Nahrung.* 31:3–8.

Simpson, H. C., Lousley, R. S., Greekie, M., Hockaday, T. D. R., Carter, R. D.and Mann, J. I. (1981). A high carbohydrate leguminous fibre diet improves all aspects of diabetes control. *Lancet.* 1:1–4.

Tharanathan, R. N. and Mahadevamma, S. (2003). Grain legumes—a boon to human nutrition. *Trends Food Science. Technology.* 14(12):507–518.

Thomsen R.W, Hundborg H.H, Lervang H.H, Johnsen S.P, Schønheyder H.C, Sørensen H.T. Risk of community‑acquired pneumococcal bacteremia in patients with diabetes: A population based case‑control study. Diabetes Care 2004; 27:1143‑7.

Thomsen R.W, Hundborg H.H, Lervang H.H, Johnsen S.P, Schønheyder H.C, Sørensen H.T. (2005) Diabetes mellitus as a risk and prognostic factor for community‑acquired bacteremia due to enterobacteria: A 10‑year, population‑based study among adults. Clin Infect Dis; 40:628‑31.

Tucker D.M, Palmer A.J. (2011). The cost-effectiveness of interventions in diabetes: A review of published economic evaluations in the UK setting, with an eye on the future. Prim Care Diabetes; 5:9-17.

United Nations. Political declaration of the High‑level Meeting of the General Assembly on the Prevention and Control of Non‑communicable Diseases. New York: United Nations; 2011. p. 12‑3.

Villegas R, Shu XO, Gao YT, Yang G, Elasy T, Li H, (2008). Vegetable but not fruit consumption reduces the risk of Type 2 diabetes in Chinese women. Journal of Nutrition; 138:574-80.

Whiting DR, Guariguata L, Weil C, Shaw J. (2011). IDF diabetes atlas: Global estimates of the prevalence of diabetes for 2011 and 2030. Diabetes Res Clinical Practice; 94:311-21.

Wild, S., Roglic, G., Green, A., Sicree, R. and King, H. (2004). Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030.*Diabetes Care.* 27:1047–1053.

Wolever, T.M, Jenkins D.J, Vuksan V, Jenkins, A.L, Buckley, G.C, Wong G.S and Josse, R.G. (1992). Beneficial effect of a low glycaemic index dietin type 2 diabetes. *Diabet Med.* 9(5):451–458.

World Health Assembly (2013). Follow‑up to the Political Declaration of the High‑level Meeting of the General Assembly on the Prevention and Control of Non‑communicable Diseases. Geneva: World Health Organization; 2013.

Zeevi, David; Korem, Tal; Zmora, Niv; Israeli, David; Rothschild, Daphna; Weinberger, Adina; Ben-Yacov, Orly; Lador, Dar; Avnit-Sagi, Tali; Lotan-Pompan, Maya; Suez, Jotham; Mahdi, Jemal Ali; Matot, Elad; Malka, Gal; Kosower, Noa; Rein, Michal; Zilberman Schapira, Gili; Dohnalová, Lenka; Pevsner-Fischer, Meirav; Bikovsky, Rony; Halpern, Zamir; Elinav, Eran; Segal, Eran (2015).