GLYCEMIC INDEX OF DIFFERENT SORGHUM VARIETIES

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ABSTRACT

Sorghum Vulgare (Jowar) has been found to have several health benefits for Diabetic, obese and Dyslipidemic patients. Due to its high fiber content Sorghum helps in maintaining satiety and helps in the managing hunger and weight loss.Glycemic index helps in understanding how fast a food can cause increase in the blood sugar levels.Foods that are high in glycemic index are absorbed and digested quickly and raise the blood sugars quickly. The present study has been done to determine the glycemic effect of different jowar varieties and supplemented in 150 subjects divided into 5 groups as Normal, obese, pre diabetic, Diabetic subject on OHA and Diabetic subjects on insulin. Results on sensory evaluation and consumer acceptability studies were acceptable with all the three varieties of sorghum. Three varieties of sorghum rava upma –Red, yellow and white varieties were supplemented. The upma, weighing 270 grams of cooked weight of 50gm of carbohydrate was given to the subjects. Blood samples were collected and measured and the Area under the Curve (AUC) for each subject was calculated and the Glycemic index was determined. The glycemic index was found to be low for yellow sorghum rava.(54.7 ±2.37).

INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by hyperglycaemia with alterations in carbohydrate, protein, and lipid metabolism. It is considered as the most common endocrine disorder and results in deficient insulin production (type 1) or combined resistance to insulin action and the insulin-secretory response (type 2). Type 2 diabetes susceptibility varies to a great extent around the globe, with Pacific Islanders, Asian Indians, and Native Americans having a significantly higher risk of developing the disorder. The number of people with type 2 diabetes began to rise globally in the 1990s, and since 2000, the world has seen a dramatic increase in the number of people with diabetes. According to the International Diabetes Federation (IDF), 8.8% of the adult population have diabetes, with men having slightly higher rates (9.6%) than women (9.0%). Current global statistics shows that 463 million and 374 million individuals have diabetes and impaired glucose tolerance (IGT), a prediabetic condition. These numbers are estimated to increase to 700 million people with diabetes and 548 million people with IGT by 2045, which represents a 51% increase compared to 2019. According to the IDF in 2019, the top three countries with the highest number of individuals with diabetes are China (116.4 million), India (77.0 million), and the United States of America (31.0 million). This trend is expected to continue in 2030 and 2045, with China (140.5 and 147.2 million) and India (101.0 and 134.2 million) continuing to have the highest burden of diabetes. (IDF, 2019).

Dietary fibers are important because of their hypoglycemic and hypolipidemic properties, which help to prevent atherosclerosis by lowering serum cholesterol levels. They are also anti-toxin and anti-cancer in nature. Unrefined whole grains and millets and bran products are highly complex substances that contain both soluble and insoluble dietary fibre as well as other biologically active substances like polyphenols, antioxidants, vitamins, trace minerals, phytoestrogens, lipids, proteins, and starch. Grains have shown to have a role in prevention and reducing the risk of Type 2 Diabetes, Coronary Heart Disease, Cancer and Obesity. (Yang et al, 2020). The major cereals and millets consumed in India are rice, wheat, jowar (sorghum), bajra, ragi (millets). These grains are the major source of energy in Indian diets contributing to around 60-70% of the daily energy intake (Misra et al, 2009). Whole grains also contain antioxidants that may help protect against oxidative damage, which may play a role in cancer development. The high demand for antioxidant and nutraceutical foods has increased during the past years to prevent oxidative stress associated to the development of chronic diseases such as cardiovascular, neuron degeneration, cancer, diabetes and hypercholesterolemia as well as being involved with the process of aging .Recent research has demonstrated that the consumption of whole grains reduces the risk of these diseases due to the dietary fibre and phytochemicals, which are mainly concentrated in the bran. The phytochemicals have gained increased interest due to their antioxidant activity, cholesterol- lowering properties and other potential health benefits. Sorghum is known to be a cheap source of energy, protein, iron and zinc next only to pearl millet among all cereals and pulses (Rao, et al, 2006). Sorghum is also grown for feed, fodder and more recently for bio-fuel purposes in the world (Ulrich, et al, 2007). Sorghum which is rich in starch, and protein (kafirin), can be regarded as substitute for the cereals that are presently used for the production of ready to eat (RTE) snacks .Fiber and certain starches found in whole grains ferment in the colon to help reduce transit time and improve gastrointestinal health. Sorghum is the fifth most important cereal crop in the world after wheat, rice, corn and barley. Sorghum outperforms other cereals under various environmental stresses and is thus generally more economical to produce. More than 35% of sorghum is grown directly for human consumption. The rest is used primarily for animal feed and alcohol and industrial products. Sorghum contains various phytochemicals (including phenolic compounds, plant sterols and policosanols) that are secondary plant metabolites or integral cellular components. Phenols help in the natural defense of plants against pests and diseases, while the plant sterols and policosanols are mostly components of wax and plant oils. 4 The phenols in sorghums fall under two major categories; phenolic acids and flavonoids. The phenolic acids are benzoic or cinnamic acid derivatives whereas the flavonoids include tannins and anthocyanins as the most important constituents isolated from sorghum to date (Gupta and Haslam, 1978).Sorghum is often recommended as a safe food for celiac patients, because it is only distantly related to the Triticeae tribe cereals wheat, rye and barley (Kasarda, 2001), being a member of the Panicoideae sub-family which also includes maize and most millets .Sorghum therefore, provides a good basis for gluten-free breads and other baked products like cakes and cookies (biscuits) and in snacks and pasta. In the US,the white sorghum products are used to a small extent to substitute for wheat in products for people allergic to wheat gluten (Fenster, 2003) Red variety of sorghum is an attractive raw material for gluten free products due to the color and low allerginicity. The Glycemic Index (GI) is a valuable indicator for the biological effects of carbohydrates that can be transformed into a useful tool called Glycemic Load (GL) that can be used for routine dietary counselling. The GI has been recommended to assist guide dietary choices because it has been observed that a high GI diet can have negative health repercussions by raising the risk of chronic disease. Major variations in the glycemic index and dietary fibre content of meals are linked to slight but significant changes in the glucose profile (Wannamethee et al 2005). Many people believe that diabetics can control their blood sugar levels by following a low-GI diet. A low GI diet may help prevent diabetes since a high GI diet causes hyperglycemia and hyperinsulinemia, which leads to beta cell malfunction over time (Ludwig 2002). Low GI diets have been linked to insulin resistance syndrome, high blood pressure, lowering HDL cholesterol, proinflammatory activity, and abnormal blood lipids, whereas high GI diets have been linked to insulin resistance syndrome, high blood pressure, lowering HDL cholesterol, proinflammatory activity, and abnormal blood lipids. However, studies demonstrating these links between a low GI diet and 5 cardiovascular disease risk factors lack long-term research and produce conflicting results. Consumption of whole grains, legumes, vegetables, and fruits, on the other hand, is linked to a lower risk of cardiovascular disease (Mann et al 2007). Jenkins and colleagues glycaemic index (GI) in the early 1980s as a concept for rating carbohydrate items based on their effects on postprandial glycemia (Jenkins et al. 1981). The GI is the incremental blood glucose area after the test food, represented as a percentage of the corresponding area after a carbohydrate equivalent load of a reference product. The GIs of white bread range from less than 20 percent to around 120 percent. Disparities in the rate of digestion or absorption of carbohydrates are the main cause of these huge GI differences, and low-GI foods release glucose into the bloodstream at a slower rate. Although the identification of foods with a low GI character was first considered primarily in diabetes (Crapo et al. 1981), the idea appears to rank foods similarly in diabetic and non-diabetic persons.

OBJECTIVES

1. To evaluate the dietary habits of subjects with different conditions – Normal,Obese,Pre Diabetic,Diabetic subjects on oral Hypoglycemic subjects,Diabetic subjects on Insulin.
2. To evaluate the effect of intake of different varieties of sorghum on Normal, Obese,Pre Diabetic,Diabetic subjects on oral Hypoglycemic subjects,Diabetic subjects on Insulin.
3. To determine the lowest glycemic index variety of sorghum .

REVIEW OF LITERATURE Sorghum can be grown in harsh environment where other crops grow or yield poorly. It is grown with limited water resources and usually without application of any fertilizers or other inputs by a multitude of small holder farmers in many countries. It is mostly referred to as "coarse grain or poor people's crop". Sorghum (Sorghum bicolor (L) Moench is the 5th major cereal of the world after maize, paddy, wheat and barley as per FAO production data 2016 USDA-2021-65.21 million tonnes world, 4.40million in India and ranks 6th in world. The world sorghum production increased significantly during 2014 to 68.9 million tonnes in 2010 after a drastic reduction in 2011 to 57 million tonnes. Africans stood to be the largest producer of sorghum during 2014 contributing about 42% of global production followed by Americas (39.75 %) and Asia (14.04%).(Rao et al 2017).

White sorghum products are used to replace wheat in products for persons who are allergic to wheat gluten in the United States. In India, roti, an unleavened flat bread, is consumed 70% of the sorghum produced. [Subramanian and Murty, 1981].

Sorghum contains a high amount of nutritional fibre and has a low glycemic index. This may aid in the prevention and management of T2DM in Indians. Fiber, magnesium, vitamin E, phenolic compounds, 15 and other nutrients are available in sorghum. When compared to wheat flour, sorghum has the same amount of starch but significantly less –amylase (40–50%) and amylolytic (10%) activity. (Zhumabekova et al., 1978) Waggle and Deyoe, 1966 stated that Proteins are the second most important component of sorghum grains. Genetic and environmental factors influence the protein content of sorghum and vary with changes in amino acid composition. The protein content of sorghum is comparable to that of wheat and maize. Sorghum grains have a high fibre content and low nutrient digestibility, both of which reduce customer acceptance. Studies conducted by Pamella 2019 on extruded sorghum treatment in overnight meal concluded that there was a body fat percentage reduction in sorghum (1.90 ± 1.82%) which was high when compated to wheat treatment (-0.23±1.46%).

Studies conducted by Lakshmi et al, 1996 on six non-insulin-dependent diabetic patients (three males and three females) aged 45-60 years. Diabetes was diagnosed according to WHO guidelines, and it lasted ranging from six months to two years. All of the volunteers had to stick to a rigorous diet. At the commencement of the study, the GTT (Glucose Tolerance Test) was done. After an overnight fast, blood was drawn intravenously to determine fasting plasma glucose levels. To assess their glucose tolerances, each patient was given a glucose load of 1 g per kg body weight (dissolved in 200 ml water). Blood glucose levels were monitored at l/2, 1 and 2 hour intervals. Fasting plasma glucose levels in diabetic patients varied from 128 to 143 mg per cent. Over the course of the time interval, plasma glucose levels gradually increased, peaked at 1 hour, and then began to fall at 2 hours. The levels did not approach the fasting level even after 2 hours. The lowest increase in glucose from baseline levels was obtained after eating whole sorghum missiroti (21.9 mg), wheat missiroti (35.3 mg), and dehulled sorghum missiroti (37.3 mg) at a 1-hour interval. The lowest increase in glucose from fasting levels was obtained after eating whole sorghum semolina upma (20.3 mg), rice semolina upma (30.8 mg), and dehulled 17 sorghum semolina upma (35.8 mg) over a 1-hour period. Though all three forms of upma produced a peak level at 1 hour, the subjects who ate whole sorghum semolina upma, rice semolina upma, and dehulled sorghum semolina upma had a lower mean percent peak rise and AUC. The lowest increase in glucose from fasting levels was observed after eating whole sorghum semolina upma (20.3 mg), rice semolina upma (30.8 mg), and dehulled sorghum semolina upma (35.8 mg) for 1 hour. The subjects who ate whole sorghum semolina upma, rice semolina upma, and dehulled sorghum semolina upma had a lower mean percent peak rise and AUC than those who ate rice semolina upma. The least increase in glucose from baseline levels was observed after eating whole sorghum dhokla (26.6 mg), rice dhokla (35.9 mg), and dehulled sorghum dhokla (47.4 mg) at 1 hour intervals. When compared to rice dhokla or dehulled sorghum dhokla, participants who ate whole sorghum dhokla had reduced mean percent pese over fasting and AUC. When whole sorghum recipes were consumed, glycemic reactions were significantly lower than when dehulled sorghum dishes were consumed. Upma, missiroti, and dhokla had the lowest percent glycemic response of all the whole sorghum dishes. Whole sorghum recipes resulted in significantly lower plasma glucose levels, a lower percent peak rise, and a smaller area under curve (AUC) in diabetic patients when compared to dehulled sorghum and wheat recipes. The lowest glycemic response was found in whole sorghum semolina upma (74.6 mg), whole sorghum Missiroti (77.8 mg), and whole sorghum dhokla (84.5 mg). The mean peak rise in plasma glucose levels in participants given wheat and dehulled sorghum recipes was not substantially different ($P < 0.05$), fine semolina upma ($P<0.05$).

Prasad et al (2014) studied the glycemic index (GI) and glycemic load (GL) of sorghum-based diets in ten healthy non-diabetic volunteers aged 20–40 years. According to the findings, the GI of sorghum-based foods including coarse semolina upma ($P< 0.05$), fine semolina upma ($P<0.01$), flakes poha ($P<0.01$), and pasta ($P<0.01$) was significantly lower than that of control (wheat/rice-based) foods. All sorghum-based foods had a significantly lower GL ($P< 0.01$) than their control (wheat/rice-based) foods.A few sorghum-based foods have a low GI (55; coarse 18 semolina upma, fine semolina upma, flakes poha, and pasta), and all sorghum-based foods (excluding sorghum roti) have a lower GL than wheat/rice-based counterparts. The researchers found that eating low-GI and low-GL sorghum-based foods could help lower postprandial blood glucose levels.

Sorghum is rich in dietary fiber and low glycemic index, which could help in prevention and control of T2D in Indians. The fiber, magnesium, vitamin -E, phenolic compounds and tannins present in foods reduces the risk of diabetes as they slower the sudden increase of blood glucose and insulin levels (Montonen et al., 2003). National Institute of Nutrition (ICMR) in 2010 assessed Glycemic Index (GI) of sorghum based foods in collaboration with the Indian Institute of Millets Research, Hyderabad under National Agricultural Innovation Project (NAIP). The results revealed that sorghum based foods have low GI and reduces the postprandial blood glucose level, glycosilated hemoglobin. Another study also points to the fact that blood glucose level of nonobese patients with non-insulin-dependent diabetes mellitus

(NIDDM), who consumed sorghum bran papadi, showed considerable reduction. (Shinde and Kamble, 2004). Studies performed on processing and cooking of white and yellow jowar varieties showed that boiled Yellow Jowar flour (coarse) had lower glycemic index compared to flour prepared from the same. Similarly chapatti prepared from white Jowar flour showed low glycemic index over yellow Jowar flour. These changes in glycemic index due to processing and cooking play an important role in diets followed in dietary management of diabetes (Vahini and Bhaskarachary, 2013). Vahini and Bhaskarachary 2012, studied the GI in common jowar cultivars and the link with wheat flour in-vitro digestibility. After being treated to various culinary processes such as boiling, roti making, porridge preparation, and sweet preparation, the Invitro GI of these flours and Rava was determined. According to the findings, the white jowar (flour) variety has a lower GI (49.85±0.29) than the yellow jowar (flour) variant (52.56± 0.87). Rava's GI ratings for different types of jowar followed a similar pattern. After boiling, the GI ratings of these jowar flours were lowered. The experiments were carried out in the same way, but with wheat flour as the boiling medium.

Both milling and heating processes were found to have an impact on the food's GI ($P< 0.001$) Factors contributing to lower GI readings include dietary fibre, resistant starch, rapidly digested starch, and alpha amylase inhibitors. When processed into rava or coarsely crushed flour, yellow jowar rava (45.23±1.22) had the lowest glycemic index of these kernels, and this rava had a significantly lower glycemic index when boiling (44.70±6.22). The difference in resistant starch concentration between the cooked rava and the kernels, which was 0.17±0.22 in the boiling rava and 0.13±0.087 in the kernels, could explain this. Because of the polyphenolic components present, yellow jowar has the strongest amylase inhibitory action. 64.33±1.34. They discovered that a food product's glycemic index fluctuates based on the processing and cooking methods used. Among the various processed and cooked wheat preparations, oiled wheat flour (41.06±0.42) had the lowest glycemic index (41.06±0.42), while vermicelli payasam had the highest (74.34±2.27). When types of jowar were subjected to various methods and preparations, the glycemic index of yellow jowar rava boiled was found to be the lowest (44.70±6.72) and the highest (74.05±1.72) in halwah made with the same rava. The lowest glycemic index 21 was found in white jowar flour chapatti (41.9±60.3), while the highest was found in white jowar flour halwah (69.9±60.3).

According to Mani et al 1993and Itagi 2003 Jowar had a GI of 70.

Carolyne 2014 did a study in which seven women and three men who were not diabetic were chosen to participate. The findings revealed the average GI values of various food products when ingested by various participants. In the diverse subjects, the highest was 87.00 % for maize meal, while the lowest was 23.00 %. The GI levels for the numerous test foods that were tested by study participants varied, according to the findings. The GI values for sorghum varied between 65.00 % and 89.00 % depending on the study participant. Cassava meal had a GI of 49.00 % to 66.50 %, millet meal had a GI of 56.00 % to 67.00 %, and banana meal had a GI of 45.00 % to 67.00 %.

Healthy human participants are suggested for routine GI testing. The study's findings of GI diversity across people consuming the same food product could be attributable to differences in metabolic pathways driven by hereditary variables. These findings imply that while using the GI concept to choose carbohydrate diets, diabetes patients should be informed about the various physiological responses to CHO foods among individuals. Foods with a high GI rating for one person may not be suitable for another. In some people, a certain food product may have a high GI, whereas in others, it may have a medium or even low GI. Furthermore, food consistency and combinations might alter bioavailability and, as a result, GI readings.

MATERIALS AND METHODS

Three different varieties of Sorghum grain (Sorghum bicolor) red sorghum variety (AKJ-1), yellow sorghum variety (M35-1), white sorghum variety (CSV-29R) of rabi crops were procured from the market. The Sorghum grains were processed into coarse rava.

SELECTION OF SUBJECTS: A total of 150 subjects were selected and divided into 5 groups of 30 each. The same subjects served as both control group and experimental group with a 2 day wash out period divided into 5 groups as Normal subjects, Obese subjects, Pre-Diabetic subjects, Diabetic subjects on Oral Hypoglycemic Agents (OHA),Diabetic subjects on Insulin.

Reference food: White bread was taken as the reference food consisting of 50grams of carbohydrates and weight 100gm.The available carbohydrate was calculated by subtracting the Total Dietary Fiber (TDF) from total Carbohydrate (CHO). Therefore, 101 g of bread contained 50 g of available CHO.

Three varieties of sorghum rava upma – Red, yellow and white varieties were supplemented. The upma weighing 270 grams of cooked weight of 50gm of carbohydrate was given to the subjects.As the ingestion of protein along with carbohydrate can increase the serum insulin response, lowering the glycemic response, protein foods such as peanuts, dhals etc were excluded in upma preparation. As the increment of blood glucose can be inhibited by fat though not significantly affecting the Glycemic Index(GI), fat in the form of oil or ghee was restricted in the upma preparation. (Wei,1999) In a study conducted by Cooke1975, it is said that fat inhibits in the form of butter might have delayed gastric emptying, may have delayed digestion and absorption of the carbohydrate in the bread and potato, thereby reducing the maximal blood sugar concentration. oil/ fat was restricted in the upma preparation due to the above fact.

Informed consent: The participants were included into the study after they signed the document .

The participants were from 35 to 55 years of age and the study details were explained to the participants in their local language and written consent form and demographic details taken from the participants. After an overnight fast, finger prick blood samples were collected before test meal. Then 70gm of sorghum rava that provided 50 g of carbohydrate and four slices of bread calculated for available carbohydrate. Water to be served along with test/reference food and should be consumed within 10 minutes (Brouns et al, 2005). Againfinger prick blood samples were collected after 15, 30, 45, 60, 90, 120 and 180 min as observed in plate 3.2. The blood glucose levels at the specified time intervals were measured by glucometer (Accu-Check meter, Roche, Switzerland).

CALCULATION OF GLYCEMIC INDEX The+IAUC for test and reference foods was calculated using thetrapezoid rule. Incremental area Under the Curve was for each meal time for the subjects taking sorghum varieties and also reference food was calculated at different intervals (Chlup, 2004).The Area under the Curve (AUC) for each subject was calculated with the following formula (Brouns, 2005). GI (%) was calculated for each test food as below:

GI = Area under curve for 50g CHO from test food x 100 Area under the curve for 50g CHO from white bread

RESULTS AND DISCUSSION

Sensory evaluation was done for sorghum ravaupma using 5 point hedonic scale to know the various sensory attributes by semi trained panel members and the results are represented in Table 1.

Values represented in mean± SD. High mean value indicates high acceptability. Significant at 0.001level.

The results revealed that the acceptability of upmainterms of colour showed that white sorghum upma was highly acceptable (P<0.001) and the (4.8±0.3) least for control (4.0± 0.5).

White sorghum upma texture (4.2±0.38) was highly acceptable (p<0.001) and the least in Red sorghum upma(3±0.18) due to its coarse texture.

Flavour was highly acceptablep<0.001 in white sorghum upma(4.4 ±0.8) and the least in control (3.9±0.37).Red sorghum upma flavour was 4.3±0.48 and Yellow sorghum upma (4.2±0.5)

White sorghum upma had the highest level of significance (P<0.001) for after taste (4.6±0.51) least was for Yellow sorghum upma(3.6±0.5) due to its little bitter after taste.

White sorghum upma had the highly significant(P<0.001) for overall acceptability (5±0) and the least for Yellow sorghum upma (4.2±0).

The bitter taste of Yellow sorghum upma's was maske and acceptability was improved later by adding ginger, curry leaves, onions and lemon (optional).

2.**Glycemic Index study for identifying low Glycemic Index ravaupma among 3 different varieties of Sorghum supplemented to Normal, Obese, Pre Diabetic, Diabetics on OHA and Diabetics on Insulin**

Subjects selected for Glycemic index studies

150 subjects were divided into 5 groups of 30 each comprising of 30 normal subjects,30 Obese, 30 Pre Diabetic subjects,30 Diabetic subjects on Oral Hypoglycemic agents (OHA), 30 Diabetic subjects on Insulin.

Subjects were given 50 gm of Carbohydrate containing 3 varieties-Red,white,yellow varieties of sorghum upma and white bread served as a reference food.

Blood samples were collected at 0,30,45,60,90,120for normal, obese and Pre Diabeticand 0,30,45,60,90,120,150 and 180 minutes for Diabetic subjects. Incremental Area under the curve was calculated using the trapezoid rule.

3. IAUC values of three varieties of sorghum ravaupma

Incremental area under the curve (IAUC) value was highly significant (P<0.001) for normal subjects supplemented with Yellow sorghum upma (118.8 ± 5.14) followed by Red sorghum upma (123.683 ± 4.64) and Whitesorghumupma (130.733 ±6.77) Table 3

Table 3 **IAUC values of three varieties of sorghum ravaupma (n=30)**

VARIETY	CRITERIA	Mean ± SD	F value	P value
Red Sorghum upma	N	123.683±4.64	2277.547	0.000
	Ob	138.967±8.5		
	Pre DM	144.1±7.14		
	DM on OHA	226.6±11.24		
	DM on Insulin	312.467±12.16		
White Sorghum upma	N	130.733±6.77	2480.948	0.000
	Ob	147.033±4.35		
	Pre DM	152.933±6.47		
	DM on OHA	219.733±9.03		
	DM on Insulin	301.767±10.76		
Yellow Sorghum upma	N	118.8±5.14	6598.125	0.000
	Ob	131.133±3.49		
	Pre DM	138.333±3.4		
	DM on OHA	209.333±4.76		
	DM on Insulin	291.033±6.84		

- N-Normal,O-Obese, DM Diabetic

The mean difference was significant at 0.001level.

Statistical analysis was done between criteria and variety which revealed that Normal subjects had the least mean IAUCvalue for Yellow sorghum upma (118.8 ±5.14).

Obese had the least mean IAUC value for Yellow sorghum upma,Pre Diabetic (138.333 ±3.4) for Yellow sorghum upma (131.133 ±3.49).Diabetic on OHA (209.333 ±4.76)for Yellow sorghum upma and Diabetic on insulin (291.033±6.84) for Yellow sorghum upma. The meandifference was significant at 0.001 level (p<0.001). Table 4 Figure 1

Table 4 **IAUC values of three varieties of sorghum ravaupma (n=30)**

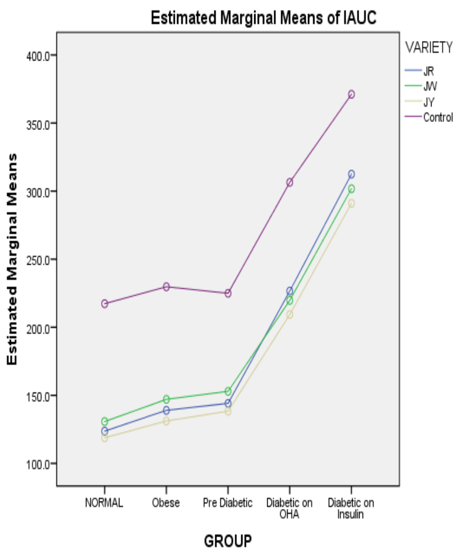
CRITERIA	VARIETY	Mean ± SD	F value	P value
Normal	RS upma	123.7±4.64	2300.69	0.000
	WS upma	130.7±6.77		
	YS upma	118.8±5.14		
	Control	217.3±4.47		
	RS upma	138.967±8.5	1791.7	0.00

Obese	WS upma	147.033±4.35	7	0
	YS upma	131.133±3.49		
	Control	229.733±6.1		
Pre Diabetic	RS upma	144.1±7.14	803.806	0.000
	WS upma	152.933±6.47		
	YS upma	138.333±3.4		
	Control	224.967±11.79		
Diabetic on OHA	RS upma	226.6±11.24	699.811	0.000
	WS upma	219.733±9.03		
	YS upma	209.333±4.76		
	Control	306.433±10.45		
Diabetic on Insulin	RS upma	312.467±12.1648	268.519	0.000
	WS upma	301.767±10.76		
	YS upma	291.033±6.84		
	Control	371.133±16.17		

*RS Red sorghum ,WS White Sorghum, YS Yellow sorghum

The mean difference was significant at 0.001level.

Figure 1 Estimated Marginal means of IAUC



JR-Sorghumred,JW-Sorghum white,JY-Sorghum yellow

It can be concluded that the 1AUC was least for Yellow sorghum upma(118.8±5.14) in normal subjects interms of varieties of sorghum as well as criteria of subjects p<0.001.

In the present study,1AUC was least for White sorghum upma(130.7±6.77) in normal subjects.

Rajendraprasad et al 2014, concluded thatIAUC of sorghum based coarse semolina upma as 114± 1.93 and fine semolina upma as 119±7.04.

In the present study, the IAUC of White sorghum upma for Diabetics on Oral Hypoglycemic agents was 219.733± 9.03.Studies conducted by Lakshmi and Vimala 1996 concluded that IAUC of dehulled sorghum semolina upma in diabetics was 370.8±67.9.

5.Glycemic Index (GI) values of three varieties of sorghum ravaupma

Glycemic index value was highly significant (p<0.001) for Normal subjects supplemented with Yellow sorghum upma (54.7±2.37) followed by Red sorghum upma (56.9±2.32) White sorghum upma (60.2 ±3.34) Table4.2.3.1

Table 5 **Glycemic Index values of three varieties of sorghum ravaupma**

VARIETY	CRITERIA	Mean ± SD	F value	P value
Red Sorghum upma	N	56.9±2.32	190.182	0.000
	Ob	60.5±4.11		
	Pre DM	64.3±5.09		
	DM on OHA	74±4.22		
	DM on Insulin	84.4±5.66		
	N	60.2±3.34	125.031	0.000

White Sorghum upma	Ob	64±2.22		
	Pre DM	68.1±4.1		
	DM on OHA	71.8±4.25		
	DM on Insulin	81.5±5.4		
Yellow Sorghum upma	N	54.7±2.37	276.793	0.000
	Ob	57.1±2.26		
	Pre DM	61.7±4.13		
	DM on OHA	68.4±2.81		
	DM on Insulin	78.6±3.82		

- N-Normal,O-Obese, DM Diabetic

The mean difference was significant at 0.001 level.

Statistical analysis was done between criteria and variety which revealed that Normal subjects had the least mean GI value for Yellow sorghum upma (54.7 ±2.37) obese subjects had the least mean GI value for Yellowsorghumupma (57.1 ±2.26), Pre diabetic for Yellowsorghumupma (61.7 ±4.13) Diabetic on OHA for Yellowsorghumupma (68.4 ±2.81), Diabetic on Insulin for Yellowsorghumupma (78.6 ±3.82).(Table 6)

The mean difference was significant at 0.001 level (p<0.001).

Table 6 **Glycemic Index values of three varieties of sorghum upma**

CRITERIA	**CRITERIA**	**Mean ± SD**	**F value**	**P value**
Normal	RS upma	56.9±2.32	31.09	0.000
	WS upma	60.2±3.34		
	YS upma	54.7±2.37		
Obese	RS upma	60.5±4.11	39.814	0.000
	WS upma	64±2.22		
	YS upma	57.1±2.26		
Pre Diabetic	RS upma	64.3±5.09	15.829	0.000
	WS upma	68.1±4.1		
	YS upma	61.7±4.13		
Diabetic on OHA	RS upma	74±4.22	16.544	0.000
	WS upma	71.8±4.25		
	YS upma	68.4±2.81		
Diabetic on Insulin	RS upma	84.4±5.66	10.121	0.000
	WS upma	81.5±5.4		
	YS upma	78.6±3.82		

The mean difference was significant at 0.001level.

Identification of low GI rava among three varieties of sorghum ravaupma

The glycemic index (GI) of yellow sorghum upma was the least (54.7±2.37), hence was selected for supplementation tohyperlipidemic and hyperglycemic subjects.

In vitro analysis done by Vahini and Bhaskarachary2013,concluded thatYellowjowarrava (45.23±1.22) had the lowest glycemic index when the jowar kernels were processed into rava or coarsely ground flour, The ravahad a substantially lower glycemic index when boiled (44.70±6.22).

In the present study, the Glycemic index of white sorghum rava was found to be 60.2± 3.34.

Mani et al 1993, reported that GI value of jowar flour was 77±8 which was given in the form of roasted bread with added spices and salt.

In vitro analysis done by Vahini and Bhaskarachary 2013 reported that GI value of white jowarrava was 45.12±7.44.

Prasad et al 2014, concluded thatGI of sorghum based coarse semolina upma as 53±2.84and fine semolina upma as 56± 9.83.

Dietary habits of the subjects selected for glycemic Index studies

Theaveragetotalcerealintakewas280±44.8g perday in Normal group and400 ± 40.9gperday for Obese,320±45.6g per day for Pre Diabetic, 340±50.7 for Diabetic on medication,360±48.2 for Diabetic on Insulin, which seem to meet the recommendeddietaryallowances (RDA). The mean intake of green leafy vegetables, other vegetables consumption was 80-100gm lower than the RDA for Diabetic subjects on OHA and Insulin. Pulses consumption was adequate., oils and fats were consumed 30gm more,15gm more in Pre Diabetics,5-10gm more in Diabetics on OHA and on Diabetics on Insulin, higher thanthe RDA.milk and milk products consumption was 40-100ml lower than that ofRDA.table- 7, Figure-2

Table 7 **Dietary habits of the subjects selected for glycemic index studies (n=30)**

Food group	**Normal N (n=30)**	**Obese O (n=30)**	**Pre DM - PD(n=30)**	**DM ON OHA - DO (n=30)**	**DM on Insulin DI(n=30)**
Cereals (g)	280 ±44.8 (350-400)	400±40.9 (350-400)	320±45.6 (350-400)	340±50.7 (350)	360 ±48.2 (350)
Pulses(g)	40 ± 15.2 (40-50)	45±18.7 (40-50)	42±21.2 (40-50)	48±22.1 (30)	45 ±20.1 (30)
GLV(g)	150± 15.5 (50-100)	60±10.7 (50-100)	100±12.7 (50-100)	120±12.9 (200)	90 ±22.6 (200)
Other Veg(g)	130 ± 40.1 (60-75)	100±28.8 (60-75)	120±25.7 (60-75)	110±13.7 (200)	100± 24.9 (200)
Milk & Milk Products (ml)	130±14.4 (200-250)	150±21.2 (200-250)	102±13.9 (200-250)	120±16.8 (150)	116 ±48 (150)
Oils & Fats(g)	30 ±13.9 (20-40)	60±18.7 (20-40)	55±11.6 (20-40)	50±14.2 (40)	45 ±13.9 (40)

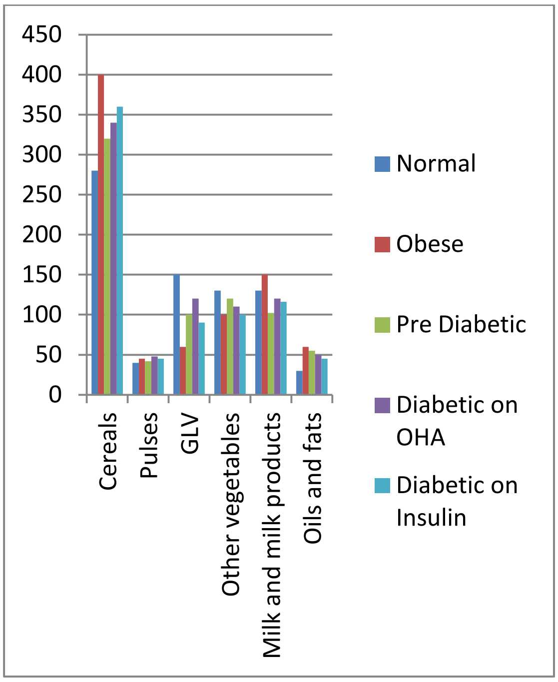
RDA VALUES IN PARENTHESIS ( )

Source:-RDA-Raghuramulu etal

RDAfordiabeticpatients(1997)

Gopalan et al,1989. A report of the Expert group of the Indian Council of Medical Research,1989.

Figure: 2 **Dietary habits of the subjects selected for glycemic index studies (n=30)**



Proximate analysis and nutritive value of sorghum ravaupma

Resultsof proximate analysis of the sorghum rava per 100 grams was 6.8% moisture,protein 8 gm, fat 1.71 gm, energy 370 kcal, carbohydrate 80.68 gm,fiber 1.73g

Table 8 **Proximate analysis of Sorghum rava (raw) per 100gm**

Nutrient	Value	Indian Institute of Millets Research (IIMR) 2017	NAIP Subproject data(coarse rava) (2008-2012)
Ash (%)	0.89	1.39±0.34	2.03
Moisture (%)	6.8	9.01±0.77	8.97
Energy (Kcal)	370/1548.08 KJ	1398±13 KJ	350 kcal
Protein(g)	8.1	9.97±0.43	7.15
Fat(g)	1.71	1.73±0.31	1.2
Carbohydrate (g)	80.68	67.68±1.03	77.74
Fiber(g)	1.73	1.73±0.40	-

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