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Research Article

Glycemic Index and Glycemic Load Determination of Ayoola and Endy Poundo Yams Consumed with *Amaranthus hybridus* (Tete) Vegetable Soup

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Abstract

High glycemic index (GI) and glycemic load (GL) foods are linked with incidence and prevalence of diabetes and cardiovascular diseases. This study therefore examined GI and GL of industrial poundo yams consumed with *Amaranthus hybridus* (AH) vegetable soup. Human subjects consumed Ayoola poundo yam with *Amaranthus hybridus* (APYAH) soup and Endy's poundo yam with *Amaranthus hybridus* (EPYAH) soup after 12 h of overnight fasting. Their blood sugar levels were determined at 30 min interval for 2h and used to determine incremental areas under curves (IUACs), while IUACs were in turn used to determine GIs and GLs. Findings showed that GIs and GLs of APYAH and EPYAH differed significantly from control meals' GI and GL. Conclusively, APYAH and EPYAH are low GI foods with moderate GL values therefore, their consumption should less predispose man to diabetes and cardiovascular diseases due to their low GI values.

Keywords: Diabetes; Glycemic Index; Glycemic Load; Industrial Poundo Yam; Predispose

Introduction

Glycemic index (GI) refers to the ranking of foods that have the ability to raise blood glucose concentrations, relative to a standard food (glucose or white bread) [1], while glycemic load (GL) is the numerical measurement of carbohydrate constituted in a meal/food by measuring the carbohydrate consumed in a particular diet and its ability to raise blood glucose level [2]. In other words, it is a number that measures how much the food taken (i.e. each carbohydrate gram in the meal) would raise the blood glucose level of the person [3]. It is a significant factor alongside GI in dietary programs that targets metabolic syndrome, insulin resistance and weight loss [4].

GI concept [5] was developed to help control blood glucose levels in diabetic patients when it was evident that high GI foods consumption was associated with an increased risk of type 2 diabetes mellitus (DM) [6]. Epidemiological and dietary intervention studies have shown that low GI and GL meals are beneficial to mankind for blood glucose control, while consumption of foods with high GI and/or (GL) is hypothesized to contribute to insulin resistance, which in turn is associated with increased risk of DM, obesity, cardiovascular diseases (CVDs) occurrence, and even cancers [7-9]. Therefore, identifying and consuming low GI and GL foods that slow down postprandial glycemic response is very important and should form the basis for dietary changes and recommendations in order to reduce the risk of having diabetes, obesity and other chronic degenerative diseases [10]. GI and GL are aspects of diet of great importance in the treatment and prevention of DM and some other chronic diseases. They are particularly relevant in the dietary prevention and control of diabetes, especially in developing countries like Nigeria, where carbohydrate foods like garri, rice, wheat, yam and various pounded yams (both local and industrial) etc form bulk of diets available to the majority of the population.

Pounded yam is a major staple food consumed across the nation (Nigeria), most especially in the south west region like Ado-Ekiti, Ondo, Oyo etc, northern areas (Niger and Abuja), and south east region like Enugu, Aba etc [11,12]. It is eaten with different soups, of which vegetable soup is one. It is a delicacy people like to eat however, its laborious or toilsome preparation is a major setback. Its pounding is strenuous [13] that is; it is tedious, menial and energy consuming. The need to prepare pounded yam meal with less stress whereby the drudgery and strenuous activities associated with the preparations of *in-situ* pounded yam (IPY) are removed, led to the production of various brands of industrial poundo yam flours (IPYFs) such as Ayoola poundo yam (APY), Endy's poundo yam (EPY), Ola-Ola poundo yam (OOPY), Iyan poundo yam (IYPY) etc that are now available in West Africa [14,15], most especially Nigeria. Thus, the strenuous pounding process/activity involved in IPY preparation that often hindered its frequent consumption by people that like to eat pounded yam has been overcome and by-passed with the production of [14]. In other words, the rigor of pounding associated with IPY preparation is needless in IPYFs preparation and has thus increased the number of people consuming pounded yam and its rate of consumption. However, information about the GIs and GLs of both IPY and IPYFs is very limited or even unavailable [16,17]. Therefore, this study was designed to determine the GI and GL of *in-situ* pounded yam and industrial (commercial) poundo yam solid pastes consumed with *Amaranthus hybridus* (tete) vegetable soup in clinically healthy human subjects, and it is hoped that findings from this study will help form basis for proper choice between these meals for lovers of our local meals, and those who may not be able to afford Western-type diet because, knowledge of GI and GL of foods is essential for rationale advice on calorie recommendation.

Subjects, Materials and Methods

Experimental subjects

Fifteen human subjects between the ages of 20-23 years, with body mass index (BMI) of 20.49 ± 1.55 kg/m2 were selected randomly from Faculty of Science, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria, after approval for the study had been obtained from the Health Research Ethical Committee of the Federal Medical Centre, Owo, Ondo State. In addition to verbal interest and agreement by the human subjects to participate in this research work, their willingness was documented. Clinically normal, non-smokers, non-alcoholics, non-hyperlipidemia and non-diabetic human subjects were used, and served as both control and test groups. The study protocols were followed without any prejudice to their social and religious status, and they remained within the confinement of the experimental area.

Food stuff

Fresh sample of *Amaranthus hybridus* (AH) vegetable, white yam (*Dioscorea rotundata*), Ayoola poundo yam flour, Endy's poundo yam flour, condiments etc were purchased at Ibaka-Akungba local market, Ondo State, Nigeria. The veggie and yam were identified by a curator, who is a senior lecturer in the Department of Plant Science and Biotechnology of Adekunle Ajasin University, Akungba Akoko, Ondo State.

Food stuff preparation

The vegetable soup (AH soup) and IPY as well as APY and EPY solid pastes were prepared according to Emaleku [12] methods. D-glucose (DG) dissolved in water served as reference meal.

Proximate composition of foods

The proximate composition of the food samples; solid pastes of IPY, APY, EPY and AH soup were determined using conventional standard methods of analysis of Association of Official Analytical Chemists, AOAC [18].

Feeding of human subjects

After 12 h of overnight fasting, the fifteen human subjects were given water-dissolved DG on the first day of the experiment, and the test meals; *in-situ* poundo yam with *Amaranthus hybridus* (IPYAH) soup, Ayoola poundo yam with *Amaranthus hybridus* (APYAH) soup, Endy's poundo yam with *Amaranthus hybridus* (EPYAH) soup and IPY on the 2^{nd}, $3^{rd,}$ 4^{th} and 5^{th} day respectively. The quantities of the meals containing 50 g available carbohydrate were given to subjects.

Blood glucose determination

The blood glucose levels of subjects were determined the procedures reported by Emaleku [12] and Emaleku., *et al*. [19].

Glycemic index determination

A modified method of Wolever., *et al*. [20] introduced by Emaleku in 2013, 2017 and Emaleku., *et al.* [19] was used to determine the GIs of each meal; DG, IPYAH, APYAH, EPYAH and IPY.

Glycemic load determination

It was calculated from GI following Emaleku [12] and Emaleku., *et al*. [19] method.

Statistical analysis

Proximate composition, blood glucose concentrations, GI and GL data were statistically evaluated with SAS version 8 software using one-way analysis of variance (ANOVA) with Duncan Multiple Range Test. The results were expressed as mean ± standard of error mean (SEM). F-test was taken at 95% (i.e. 0.05) level of significance and used to assess significant difference. A value of $P < 0.05$ was considered to indicate significant difference between and within groups.

Results

Table 1 result showed that; APY and EPY's ash, protein and fat contents were significantly different from that of IPY, but no significant difference exists in their fiber contents. Moreover, APY's moisture, protein and carbohydrate contents were significantly different from that of EPY.

Table 2 result showed that there was no significant difference in baseline blood glucose levels (i.e. fasting blood sugar) of human subjects before the consumption of the various meals however, 30 min after meals' consumption, the blood glucose levels of human subjects when APYAH was consumed differed significantly from when IPY and DG were consumed, but did not differ significantly from when EPYAH and IPYAH were consumed. A very similar trend was observed 90 min after meals' consumption.

Sample ID	Moisture (%)	Ash (%)	Fat (%)	Fiber (%)	Protein (%)	Carbohydrate (%)
IPY	53.71 ± 0.26^{b}	1.24 ± 0.11^{a}	4.15 ± 0.42^{a}	0.51 ± 0.09^{a}	6.63 ± 0.07^{a}	33.76 ± 0.70^{b}
APY	50.36 ± 0.25^{c}	0.49 ± 0.04^{b}	2.92 ± 0.19^{b}	0.74 ± 0.10^{a}	5.60 ± 0.25^{b}	39.89 ± 0.32^{a}
EPY	58.31 ± 0.28^{a}	0.45 ± 0.05^{b}	3.22 ± 0.14^{b}	0.58 ± 0.07^{a}	4.18 ± 0.26^{c}	33.27 ± 0.13^{b}
AHS	63.45 ± 0.21	2.13 ± 0.06	11.95 ± 0.05	5.67 ± 0.26	12.90 ± 0.21	3.90 ± 0.56

Table 1: Proximate analysis of food samples.

Note: These results are presented in mean ± standard error mean (SEM). Comparison is strictly within the same parameter. At (P<0.05) significance, values with the same notation (s) do not differ significantly, but those with different notations do. Key: IPY: *In-situ* Pounded Yam; APY: Ayoola Poundo Yam; EPY: Endy's Poundo Yam, AHS: *Amaranthus hybridus* Soup.

Time (Min)	0	30	60	90	120
Meals/Blood glucose (mg/dl)					
DG	84.00^{A} ± 6.08	132.00^{A} ± 4.04	118.67^{A} ± 4.81	109.33^{A} ± 4.49	86.67^{A} ± 4.41
IPY	85.67^{A} ± 3.71	119.33^{BA} ± 8.74	107.00^{A} ± 6.56	97.67^{BA} ± 4.33	93.67^{A} ± 6.07
IPYAH	83.00^{A} ± 4.04	107.00^{BC} ± 4.51	107.33^{A} ± 3.53	100.00^{BA} ± 2.31	94.00^{A} ± 4.16
APYAH	83.33^{A} ± 4.06	92.33^{C} ± 6.23	102.33^{A} ± 9.68	94.67^{B} ± 3.28	86.00^{A} ± 5.51
EPYAH	88.00^{A} ± 5.69	106.33^{BC} ± 3.38	108.00^{A} ± 4.51	101.67^{BA} ± 3.18	94.00^{A} ± 2.89

Table 2: Mean blood glucose response values of various meals consumed by human subjects.

Note: These results are presented in mean ± standard error mean (SEM). Comparison is strictly within the same parameter. At (P<0.05) significance, values with the same notation (s) do not differ significantly, but those with different notation (s) do. Key: DG: D-Glucose; IPY: *In-situ* Pounded Yam; IPYAH: *In-situ* Pounded Yam with *Amaranthus hybridus*; APYAH: Ayoola Poundo Yam with *Amaranthus hybridus*; EPYAH: Endy's Poundo Yam with *Amaranthus hybridus.*

Table 3 results revealed that the GIs and GLs of APYAH and EPYAH were significantly different from that of IPYAH, IPY and DG. And there was significant difference between GIs of IPYAH and IPY and DG, but no significant difference exists between IPYAH and IPY's GLs, nevertheless their GLs differed significantly from that of DG.

Figure 1 showed that APYAH and EPYAH caused the least postprandial glucose peak and incremental area under curve (IAUC) 2 h after meals' consumption when compared with IPYAH, IPY and DG. For example, 30 min after consumption, APYAH and EPYAH increased blood glucose levels of subjects slightly by 9 mg/dl and 18 mg/dl respectively, while IPYAH and IPY increased moderately by 24 mg/dl and 33.66 mg/dl respectively, and DG increased greatly by 48 mg/dl. The figure further revealed that; consumption of IPYAH when compare with IPY caused reduction in postprandial glucose peak and IAUC, and consumption of IPY without AH soup

Food samples	Glycemic index (%)	Glycemic load
D-Glucose	100.00^{A} ± 0.00	50.00^{A} ± 0.00
IPY	65.33^{B} ± 0.88	33.00^{B} ± 0.58
IPYAH	56.33^{C} ± 3.28	30.33^{B} ± 1.76
APYAH	39.00^{D} ± 2.08	20.67^{C} ± 1.20
EPYAH	43.67^{D} ± 1.45	23.67^{C} ± 0.88

Table 3: Glycemic index and glycemic load of meals (food samples).

Note: These results are presented in mean ± Standard error mean (SEM). Comparison is strictly within the same parameter. At (P<0.05) significance, values with the same notation (s) do not differ significantly, but those with different notations do. Key: IPY: *In-situ* Pounded Yam; IPYAH: *In-situ* Pounded Yam with *Amaranthushybridus*; APYAH: AyoolaPoundo Yam with *Amaranthushybridus*; EPYAH: Endy'sPoundo Yam with *Amaranthushybridus*.

raised postprandial glucose peak and IAUC than all the other meals except DG.

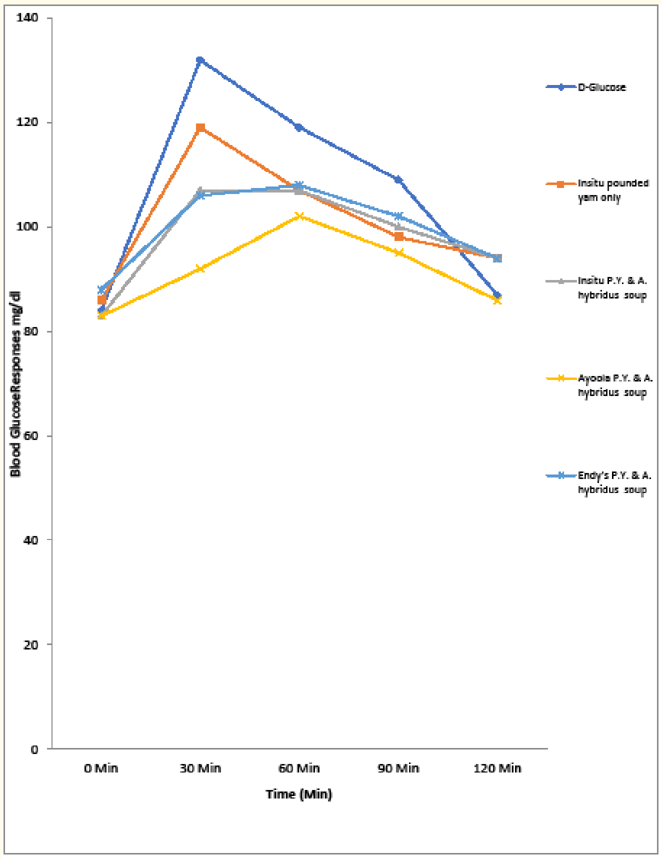

Figure 1: Mean blood glucose response curve of human subjects after meals' consumption.

Discussion

The high crude fat and protein contents of IPY suggests that it is not altogether a bad meal as many people thought and feared, and hence should not be completely avoided. According to Henry., *et al*. [22], high fat and protein contents have the potential to reduce glycemic response and thereby lower overall GI of the food. Similarly, Chen., *et al*. [23] reported that; Owen and Wolever in 2003 found that eating white bread (a high glycemic index meal) containing 50 g of available carbohydrate with a high quantity (40 g) of non-hydrogenated margarine fat significantly reduced IAUC and blood glucose response by 30%. The mechanisms by which these nutrients affect blood glucose concentration have been proposed in many studies. For instance, high protein level produces greater gastric inhibitory peptide (GIP), which is also known as glucose-dependent insulinotropic peptide, an inhibitory hormone that induces insulin secretion/activity and prompts insulin responses that results in low postprandial peak, and reduced glycemic response [24]. Similarly, high fat content has the potential to delay gastric emptying, which in turn slow down digestion and absorption of glucose [22] and prevents eating binge (overeating) that could on long term results in insulin resistance, a metabolic deranged condition commonly found in people consuming high GI foods due to sustained insulin spike. Fat may also affect the interaction of plasma glucose, insulin and GIP [25]. So, IPY has good crude fat and protein contents of great importance.

Furthermore, the higher fiber content of APYAH and EPYAH than IPY is a good nutritional property of great health benefits. Fibers in foods are plant non-digestible carbohydrate and lignin, which have been shown to have many profitable medicinal effects [26] and research evidence abound that linked dietary and functional fibers to positive health outcomes. According to Turner and Lupton [26], Oko., *et al*. [10] and Rudrappa [27], health benefits of increased dietary fiber in foods include; reduction in blood cholesterol and bad low density lipoprotein cholesterol (LDL-C) levels, slow glucose absorption, improved insulin sensitivity; as well as reduced incidence of obesity, coronary heart diseases (CHDs), type 2 DM, digestive disorders (constipation) and some cancers. In fact, low level consumption of fiber over time leads to several adverse physiological responses most especially, increased risk of CHD [28]. Therefore, the high fiber content of AHS could be said to have worked in tandem with that of APY and EPY for the overall characteristics of these industrial poundo yams (APYAH and EPYAH) that include; gradual digestion, absorption, assimilation [10], low blood glucose (glycemic response) and low insulin spike, and which in turn resulted in the observed low postprandial glucose peak and IAUC shown in Figure 1 and also the low GI and GL values shown in Table 3.

Moreover, the little increase in human subjects' blood glucose levels (83.33 - 92.33 mg/dl and 88.00 – 106.33 mg/dl) i.e. an increase of 9.00 mg/dl and 18.00 mg/dl for APYAH and EPYAH respectively 30 min after meals, where APYAH value in particular is significantly lesser than that of other meals except EPYAH, demonstrates the low blood glucose spike (glycemic responses) ability of these meals (industrial poundo yams).It suggests that these meals were gradually digested and released into the blood stream, and did not cause any spike in insulin levels that could increase the chance of having DM, CVDs and other chronic diseases [4,29] thus, 2 h after meals' consumption blood glucose of subjects was nearly returned to baseline values as shown in Table 2 and Figure 1, and these are characteristics of low GI foods.

The significantly lower GI values (39.00% and 43.67%) of APYAH and EPYAH respectively than that of IPYAH (56.33%) and IPY (65.33%) further give insight to their observed better glycemic effects earlier stated as shown in Table 2 and Figure 1. Low GI meals slightly raise blood glucose levels of subjects to cause little spike in insulin level with low glycemic response that in turn leads to minimal postprandial glucose peak and little IAUC [19,29]. In a nutshell, GI is directly proportional to blood glucose level, insulin level, glycemic response, postprandial glucose peak and IAUC. The lower the GI value of a meal; the lower the blood glucose level, insulin level, glycemic response, postprandial glucose peak and IAUC, and vice versa [19,21]. However, it is imperative to note that; in spite of the significantly low GI values of APYAH and EPYAH their GLs (20.67 and 23.67 respectively) are still high based on international classification standard, which classifies GL of ≥20 as high GL. This is particularly worrisome and calls for caution for those that delight in their regular consumption because, high GL meals connote; their consumption for a prolong period of time could cause repeated blood glucose and insulin spike that might in turn lead to insulin resistance, which would then increase the chance of the individual having DM and CVDs. This brings to mind the statement of Foster-Powell., *et al*. [2] that "GL is a better indicator of how carbohydrate food would affect blood glucose than GI". In fact, GL helps to select the appropriate portion (size or quantity) of a meal that is good for one's health. Since it is apparently evident that GI and GL are aspects of diet of great importance in the treatment and prevention of these chronic diseases, it is therefore obvious that consumption of APYAH and EPYAH containing 50 g of available because of their high GLs might still predisposes man to DM and CVDs if consumed regularly but below 50 g of available carbohydrate might not.

Summarily, based on this study, individuals with impaired glucose tolerance or people that are concern with their diets and health may consider the consumption of APYAH and EPYAH to IPY due their low GI values. However, because of their high GL values; they should be eaten with caution, and quantity containing less than 50 g of available carbohydrate is thus recommended.

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