GLYCEMIC RESPONSE OF TWO COMPOSITE FLOURS: WHEAT-INNALA (*Plectranthus rotundifolius*) AND WHEAT-KIRI ALA (*Xanthomonas sagitifolium*)

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Abstract
Prevalence of chronic diseases such as obesity and type-2-diabetes requires dietary manipulation. Roots and tubers are mostly grown in tropical and sub-tropical regions and are underutilized and generally they are good sources of carbohydrates. Innala, Plectranthus rotundifolius and Kiri ala, Xanthomonas sagitifolium are two of underutilized yams available in Sri Lanka. It was hypothesized that wheat-yams composite food products will reduce the spike of blood glucose and increase satiety. In this study, these two yams were analysed for their proximate composition, protein, fat, minerals, fiber and carbohydrates using AOAC procedures. Flours were prepared from these yams and then two composite flours were prepared by incorporating 10% each yam to all purpose wheat flour. Then these composite flours were evaluated for their postprandial glycemic response using selected healthy individuals. Two yams studied have shown that they are rich in minerals and dietary fibers. Flours prepared from yams can be used to prepare composite flour with all purpose wheat flour. These two yams incorporated (10%) composite flours exhibit lower postprandial glycemic response than 100% wheat flour. Among the two yams studied kiri ala showed the lowest peak with reference to the 100% wheat flour. Based on the results of the present study, it can be concluded the glycemic response value varies significantly with the yam. Effective low glycemic index high-fiber products such as these yams could play an important role in increasing fiber intakes and reducing the glycemic load of the diet. We conclude that addition of yam flour at 10 % to all purpose wheat flour based products like flat bread, that is acceptable to eat, causing no physical discomfort and lowers the glycemic response.

Key words: *Plectranthus rotundifolius, Xanthomonas sagitifolium,* postprandial glycemic response, diabetes, yams

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INTRODUCTION

Sri Lanka has many tropical root and tuber crops that can be used as alternative sources of carbohydrate. Most of available roots and tuber crops have not been fully exploited for any industrial uses. Cocoyam (*Colocasia esculenta)*, kiriala (*Xanthosoma sagittifolium)* and innala *(Plectranthus rotundifolius)* are a few examples of these crops. According to the literature, flours prepared from roots and tubers usually have a higher viscosity compared to that of cereal flours, which allows them to be used as thickening or gelling agents in some food products and less starchy flavours compared to cereal flours (Moorthy, 2002). Moreover, these materials also offer health benefits especially in preventing obesity, constipation, cardiovascular disease, diabetes and colon cancer due to the high amount of fiber content (Chen et al., 2003). The absence of gluten within these materials may help provide nutrition for those who allergic to gluten too (Van Hung and Morita, 2005).

Except for cassava and sweet potato, many of these starchy materials have not been utilized optimally due to the lack of knowledge of suitable processing techniques and product development (Deshaliman, 2003). Kiriala and innala like crops even though they have been consumed as a source of carbohydrate by local people in rural areas but not as a food ingredient. Flour made from these crops may have unique characteristics that may be important for use in some food applications (Thitipraphunkul et al., 2003). Recently, the growing awareness of consumers on the

relationship between foods and health has led to an increasing demand for functional foods. Prebiotic is one of the most promising functional foods as a component presented in foods that contribute health benefits by promoting the growth of beneficial bacteria (probiotics) in the intestinal tract (Gibson et al., 1995), being as a soluble dietary fiber with low caloric value and health related benefits (Roberfroid, 1999). Prebiotics such as inulin and oligofructose are found naturally in a variety of foods including some yams (Moongngarm et al., 2011). However, the prebiotic effect of Cocoyam, kiriala and innala like crops has not being fully exploited.

Kiriala is a herbaceous perennial plant having a corm or main underground stem in the form of a rhizome from which swollen secondary shoots, or cormels, sprout. Several large leaves also sprout from the main stem. It belongs to the family Araceae. The most popular variety of Kiriala grown in Sri Lanka is *Xanthosoma sagittifolium* (Figure 1 B). The growth cycle lasts from nine to 11 months. During the first six months the corms and leaves develop and in the last four months, the foliage remains stable and, when it begins to dry, the plants are ready for the cormels to be harvested. They require well-drained soils and do not tolerate the permanent presence of water. The mean temperature for their optimum growth must exceed 20°C. Kiriala was originated in Central America and cultivated mostly in Carribean islands, South America and some parts of Africa and Asia. There are few varieties of Kiriala such as "Ada dam kiriala, Kalu kiriala and Rathu iri Kiriala" found in Sri Lanka. Rathu iri kiriala is the major variety cultivated and commonly known as "Isuru". It is widely available in the market during the season. But it can be grown throughout the year and with sufficient water supply it can be cultivated in areas having elevation up to 1500m above mean sea level. They are consumed in households as a food by boiling and preparing curries.

Despite the availability of starchy materials derived from roots and tubers as mentioned above, rice and wheat are still the main sources of carbohydrates in Sri Lanka. The need for wheat in Sri Lanka is relatively high and entirely it is fulfilled by importation. Periodical increments of wheat prices have greatly affected the consumption pattern of wheat flour based food products. Furthermore, the domestic wheat flour demand is totally fulfilled by importation and it is a large financial burden to the country costing Rs 40 098 millions in 2013 (Central Bank Report, 2013). Nutritional limitations of a wheat based products are its low content of essential amino acids (Hefnawy et al. 2012). Wheat has high glycemic index too (Foster-Powell et al. 2002). However, glycemic index is not solely responsible for the rise in blood glucose concentration with a carbohydrate food, glycemic response is also influenced by the glycemic load or the amount of high glycemic carbohydrate in the food (Venn and Green 2007). According to the current research, habitual consumption of high glycemic index foods at high glycemic load is associated with tissue and organ damage such as microangiopathy, diabetic nephropathy or retinopathy whereas low glycemic index foods consumed at moderate glycemic load are associated with reduced rates of coronary arterial diseases and type-2 diabetes (Brownlee 2003; Liu et al. 2000). Partial substitution wheat flour with other flours derived from underutilized roots and tubers, which are widely available in Sri Lanka, may provide a solution to this need. Therefore, the objective of this study will be to determine the suitability and the level of substitution of flour made from locally available two yams. The information obtained in this study will be useful to lessen the dependency on wheat flour as one of the main source of carbohydrate in Sri Lanka. Furthermore, the results will broaden the application of flours prepared from these underutilized tuber and roots crops in the food industry with particular emphasis on bakery products with the aim of producing functional formulations with low glycemic index values.

MATERIALS AND METHODS

1. Raw Material and Products

Kiriala (*Xanthosoma sagittifolium*) was obtained from a local market in Weyangoda in Gampaha district. Innala (*Plectranthus rotundifolius*) was obtained from a local market in Makandura area in Kurunegala district, Sri Lanka. All Purpose wheat flour (brand name: Prima) was obtained from Cargills Food City, Dankotuwa, Sri Lanka. All the chemicals used for the study were of analytical grade.

2. Preparation of flour from yams

Flours from these yams were prepared according to the method of Senanayake et al., (2012) with some modifications. About 10kg of the tubers were washed, hand peeled and trimmed to remove defective parts and then the tubers were grated into thin chips (~5mm) and immediately soaked in 0.25% citric acid and were dried in a dehydrator at 50˚C for 24 hours to 14% moisture. Then the dried tubers were powdered using a laboratory scale grinder (Jaipan Grinder model IS:4250) and sifted through 250µm sieve.

3. Proximate composisiton of yam's flour

All three flour samples were tested for moisture, ash, crude protein, crude fat, crude fibre and mineral (Ca, Mg, Fe, Cu, Zn, Al, Mn, Co) contents. Quantitative estimation of moisture, ash, fat and protein were done by standard AOAC methods (2000). Crude fiber contents were determined by Weendy method using FibertecTM M6 fiber analysis system.

4. Composite flour preparation

Two composite flours were prepared by incorporating 10% yams flour as mentioned in 2.2 with all purpose wheat flour, Composite flour A: 90% Wheat flour and 10% Kiriala flour; Composite flour B: Wheat flour and 10% Innala flour.

5. Flat bread (roti) preparation

Two separate flat breads were made with these wheat-yam composite flours. Composite flour, coconut scrapings, salt and water were used to prepare flat breads according to the traditional recipe. Flat Bread made with 100% wheat flour was used as reference food and it was based on a traditional Sri Lankan recipe. The ratios of different ingredients used to prepare flat breads are shows in Table 1. Available carbohydrate (CHO) level was maintained constant for each and every treatment.

Table 1: Data for the composition of wheat, innala and kiri ala roti used in the study

CHO source	Wheat flour (g)	Coconut scrapes (g)	Yam flour (g)	Available CHO (g)
Glucose	-	-	-	50.4g
Control (Wheat flat bread)	45g	22.5g	-	50.4g
Innala flat bread	41.5g	22.5g	4.15g	50.4g
Kiriala flat bread	41.5g	22.5g	4.15g	50.4g

Available carbohydrate was taken from USDA data base for wheat and coconut scrapes (40%). Available carbohydrates of Innala and Kiriala were mentioned as 77.84% and 77.19%

6. Study design

Five healthy volunteers, age 25±1 years, BMI 22.02 ± 2.20 kg/m^2 (Table 2) participated in the study. All participants were provided with specific written consents obtained prior to entrance into the study. Each individual was extensively interviewed by Researchers who filled in a structured questionnaire specifying following conditions: Abstention from i) alcohol, ii) fiber-rich foods, iii) medicines, iv) dietary supplements, v) excessive physical exercise and vi) smoking for at least 24 hours prior to each study day. Fasting blood samples were collected prior the consumption of the respective test flat bread samples (empty stomach). Each test flat bread samples (wheat, innala and kiriala flat breads) was designed to contain 50.4 g available carbohydrates. Glucose 50.4g was used as the reference food. Each subject was served 250mL of drinking water. Finger prick capillary blood samples were taken before the meal and at 15, 30, 45, 60, 90 and 120 minutes after the meal. Blood glucose concentration was determined with the blood glucose meter (Glucometer-Prodigy autocode blood glucose meter: NC28269 USA). The time interval between testing different flat bread was at least three days.

Table 2. Descriptive characteristics of the participants

Participant No.	Age	Weight (kg)	Height (cm)	BMI (kg/m^2)
01	25	58	167	20.80
02	24	52	166	18.87
03	24	56	154	23.61
04	27	60	157	24.34
05	25	54	155	22.48
Average	25± 1	56± 3.16	159.8± 6.22	22.02± 2.20

RESULTS AND DISCUSSION

Roots and tubers are mostly grown in tropical and sub-tropical regions and some species in temperate climate. They are the plants that produce stems, corms, rhizomes, tubers and starchy roots. These underground organs of these plants store energy in the form of starch or sugar. The yam tubers are accounting for a major part of the daily diet of millions of people in Africa, Asia, South America and the Pacific countries. Nowadays it is a mean of ensuring food security worldwide (Oke & Bolarinwa, 2011). Carbohydrate based foods are generally classified as low or high glycemic index depending upon the rate of their digestion and absorption and their relative impact on raising blood glucose concentration. In most cases, glycemic index of a food is measured by comparing the rise in blood glucose to that of a reference food (glucose) containing the same amount (25 g/50 g) of carbohydrate consumed by the same individual on two different days (FAO/WHO 1998). In the present study, the post-prandial glycemic, responses to flat breads made from all purpose wheat flour or composite flours of wheat and yams were determined in healthy subjects.

Table 3 shows the proximate composition of Kiriala and Innala. The highest moisture content (80.46±1.41%) was recorded for innala (77.91±1.06%) when compared with Kiriala (69.77±1.09%) and Innala. There was no any significant difference ($p<0.05$) in the ash content of Kiriala and Innala flours. Ash contents of three flours ranged from 2.08 to 2.47%. It has been suggested that higher ash contents of starch are a result of the presence of material commonly referred to as “fine fibre” (Hoover & Rathnayake, 2002). The amount of crude protein present in two flour types ranged from 5.3 to 9.6 % (Table 3). Innala flour exhibited the higher protein content. According to Premathilake (2010) Innala raw tubers are said to have 0.1-0.2g of fat per 100g of raw tubers. Crude fibre content of Kiriala and Innala flour was considerably high ranging from11.25±3.32% to 13.75±9.73% (Table 3). There was no significant difference among crude fibre contents of two flour types ($p<0.05$).

The post-prandial blood glucose level after consumption of flat bread prepared with composite flours of wheat and yam’s flour is reported in Figure 1. Following the consumption of test meals, plasma blood glucose concentrations increased, reaching a peak after 45 min and then decreasing towards values which were similar to baseline after 120 min. The peak blood glucose response was observed 60 min. after the ingestion of flat bread prepared only with wheat bread and the peaks blood glucose responses after the ingestion of flat breads prepared with the wheat-yams composite flour showed at around after 45 min. This reveals that the only wheat flour takes longer time to be digested in healthy subjects compared to the composite flour of 10% yams (Figure 1). However, the highest postprandial blood glucose levels after the consumption of 10% yams flour added flat breads were significantly ($p<0.05$) lower than that of only what flour added flat bread. Among the yams flour added flat breads, flat bread prepared with 10% kiriala flour have shown significantly lower peak compared with the control and innala flour added flat bread.

Diets that result in gradual and slow increase in postprandial blood glucose concentration are gaining increased attention as they can potentially reduce the risk of chronic diseases related to impaired glucose metabolism such as diabetes (Brigheuti *et al*., 2006).

Table 3: Proximate composition of two yams flours

Flour type	Moisture %	Ash %	Crude Protein %	Crude Fat %	Crude Fibre %
Kiriala	69.77±1.1[b]	2.47±0.0[a]	5.39±1.1[b]	0.57±0.358[a]	13.75±9.7[a]
Innala	77.91±1.1[a]	2.08±0.6[a]	9.63±1,0[a]	0.01±0.003[b]	11.35±9.6[a]

Data are presented as means ±standard deviations of three replicate determinations. Columns with different letters for each yams are significantly different ($p < 0.05$).

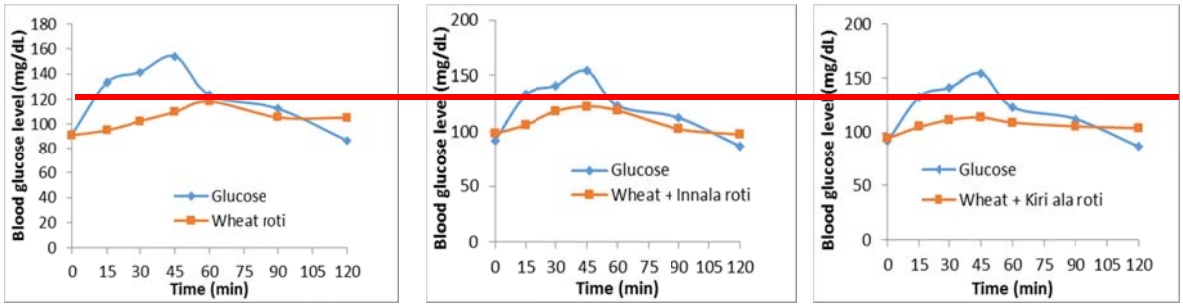

Figure 1. Variation of postprandial blood glucose level of healthy individuals after the consumption of wheat (A), Innala (B) and Kiriala (C) flat breads compared with glucose

Therefore, kiriala and innala which fall into lower GI foods compared with all purpose wheat flour would be beneficial to balance blood glucose level in diabetics when they are incorporated in their diets.

Effective low glycemic index high-fiber products such as these yams could play an important role in increasing fiber intakes and reducing the glycemic load of the diet. The availability of functional food products such as yams naturally enriched with dietary fiber and slightly processed in order to prevent starch gelatinization like traditional flat bread, could help the public to increase dietary fiber intake and to maintain protective post-prandial metabolic patterns. However, further research need to perform for comprehensive analysis of these underutilized yams species for better nutrition for future.

CONCLUSION

Roots and tubers are mostly grown in tropical and sub-tropical regions and are underutilized. Two yams studied have shown that they are rich in minerals and dietary fibers. Flours prepared from yams can be used to prepare composite flour with all purpose wheat flour. These two yams incorporated (10%) composite flours exhibit lower postprandial glycemic response than 100% wheat flour. Among the two yams studied kiriala showed the lowest peak with reference to the 100% wheat flour. Based on the results of the present study, it can be concluded the glycemic response value varies significantly with the yam. Effective low glycemic index high-fiber products such as these yams could play an important role in increasing fiber intakes and reducing the glycemic load of the diet.

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