ORIGINAL

Carbohydrate Profile, Total Dietary Fiber and *In vitro* Glycemic Index of Taro- Corn and Sweet Potato- Corn noodles.

Hazel T. Lat[1*], Wilma A. Hurtada[2], Erlinda I. Dizon[3], Aimee Sheree A. Barrion[2]

[1]*Department of Science and Technology-Food and Nutrition Research Institute, Bicutan, Taguig City, Philippines.*
[2]*Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños, Philippines.*
[3]*Institute of Food Science and Technology, Food Science Cluster, College of Agriculture, University of the Philippines Los Baños, Philippines.*

(received January 30, 2019)

ABSTRACT *Background.* The carbohydrate profile and *In vitro* glycemic index of taro, sweet potato and IPB var. 6 white corn flours and the noodles from taro-corn and sweet potato-corn flour mixtures were studied. *Results*. Processing the flours into noodles significantly affected its carbohydrate profile (starch and amylose), total dietary fiber and glycemic index. There was a significant reduction ($p<0.05$) in the starch content when the flours were processed into noodles, but a significant increase ($p<0.05$) in the amylose content, total dietary fiber and glycemic index when the flours were processed. *Conclusion*. The results of this study may provide opportunities to promote and support the use of the taro, sweet potato and IPB var. 6 white corn flours into processed foods like noodles which can help improve its production and utilization potentials.

Keywords: Taro; Sweet Potato; Corn; Dietary Fiber; Glycemic Index

INTRODUCTION

Carbohydrates, such as rice, breads, and noodles are the major sources of food, because it provides most of the daily energy needs. Among these, noodles are popularly known for their ease of preparation, availability and deemed as a cheap source of carbohydrates. Even in disaster situations, noodles are usually being provided as a source of nourishment. Noodles are usually prepared using ingredients such as wheat flour, egg and salt. These ingredients provide high energy, but most often, it does not contain other nutrients that are beneficial for growth and development. That is why, noodles in the country are starting to be fortified with vitamins and also have additional vegetable ingredients. Although, it will be good to try substituting wheat flour with indigenous flours, for added nutritional and health benefits, such as taro flour, sweet potato flour, and corn flour.

Tubers and root crops, such as taro, sweet potato and crops such as corn or maize, are basically important sources of carbohydrates as an energy source and as a staple in the tropical and sub-tropical countries (1). These products have nutritionally beneficial components high dietary fiber content and have a lower glycemic index value (2).

Dietary fiber is an important part of a healthy diet. It is the remnants of the edible part of plants and analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the human large intestine (3), while the glycemic index of foods was introduced to provide additional information about foods and to classify them in terms of their glycemic response whether foods eaten release glucose rapidly or in a slow and sustained fashion for a period of time (4). From a nutrition perspective, it is not particularly important to know the exact GI value of every food as this will change depending on various factors. What is important is to be able to identify which foods are absorbed over a longer period of time (low GI; GI <55), which foods elicit a rapid surge of glucose (energy) into the bloodstream (high GI; GI > 70), and which are in between (intermediate GI; GI 55-70). Consequently, foods high in carbohydrates can thus be arranged into these broad categories to guide dietary choices (5).

This study specifically determined the carbohydrate profile (starch and amylose), total dietary fiber content and in vitro glycemic index of the taro [Colocasia esculenta (L.) Schott], sweet potato [Ipomoea batatas (L.) Poir], IPB var. 6 white corn [Zea mays L] flours, and the cooked and uncooked taro-corn and sweet potato-corn noodles to determine the effect of processing. The results of this study may provide opportunities to promote and support the use of the taro, sweet potato and IPB var. 6 white corn flours into processed foods like noodles which can help improve its production and utilization potentials.

This study was conducted at IHNF, UPLB from May to June 2014.

---

[*] To whom correspondence should be addressed: lat.hazel@gmail.com

METHODS

Experimental Materials

Quality Protein Maize (IPB var. 6) and Sweet Potato (NSIC 31 variety) were obtained from the Institute of Plant Breeding, College of Agriculture, University of the Philippines Los Baños, Laguna. Taro corms (NSIC V9 variety) were obtained from the Philippine Root Crop Research and Training Center, Visayas State University (VSU), Visca, Baybay City, Leyte.

Processing of taro corms and sweet potato roots

The raw taro corms and sweet potato roots underwent different physical treatments such as washing, peeling, dicing, soaking, drying and milling before they were processed into taro and sweet potato flour. The taro and sweet potato flour was then mixed with the IPB var. 6 white corn flour and was used in the preparation of the noodles. It was analyzed for its carbohydrate profile, total dietary fiber content and *in vitro* glycemic index. All the chemical analyses were done at the Analytical Laboratory of the Institute of Human Nutrition and Food at the University of the Philippines Los Baños.

Preparation of the taro-corn and sweet potato-corn noodles

The taro, sweet potato and IPB var. 6 white corn flours were used in the preparation of the noodles. The recipes were standardized to determine the right proportion of the ingredients that yielded the most acceptable product.

Selection of flour proportion for noodle production

Preliminary study was conducted to produce flat noodles from the different possible combinations of the taro-corn flour and sweet potato-corn flour (100:0, 90:10, 80:20,70:30, 60:40, 50:50, 40:60, 30:70, 20:80, 10:90 and 0:100). The 70:30 taro-corn and 70:30 sweet potato-corn noodles were both slightly liked for their aroma, texture and flavour, and was acceptable as compared to the other proportions.

Chemical analyses

Starch content was determined using the anthrone method while the amylose content was determined using a colorimetric assay by Williams *et al.* (6).

Total Dietary Fiber

The total dietary fiber was determined using the enzymatic-gravimetric method using the total dietary fiber assay kit (TDF-100 A and TDF – C10) of Sigma-Aldrich, Inc.

Estimation of Glycemic Index

The kinetics of in vitro starch digestion was followed by a nonlinear model established by Goni *et al.* (7).

Statistical analysis

Results of the chemical tests were analyzed using ANOVA and LSD. All the statistical tests were performed at 5% level of significance.

RESULTS AND DISCUSSION

Carbohydrate Profile

The taro flour has the highest starch content at 75.22 % followed by the sweet potato flour at 71.45 % and the IPB var. 6 white corn flour at 70.98 %. As for the noodles, the sweet potato-corn uncooked noodles have higher starch content at 65.32 % as compared to the uncooked taro-corn noodles at 52.79 %. There was a significant decrease in the starch content when the noodles were cooked, from 52.79 % starch content of the uncooked taro-corn noodles to 30.91 % in the cooked taro-corn noodles, as well as in the sweet potato-corn noodles at 65.32 % for the uncooked noodles to 55.42 % in the cooked noodles (Table 1).

Table 1. Starch and amylose content of taro, sweet potato, IPB Var. 6 flour and taro-corn and sweet potato-corn noodles

Sample	Starch (%)	Amylose (%)
Taro Flour	75.22 $\pm$ 1.30^{a}	39.75 $\pm$ 2.33^{b}
Sweet Potato Flour	71.45 $\pm$ 2.24^{b}	18.57 $\pm$ 0.21^{f}
Quality Protein Maize Flour	70.98 $\pm$ 0.62^{b}	30.45 $\pm$ 0.21^{e}
Taro-Corn uncooked noodles	52.79 $\pm$ 0.76^{d}	33.52 $\pm$ 0.58^{d}
Taro-Corn noodles	46.80 $\pm$ 0.91^{e}	36.27 $\pm$ 1.07^{c}
Sweet potato-Corn uncooked noodles	65.32 $\pm$ 1.96^{c}	39.05 $\pm$ 1.15^{b}
Sweet potato-Corn cooked noodles	55.42 $\pm$ 1.82^{f}	45.14 $\pm$ 2.21^{a}

Means that share the same letter within columns are not significantly different at p (<0.05).
Waxy (0-5% amylose); very low (5-12% amylose); low (12-20%); intermediate (20-25%); high (25-33%)

The taro flour has the highest amylose content at 39.75 % followed by the IPB var. 6 white corn flour at 30.45 % and the sweet potato flour at 18.57 %. For the noodles, there was a significant increase in the amylose content after cooking, from 33.52 to 36.27 % in the taro-corn noodles and from 39.05 % amylose content in the uncooked sweet potato-corn noodles to 45.14 % after cooking. Also, the amylopectin content was measured. The sweet potato flour has the highest amylopectin content at 40.53 % followed by the IPB var. 6 white corn flour and the taro flour at 40.53 and 35.47 % respectively.

The amylose content in starch is one of the important factors influencing starch pasting and the strength of starch gel due to its quick retrogradation, association and interaction to lipids, and amylopectin form helical complex giving strong gel structures. Starches with high amylose content were desired for manufacture of starch noodles (8). Taro has a smooth-textured gel, which would be suitable for noodle processing, which requires a smooth mouth feel and avoidance of grainy texture. Also, past studies have shown that sweet potato flour may potentially be used in noodle processing and bread production (2). However, it was also reported that high amylose corn starch was not suitable for noodle making because it was not sufficiently gelatinized at atmosphere condition, leading to almost no amylose molecules released to participate into the noodle structure formation (8). As what was observed in the preliminary study wherein the 100% corn flour cannot be formed into noodles. However, if mixed into starches with high amount of protein, lipid and ash, which can reduce the clarity of starch paste and hinder the swelling of the starch granule because of the high rate formation of amylose-lipid complex. Nevertheless, the protein and lipid played important role in retention of amylose in starch noodles during cooking, resulting in minimizing cooking loss (8).

Total Dietary Fiber

Among the three flours, the sweet potato flour has the highest total dietary fiber content at 4.74 %, followed by the IPB Var.6 white corn flour and the taro flour at 2.71 % and 2.63 % respectively. The total dietary fiber content of the cooked noodles increased from, 5.02 % to 5.36 % in the cooked taro-corn noodles while the uncooked sweet potato-corn noodles also increased from 7.21 % to 10.17 % in the cooked sweet potato-corn noodles (Table 2). This could have been due to the fact that an increase in temperature leads to a breakage of weak bonds between polysaccharide chains. Also, glycosidic linkages in the dietary fiber polysaccharides may be broken (9). According to Dhingra *et al.* (10), grinding may affect the hydration properties, in particular, the kinetics of water uptake as the result of the increase of surface area, the fiber hydrates more rapidly. Heating generally changes the ratio of the soluble to insoluble fiber. Simple processes, such as soaking and cooking tend to modify the composition and availability of nutrients. This may also modify the plant cell wall material that may have physiological effects. In a study done in wheat bran, it has been found out that thermal treatment, such as boiling, cooking or roasting-originate an increase of total fiber that is not due to new synthesis but rather to the formation of fiber-protein complexes that are resistant to heating and are qualified as dietary fiber. According to Pushparaj and Urooj (11) changes in dietary fiber composition of processed cereal and pulses have been reported where increase in the total dietary fiber content could be due to formation of resistant starch.

The amount of total dietary fiber is important because of its influence on glucose absorption, post-prandial glucose levels, and glycemic index (12).

Table 2. Total dietary fiber content

Sample	Total Dietary Fiber (%)
Taro Flour	2.63 ± 0.21^{d}
Sweet Potato Flour	4.74 ± 0.59^{c}
Quality Protein Maize Flour	2.71 ± 0.21^{d}
Taro-Corn uncooked noodles	5.02 ± 0.24^{c}
Taro-Corn noodles	5.36 ± 0.68^{c}
Sweet potato-Corn uncooked noodles	7.21 ± 0.86^{b}
Sweet potato-Corn cooked noodles	10.17 ± 0.68^{a}

Means that share the same letter within columns are not significantly different at p (<0.05)

Glycemic Index

The classification of foods based on their glycemic index has dispelled the repeatedly suggested dietary notion that carbohydrate-rich foods have deleterious health effects, and as such, consumption should be limited. In fact, there are numerous evidence-based studies which dismiss the negative view of carbohydrate-rich foods and clearly demonstrate that "not all carbohydrates are created equal". Furthermore, variations in the physicochemical properties of complex carbohydrates have been shown to elicit dissimilar physiological effects when consumed. Also, some complex carbohydrate-rich foods are undeniably beneficial and do not cause blood glucose levels to spike any greater than simple sugars. However, food preparation is important and should be considered, as the method of cooking can alter the structure and the nature of the starches (13).

Enzyme hydrolysis of starch molecules to produce glucose is important to provide energy for plant metabolism, food, feeds and ethanol production. The starch granules are hydrolyzed at a slower rate by enzymes than the gelatinized, amorphous starch molecules. The susceptibility of the starch granules depends on the granular size, the structure of the amylopectin, the amylose content, the lipid content, and the reaction pattern of the enzyme. Generally, the larger the starch granule, are normally digested at a slower rate than the smaller starch granules because the larger granules have a smaller relative surface area for enzyme hydrolysis (14).

White bread, used as reference in this study, showed a digestion value of 75.3 % at 180 minutes (Figure 1), which resembles that reported by Goñi *et al.* (7), but previous works, such as the one done by Grandfelt *et al.* (15) as reported by Tovar *et al.* (2002) have found that white bread showed a digestion value of 50 %. This could be explained, due to the different methodologies that were used, such as the inclusion of pepsin in the hydrolysis and the use of an unrestricted system (7).

Among the flours, the IPB Var. 6 white corn flour has the lowest total starch hydrolysis rate at 29.13 % and the sweet potato flour has the highest rate at 51.66 % as compared to that of the white bread. The cooked taro-corn and sweet potato-corn noodles also showed a high starch hydrolysis rate of 67.05 % and 62.22 % respectively (Figure 1).

The course of hydrolysis differed greatly among various samples, being markedly slow in the case of IPB Var. 6 white corn flour, sweet potato flour, taro flour and the uncooked taro-corn noodles and sweet potato-corn noodles, but much more rapid in the case of white bread and that of the cooked taro-corn and sweet potato-corn noodles, which showed higher hydrolysis index. However, it should be kept in mind that ingredients included in the noodle formulation might have also affected starch digestibility (16).

The rate of starch hydrolysis in the samples varied widely suggesting that other factors other than hydrolytic enzyme activity. It can be observed that the cooked noodles hydrolyzed more rapidly as compared to the uncooked noodles. This is because cooking greatly increased the rate at which starch can be hydrolyzed by gelatinizing the starch and making it more readily available for enzymatic attack (17). The degree of starch gelatinization is not the only factor that affects susceptibility of starch to enzyme action. The digestibility of starch can be affected by several factors including the composition and physical form of the starch, protein-starch interactions, the physical form of the food, the integrity of the starch-containing cells, and presence of anti-nutritional factors (18), while the lower levels of starch hydrolysis that were observed in the taro, sweet potato and IPB var 6 white corn flour, may be attributed to the presence of cell wall and other components such as the dietary fiber and mucilage (19) as what was observed by Bordoloi *et al.* (20) in the starch of cooked potatoes.

Table 3 shows that the reference sample, white bread has an estimated glycemic index of 94.61. For the flour samples, the sweet potato flour has the highest glycemic index at 77.20, followed by the taro flour and the IPB Var 6 white corn flour at 65.46 and 60.79 respectively. For the noodles, cooking showed a decrease in the glycemic index of the taro-corn and sweet potato-corn noodles at 84.92 for the uncooked taro-corn noodles to 72.24 for the cooked taro-corn noodles, and the uncooked sweet potato-corn noodles at 88.43 to 74.45 for the cooked sweet potato-corn noodles.

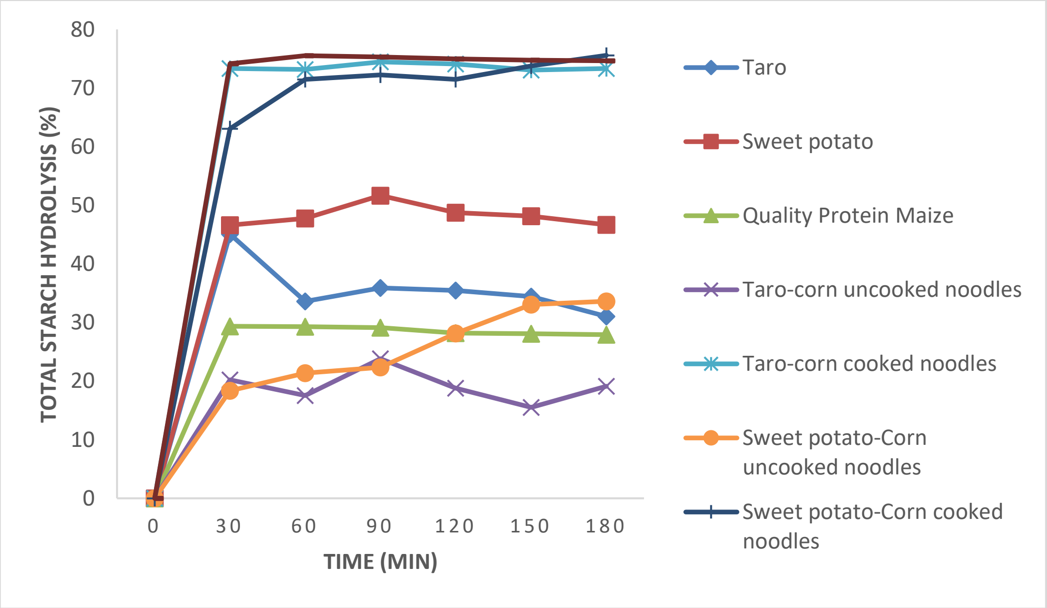

Figure. 1. Average hydrolysis curves of starch in taro flour, sweet potato flour, IPB var. 6 white corn flour (QPM), and cooked and uncooked taro-corn and sweet potato-corn noodles.

Table 3. Starch hydrolysis and estimated glycemic index (EGI) of flour and noodles

SAMPLE	H_{90}	$C\infty$	k	HI	EGI
White Bread	75.30 ± 1.19^{a}	79.29^{a}	0.03	100 ± 0.00^{a}	94.61 ± 0.00^{a}
Taro Flour	35.91 ± 3.41^{bd}	39.34^{bd}	0.03	46.91 ± 6.11^{bd}	65.46 ± 3.35^{bd}
Sweet Potato Flour	51.66 ± 1.99^{c}	55.46^{c}	0.03	68.28 ± 3.80^{ch}	77.20 ± 2.08^{ch}
Quality Protein Maize Flour	29.13 ± 5.13^{d}	32.31^{d}	0.03	38.38 ± 6.71^{d}	60.79 ± 3.70^{d}
Taro-Corn uncooked noodles	62.22 ± 1.85^{eh}	66.04^{ec}	0.03	82.34 ± 0.95^{e}	84.92 ± 0.52^{e}
Taro-Corn noodles	44.88 ± 0.82^{fbc}	48.43^{fbc}	0.03	59.25 ± 2.01^{fh}	72.24 ± 1.10^{fh}
Sweet potato - corn uncooked noodles	67.05 ± 4.12^{ga}	70.93^{gae}	0.03	88.74 ± 4.58^{g}	88.43 ± 2.52^{g}
Sweet potato – corn cooked noodles	47.89 ± 2.69^{hc}	51.52^{hcf}	0.03	63.27 ± 4.25^{h}	74.45 ± 2.33^{h}

Means that share the same letter within columns are not significantly different at p (<0.05)
GI Classification: Low GI <55; intermediate 55-70; High >70;
H_{90} – Starch hydrolysis at 90 minutes; $C\infty$ - Equilibrium concentration; k- Kinetic Constant; HI- Hydrolysis Index

The sweet potato flour exhibit the highest GI value among the three flours at 77.20 and also the lowest amylose content at 18.57 %, while the taro flour and the IPB var. 6 exhibited an intermediate GI value at 65.46 and 60.79 respectively, and also exhibited a higher amylose content than that of the sweet potato flour at 39.75 and 30.45 % for taro and IPB var. 6 white corn flour respectively. When the flours are made into noodles, it resulted in higher amylose content for the sweet potato-corn uncooked and cooked noodles at 39.05 to 45.14 % respectively. As for the taro-corn noodles, when the noodles were cooked it resulted in a higher amylose content at 33.52 % for the uncooked noodles to 36.27 % for the cooked noodles. When the noodles are cooked, the amylose content increases, but the GI value decreased, from the GI value of 84.92 to 72.24 for the taro-corn noodles and the GI value of 88.43 to 74.45 for the sweet potato-corn noodles (Figure 1). Bahado-Singh *et al.* (13) reported that rice with high amylose content was accompanied by a lower metabolic response to and lower GI values. Also, boiling lowers GI values. This may be link to the chemical structure of starches - that is the amylose-amylopectin ratio (21). The amylose content is known to be negatively correlated with the starch susceptibility to amylase hydrolysis (22). Juliano (23) suggested the classification of amylose content in rice as waxy (0-5 %), very low (5-12 %), low (12-20 %), intermediate (20-25 %) and high (25-33 %). Waxy starch granules are more susceptible to enzyme hydrolysis than intermediate starch granules, and the intermediate starch granules are more susceptible to enzyme hydrolysis than high-amylose starch granules (24-25). Concomitantly, greater amounts of resistant starches may have been retained in the boiled foods. Furthermore, as these foods cool, the possibility of forming resistant starches increases. This occurs as the starches undergo recrystallization due to the formation of the intermolecular hydrogen bonds. Also, these resistant starches, after the leaching of free sugars during the boiling process also play a role in retarding the enzymatic degradation of the starches, thus reducing the glycemic response (13). Also, apart from the amylose content, high dietary fiber was believed to reduce the blood glucose response, and thus lower the GI value of a food. Dietary fiber influences the starch digestibility by changing the microstructure of foods, which decreases the susceptibility of starch to amylolytic attack, and by limiting water availability, which restricts starch gelatinization (26).

The sweet potato flour has the highest total dietary fiber content and the highest GI value among the three flours, followed by the taro and the IPB Var. 6 QPM white corn flour (Figure 2). This was because grinding has an effect on the gross matrix structure of the flour. The grinding process increases the glycemic response and glycemic index of the flours (27). The uncooked sweet potato-corn noodles has a lower dietary fiber content but have a higher GI value as compared to the cooked sweet potato-corn noodles. The same can be observed in the taro-corn noodles wherein there was an increase in the dietary fiber content and a decrease in the GI value after cooking. This might be due to the higher amylose content of the cooked noodles as compared to the uncooked noodles. This is due to high amylose slowed the digestion rate. There is greater hydrogen bonding between glucose units in amylose molecule than the amylopectin molecule, thus less exposure to enzymatic digestion (28).

Wolever (29), studied naturally present fiber contents in foods and their subsequent glycemic response, and revealed that the total dietary fiber was significantly related to the glycemic index of foods. This was supported by the study done by Brouns *et al.* (27), Riccardi *et al.* (30) and Allen *et al.* (12), that stated that foods that are rich in fiber generally have a low glycemic index, although not all foods with a low glycemic index necessarily have high fiber content, as what have been observed between the glycemic index values and the total dietary fiber values of the uncooked and cooked noodles.

Thus, the presence of amylose and dietary fiber in the different samples used affects its glycemic index. The combined effect of amylose and dietary fiber contributed in the low glycemic index value in the cooked taro-corn and sweet potato-corn noodles.

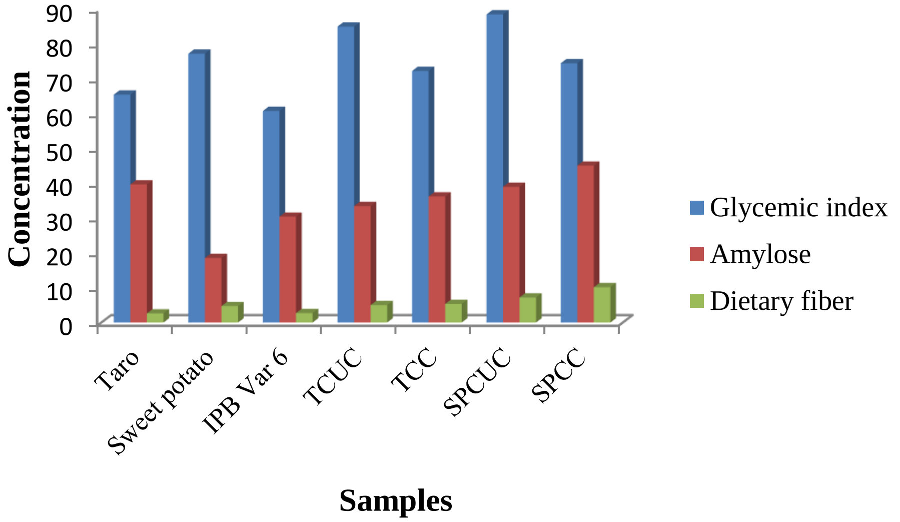

Figure 2. Comparison between the glycemic index, amylose content and total dietary fiber for each sample.

CONCLUSION

The results of the study revealed that processing the taro flour, sweet potato flour, IPB var.6 white corn flour, and the uncooked and cooked taro-corn and sweet potato-corn noodles significantly affected the carbohydrate profile, specifically, the starch and amylose content, the total dietary fiber content and the glycemic index. Boiling the noodles significantly decreased its starch content, and its glycemic index, while significantly increasing its amylose content and total dietary fiber content.

Studies on the shelf life and effect of storage temperature to the flours, as well as the noodles must be done. Another area of interest would be the utilization of the taro and sweet potato flours as an ingredient in other products to improve its palatability, especially for children. Also further studies regarding the cost analysis/profitability in the production of the flours, and its products, like the noodles should be pursued. Lastly, the use of the taro-based and sweet potato-based products in feeding programs should be tested to know whether it can help improve the nutritional status, and thus preventing malnutrition.

ACKNOWLEDGEMENT

Special thanks to the Department of Science and Technology- Accelerated Science and Technology Human Resource Development Program (DOST-ASTHRDP) for the full financial support and scholarship grant; to Dr. Dilberto Ferraren of Philippine Root Crop Research and Training Center, Visayas State University, Visca, Baybay City, Leyte, for providing the taro samples, and to Prof. Felicito Rodriguez of the Institute of Plant Breeding and Institute of Human Nutrition and Food, University of the Philippines, Los Baños for providing the sweet potato samples.

REFERENCES

1) Liu Q, Donner E, Yin Y, Huang RL, Fan MZ. The physicochemical properties and in vitro digestibility of selected cereals, tubers, and legumes grown in China. Food Chemistry 99: 470-477. 2006.

2) Aprianata A, Purwandari U, Watson B, Vasiljevic T. Physico- chemical properties of flours and starches from selected commercial tubers available in Australia. International Food Research Journal. 16: 507-520.2009.

3) [AACC] American Association of Cereal Chemist. The Definition of Dietary Fiber. Cereal Foods World. Vol 46, No 3:112-126. 2001.

4) Jenkins DJA, Thomas DM, Wolever TMS. Glycemic Index of Foods: A Physiological Basis for Carbohydrate Exchange. Am J Clin Nutr. 34: 362-366. 1981.

5) Gibson N. Development of a Rapid Assessment Method for the Glycaemic Index. Master's Thesis. University of Pretoria. 2010.

6) Williams VR, Wu WT, Tsai TY, Bates HG. Varietal differences in amylase content of rice starch. J. Agr. Food Chem. 6:47-48.1958.

7) Goñi I, Garcia-Alonso A, Saura-Calixto F. A Starch Hydrolysis Procedure to Estimate Glycemic Index. Nutrition Research. Vol 17, No.3:427-437. 1997.

8) Thao HM, Noomhorm A. Physicochemical properties of sweet potato and mungbean starch and their blends for noodle production. J Food Process Technol 2:1.2011.

9) FAO. Carbohydrates in Human Nutrition. Agriculture and Consumer Protection. Rome:WHO. 1997.

10) Dighra D, Michael M, Rajput H and Patil RT. Dietary foods: A review. J Food Sci Technol. 49 (3):255-266. 2012.

11) Pushparaj FS, Urooj A. PUSHPARAJ FS, 2011. Influence of processing on dietary fiber, tannin, and in vitro protein digestibility of pearl millet. Food and Nutrition Sciences. 2:895-900. 2011.

12) Allen JC, Corbitt AD, Maloney KP, Butt MS, Truong VD. Glycemic index of sweet potato as affected by cooking methods. The Open Nutrition Journal 6, 1-11. 2012.

13) Bahado-Singh PS, Riley CK, Wheattey AO, Lowe HIC. Relationship between processing method and the glycemic indices of ten sweet potato (Ipomoea batatas) cultivars commonly consumed in Jamaica. J Nutr Metab. 2011:584832. 2011.

14) Tester RF, Karkalas J, Qi X. Starch Structure and digestibility Enzyme-Substrate Relationship. World's Poult Sci J. 60:185-195. 2004.

15) Grandfelt Y. Food Factors Affecting Metabolic Responses to Cereal Products. PhD Dissertation. University of Lund: Sweden.1994.

16) Tovar J, Sayago-Ayerdi SG, Peñalver C, Paredes-Lopez O and Bello-Perez LA. In vitro starch hydrolysis index and predicted glycemic index of corn tortilla, black beans (Phaseolus vulgaris L.) and Mexican "taco". Cereal Chem. 80 (5): 533-535.2002.

17) Snow P, O'dea K. Factors Affecting the Rate of Hydrolysis of Starch in Food. Am J Clin Nutr. 34:2721-2727.1981.

18) Siller ADCP. In Vitro Starch Digestibility and Estimated Glycemic Index of Sorghum Products. Master's Thesis. Texas A & M University. Available at <http://repository.tamu.edu>. Accessed 13 November 2014.

19) Mbofung CMF, Aboubakar YN, Njintang A, Abdou B, Baalam F. Physicochemical and Functional Properties of Six Varieties of Taro (Colocasia esculenta (L.) Schoot) Flour. J. Food Tech. 4(2): 135-142. 2006.

20) Bordoloi A, Jaspreet S, Kaur L. In vitro digestibility of starch in cooked potatoes as affected by guar gum: microstructural and rheological characteristics. Food Chemistry 133;1206-1213.2012.

21) Bjork I, Grandfelt Y, Liljeberg H, Tovar J, Ng ASP. Food Properties Affecting the Digestion and Absorption of Carbohydrates. Am J clin Nutr. 59(3). 1994.

22) Hasjim J. Enzyme Digestibility of Starch and Methods to Produce Enzyme- Resistant Starch to Improve Human Health. PhD Thesis. 2009. Iowa State University.Available at <http://lib.dr.iastate.edu/etd>. Accessed on 12 November 2014.

23) Juliano BO. Grain Quality of Philippine Rice. Muñoz Nueva Ecija, Philippines: 70pp Philipp Rice Res Inst.1992.

24) Fuwa H, Nakajima M, Hamada A, Glover DV. Comparative Susceptibility to Amylases of Starches from Different Plant Species and Several Single Endosperm Mutants and their Double-Mutant Combinations with Opaque-2 Inbred Oh43 Maize. Cereal Chem. 54:230-237.1977.

25) Jane J, Ao Z, Duvick SA, Wiklund M, Yoo SH, Wong KS, Gardener C. Structures of Amylopectin and Starch Granules: How are they synthesized. J Appl Glycosci. 50:167-172. 2003.

26) Kim HJ, White PJ. In vitro digestion rate and estimated glycemic index of oat flours from typical and high β-glucan oat lines. J Agric Food Chem. 60. 5237-5242.2012.

27) Brouns F, Bjorck I, Frayn KN, Gibbs AL, Lang V, Slama G, Wolever TMS. Glycaemic index methodology. Nutrition Research Reviews. 18, 145-171. 2005.

28) Shanita SN, Hasnah H, Khoo CW. Amylose and Amylopectin in Selected Malaysian Foods and its Relationship to Glycemic Index. Sains Malaysiana. 40 (8): 865-870. 2011.

29) Wolever TMS. Relationship between dietary fiber content and composition in foods and the glycemic index. Am J Clin Nutr. 51:72-5. 1990.

30) Riccardi G, Rivellese AA, Giacco R. Role of glycemic index and glycemic load in the healthy state, in prediabetes, and in diabetes. Am. J. Clin. Nutr. Vol. 87 no. 1 269S- 274S. 2008.