

Glycemic responses by coconut (*Cocos nucifera*) jaggery and cane sugar (*Saccharum officinarum*): A comparative study

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ABSTRACT

Aim: Cane sugar (*Saccharum officinarum*) and (*Cocos nucifera*) jaggery are prominent sweeteners. The aim of this study is to evaluate Glycemic Indices (GI) of cane sugar and coconut jaggery using healthy human subjects.

Place and Duration of Study: The research was conducted as a collaborative project with Coconut Research Institute Sri Lanka and National Hospital Colombo Sri Lanka, between 2019 to 2020.

Methodology: Starch fractions (Total starch - TS, Resistant starch – RS and Digestible starch – DS) and sugar profile of two test foods were analyzed. Thirty six (n=36) healthy volunteers were recruited and were subjected to health screening. Fifty grams of digestible carbohydrate containing test food portions were given for each subject who had been fasting for 8 - 12 hours. Intravenous blood samples were collected to analyze blood glucose concentration and GI of food.

Results: Cane sugar contained high percentages of TS (95.86 ± 1.58 %), DS (95.73 ± 1.59 %) and RS was just 0.13 ± 0.02 %. Coconut jaggery contained a lower percentage of sucrose (76.12 ± 1.62 %) and glucose (5.22 ± 0.11 %). Healthy volunteers (25.95 ± 3.62 years) whom were

having healthy fasting blood glucose concentrations (73.54 ± 8.89 mg/dl) and HbA1c (5.05 ± 0.35 %) were tested with glucose, and the two test foods.

Conclusions: There was no significant difference ($P > 0.05$) between blood glucose response curves and GI of coconut jaggery (65.19 ± 36.53) and cane sugar (60.76 ± 35.80), where both can be considered as moderate GI sweeteners.

Key words: cane sugar, glycemic Index, coconut jaggery, glucose response

1. Introduction

Sugar cane, sugar beet and palm trees are used for sugar production to accomplish the consumer demands. Asia is the world largest sugar consumer which includes 6.3 million tons of annual consumption of sugar with the 14.9 kg of per capita sugar intake [1]. Sweetness, texture and viscosity of food and beverages are enhanced with natural and synthetic sweeteners. Greater consumption of such food has impacted on the rise of non-communicable diseases such as diabetes, obesity, hypertension, heart diseases and many other related concerns [2]. Therefore, consumers prefer sweeteners such as jaggery which is a traditional sweetener, especially among rural communities, which is believed to be healthier.

Solid jaggery, liquid jaggery and powdered jaggery are the main three forms of jaggery sold in the world market.

The collected juice is concentrated and removed from the pan when the temperature reaches to the 103°C to 106°C with 60 to 70 total soluble solids when the liquid jaggery is prepared. Water content of liquid jaggery is high (30-36%) and it is rich source of sucrose (40-60%) and low concentration of invert sugars (15-25%). Solid jaggery is prepared by concentrating syrup at 118°C and its transfer into molds to make the desired shape [3]. The concentrated jaggery syrup is rubbed by wooden or stainless steel scraper to form grains and it is cooled and sieved ($< 3\text{mm}$) to prepare powdered jaggery. The temperature at 120°C increases the quality of powder with high amount of sucrose ($> 88.6\%$) and low moisture (1.65%) [3].

India is the pioneer of sugar and jaggery producer in the world which accounted more than 70% of the total production. Sugarcane jaggery is more popular and it is about 65 % of world jaggery production [4]. The remaining 35% of the world jaggery requirement is fulfilled by the harvested palm sap. Palm jaggery is prepared from concentrating palm sap/nectar that is collected from tapping of immature inflorescence [5] with the help of fermentation inhibitors. Different types of palm tree such as Palmyra (*Borassus flabellifera*), wild date palm (*Phoenix sylvestris* L), kitul (*Caryota urenes*) and coconut (*Cocos nucifera* L.) are tapped for unfermented sap collection followed by preparation of jaggery [6] by concentrating it. Jaggery is rich with Fe and it helps in reduction of anemia. It has the ability of cleaning the blood, lungs, stomach, intestine, respiratory track and curing ability against asthma, cough and congestion [7].

Digestibility of food depends on the physical and chemical characteristics; if rich in dietary fiber, lower rate of digestibility has been observed [8]. Lowest rate of glucose response could be observed in the low digestible food and based on glucose response behavior food is categorized into different groups of glycemic indices (GI). GI is defined as the area under the β -glucose response curve (IAUC) after consuming 50g of digestible carbohydrate contain test meal to the blood glucose response of 50 g of pure glucose or white bread by the same healthy individual. Glucose or white bread is used

as standard food with a GI value of 100 [9]. Then, food is ranked in three categories as a low glycemic food (<55), medium glycemic food (56-69) and high glycemic food (>70) [10].

The coconut sap collection method and processing methods may impact on physical and chemical nature of the food and eventually, to blood glucose responses. Therefore, this study aims to investigate glycemic responses by pure coconut jaggery prepared using a novel sap collection method that didn't use any fermentation inhibitors, and to compare that with cane sugar's GI using human subjects.

2. MATERIAL AND METHODS

2.1 Test foods

Unfermented coconut sap was collected from a novel sap collection device developed at the Coconut Research Institute - Sri Lanka, without adding any anti-fermenting agents. The device comprised with a cooling compartment with ice cubes to keep coconut sap sugar without getting fermented to alcohol. The sap collected as above was used for the preparation of coconut jaggery. The jaggery was stored in dried clean glass bottles until further analysis. The cane sugar and the reference (glucose) was purchased from the local market.

2.2 Total starch, Resistant starch and Digestible starch

Proportions of total starch (TS) and resistant starch (RS) of jaggery and cane sugar were analyzed by an in-vitro enzyme analysis method [11]. Glucose concentration of the sample was analyzed by the glucose determination kit (GOD PAP, France) and starch percentage were calculated by multiplying factor of 0.9. Digestible starch (DS) fraction of the sample was determined by subtracting the values of resistant starch from total starch.

2.3 Sugar profile

Sugar profiles of the samples were analyzed using High Performance Liquid Chromatography (HPLC-Agilent1100) using a Waters™ Sugar-Pak™ column at 90 °C. Coconut sap and cane sugar was diluted 200 times with MilliQ water and filtered through 0.45 µm nylon syringe filter. 20 µl was injected manually. The calibration curves for sucrose, glucose and fructose were constructed using a standard sugar solution from 0.05 % to 2%. The sample was eluted with Milli-Q water at 0.5 ml/min flow rate and detected through the RID detector (Agilent 1100). The concentration of each sugar type was determined using calibrated curves. The total sugar content of each sample was calculated by compiling value of each type of sugar concentration.

2.4 Selection of healthy volunteers

The ethics clearance was granted by the Ethical Review Committee of the National Hospital Colombo Sri Lanka (ETH/COM/2017/03). The subjects (n=36) were recruited by randomized method, keeping an equal gender balance. Healthy volunteers were recruited and the age of the participants were 20-40 years with body mass index 18-25. Initial health assessments of subjects were done through evaluating blood pressure, FBS, HbA1c and lipid profile to make sure they are not having any non communicable health disorders.

2.5 Experimental design

Written consent from the subjects was taken and they were educated with the protocol of the experiment. The subjects were advised to fast 8-12 hours overnight. Cane sugar, pure coconut jaggery and the standard (glucose) were served three days by keeping a weeks' gap. Fifty grams of digestible carbohydrate containing test food portion sizes were used in wet weight basis. Cane sugar and glucose were dissolved in 250 ml of water and coconut jaggery was served as a solid food with 250 ml of water. The subjects were requested to complete consumption within 10 minutes after ingestion.

2.6 Blood sample collection

After the fasting period, intravenous blood samples of subjects were collected from the antecubital fossa as baseline data. Blood samples were collected during a 2 hr period, keeping 30 min gaps (0 min, 30 min, 60 min, 90 min, and 120 min). The sample collection was done by a well trained nurse at *the Center for Diabetes, Endocrinology and Cardio Metabolism (Pvt) Ltd.*

2.7 Blood sample analysis

Blood glucose concentration was analyzed using Randex Imola (RX 4900) fully automated glucose testing machine after the separation of plasma using a centrifugal force (Avanti J -15R) at 2500 rpm for 10 min.

2.8 Area of glucose response curve of subjects and Glycemic Index

Mean blood glucose concentration (BGC) values were plotted against the time as described by FAO (1998) [9] to obtain β -glucose response curve. Mean value of glycemic index for both test foods was calculated, using glucose as the standard. Fasting blood glucose response of each subject was considered as the baseline for the area calculation. The area under the curve (AUC) of graphs were calculated by the trapezoid rule by dividing graph into trapeziums and triangles. Glycemic indices of the samples were determined by dividing AUC of the test food by the AUC of the standard [12].

2.9 Peak delay and percentage of peak reduction

Peak delay was evaluated as the time difference between the peak points of the standard (glucose) and test foods. The difference in BGC of the test food and the standard was calculated and it was divided by the fasting BGC of reference food to take a percentage of peak reduction of the test food sample.

$$\% \text{ Peak reduction} = \frac{\text{Peak BGC of standard} - \text{Peak BGC of test food}}{\text{FBGC of the standard}} \times 100 \%$$

2.10 Data analysis

AUCs were calculated using Microsoft excel. Minitab software was used to analyze the difference of BGC at each sampling point through ANOVA. There mean values were separated from Tukey's test at the significance level of 0.05.

3. Results and Discussion

3.1 Total starch, Resistant starch and Digestible starch

Table 1 shows the total starch (TS), resistant starch (RS), digestible starch (DS) and sugar profile of cane sugar and coconut jaggery.

Total starch and digestible starch content of cane sugar were higher in contrast to the comparatively high resistant starch content in the coconut jaggery. The glycemic index of a food depends on the proportions of resistant starch; amylose, amylopectin ratios and many other facts [13]. Minor differences in resistant starch quantities between coconut jaggery and cane sugar might not have a considerable role in the reduction of glycemic responses. Although resistant starch has an ability of escaping digestion in the small intestine [14].

Table 1. Starch fraction and sugar profile of cane sugar and coconut jaggery

Treatment	TS%	RS%	DS%	Total sugar %	Sucrose %	Glucose %	Fructose %
Cane Sugar	95.86 ± 1.58 ^a	0.13±0.02 ^b	95.73 ± 1.59 ^a	95.53±0.62 ^a	86.99±1.43a	8.57±0.93a	0.00b
Coconut Jaggery	85.69 ± 0.94 ^b	0.28± 0.07 ^a	85.42± 1.00 ^b	88.04±1.03b	76.12±1.62b	5.22±0.11b	6.69±0.47a

Means with different superscripts are significantly (p<0.05) different from each other's along each column. TS% - Total starch, RS% - Resistant starch, DS% - Digestible starch

According to the sugar profile of cane sugar and coconut jaggery, fructose is existing only in coconut jaggery. Significantly higher glucose (8.57±0.93%) and sucrose (86.99±1.43%) was in cane sugar. Glucose has ability to absorb into the blood directly without going through the hydrolysis process and eventually it can raise blood glucose response. The fructose is a simple sugar, that has a low glycemic index of 23 and it is suggested as a healthy sweetener for diabetic patients [15]. Therefore, the fructose quantity of coconut jaggery does not affect significantly to increase the blood glucose response.

3.2 Health characteristics of subjects

The results of the initial health screening test of healthy volunteers are shown in Table 2.

Table 2. Characteristics of healthy volunteers

Gender	Female	Male	Whole group	Reference
Age (Years)	26.41±4.42	25.63±2.99	25.95±3.62	20-40
BMI(Kg/m ²)	20.88±2.43	22.86±2.36	22.04±2.56	18-24
Pulse rate (min ⁻¹)	77.59±9.10	70.67±7.68	73.54±8.89	60-100
Blood pressure (torr)	109.82±13/77.12±8	118.67±11/74.67±11	115.00±13/75.68±10	90-120/ 60-80
FBS mg/dl	83.53±6.45	90.33±7.41	87.51±7.73	<100
TC mg/dl	206.76±41.57	189.17±38.08	196.46±40.03	<200
LDL mg/dl	113.65±29.03	119.25±32.05	125.22±31.29	<100
Triglycerides mg/dl	69.41±15.63	126.79±64.65	114.20±73.10	<150
HDL mg/dl	53.88±15.41	44.63±9.57	48.46±13.00	<40
VLDL mg/dl	19.00±10.21	24.96±16.86	22.49±14.63	10-30
Non HDL mg/dl	152.88±34.99	144.54±36.15	148.00±35.48	<130
Total CHOL/HDL	3.95±0.94	4.32±1.10	4.17±1.04	<3.5

HbA1c (%)	4.98±0.32	5.07±0.38	5.03±0.35	4.3-5.6
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BMI; Body Mass Index, FBS; Fasting Blood Sugar, TC; Total Cholesterol, LDL; Low Density Lipoprotein, HDL; High Density Lipoprotein, VLDL; Very Low Density Lipoprotein, HbA1c – Amount of sugar attached to the hemoglobin

The study group consisted with 36 subjects with female (18) and male (18). The average fasting blood glucose concentration of the study group is 87.51±7.73 mg/dl and they did not show pre-diabetic (100 to 109 mg/dl) or diabetic status [16]. Percentage of HbA1c further conformed their average plasma glucose during twelve weeks, which should be less than 5.03±0.35 % level to be a healthy person [17]. Therefore, screening results clearly confirms that selected subjects were free of diabetes and they are healthy persons for this experiment.

3.3 Glucose responses by subjects

Glucose responses of cane sugar and coconut jaggery are presented Figure 1 with respect to the standard (glucose).

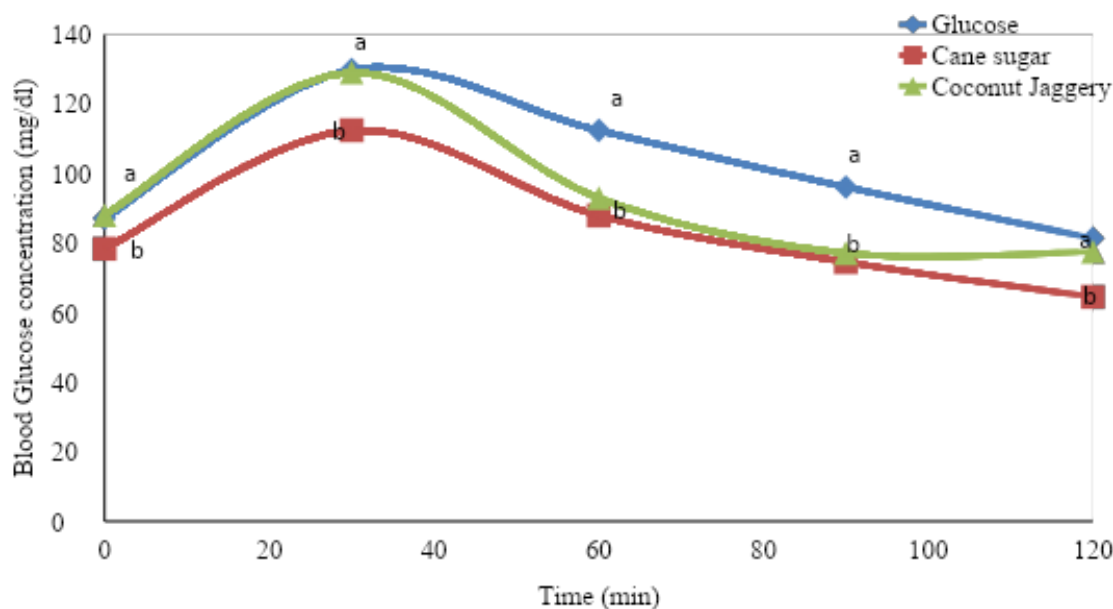


Figure 1: Glucose response curve of cane sugar and coconut jaggery

The peak glucose concentration of the standard and coconut jaggery were surging rapidly than the cane sugar, showing a significant ($p < 0.05$) difference at the 30 minute peak. The BGR curve of coconut jaggery has decreased rapidly to the 92.93 mg/dl, which is very similar to cane sugar at 90 minutes after food digestion. The blood glucose response of the standard was significantly greater at 60 and 90 min than both test foods. BGR curves prove that there was no significant different ($P > 0.05$) between cane sugar and coconut jaggery during in controlling glucose responses.

3.4 Peak delay and percentage of peak reduction

The blood glucose peak of the standard (glucose), cane sugar and coconut jaggery were in the similar position and it is 30 min after the food intake. Therefore, there is no peak delay for coconut jaggery and cane sugar.

The peak of glucose, cane sugar and coconut jaggery were 129.85 mg/dl, 112.45 mg/dl and 129.07 mg/dl respectively. Results of peak reduction evidently elicited that cane sugar has higher peak reduction of 19.98 % than the coconut jaggery (0.89 %). Thus, pure jaggery does not cause a significant peak blood glucose reduction.

3.5 Glycemic Indices

Glycemic indices of cane sugar and coconut jaggery are presented in Figure 2. There is no significant difference ($P>0.05$) between the glycemic index of cane sugar (60.76 ± 35.80) and pure coconut jaggery (65.19 ± 36.53). If the value of glycemic index of the test food is lower than 69 and can be considered as a medium GI food. The glycemic indices coconut jaggery and cane sugar can be categorized as medium glycemic sweeteners.

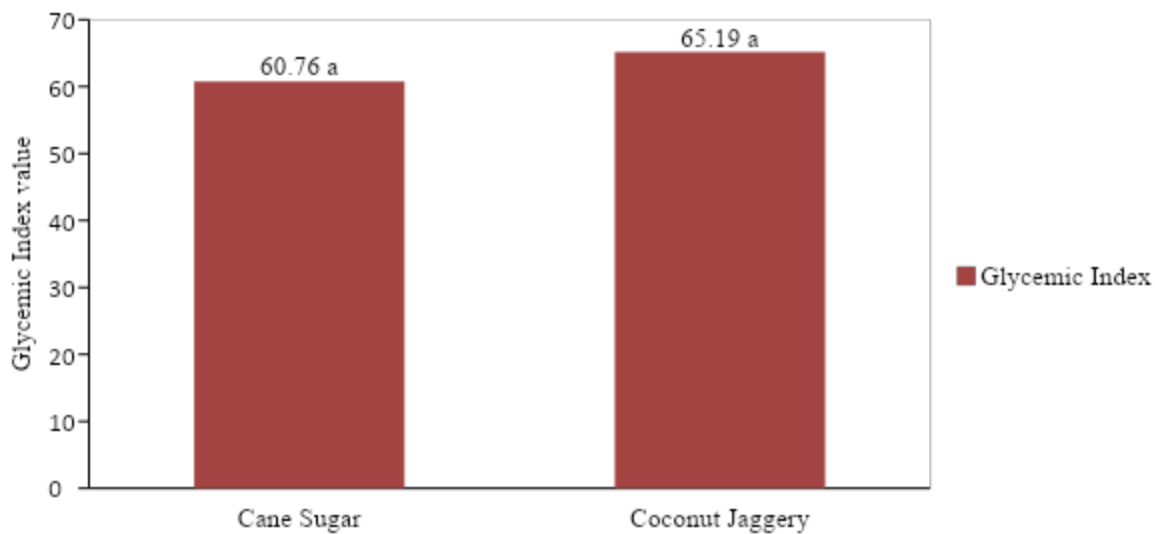


Figure 2: Glycemic Index of cane sugar and coconut jaggery

A previous study has proven that glycemic indices of Palmyra palm sugar, coconut sugar and cane sugar as 60 ± 4.2 , 56 ± 3.6 and 60 (medium GI food) respectively, and the results revealing that there was no significant difference ($P>0.05$) among three types of sweeteners [18]. Kalpana, 2014 [18] further said that, the slight reduction of GI of coconut sugar, might be due to the low concentration of fructose. Fructose is not absorbed directly and it's broken-down to glucose in the liver and a small concentration of glucose is released into blood circulation [19].

There is a negative relationship between resistant starch percentage and glycemic index of the food [20]. Different types of resistant starch such as matrix embedded starch (RS1), untreated resistant starch granules (RS2), debranched and recrystallized resistant starch by cooking and cooling processing (RS3) and structurally (chemically) modified resistant starch (RS4) have different glucose lowering potentials while RS4 has greater glucose lowering ability. Glycemic indices of beverages with two types of resistant starch of RS2 and RS4 were $34.9 \pm 11\%$ and $11.3 \pm 10\%$ respectively [21].

The largest discrepancy of glycemic indices of rice can be observed due to the processing methods, storage, cooking method [22]. The extrusion and parboiling process also increases the resistant starch content of the rice [23]. Moreover, the level of resistant starch and structure of resistant starch is affected for the variation of glycemic index of rice [24].

The glycemic indices of coconut jaggery and cane sugar in this study did not show significant differences ($P>0.05$) even though they had significantly different ($P<0.05$) level of resistant starch. **It might be due to the variation of resistant starch structure of the coconut jaggery and cane sugar.** The same results was resulted for edible film coated two types of rice varieties [25].

4. Conclusions

There were no significant ($P>0.05$) difference between glycemic indices of cane sugar (60.76 ± 35.80) and coconut jaggery (65.19 ± 36.53). Both cane sugar and coconut jaggery can be categorized as moderate GI foods.

Competing Interests

We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. We know of no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome. As Corresponding Author, I confirm that the manuscript has been read and approved for submission by all the named authors.

Authors

'H.P.D.T. Hewa Pathirana' designed the study, performed the experiment and wrote the first draft of the manuscript. 'W.L.I. Wijesekara', 'L.L.W.C. Yalagama', 'M.A. Jayasinghe' and 'K.P. Waidyarathne' managed the analyses of the study, managed the literature searches and manage the data analysis. All authors read and approved the final manuscript".

Consent

All healthy volunteers gave their written consent for the sample collection. The form of written consent is attached herewith.

Ethical Approval

The ethics clearance was granted by the Ethical Review Committee of the National Hospital Colombo Sri Lanka (ETH/COM/2017/03).

References

1. Joan, Q.I., 2013. Consumption patterns and recommended intakes of sugar. *Nutr Hosp.* 28, 32-39.
2. Margaret, Z., Maissam, G., Seba, H., 2018. Sugars: Types and Their Functional Properties in Food and Human Health. *International Journal of Public Health Research.* 6:4, 93-99.
3. Nath, A., Dutta, D., Kumar, P., Singh, J., 2015. Review on recent advances in value addition of jaggery based products. *Journal of Food Process. Technology* 4–7. [https://doi.org/ 10.4172/2157-7110.1000440](https://doi.org/10.4172/2157-7110.1000440), 06.
4. Statistics (2002). *Indian Sugar.* 52:9, 134-135.
5. Borse, B. B., Rao, L. J. M., Ramalakshmi, K., Raghavan, B., 2007. Chemical composition of volatiles from coconut sap (neera) and effect of processing. *Food Chemistry.* 101:3, 877–880. doi:10.1016/j.foodchem.2006.02.026.

6. Pattnayak, P.K. Misra, M.K., 2004. Energetic and economics of traditional gur preparation: a case study in Ganjam district of Orissa, India. 26:1,79–88. doi:10.1016/s0961-9534(03)00061-8.
7. Sahu, A.P., Saxena, A.K., 1994. Enhanced translocation of particles from lungs by jaggery. *Environmental Health Perspectives*. 102, 211–214.
8. Granfeldt, Y., Hagander, B., Björck, I., 1995. Metabolic responses to starch in oat and wheat products. On the importance of food structure, incomplete gelatinization or presence of viscous dietary fibre, *European Journal of Clinical Nutrition*. 49(3),189-99.
9. Food and Agriculture Organization, 1998. The role of the glycemic index in food choice, a Joint FAO/WHO Report, FAO carbohydrates in human nutrition, Rome.
10. Jenkins, D. J., Wolever, T. M., Taylor, R. H., 1981. Glycemic index of foods: A physiological basis for carbohydrate exchange. *American Journal of Clinical Nutrition*. 34, 362–366.
11. Goni, I, Garcia-Alonso, A, Saura-Calixto, F.A., 1997. Starch hydrolysis procedure to estimate glycemic index. *Nutrition Research*. 17, 427-437.
12. Wolever, T.M.S., Jenkins, D.J.A., Jenkins, A.L., Josse, R.G., 1991. The glycaemic index: methodology and clinical implications. *American Journal of Clinical Nutrition*. 54, 846–854.
13. Allen, J.C., Alexis, D.C., Katherine, P. M., Masood, S.B., Van-Den, T., 2012. Glycemic Index of Sweet Potato as Affected by Cooking Methods. *The Open Nutrition Journal*. 6, 1-11.
14. Cummings, J.H., Englyst, H.N., 1995. Gastrointestinal effects of food carbohydrates. *American Journal of Clinical Nutrition*. 61, 938–945.
15. Foster-Powell, K., Holt, S. H. A., Brand-Miller, J. C., 2002. International table of glycemic index and glycemic load values:. *American Journal of Clinical Nutrition*. 76(33–35,41), 45–46.
16. Borch-Johnsen, K., Colagiuri, S., Balkau, B., 2004. Creating a pandemic of prediabetes: the proposed new diagnostic criteria for impaired fasting glycaemia. *Diabetologia*. 47, 1396–1402.
17. Nathan, D.M., Davidson, M.B., DeFronzo, R.A., Heine, R.J., Henry, R.R., Pratley, R., 2007. Zinman American Diabetes Association. Impaired fasting glucose and impaired glucose tolerance: implications for care. *Diabetes Care*. 30:3, 753-9.
18. Kalpana, N.,2014. Determination of glycemic index of selected foods and formulation of low glycemic index food products. Thesis of Doctor of Philisophy, Department of Food Service Management and Dietetics, Coimbatore.
19. Delarue, J., Normand, ., Pachiaudi, C. 1993. The contribution of naturally labeled ^{13}C fructose to glucose appearance in humans. *Diabetologia*. 36, 338-345. Doi.org/10.1007/BF00400238.
20. Brand-Miller, J., Wolever, T. M. S., Colagiuri, S., Foster-Powell, K., 1999. *The Glucose Revolution: The Authoritative Guide to the Glycemic Index*. Marlowe & Company, New York.

21. Haub, M.D., Hubach, K.L., Al-tamimi, E. K., Ornelas, S., Seib, P. A., 2010. Different Types of Resistant Starch Elicit Different Glucose Responses in Humans. *Journal of Nutrition and Metabolism*, 1–4. doi:10.1155/2010/230501.
22. Frei, M., Siddhuraju, P., Becker, K., 2003. Studies on the in vitro starch digestibility and the glycemic index of six different indigenous rice cultivars from the Philippines. *Food Chemistry*. 83, 395–402.
23. Juliano, B.O., 2007. *Rice Chemistry and Quality*. Philippine Rice Research Institute, Munoz, Nueva Ecija.
24. Panlasigui, L.N., Thompson, L.U., Juliano, B.O., Perez, C.M., Yiu, S.H., Greenberg, G.R., 1991. Rice varieties with similar amylose content differ in starch digestibility and glycemic response in humans. *American Journal of Clinical Nutrition*. 54, 871–877.
25. Yulianto, W. A., Susiati, A. M., Adhini, H.A.N., 2018. Evaluation of resistant starch, glycemic index and fortificants content of premix rice coated with various concentrations and types of edible coating materials. *IOP Conference Series: Earth and Environmental Science*, 102 (1), 012101. doi:10.1088/1755-1315/102/1/012101