SLJoAS Sri Lankan Journal of Applied Sciences

Research Article

www.sljoas.uwu.ac.lk/index.php/sljoas

Determination of glycaemic index and market potential of coconut treacle as an alternative sweetener among young adult population in Sri Lanka

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(Received 4th June 2024; accepted 25th August 2024)

Abstract

This study aimed to determine the glycaemic index (GI) and market potential of coconut treacle (CT) to assess its probability as a low GI sweetener. Total sugar content was determined following AOAC guidelines. GI was determined using a standard clinical method with 30 healthy individuals (18-26 years, 18.5-23.5kg/m2). Following an 8-hour fasting, blood glucose level (BGL) was measured. Then, participants consumed glucose and BGL was measured at 15th, 30th, 45th, 60th, 90th, and 120th minutes. The procedure was repeated and duplicated with CT in another 2 separate sessions. A cross-sectional study was performed with 365 undergraduates to assess the market potential via Google Forms. The study concluded that the CT belonged to the low GI category (53.6) with a moderate amount of total sugar (66.68g/ 100g). The majority of students (74.2%) preferred CT and 35.9% liked to consume CT for health benefits. Purity, texture, and taste were identified as important factors influencing purchasing decisions and 52.6% opted for supermarket purchases. More consumers (97%) exhibited adequate knowledge regarding the health attributes of CT and 72.6% perceived that CT can replace refined sugar. The complete substitution of table sugar to CT in diet and the improvement in BGL should be further studied.

Keywords: Alternative sweetener, Coconut treacle, Diabetes, Glycaemic index, Market Potential

1. Introduction

The concept of the Glycaemic Index (GI) serves as a vital tool in assessing the risk of hyperglycaemia, particularly concerning the impact of carbohydrates on plasma glucose levels [1]. GI is categorized as low (0-55), medium (56-69), and high (70-100), and low-GI foods have the potential to mitigate postprandial blood glucose and insulin responses, reducing the risk of obesity and type 2 diabetes mellitus [3]. Refined sugar, commonly used as a sweetener in Sri Lanka, is a major contributor to high dietary intake. Its ability to significantly raise blood glucose levels (BGL) is associated with obesity and type 2 diabetes mellitus. According to WHO STEPS survey in 2015 [4], in Sri Lanka, 8.5% of adults have diabetes and 29% are obese, and the prevalent use of refined sugar exacerbates these health concerns. Coconut treacle (CT) is a well-known sweetener among Sri Lankans. Previous studies have demonstrated that the GI of coconut sap sugar and syrup falls within the lower category [2_5]. Sri Lanka's year-round coconut (*Cocos nucifera* L.) cultivation, due to its tropical climate, ensures that the production remains unaffected by seasonal changes. Therefore, if CT is proven to have a low GI, it could serve as an affordable alternative sweetener that is accessible to people from different economic backgrounds.

Transitioning from conventional sweeteners to alternatives involves considerations of affordability, availability, and consumer preferences. To address market gaps and facilitate this shift, a comprehensive investigation into consumer decision-making during CT purchases is crucial. This research aims to evaluate CT's potential as an alternative sweetener by examining total sugar content, GI, and potential adverse effects. Additionally, it provides valuable marketing insights for manufacturers and marketers by assessing product attributes, sociodemographic factors, consumer's knowledge, preferences, and perceptions regarding CT.

2. Material and methods

2.1. Study for the glycaemic index of CT

Ethical approval for the clinical trial (KIU/ERC/23/026) was obtained from Ethics Review Committee of KAATSU International University (KIU), Sri Lanka. Consent of

participants was obtained through a signed consent form stating "I give my consent to obtain finger prick samples according to the test procedure and information through an interviewer-administered questionnaire for this research". Standard proximate analysis of CT was performed to determine the total sugar content using the Lane-Eynon general volumetric method [7]. Precisely, 5 g of CT was measured and diluted with 250 ml distilled water. Then, 50 ml filtrate was mixed with HCl. After 24 hours, it was neutralized against 20% NaOH by adjusting it with 1N HCl. It was used as a working sample and used for titrations.

The GI of CT was determined by a standard method [8_9]. The undergraduate students at KAATSU International University (KIU) volunteered to participate and provided their BMI, fasting blood sugar (FBS) levels, and basic personal details. From this group, 30 healthy undergraduates within the young adult age range of 18-26 years, BMI range of 18.5-23.5 kg/m², and FBS levels ranging from 70-100 mg/dl were selected for a randomized clinical trial conducted for 10 days at the KIU laboratory. Participants were instructed to abstain from smoking, alcohol consumption, and strenuous physical activity throughout the study period.

In session-1, following an overnight fast of 8-10 hours, finger-prick capillary blood samples were collected according to the standard procedure [10]. BGL were determined using a professionally calibrated "Accu-Chek" glucometer. Subsequently, participants were asked to consume 50 g "Glucomile" of Morrison (Pvt) Ltd. containing 100% glucose monohydrate (standard food) mixed with 150 ml of pure water (the standard drink). After the ingestion, finger-prick capillary blood samples were collected at 15th, 30th, 45th, 60th, 90th, and 120th minutes and BGLs were determined by the glucometer. Following a three-days interval, the same procedure was repeated in session-2 with 74.9g of "Ceylon Coconut Company Coconut Honey" (CT)purchased from "Ceylon Coconut Company (Pvt) Ltd." containing 50 g digestible carbohydrates replacing only the standard food. After another three-day gap, session-2 was duplicated in session-3. The results of 2-hour blood glucose responses were graphed and the glycaemic index (GI) for each person was calculated using the incremental area under the curve (IAUC) of 2 hours. The average GI was then calculated.

To observe the adverse effect (any discomfort or undesired effects) caused by CT, we collected two sets of data during both session-2 and session-3. The first set of data was collected immediately after CT consumption, and the second set of data was collected during the 2-hour study period. After a one-week follow-up, we collected a final set of responses from each participant through a questionnaire using "Google Forms" to inquire about any adverse effects.

Statistical Package for Social Science (SPSS) Software (version 25), Microsoft Office Excel 2016 and GraphPad prism 9.5.1.733 were used for the data analysis.

2.2. Study for the market potential of CT

A cross-sectional study was performed among 365 students of KIU undergraduates to analyse the market potential of CT. The sample size was 357 according to calculation for a finite population [6]. The data including socio-demographic details, consumption habits, purchasing habits, knowledge, perceptions, and preferences regarding CT were collected using a pretested questionnaire through "Google form".

3. Results and discussion

3.1. Study of glycaemic index

Dietary modifications play a crucial role in reducing the incidence of metabolic syndrome among non-diabetic individuals and in maintaining glycaemic control for both type 1 and type 2 diabetic patients [11]. Sri Lanka has witnessed a concerning increase in the number of diabetic and pre-diabetic cases, especially among the adult population [4_12,13,14]. The consumption of excessive amounts of refined or cane sugar as a sweetener has seen a notable increase among Sri Lankans. The high-calorie content derived from sugar consumption leads to elevated postprandial blood glucose levels and contributes to long-term diabetes risks [15].

Traditional sweeteners have already been used in Sri Lankan households. Palmyra treacle, kithul jaggery, and coconut treacle are familiar sweetening agents following the massive consumption of refined sugar. The fresh coconut (*Cocos nucifera*) sap in the inflorescence is tapped from the palm's spadix. The collected sap is boiled to evaporate the water until the liquid becomes sticky. This sticky liquid is called coconut honey or coconut treacle (CT) [16_17]. This natural sweetener has been used in foods and beverages in Asian communities.

According to the proximate analysis, digestible carbohydrate was determined as 66.68 g per 100 g CT. The mean age of the participants was 24.07±2.07 years and the mean BMI was 21.15±2.35 kg/m^2. Among the participants, 16 were males and 14 were females.

Figure 1 shows the mean BGL of CT which was lower than that of glucose. When the levels reached their peak at 30 minutes, the percentage reduction of peak blood glucose level for CT was 28 mg/dL lower than that for glucose. Subsequently, the mean BGLs of glucose and CT followed a gradual decline and reached 90.16 mg/dL and 88.70 mg/dL, respectively, at 120th minutes. However, throughout the duration, the mean BGL for CT remained lower than that

for glucose. Further, the results indicated that CT has significantly lower effects (P<0.05) on the BGL compared to glucose in healthy individuals. Based on the results, the GI of CT belonged to the low GI category which was calculated as 53.6%.

According to Asghar et al, 2020 [5], sucrose content in cane sugar juice is higher than in coconut sap. However, the total sugar content of coconut sap [5] is significantly lower than the calculated sugar content of CT used in the present study. Furthermore, coconut sap was richer in vitamins such as vitamin C, B3, B4, B2, and B10 and minerals such as sodium, potassium, and iron and has significantly higher antioxidant activity than refined/ cane sugar [5_16,17]). Coconut sap syrup of East Asia was calculated as 39±4 [2]. Our finding indicates a slightly higher GI. According to available data [18], there was no significant difference in the IUAC of blood glucose response between coconut jaggery and cane sugar. Further, this study found that CT has a GI of 53.6, which is 46.4 lower than glucose (GI=100). However, further studies are recommended to analyse how refined sugar used in Sri Lankan households affects the BGL. Furthermore, the variation observed in GI across different studies can be attributed to several factors, including disparities in testing procedures, variations in food portion sizes [19], and variations in heat treatment [20_21].

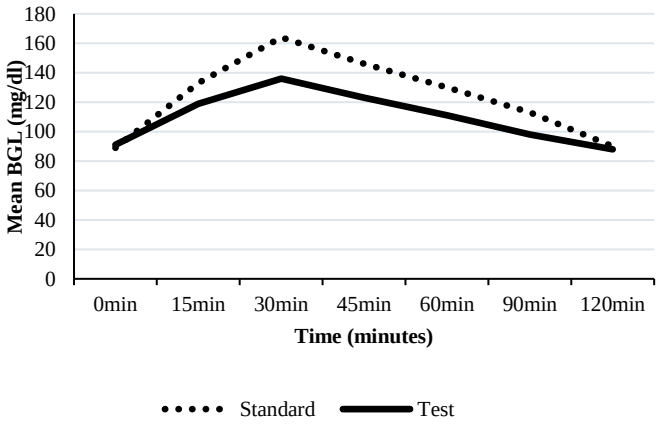

Fig 1. The mean blood glucose concentrations of glucose (standard food) and coconut treacle (test food)

3.2. Study for the market potential of CT

The consumption of CT is influenced by a number of variables, including product attributes, sociodemographic factors, consumer preference, perception, and knowledge. Among the total of 365 participants, 57% were males and 43% were females. Consumers' age ranged between 17-28 years. The majority of the participants were between 17-25 years (74.52%), unemployed (34.2%), and from the Colombo district (20.8%). About 31.5% of respondents had a family income of between 60,000-80,000 LKR per month while 66.6% of respondents were from households with 4-6 people (Supplementary data-5,6,7&8).

The study's findings indicated that more than half of the respondents (97%) had a solid understanding of the beneficial properties of CT. The mean consumer knowledge score was calculated as 48.6±4.3 (Supplementary data-11). The data analysis was performed at a significance level of 0.05. The research results further revealed a significant relationship between the total knowledge level and socio-demographic factors, such as gender, ethnicity, and employment status (Table 1).

In order to assess consumer perceptions of CT as shown in Table 2, responses such as "agree" and "strongly agree" with total relative frequencies (TRF) above 50% were categorized as positive perceptions. However, no statement received TRF above 50% for "disagree" and "totally disagree,", signifying an absence of negative perceptions.

Table 1

Association between total knowledge level and socio-demographic characteristics of participants.

Socio demographic Factor		Knowledge category			p value
		Average	Good	Poor	
		%	%	%	
Gender	Male	30.3	68.8	1.0	0.002
	Female	40.1	58.0	1.9	
Household members	>6	16.4	82.2	1.4	0.205
	1-3	36.7	63.3	0	
	4-6	39.5	58.8	1.6	
Monthly income of the family (LKR)	20,000-40,000	50.0	45.7	4.3	0.061
	40,000-60,000	18.7	81.3	0	
	60,000- 80,000	32.2	67.8	0	
	80,000- 100,000	36.8	60.5	2.6	
	<20,000	54.5	36.4	9.1	
	> 100,000	42.9	57.1	0	
Ethnicity	Moors	50.0	50.0	0	<0.001
	Muslims	35.0	63.1	1.5	
	Sinhalese	42.2	56.3	1.5	
	Tamils	14.5	85.5	0	
Employment status	Contact-based	0.0	100	0	0.031
	Full time	54.5	45.5	0	
	Other	55.6	40.7	3.7	
	Part time	24.0	76.0	0.0	
	Training or Internship	26.7	73.3	0.0	
	Unemployed	44.0	52.8	3.2	

The results revealed that the majority of the undergraduates had adequate knowledge regarding the medicinal properties and health benefits of CT owing to larger proportion of

participants following healthcare-related degree programs such as Biomedical science. The large percentage of respondents who agreed with the claims that "CT is good for health" and "CT has anti-oxidant and medicinal properties" confirms that the community has long held the benefits of CT as a reliable recipe for illness prevention.

More than 80% of participants perceive CT as a tasty, and healthy product and they are satisfied with the quality of CT sold in Sri Lanka. Nearly three parts of the population have the opinion that CT can substitute sugar. Several consumers prefer to consume directly while some prefer to mix it into foods. Age, occupation, and education all have a big impact on consumer preferences.

In terms of purchasing preferences, it's noteworthy that, 52.6% of consumers preferred to purchase CT from supermarkets, while only 1.4% showed interest in purchasing in pharmacies (western/ indigenous). A total of 25.8% of participants opted for manufacturers, while 20.3% preferred open-air markets as their choice of place to make purchases.

Table 2

Knowledge and perception about coconut treacle.

Statement	SA	A	N	D	SD	TPP
CT tastes good	41.1	47.7	6.3	4.7	0.3	88.8
CT is good for health	37.8	48.5	11.8	1.6	0.3	86.3
CT is a nutritious product	36.4	49.9	12.3	1.1	0.3	86.3
CT is a product with low calories	9.3	59.7	25.5	4.4	1.1	69.0
CT has antioxidant and medicinal properties	11.8	62.7	23.0	1.9	0.5	74.5
CT has low glycaemic index	24.7	55.9	18.4	0.8	0.3	80.6
CT is safe to be consumed	12.1	60.5	23.8	3.0	0.5	72.6
CT can replace sugar	13.7	58.9	24.4	2.5	0.5	72.6
CT can be consumed at any age	47.1	39.5	11.0	2.2	0.3	86.6
It is easy to find CT in Sri Lanka	51.5	42.2	4.4	1.1	0.8	93.7
When purchasing CT, product packaging is highly important	41.4	42.5	12.9	2.5	0.8	83.9
CT sold in Sri Lanka are of good quality	41.4	42.5	12.9	2.5	0.8	83.9

SA - Strongly agree, A – Agree, N – Neither agree nor disagree, D – Disagree, SD - Strongly disagree, and TPP-Total positive perceptions (n = 365, values in %)

Table 3

Purchasing habits of participants.

Variables	Responses	%
Q1. How often do you buy treacle?	At least once a month	29.6
	Once in 3 months	35.9
	Once in 6 months	34.5
Q2. Where do you prefer to buy Coconut treacle?	From manufacturers	25.8
	Open air markets	20.3
	Pharmacies	1.4
	Supermarkets	52.6
Q3. Quantity of Coconut treacle purchased in the last month	Between 0.5 and 1 litre	65.5
	More than 1 litre	34.5
Q4. Main characteristics for deciding to purchase Coconut treacle	Colour	6.3
	Taste/Flavour	14.0
	Label/Brand	5.8
	Purity	57.0
	Texture	17.0
Q5. Criteria indicating Coconut treacle quality	Colour	31.5
	Taste/Flavour	15.6
	Nutritional Value	14.0
	Smell	17.5
	Texture	21.4
Q6. Are you satisfied with the quality of Coconut treacle that you currently buy	Moderately satisfied	38.9
	Not satisfied	7.7
	Satisfied	53.4

Consumers significantly pay attention to the product's purity, and nutritional value while purchasing. Brand reputation, packing, and price are additional important factors that affect purchasing decisions. Purity/ being natural (57.0%), texture (17.0%), and taste/ flavour (14.0%) were identified as the influential factors for purchasing decisions. In the previous month, 35.9% of the respondents purchased between 0.5 and 1 litre of CT, and they did so at least once every three months. More than half of the participants (53.45%) expressed satisfaction with the quality of CT they had purchased, as detailed in Table 3.

Significantly, Table 4 revealed a notable association ($p<0.05$) between gender and various aspects of consumption and purchasing habits of CT, including annual consumption, preferred purchase location, purchase quantity, primary factors influencing purchasing choices, satisfaction with the available CT, and the rationale behind their purchases.

Table 4

Association between gender and consumer habits

Variables	Responses	Male (%)	Female (%)	p value
What is the frequency of coconut treacle consumption?	Daily	19.7	15.3	<0.001
	Once a month	21.6	35.7	
	Once a week	39.9	16.6	
	Rarely	18.8	32.5	
How often do you buy coconut treacle?	At least once a month	40.4	15.3	0.003
	Once in 3 months	32.2	40.8	
	Once in 6 months	27.4	43.9	
Where do you prefer to buy coconut treacle?	Directly from the producers	22.1	30.6	0.025
	Open air markets	22.6	17.2	
	Pharmacies	1.0	1.9	
	Supermarkets	54.3	50.3	
Quantity of coconut treacle purchased in the last month	Between 0.5 and 1 litre	57.7	75.8	0.004
	More than 1 litre	42.3	24.2	
Main characteristics for deciding to purchase coconut treacle	Colour	8.2	3.8	0.031
	Flavour	11.5	17.2	
	Label	6.7	4.5	
	Purity	56.3	58	
	Texture	17.3	16.6	
Criteria indicating	Colour	39.4	21	0.216
	Flavour	3.9	17.8	
	Nutritional Value	8.2	21.7	

coconut treacle quality	Smell	21.6	12.1	
	Texture	16.8	27.4	
Are you satisfied with the quality of coconut treacle that you currently buy?	Moderately satisfied	32.2	47.8	0.011
	Not satisfied	6.7	8.9	
	Satisfied	61.1	43.3	
Reason for purchasing coconut treacle	Business	0.05	0.6	<0.001
	Family	50	69.4	
	Personal	49	29.9	
Do you increase the coconut treacle consumption in any specific season?	Yes	14.4	14.6	0.321
	No	85.6	85.4	

There is a statistical significance ($p<0.05$) between the frequency of CT consumption and gender ($p<0.001$), degree program ($p=0.001$), monthly family income ($p=0.001$), numbers of household members ($p=0.048$) and employment status ($p<0.001$). Consumers with income less than 20,000 LKR do not show much interest in consuming CT. They might have not changed to organic alternatives due to the affordable price of refined sugar available in the shops. Therefore, manufactures should target to increase the affordability and availability among these people. High consumption was found in families with a monthly income between 60,000- 80, 000 LKR while the next majority was shared between income of 40,000– 60,000 and 80,000–100,000. Hence, traders can aim these groups to increase consumption.

It was concluded that, CT belonged to the low GI category which was calculated as 53.6 % making it a possible sugar substitute in the diets of diabetic and pre-diabetic patients. A majority of the young population prefers to consume CT. Several consumers perceive CT as a health supplement and prefer to consume it directly. The findings provide insights that can be used by marketers to develop effective strategies and enhance CT consumption.

Conflicts of Interest

There are no conflicts to declare.

Acknowledgments

Financial assistance from KAATSU International University (KIU) and Ceylon Coconut Company (Pvt) Ltd. (CCC) is acknowledged.

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