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Effects of organic coconut flower syrup with and without inulin on glucose and insulin responses

Naruemon Leelayuwat[1,2, *], Benja Songsaengrit[2,3], Yupaporn Kanpetta[4,] Ploypailin Aneknan[2], Terdthai Tong-Un[1,2]

[1] Department of Physiology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand
[2] Exercise and Sport Sciences Development and Research Group, Khon Kaen University, Khon Kaen, Thailand
[3] Cardiac Rehabilitation Group of Queen Sirikit Heart Center of the Northeast, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand
[4] Development of Sport Science, Faculty of Science, Buriram Rajabhat University, Thailand
[*]Corresponding Author: E-mail: naruemon.leelayuwat@gmail.com

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Abstract

The glycemic index (GI) and insulinemic index (II) classify foods based on the blood glucose and insulin concentrations they produce, which are then associated with the risk of developing metabolic diseases. Thus, a database indicating the GIs and IIs of different foods is necessary for providing people with health information. Nowadays, the consumption of the natural sweetener product, organic coconut flower syrup (OCFS), is increasing. However, there has been no research investigating the GI and II of OCFS. Moreover, its consumption still increases blood glucose concentrations, therefore, adding an antihyperglycemic ingredient such as inulin, may be useful to reduce its GI and II. This study aimed to measure the GI and II of OCFS without inulin and with 1.5% and 3% inulin in healthy subjects between 20 and 40 years of age. The GI and II were calculated from the area under the curve (AUC) of blood glucose and serum insulin concentrations after the consumption of OCFS. Results showed that the GIs of OCFS, OCFS mixed with 1.5% inulin, and OCFS mixed with 3% inulin were 51.2 ± 9.26, 48.3 ± 8.5, and 45.4 ± 10.0, respectively and that IIs were 45.4 ± 10.0, 20.7 ± 5.1, and 18.4 ± 5.7, respectively. These results suggest that the GI and II of all OCFS test foods are low.

Keywords: health promotion, organic coconut flower syrup, blood glucose concentration, serum insulin concentration

1. Introduction

The glycemic index (GI), first introduced in 1981 [1], is a classification of the blood glucose-raising potential of carbohydrates (CHO) in foods [2]. It is defined as the incremental area under the curve (AUC) of blood glucose of a 50-g CHO portion of a test food, and is expressed as a percentage of the response to 50 g of CHO of a standard (reference) food consumed by the same subject [3]. There are 3 types of GIs: low (LGI) (GI value ≤55), medium (MGI) (GI value 56–69), and high (HGI) (GI value ≥70) GI [4]. Increased blood glucose levels induced by HGI diets stimulate insulin secretion, which contributes to fat accumulation [5 & 6], leading to obesity, as well as insulin resistance [7]. Insulin resistance is a significant cause of metabolic diseases, such as type 2 diabetes [8] , cardiovascular disease [8], and cancer [9]. Meanwhile, LGI diets are associated with a decreased risk of the above diseases [10-13]. The different effects may be explained by a decrease in blood glucose concentration, leading to improved insulin sensitivity. The insulinemic index (II) also classifies foods based on the blood insulin concentrations they produce. It is positively associated with insulin resistance [14], which is why the II can be used to indicate the risk of developing metabolic diseases. The insulinemic response is also related to cellular dysfunction [6], resulting in metabolic diseases. Nowadays, the consumption of organic coconut flower syrup (OCFS), a natural product advertised as part of the LGI diet [15], is increasing. However, its consumption still increases blood glucose concentrations. Therefore, adding an ingredient to reduce its GI may be useful to reduce the effect on blood glucose concentrations. Inulin, which is a water-soluble and non-digestible CHO, has been suggested to be a choice of additive to reduce blood glucose levels because it has been shown to reduce post-prandial blood glucose levels in healthy volunteers [16]. The development of a new kind of OCFS with lower GI offers an important and interesting choice for a natural sweetener. However, there have been no previous studies examining glycemic and insulin responses resulting from the consumption of OCFS alone versus combined with inulin. The present study thus investigated the acute effects of ingestion of OCFS alone and adding inulin to OCFS on glycemic and insulin responses.

2. Materials and methods

2.1 Subjects

Ten healthy women between 20 and 40 years of age were recruited. They were examined using a questionnaire, electrocardiogram, blood pressure test, and blood sampling to determine their lipid profile and blood glucose, creatinine, and alanine aminotransferase (serum glutamic pyruvic transaminase, SGPT) levels. The exclusion criteria included having any of the following: body mass index (BMI) > 23 kg/m^2; cardiovascular disease or hypertension; orthopedic problems; neuromuscular, liver, or kidney disorder; diabetes mellitus; infection, e.g., fever; or history of taking medication, smoking, or drinking alcohol regularly. All subjects were informed verbally and in writing of the experimental protocol and possible risks involved. The consent form was approved by the Ethical Committee of Khon Kaen University in accordance with the 1964 Declaration of Helsinki (HE501046).

2.2 Test foods

There were four kinds of test foods used in the study:

(1) Glucose, as a reference food
(2) OCFS
(3) OCFS mixed with 1.5% inulin added (OCFS+1.5%Inu)
(4) OCFS mixed with 3% inulin added (OCFS+3%Inu)

The experimental portions (g) and total CHO (available and unavailable) (g/100 g) of test foods are shown in Table 1. Having the value of total CHO weight per 100 g of the total test food, the portion of the test food that contains 50 g CHO was calculaed. Glucose had the lowest experimental portion and the highest total CHO. In contrast, OCFS with 3% inulin had the highest experimental portion and the lowest total CHO.

Table 1 Experimental portion (g) and CHO weight (g) of reference and test foods

Test food	Experimental portion (*g*)	Total CHO (*g/100 g*)
Glucose	50.0	100.0
OCFS	65.5	76.3
OCFS+1.5%Inu	65.3	76.6
OCFS+3%Inu	65.1	76.8

OCFS, Organic coconut flower syrup; Inu, Inulin; CHO, carbohydrate

2.3 Study design and protocol

This study was an experimental prospective study. All subjects underwent four visits. On the first visit, they consumed the reference food, which was 50 g of anhydrous glucose (GL group). During this visit, subjects who had 2-h post-consumption plasma glucose concentrations greater than 140 mmol/L were excluded because this showed that they had impaired glucose tolerance. During the next three visits, the subjects randomly ingested three kinds of test foods: OCFS (OCFS group), OCFS mixed with 1.5% inulin added (OCFS+1.5%Inu group), and OCFS with 3% inulin added (OCFS+3%Inu group) on separate days, at least 5 days apart. The amount of the experimental portion was calculated based on the CHO weight per 100 g of the total test food. Then, the portion of the test food that contained 50 g of CHO was used. On the day prior to each test, subjects were asked to restrict their intake of alcohol- and caffeine-containing drinks and to restrict their participation in intense physical activity, e.g., long periods at the gym, excessive swimming, running, or aerobics [2]. Subjects were instructed not to eat or drink after 24:00 h the night before the test, although drinking water was allowed in moderation. Blood samples to measure glucose and insulin concentrations were acquired immediately before the consumption of the test foods and at 15, 30, 45, 60, 90, and 120 min after consumption initiated.

2.4 Blood glucose and insulin measurements

Blood glucose concentrations were measured using the glucose oxidase method (using YSI 2300 STAT Plus™, USA). Serum insulin concentrations were measured by radioimmunoassay using a commercial kit (125/RIA) from MP Biomedicals, LLC (CA, USA).

2.5 Calculations of GI and II

The incremental AUC of blood glucose and serum insulin, ignoring the area beneath the baseline, was calculated geometrically for each test food. The AUC for each test food was then expressed as a percentage of the mean AUC for the reference food consumed by the same subject [2].

*GI = (*AUC of blood glucose concentration of *test food containing 50 g CHO/AUC 50 g glucose) × 100* [17]
*II = (*AUC of serum insulin concentration of *test food containing 50 g CHO/AUC 50 g glucose) × 100* [18]

2.6 Statistical Analysis

All data are expressed as mean ± standard error unless stated otherwise. Descriptive statistics were used to express the baseline subject characteristics, GI, and II. If the statistical probability value (p-value) was less than 0.05, the difference was considered to be statistically significant.

3. **Results**

3.1 Subjects

The 10 women participating in the study had normal weights. They also had no liver, kidney, or cardiovascular diseases; diabetes; dyslipidemia; or obesity (Table 2).

Table 2 Anthropometric and physiological characteristics of subjects

	Women (*n = 10*)
Age (yr)	29 ± 1.4
Body mass (kg)	47 ± 1.2
Height (cm)	157 ± 1.1
Body mass index (kg/m^2)	18.9 ± 0.4
Waist circumference (cm)	70 ± 1.9
Hip circumference (cm)	89 ± 1.3
Waist/hip circumference ratio	0.79 ± 0.1
Heart rate (/min)	66 ± 3.3
Blood pressure (mmHg)	110 ± 3/67 ± 2
Fasting blood glucose (mg/dL)	82.4 ± 7.6
Creatinine (µmol/L)	73.7 ± 2.66
Alanine aminotransferase (U/L)	11 ± 0.7
Cholesterol (mmol/L)	5.26 ± 0.37
Triglyceride (mmol/L)	0.89 ± 0.07
High-density lipoprotein (mmol/L)	1.63 ± 0.07
Low-density lipoprotein (mmol/L)	3.22 ± 0.37

Data are represented as mean ± SD; n = 10 women.

3.2 Findings

The AUCs of blood glucose and serum insulin concentrations in all OCFS groups were less than those in the GL group ($p < 0.01$), without any differences between the OCFS groups (Figure 1). Timing of achieving maximal concentration of glucose and insulin in all OCFS groups were 30 min. The GI and II values for all test foods are shown in Table 3. All OCFS groups were shown to have low GI and II values (Table 3). GI and II values were the highest in the OCFS group and gradually decreased to the lowest in the OCFS+ 3% Inu group (Table 3).

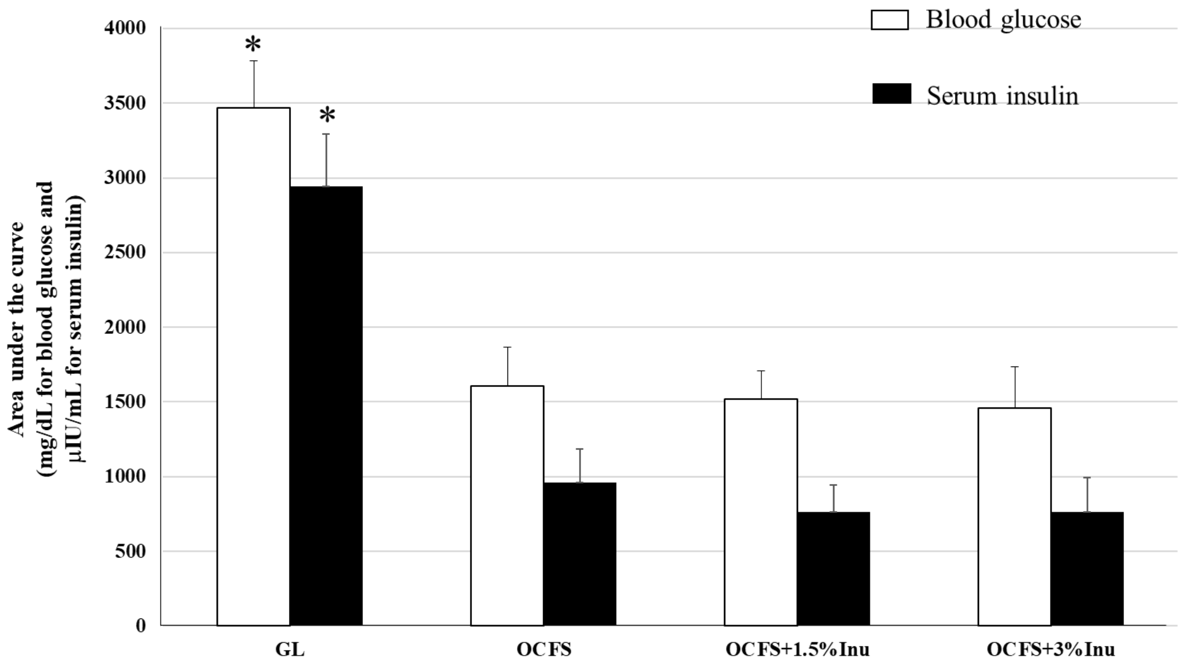

Figure 1 Area under the curve of blood glucose (mg/dL) and serum insulin (μIU/mL) concentrations in glucose reference food (GL), organic coconut flower syrup (OCFS), organic coconut flower syrup mixed with 1.5% inulin added (OCFS+1.5%Inu), and organic coconut flower syrup mixed with 3% inulin added (OCFS+3%Inu). Data are expressed as mean ± SE; n = 10 women. * Significantly different from OCFS groups (p < 0.01)

Table 3. Glycemic index (GI) and insulinemic index (II) values for test foods

Test food	GI	II
OCFS	51.2 ± 9.26	36.7 ± 20.0
OCFS+1.5%Inu	48.3 ± 8.5	20.7 ± 5.1
OCFS+3%Inu	45.4 ± 10.0	18.4 ± 5.7

Data are expressed as mean ± SE; n = 10 women.
OCFS, Organic coconut flower syrup; Inu, Inulin

4. Discussion

The present study demonstrated the effects of consuming OCFS with and without inulin on blood glucose and insulin concentrations. This is the first study to show that OCFS produced lower blood glucose and serum insulin concentrations than those by glucose, the reference food. The GI and II values of all OCFS test foods were low.

OCFS is a natural product advertised as part of the LGI (GI = 40) diet [15]. However, no scientific study has been conducted to prove this advertisement. Therefore, this is the first scientific study to confirm that it is an LGI (GI < 55) food, as advertised. However, this study was conducted in healthy subjects. Considering different glucose kinetics between healthy individuals (with normal glucose kinetics) and patients with metabolic diseases (with abnormal glucose kinetics), the results may not be applicable to patients. Further research conducted in patients is needed.

The antihyperglycemic response to OCFS compared with that to the reference food in this study, which leads to OCFS being a part of an LGI diet, could be due to the contents of OCFS, available (i.e., fructose) and unavailable (i.e., dietary fiber (about 0.1%)) CHO [19], which are known to decrease hyperglycemia [20]. Although we did not analyze both contents, a paper on a nutritional study by Mahidol University reported that OCFS comprises these two contents. The former was shown to [21] interfere with CHO absorption through the inhibition of intestinal disaccharidases and glucose transportation. The latter also decreased the absorption of CHO, leading to low post-prandial hyperglycemia [22]. The antihyperglycemic effect of OCFS in this study is confirmed by the low insulin response. This could be due to lower post-prandial blood glucose concentrations, which are a main stimulator of insulin secretion.

In this study, the GI values of OCFS with 1.5% and 3% inulin were lower than that of pure OCFS. This outcome may be the result of the added inulin, as it was the only substance added to the syrup. The unavailable CHO and high fiber content of inulin, especially of soluble fiber, may delay the glycemic response. Many authors explain this antihyperglycemic effect of fiber in terms of four mechanisms [23-25], or in terms of the delaying of four parameters: the transition time of the stomach contents to the duodenum; the diffusion tempo of different saccharides in the duodenum; the hydrolysis of polysaccharides in the upper part of the duodenum; and finally, the absorption tempo of monosaccharides through the microvilli of the epithelial cells of the jejunum and the upper part of the ileum. Moreover, in vitro studies have suggested that dietary fiber can alter the activity of pancreatic amylase [26]. The inhibitory effects of fiber on pancreatic enzyme activities have been attributed to various factors, including pH changes, ion exchange properties, enzyme inhibitors, and adsorption [26]. Therefore, the high fiber content of a food contributes to lower blood glucose and insulin responses.

This study also found low II values for all OCFS types, with OCFS mixed with 3% inulin showing the lowest II value. The low insulin response is supported by a previous study, which also found low insulin responses to LGI meals [17]. Taken together with the antihyperglycemic effect, all types of OCFS may contribute to preventing beta cell dysfunction, as hypersecretion of insulin did not occur. This may not only prevent healthy non-diabetes mellitus from developing into diabetes mellitus, but could also prevent complications in patients with diabetes mellitus. An increased insulin concentration stimulates interleukin-6 (IL-6) secretion from fat cells, resulting in a release of high-sensitivity C-reactive protein (hsCRP), which is an indicator of cardiovascular diseases [27]. Unfortunately, we did not measure IL-6 and hsCRP. Thus, further investigation of the effects of OCFS alone and mixed with inulin on these parameters is needed. Although glucose was the reference food for calculating the insulin index in this study, it could be argued that white bread rather than glucose is the standard food for measuring the insulin index. However, the insulin responses to OCFS in the present study were minimal. This confirms the low GI of all OCFS types.

This study indicates that the consumption of OCFS, either alone or mixed with 1.5% or 3% inulin, results in lower glucose and insulin responses, compared with those of a glucose solution, indicating that OCFS with or without inulin may be another choice of natural sweetener. However, these syrups should not be consumed in excessively high quantities or too often, as prolonged overconsumption may cause hyperglycemia, resulting in insulin resistance. This idea is the same as that of the food and beverage industry, which has been exploring ways to decrease the levels of free sugars within their products to comply with guidelines and regulations, such as those of the World Health Organization (WHO) [3]. A strong recommendation by the WHO is to decrease the sugar levels in products to 5–10%. To achieve this goal, it is important to explore current information regarding calorie-free or low-calorie sweeteners. There are many calorie-free or low-calorie sweeteners, such as cyclamate, steviol saccharin, acesulfame-potassium, glycosides/Stevia, aspartame, thaumatin, and sucralose/Splenda; exceedances have been noted for acesulfame-K, cyclamate, steviol glycosides, and saccharin in some populations. However, this study did not measure energy of the test foods.

Further research examining the energy of all test foods is worth performing. Further studies investigating post-prandial CHO and fat utilization and energy expenditure should be conducted to provide important information that may be used to confirm test foods' role in weight reduction or improve fat metabolism in patients with metabolic diseases.

5. Conclusion

The results of this study suggest that GI and II values of all OCFS test foods were low.

6. Acknowledgments

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