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The effects of isomaltulose-based beverage on postprandial plasma glucose and lipid profiles in obese men

Phim-on Suklaew[1], Passakorn Suraphad [1], Sirichai Adisakwattana[2,3], Sathaporn Ngamukote[2,3], Sriwatana Songchitsomboon[4] and Kittana Mäkynen[2,3]*

[1]Graduate Program in Food and Nutrition, Department of Nutrition and Dietetics, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok 10330, Thailand

[2]Department of Nutrition and Dietetics, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok 10330, Thailand

[3]Research Group of Herbal Medicine for Prevention and Therapeutic of Metabolic Diseases, Chulalongkorn University, Bangkok 10330, Thailand

[4]Graduate Program of Nutrition, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok 10400, Thailand

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ABSTRACT

Obesity is one of the most important factors causing metabolic diseases. High-fat diet and excessive sugar consumption which are associated with the development of obesity and metabolic syndrome can induce insulin resistance and inflammation. In addition, high glycemic index (GI) sugar such as sucrose may contribute to weight gain and type 2 diabetes, compared with low GI sugar. It has been shown that isomaltulose, a low GI sugar, can improve postprandial glycemia (both first and second meal effects). However, no studies on the second meal effect of isomaltulose with high-fat diet as first meal were found. This study was aimed to investigate the first and second meal effects of an isomaltulose-based beverage with high-fat meal on postprandial plasma glucose and lipid profiles in obese. Twelve obese men between the ages of 20 and 35 years were participated in this randomized, cross-over study. The subjects consumed a high-fat meal with sucrose or isomaltulose beverage as the first meal, following by standard second meal. Postprandial plasma glucose, triglycerides and free fatty acid levels (FFA) were examined at each time points for 480 min. The results showed that the incremental area under the curve (iAUC) of postprandial plasma glucose and triglycerides in isomaltulose group were significantly lower than those of sucrose group ($p<0.01$, and $p<0.05$, respectively). In addition, the isomaltulose group tended to have lower iAUC of FFA than that of sucrose group, but not significant ($p=0.194$). In conclusion, this study demonstrated that replacing sucrose with isomaltulose when consumed with high-fat diet, exhibited beneficial effects on postprandial glucose and triglycerides after the first and second meals, that may reduce the metabolic risks in obese men.

* *Corresponding author*: Tel.: +66804067161
Email: malynn.porayanee@gmail.com

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Introduction

Obesity is a worldwide public health concern due to an increase in the prevalence during the last decade (Ogden and Statistics, 2012). Other causal factors of obesity progression also include genetics, age, gender, disease and medicines (Bray, 1999). Excessive body fat accumulation has shown the adverse effects on both mental and physical health which contribute to various metabolic diseases such as cardiovascular diseases, type 2 diabetes (T2DM) and colon cancer (Vainio and Bianchini, 2001).

Dietary fat consumption is one major factor of weight gain resulting to the development of obesity and metabolic diseases. (Ludwig *et al.,* 1999). Consumption of a high-fat diet is associated with a rise of triglyceride level and poor controlling glycemic variability (Buettner *et al.,* 2006) and it may contribute to insulin resistance by increasing free fatty acid (FFA) in blood circulation. In meantime, excessive sugar consumption is also the likely cause of obesity.

Isomaltulose is a low glycemic index (low-GI) reducing disaccharide sugar (Lina *et al.,* 2002). Commercial isomaltulose (Palatinose®) was manufactured from food-grade sucrose by enzymatic rearrangement of the glycosidic linkage followed by crystallization (Weidenhagen and Lorenz 1957). This sugar gives 4 kcal per gram as same as sucrose but it has lower glycemic index (GI=32) (Holub *et al.,* 2010) than that of sucrose (GI=65) (Liljeberg and Björck 2000).

Moreover, it was proved that isomaltulose improved postprandial glycemic and lipid profiles in healthy and diabetic patients without toxicity or adverse effect on the gastrointestinal system (Ludwig 2002; Thomas and Elliott 2010). It is possible that replacing refined sugar with isomaltulose in a high-fat first meal may help obese people to control postprandial blood glucose and lipid profiles and consequently regulate their profiles after consumption of second meal.

Therefore, the aim of this study was to investigate the effect of isomaltulose-based beverage consumption with a high-fat diet as the first meal, followed by a second regular meal on the postprandial plasma glucose, triglycerides and free fatty acids in obese men.

Materials and methods

Participants

Twelve healthy obese male participants were recruited from local community via poster advertisement at Chulalongkorn University The participants were eligible if they had following inclusion criteria: male aged between 20 - 35 years old; body mass index (BMI) between 25.0 - 29.9 kg/m^2 [Class I obesity according to the classification of WHO 2004 (Asia-Pacific criteria)]; fasting blood glucose < 126 mg/dL; total cholesterol < 200 mg/dL; triglycerides < 150 mg/dL; blood pressure < 140/90 mmHg; blood creatinine level between 0.7 – 14 g/dL; BUN between 25 – 50 mg/L; ALT < 40 IU/L; nonsmoker; and no eating disorder problem. The participants were excluded if they had taken any dietary supplements or medicines within 1 month before the experiment. The participants in this study were 25.9±1.2 years old with BMI 25.7±0.1 kg/m^2, and other parameters were in accordance with the inclusion criteria. The study protocol was approved by the Ethics Review Committee for Research Involving Human Research Subjects, Human Science Group, Chulalongkorn University [code no. 134/56].

Experimental design

The experimental design of this study was a randomized, single-blind, placebo-controlled, crossover trial. The study consisted of two intervention periods with two-week washout period. At each intervention period, after 12-hr fasting, the participants received an isocaloric high-fat breakfast with 300 mL of either sucrose-based beverage (sucrose intervention; 40 g sucrose) or isomaltulose-based beverage (isomaltulose intervention) [the first meal containing 621 kcal; % caloric distribution of carbohydrate: protein: fat = 43: 15: 42], followed by a regular diet with 300 mL sweet drink (40 g sucrose) for lunch (the second meal containing 625 kcal; % caloric distribution of carbohydrate: protein: fat = 55: 15: 30). All participants were instructed to completely consume both breakfast and lunch within 10 min since the meals were served. Venous blood samples were collected by catheter inserted into forearm for a total 480-min period since the first meal started until the intervention period ended.

Blood sample collection and Biochemical analyses

Plasma glucose was measured by the glucose oxidase method, using the GLUCOSE Liquicolor (HUMAN, Germany). Plasma triglycerides were measured by the enzymatic colorimetric method, using TRIGLYCERIDES liquicolor mono (HUMAN, Germany) and plasma free fatty acids (FFA) were analyzed by colorimetric method, using NEFA (non-esterified fatty-acids) assay (RANDOX, UK).

Statistical analyses

Data are expressed as mean ± SEM. Variables were assessed for normality of distribution by Kolmogorov Smirnov test. The data of incremental plasma glucose, triglycerides and free fatty acids at each time point after the meals consumption were analyzed using a repeated measured ANOVA, followed by the LSD *post hoc* test for multiple comparisons. Significant differences of iAUCs of plasma glucose, triglyceride and free fatty acids between intervention groups were assessed by a paired Student-t test. For all the statistical tests, p-value < 0.05 was considered as statistically significant.

Results and discussion

Postprandial plasma glucose after each meal consumption

The effects of a high-fat breakfast with sucrose- or isomaltulose-based beverage, followed by a regular lunch on the incremental postprandial plasma glucose are shown in Table 1. Our study showed that during isomaltulose intervention, obese participants had lower incremental area under the curves (iAUCs) of postprandial plasma glucose than during the sucrose intervention. It may explain that the chemical structure of isomaltulose cause the slower digestion rate than sucrose (Lina *et al.,* 2002). In addition, previous studies found that consumption of isomaltulose and isomaltulose-blended sugar decreased postprandial plasma glucose levels in healthy subjects (Okuno *et al.,* 2010), sedentary adults (Vanschoonbeek *et al.,* 2009) and diabetic patients (Wolever *et al.,* 1988).

Table 1 Incremental AUCs for postprandial postprandial plasma glucose, triglycerides and FFA after the consumption of a high-fat breakfast with sucrose- or isomaltulose-based beverage, followed by a regular lunch.

Blood parameters	Incremental Area Under the Curves (iAUCs)	
	Sucrose	Isomaltulose
Postprandial plasma glucose (mg×min/dL)	12,596.62 ± 1,139.14	6,245.58 ± 1,139.14*
Postprandial plasma triglycerides (mg×min/dL)	15,492.46 ± 2,936.08	7,6817.02 ± 1,745.27*
Postprandial plasma FFA (umol×min/L)	3,614.20 ± 1,181.60	1,230.80 ± 1,315.51

Data are expressed as mean ± SEM (n=12). * Mean values were significantly different when compared to sucrose (p<0.05, compared with sucrose).

Postprandial plasma triglyceride after each meal consumption

The iAUC for triglycerides of obese participants during isomaltulose intervention was significant lower than that of sucrose intervention (Table 1). The remarkable observation may be due to low GI property of isomaltulose, as a consequence of delaying glucose absorption after further meal intake (Wolever *et al.,* 1988). The increasing of triglyceride levels depend on various factors such as quantity of carbohydrate, fiber content, and types of fat (Fried and Rao 2003). Some previous studies demonstrated that high-fat diet consumption could increase blood triglycerides more than that found in low-fat diet (Pejic and Lee 2006; Robertson *et al.,* 2002). Furthermore, substituting sucrose for starch was effective to escalate postprandial triglyceride level (Albrink and Ullrich 1986). However, the knowledge about dose-response for the effect of sucrose on triglyceride levels in moderate carbohydrate and high-fat diet is still unclear. Moreover, the previous study showed that isomaltulose also decreased plasma triglycerides in T2DM by long-term consumption (Brunner *et al.,* 2012).

Postprandial plasma free fatty acids (FFA) after each meal consumption

There were no significant differences between isomaltulose and sucrose intervention for the iAUC of postprandial plasma FFA, but isomaltulose intervention tended to have greater decrease in iAUC of FFA than sucrose intervention (Table 1). The high level of plasma FFA is usually seen in the obese, due to high release from the enlarged adipocyte and slow clearance rate (Karpe *et al.,* 2011). Long-term high level of FFA in the circulation could trigger insulin resistance and leading to T2DM (Ludwig 2002). Furthermore, a high-GI meal rapidly escalates plasma glucose and insulin levels, followed by individual hypoglycemia. This activates counter-regulatory hormone to recover euglycemia and elevates FFA while the same mechanism is not triggered by low-GI diet (Ludwig 2002). The increasing FFA in blood can cause the insulin resistance and increase blood glucose by inducing hepatic glucose output (Ferrannini *et al.,* 1983). Therefore, consumption of breakfast which be able to delay FFA releasing may bring about to improve insulin sensitivity and decline blood glucose all the day.

Consumption of the low-GI meals or low-GI substitution in high-fat or high-carbohydrate meal not only decrease postprandial glycemia and lipid profiles after first meal, but also showed the same effects after the second meal (Arai *et al.,* 2007). Thus, isomaltulose may be used as a potential alternative sweetener to replace sugar for obese people to maintain their daily glycemic control and reduce risks of metabolic syndromes.

Conclusion

This study showed that the consumption of isomaltulose-based beverage together with a high-fat meal as the breakfast attenuated the levels of postprandial plasma glucose, triglycerides and FFA. In addition, these effects still remained after the consumption of a regular second meal at lunch time. Therefore, isomaltulose may be an alternative sweetener that provides the benefits after first high-fat meal and prolong these beneficial effects to the second meal (so called the second meal effect) for obese participants with a high prevalence of metabolic syndrome.

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