Development of New Lemon-Lime Flavored Beverage for OGTT: Acceptability and Reproducibility

Phawinpon Chotwanvirat MSc*, Yotsapon Thewjitcharoen MD*,
Wyn Parksook MD*, Sirinate Krittiyawong MD*,
Kritchana Hutaphat BSc**, Soontaree Nakasatien RN**,
Sming Kaocharoen MD*, Thep Himathongkam MD, FACP, FACE*

** Diabetes and Thyroid Center, Theptarin Hospital, Bangkok, Thailand*
*** Theptarin Research Center, Theptarin Hospital, Bangkok, Thailand*

Background: *The oral glucose tolerance test (OGTT) is essential procedure in both screening and diagnosis of impaired glucose tolerance (IGT), impaired fasting glucose (IFG) and diabetes mellitus (DM), but it is not easy to perform because of intense sweetness of the 75-g glucose test beverage causing abdominal discomfort post-testing. Therefore, the new formula of non-carbonated lemon-lime flavored beverage was developed to increase its palatability and better compliance.*
Objective: *To develop a new non-carbonated lemon-lime flavored beverage to replace the standard beverage for OGTT. Subsequently, the diagnostic value and acceptability between the new formula and the traditional 75-g OGTT formula were compared in healthy subjects.*
Material and Method: *The new lemon-lime flavored formula was developed to replace the standard beverage for OGTT by adding 1,000 milligram of citric acid and 0.03 gram of lime flavor to 75 gram of anhydrous glucose to a final volume of 300 ml. The study was conducted in 30 healthy subjects who underwent the traditional 75-gram OGTT test and the new formula of OGTT beverage one week later, or vice versa, to access acceptability, indices markers of insulin secretion, and insulin sensitivity. Palatability was determined by rating on a 9-point Hedonic Scale.*
Results: *Thirty healthy subjects (15 females) with the age of 33.2±7.5 years and body mass index of 22.9±3.5 kg/m^2 were enrolled. No significant difference was found between plasma glucose in 0, 30, 60, 90, and 120 minutes, insulin level (0 and 120 minutes) and four insulin surrogate markers in both traditional 75-gram OGTT and new formula of lemon-lime flavored OGTT beverage. The overall satisfaction score of the new formula OGTT was better when compared with the scores of the traditional OGTT (7.1±1.8 vs. 4.7±2.0). Only one subject complained about abdominal discomfort in both episode of OGTT.*
Conclusion: *The modified lemon-lime flavored beverage for OGTT demonstrated better acceptance in the subjects without difference in plasma glucose values and OGTT derived parameters responses to OGTT in comparison to the traditional formula.*

Keywords: *OGTT, Repeatability, Sensory evaluation*

J Med Assoc Thai 2016; 99 (5): 497-504
Full text. e-Journal: *http://www.jmatonline.com*

Despite the myriad of advanced treatment on diabetes and the increasing accessibility to the information, the prevalence of diabetes continues to rise in every region of the world including Thailand. In 2013, 382 million people or 8.3% of world adult-population had diabetes, while 175 million of people were undiagnosed. About 316 million people or 6.9% of population were estimated to have impaired glucose tolerance (IGT), an early stage of the disease, which was undetectable by traditional fasting plasma glucose[1].

Recently, research data suggested that the lifestyle intervention was able to decrease the occurrence of type 2 diabetes[2]. It has been agreed upon that prevention is less costly and more effective than medical treatment.

Identification of high-risk cases is the first step to facilitate prevention. The American Diabetes Association (ADA) recommended using the oral glucose tolerance test (OGTT) for diagnosis of IGT,

Correspondence to:
Chotwanvirat P, Nutrition and Dietetics Program, Faculty of Science and Technology, Valaya Alongkorn Rajabhat University under the Royal Patronage, Pathumthani 13180, Thailand.
Phone: +66-84-0947015
E-mail: phawinpon@dietitian.in.th

impaired fasting glucose (IFG), and diabetes[3]. Recent study revealed that, only fasting plasma glucose test missed 46.3% and 54.7% of all prediabetes and diabetes cases in Thai population respectively[4]. However, some patients complained about the intense sweetness of the test beverage and nausea and vomiting after testing due to hyperosmolarity of monomeric glucose[5-7]. Moreover, the inconvenience of the procedure is the perceived barriers for both patients and physicians to perform this test[8].

To overcome these problems, many attempts were developed to replace the traditional OGTT including muffin[9], jelly bean[10] and ice cream[11]; but only commercial flavored beverages for OGTT were adopted in clinical practice[8,12].

The objective of the present study was to develop a new non-carbonated lemon-lime flavored beverage to replace the standard beverage for OGTT. Subsequently, the diagnostic value and acceptability between the new formula and the traditional 75-g OGTT formula were compared in healthy subjects.

Material and Method

The present study was performed between January and April 2015 at Theptarin Hospital, Bangkok, Thailand. It was divided into two phases. The first phase was to develop the lemon-lime flavored formulas and panel screening for the most suitable product. The second phase was to assess the reproducibility of the selected formula and assess sensory evaluation between the traditional and the new OGTT formula.

Subjects

During development phase, 10 subjects were selected from hospital staffs who had undergone the traditional OGTT in the past. They were received a brief introduction for panel screening process and served as panelists for selecting the most suitable formula. During evaluation phase, healthy hospital personnel were invited to join the study. The sample size that was determined by the method of Dupont and Plummer[13] indicated that 30 healthy subjects were needed. Those between the age of 25 and 69 years old and BMI range 18.5 to 35.0 kg/m^2 were recruited. Those who had abnormal glucose level, pregnancy, acute illness, fever, liver disease, delayed gastric emptying time, maldigestion, or malabsorption were excluded from the present study.

Development phase

The new lemon-lime flavored formulas were prepared by mixing 75 grams of anhydrous glucose powder with 400, 600, 800, 1,000, 1,200, and 1,500 mg of citric acid and 0.03 gram of lime flavor to final volume of 300 ml. The random 3-digit code number was assigned to each formula. The 60 ml of samples were refrigerated to 20°C and were presented in blinded order for each panelist. Each formula was tested by scoring sensory attitude with 9-point Hedonic Scale. For the sensory evaluation, the new formulas were evaluated in terms of sweetness, sourness, slipperiness, heaviness, viscosity, in-mouth aroma, ease of drinking, and overall satisfaction. The formula with the highest sensory score was selected for evaluation phase.

Evaluation phase

After the new lemon-lime flavored formula OGTT beverage had been developed with 1,000 mg of citric acid, the prospective crossover OGTT was conducted. The diagnostic results of OGTT were included plasma glucose levels, insulin levels, area under the curve (AUC)[14] of plasma glucose and insulin levels, time to glucose peak, Matsuda's insulin sensitivity index, HOMA-IR for insulin resistance[15,16], HOMA-β for beta-cell function[17,18] and Stumvoll MCR[19] for insulin sensitivity. The diagnostic results between traditional and the new lemon-lime flavored formula OGTT were compared. The sensory evaluations by scoring sensory attitude with 9-point Hedonic Scale were also evaluated to determine acceptability of the new formula. All subjects were instructed to consume 150 grams or more of carbohydrate at least three days prior to intervention period. Before the OGTT, participants were asked to fast for at least eight hours. The OGTTs were scheduled to begin in the morning and each individual completed the test within two hours after ingestion of OGTT beverage. The blood samples were collected at 0, 30, 60, 90, and 120 minutes after ingestion of selected formula for measuring plasma glucose and insulin levels. The adverse effects from the OGTT were closely monitored by investigators during the two hours of intervention.

After completion of the traditional OGTT test, the sensory and palatability evaluations were rate on a 9-point Hedonic Scale. The repeat OGTT with the newly developed lemon-lime flavored formula was done after one week of washout period.

Determination of glucose and insulin levels

Glucose levels were quantified by UV-enzymatic method with hexokinase, GLUC3 kit, Roche Diagnostic for Cobas Analyzer. The kit had a

coefficient of variation of 0.7% or standard deviation of ≤2 mg/dl. Insulin levels were measured by electrochemiluminescence immunoassay, Roche Diagnostic for Cobas Analyzer. The assay had a coefficient of variation of ≤1.5% and standard deviation of ≤23.1 pmol/L in intermediate precision and repeatability testing.

Statistical analysis

The mean and standard deviation (SD) were used to describe the data of blood glucose levels and AUC of glucose, while paired t-test was used to analyze the difference of the two parameters between both formulas[20]. The time to glucose peak, insulin levels, AUC of insulin and the four surrogate markers were presented by median and the interquartile range (IQR) and the difference was evaluated by the Wilcoxon Signed-Rank test. The sensory evaluation scores were displayed in mean and standard deviation. The differences of their favor were also detected by paired t-test. The *p*-value less than 0.05 was considered significant. All statistical analyses were conducted using the Statistical Package for Social Sciences (version 17.0.; SPSS, Chicago, IL, USA).

Ethical consideration

The present study was approved by the Institutional Review Boards at Theptarin Hospital (EC. 01-2015). The purpose and intervention procedures were informed and the written consents were obtained from all participants prior to enrolment. This trial was registered at the clinicaltrials.in.th as TCTR20150405001.

Results

The result of the development phase revealed that at the dose of 1,000 mg of citric acid was rated with the highest score for sensory attitude (data not shown). Therefore, 1,000 mg of citric acid was used to produce the new lemon-lime flavored formula OGTT beverage for further evaluation.

For evaluation phase, there were 30 subjects, a half of which were females. Their mean age, body weight, BMI, waist and hip circumference were 33.4±7.6 years, 62.0±11.4 kg, 22.9±3.5 kg/m^2, 83.2±9.8 cm and 94.8±7.2 cm respectively.

The means of plasma glucose of traditional compared with the new OGT formula at 0, 30, 60, 90, 120 minutes were 87±6 vs. 88±7 mg/dl, 136±25 vs. 144±19 mg/dl, 130±27 vs. 136±29 mg/dl, 113±22 vs. 112±23 mg/dl, 99±18 vs. 103±20 mg/dl respectively. No significant difference of means plasma glucose was observed between both formulas as well as the diagnostic result. The AUC of glucose levels of both formulas were 14,161±1,953 vs. 14,622±2,002 mg/dl^{-1} 120 mins^{-1}. No statistical significant difference of glucose AUC was found between both formulas. The means of plasma

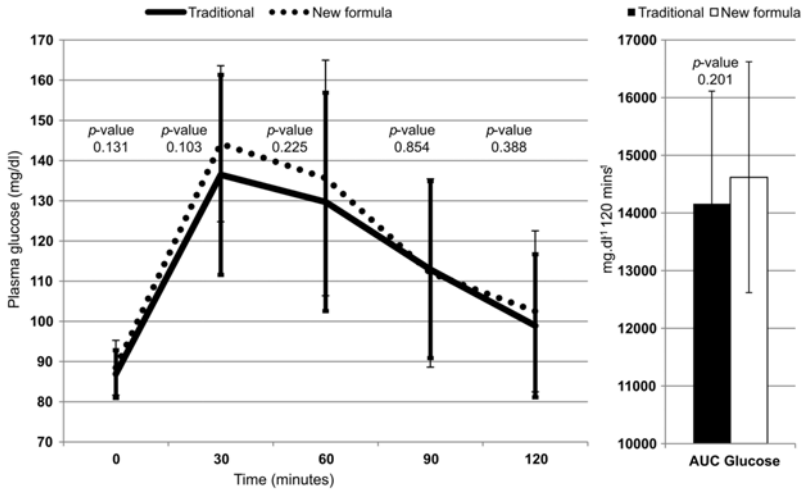

Fig. 1 Mean glucose responses to OGTT and their AUC of both formulas in 30 healthy subjects in each time point. The values present as mean, the error bars represent standard deviation for each values and *p*-value of paired t-test for comparison between both formulas at each time point. The mean AUC of both formulas are illustrated in bar chart, the error bar represent standard deviation of AUC and the *p*-value of paired t-test for comparison between both formulas.

Table 1. Surrogate markers of plasma glucose and insulin level and time to glucose peak response on both OGTT formulas via Wilcoxon signed-rank test

	Median (25^{th}-75^{th}) (n = 30)		*p*-value	Z score
	Traditional	New formula		
Insulin 0 (μU/ml)	6.75 (4.38-10.18)	7.90 (5.15-12.83)	0.147	-1.450
Insulin 120 (μU/ml)	25.15 (9.05-46.38)	27.80 (9.43-58.3)	0.299	-1.039
AUC insulin	482.25 (248.63-789.0)	542.75 (217.88-1,209.0)	0.144	-1.460
Matsuda composite index	9.08 (5.57-14.44)	7.52 (3.62-18.92)	0.289	-1.059
HOMA-IR	1.52 (0.98-2.27)	1.77 (1.15-2.79)	0.088	-1.707
HOMA-β	98.90 (64.65-157.96)	113.79 (72.0-186.53)	0.329	-0.977
Stumvoll MCR	10.42 (8.72-10.85)	9.85 (8.75-11.14)	0.393	-0.854
Time to glucose peak (minutes)	30.00 (30-60)	30.00 (30-60)	0.394	-0.853

HOMA-IR = Homeostatic model assessment-insulin resistance; HOMA-β = Homeostatic model assessment-β-cell; Stumvoll MCR = Stumvoll metabolic clearance rate

glucose levels and their AUCs were displayed in Fig. 1.

The median and IQR of plasma insulin of both formulas at 0 and 120 minutes were 6.75 (4.38-10.18) vs. 7.90 (5.15-12.83) μU/ml and 25.15 (9.05-46.38) vs. 27.80 (9.43-58.3) μU/ml. The median AUC of insulin levels of both formulas were 484.25 (248.63-789.0) vs. 542.75 (217.88-1,209.0) $\mu U.ml^{-1}$ 120 $mins^{-1}$ respectively. The Matsuda index, HOMA-IR, HOMA-β and Stumvoll MCR of both formulas were 9.08 (5.57-14.44) vs. 7.52 (3.62-18.92), 1.52 (0.98-2.27) vs. 1.77 (1.15-2.79), 98.9 (64.65-157.96) vs. 113.79 (72.0-186.53) and 10.42 (8.72-10.85) vs. 9.85 (8.75-11.14) respectively. No significant difference was found in these parameters by Wilcoxon Signed-Rank test. In both samples, the medians of time to glucose peak were at 30 minutes and no statistical significant difference was observed between both groups (Z = -0.853, *p*-value = 0.394). The additional parameters were shown in Table 1. Only one participant complained about abdominal discomfort during both episodes of OGTT but the symptom resolved within one hour after ingestion.

For sensory evaluation, the scores of the new formula were significantly better than that of the traditional OGTT for all aspects (*p*-value <0.05). The sweetness and drinkable score of the new formula were better than that of the traditional OGTT (4.8±2.3 vs. 6.3±1.8, *p*-value = 0.007, 5.3±2.4 vs. 7.3±1.8, *p*-value <0.001). The overall satisfaction of the new formula was greater than the traditional formula (4.7±2.0 vs. 7.1±1.8, *p*-value <0.001). The palatability scores in terms of nausea/vomiting and abdominal discomfort were lesser but no statistical significant. The sensory evaluation was shown in Fig. 2.

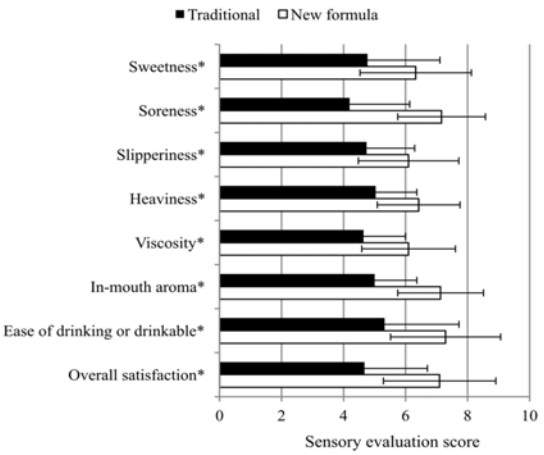

Fig. 2 Sensory evaluation scores of two formulas were presented as mean ± SD, the statistical significant different was indicated by * in each aspect (*p*-value <0.05, n = 30).

Discussion

The use of OGTT in the diagnosis of diabetes has become increasingly recognized because the classification of glycemic status in high-risk groups could be misclassified if fasting plasma glucose is solely used in screening[4]. The IGT is not the only group of at higher risk of developing diabetes, but also the important risk factor for many other adverse health conditions and mortality. However, the poor reproducibility and palatability of OGTT have often hampered the widespread use of this test in clinical practice.

Previous studies had explored the several

methods for replacing traditional OGTT beverage. The partial hydrolysate dextrin is widely use in commercial glucose solution such as Lucozade®, Glucola® and Toleran®. Carbohydrate containing solid foods, as muffin[9], cookie[21], or DSP standardized mixed meal[22], were also investigated for substitution of the traditional method. The muffin composed of carbohydrate (CHO) 56 grams, fat 18 grams, protein 6 grams, and provided 410 kcal per piece. A package of cookie contained 75 grams of CHO from 63.8 grams of starch and 11.2 grams of maltose, butter fat 25 grams, protein 7 grams, and provided 553 kcal. Both of them were served with either water, coffee or tea. The DSP standardized mixed meal is wafers made of oat-fractionation, soy protein, canola oil and honey. The serving size of DSP standard serving was 87 grams comprising of 41.1 grams of starch, 8.9 grams of simple sugar, 3.8 grams of dietary fiber, 10.7 grams of fat, 12.1 grams of protein yielded 345 kcal per five pieces. While the carbohydrate content in those substitutions varied in amount, the diagnostic value of blood glucose responses to commercial OGTT was comparable. The mixed meal test diets were lower osmolarity than the OGTT beverage and resulted to no gastrointestinal adverse effects. However, the recent study showed that macronutrients in mixed meal could diminish glucose excursion and delayed gastric emptying when compared with glucose alone[23]. Therefore, to adopt mixed meal test in replacement of traditional OGTT in diagnosis of diabetes is still problematic.

Adoption commercial OGTT beverages in routine testing, was used for decades in gestational diabetes screening[24]. In theory, the partial hydrolysate liquid glucose that was used in commercial OGTT beverages could lower solubility than that of monomeric glucose. As a result, the gastrointestinal adverse effects will be lesser. However, these commercial OGTT beverages for ready-to-drink format are not available in Thailand yet and the cost of these beverages could be a major obstacle to import from aboard and use widely in rural area.

Moreover, Harano et al reported 26.3% (5 from 19 persons) of epigastric symptoms after OGTT with commercial liquid glucose[21]. The present study showed that the commercial OGTT was still had anhydrous monomeric glucose that contributed to high osmolality comparing to liquid glucose or other mixed meal test diets.

To find an innovation in preparing OGTT beverage, our study confirmed that by mixing 75 grams of anhydrous glucose powder with a 1,000 mg of citric acid in lemon-lime flavored formula could improve tolerability and retained the comparable OGTT data. The advantages of this new formula were convenience to perform, long shelf life and low cost of transportation. The component of dry powders can be produced in a 300 ml empty bottle and kept for a long period due the low water activity of the product. The preparation took only three minutes by mixing with warm water.

The authors acknowledged some drawbacks in the present study. Firstly, the concern of poor repeatability from OGTT itself might affect for comparison results from conducted study one week apart. Actually, the reproducibility of traditional OGTT data had been debated and reported in several studies[25,26]. In theory, the variation of glycemic responses to OGTT depended on quantity of carbohydrate intake at least three days prior to the test date[27,28], fasting duration[29], quantity of glucose and its loading volume[30], time of the day[29], and intra-subject variation of glycemic control[31].

However, several recent studies confirmed the possibility to repeat various OGTT derived outcomes. The defined outcomes of OGTT were possible to be reproducible with well-arranged method to avoid concerned factors as mentioned. Area under the curve (AUC) of glucose responses to OGTT was considered as accepted reproducible[31]. Measurements of time to peak of glucose and insulin level were reproducible in both normal and abnormal glycemic status[32]. The time to glucose peak in normal individual is 30 minutes and delayed to 60 to 90 minutes in diabetes individual. The test was set in the morning to avoid the effect of time of the day along with consistency of loading volume to lesser the consequence of gastric emptying time. The participants were also asked to fast at least 8 hours prior to starting time, to consume carbohydrate more than 150 grams at least three days prior to diminish the confounding factors as much as possible. Finally, our study was non-randomized control trial. We acknowledged that the randomized controlled trial has long been the gold standard for clinical research, representing the best way to determine efficacy and effectiveness for many intervention and prevention programs. However, the added flavor and taste of each formula influenced the perception of the participants in sensory evaluation so randomization may not be feasible in our setting.

In the future, we recommend that the new modified formula should be validated again in a large cohort study and various traditional Thai flavored herbs might be developed to increase the pleasantness of

OGTT tests for our patients.

Conclusion

The OGTT is essential diagnostic procedure for both diagnosis and screening of diabetes and important perceived barriers for both patient and practitioner. However, the major problems of traditional OGTT were time consuming, intense sweetness of glucose beverage and abdominal discomfort after testing. The lemon-lime flavor and citric acid were added to minimize the intense sweetness problem of the conventional OGTT beverage. The results proved better acceptance among the healthy subjects without alteration of glycemic and insulin surrogate markers response to OGTT of the modified formula when comparing to the traditional formula.

What is already known on this topic?

The traditional beverage for OGTT provides intense sweetness, causing nausea and vomiting after testing. Several methods were developed to substitute the traditional beverage or testing procedure but there was no accepted alternative solution available in Thailand.

What this study adds?

The new lemon-lime flavored beverage for OGTT can be replaced the traditional beverage with greater accepted taste and comparable diagnostic outcomes in healthy subjects.

Acknowledgements

The study was not possible without support from R&B Food Supply Co. Ltd. for supplying the lemon-lime flavor and staffs of Theptarin Research Center for their facilitations in this study. We thank Prof. Emeritus Rajata Rajatanavin, consultant of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University, for his generous advice, inspiring guidance and invaluable comments.

Funding source

The authors acknowledge the support of the Foundation for the Development of Diabetes Care (FDDC) in the present study.

Potential conflict of interest

None.

References

1. International Diabetes Federation. IDF diabetes atlas [Internet]. 7th ed. Brussels, Belgium: IDF; 2015 [cited 2016 Jan 31]. Available from: http://www.diabetesatlas.org/
2. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002; 346: 393-403.
3. American Diabetes Association. 2. Classification and diagnosis of diabetes. Diabetes Care 2015; 38 (Suppl 1): S8-16.
4. Aekplakorn W, Tantayotai V, Numsangkul S, Sripho W, Tatsato N, Burapasiriwat T, et al. Detecting prediabetes and diabetes: agreement between fasting plasma glucose and oral glucose tolerance test in Thai adults. J Diabetes Res 2015; 2015: 396-505.
5. Schwartz JG, Phillips WT, Aghebat-Khairy B. Revision of the oral glucose tolerance test: a pilot study. Clin Chem 1990; 36: 125-8.
6. National Health and Nutrition Examination Survey (NHANES). Oral Glucose Tolerance Test (OGTT) procedures manual [Internet]. 2007 [cited 2016 Feb 1]. Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_ogtt.pdf
7. Leonard S Jr, McCullagh EP, Christopher TC. A new carbohydrate solution for testing glucose tolerance. Diabetes 1965; 14: 96-9.
8. Aujla N, Stone MA, Taub N, Davies MJ, Khunti K. Identifying people with type 2 diabetes and those at risk: lessons from the measure your waist (MY-WAIST) mixed-methods study in UK primary care. Prim Care Diabetes 2013; 7: 261-7.
9. Traub ML, Jain A, Maslow BS, Pal L, Stein DT, Santoro N, et al. The "muffin test"—an alternative to the oral glucose tolerance test for detecting impaired glucose tolerance. Menopause 2012; 19: 62-6.
10. Lamar ME, Kuehl TJ, Cooney AT, Gayle LJ, Holleman S, Allen SR. Jelly beans as an alternative to a fifty-gram glucose beverage for gestational diabetes screening. Am J Obstet Gynecol 1999; 181: 1154-7.
11. Chaprasertpinyo W, Sriphrapradang C, Phanachet P, Bhirommuang N, Tungsermwong T, Surawattanawiset T. Using ice cream for diagnosis of diabetes mellitus and impaired glucose tolerance: an alternative to oral glucose tolerance test. The 30th Annual Meeting of the Royal College of Physicians of Thailand; April 23-26, 2014. PEACH Royal Cliff Beach Resort Pattaya, Thailand.

12. Arnott S. Diagnosing diabetes [Internet]. 2014 [cited 2016 Jan 31]. Available from: http://www2.nhslanarkshire.org.uk/Services/Diabetes/Diabetes%20Clinical%20Guidelines/Documents/Diagnosing%20Diabetes%20final%20May14.pdf
13. Dupont WD, Plummer WD Jr. Power and sample size calculations. A review and computer program. Control Clin Trials 1990; 11: 116-28.
14. Tai MM. A mathematical model for the determination of total area under glucose tolerance and other metabolic curves. Diabetes Care 1994; 17: 152-4.
15. Matsuda M, DeFronzo RA. Insulin sensitivity indices obtained from oral glucose tolerance testing: comparison with the euglycemic insulin clamp. Diabetes Care 1999; 22: 1462-70.
16. De Fronzo RA, Matsuda M. Reduced time points to calculate the composite index. Diabetes Care 2010; 33: e93.
17. Levy JC, Matthews DR, Hermans MP. Correct homeostasis model assessment (HOMA) evaluation uses the computer program. Diabetes Care 1998; 21: 2191-2.
18. Wallace TM, Levy JC, Matthews DR. Use and abuse of HOMA modeling. Diabetes Care 2004; 27: 1487-95.
19. Stumvoll M, Mitrakou A, Pimenta W, Jenssen T, Yki-Jarvinen H, Van Haeften T, et al. Use of the oral glucose tolerance test to assess insulin release and insulin sensitivity. Diabetes Care 2000; 23: 295-301.
20. Schuirmann DJ. A comparison of the two one-sided tests procedure and the power approach for assessing the equivalence of average bioavailability. J Pharmacokinet Biopharm 1987; 15: 657-80.
21. Harano Y, Miyawaki T, Nabiki J, Shibachi M, Adachi T, Ikeda M, et al. Development of cookie test for the simultaneous determination of glucose intolerance, hyperinsulinemia, insulin resistance and postprandial dyslipidemia. Endocr J 2006; 53: 173-80.
22. Wolever TM, Chiasson JL, Csima A, Hunt JA, Palmason C, Ross SA, et al. Variation of postprandial plasma glucose, palatability, and symptoms associated with a standardized mixed test meal versus 75 g oral glucose. Diabetes Care 1998; 21: 336-40.
23. Alsalim W, Tura A, Pacini G, Omar B, Bizzotto R, Mari A, et al. Mixed meal ingestion diminishes glucose excursion in comparison with glucose ingestion via several adaptive mechanisms in people with and without type 2 diabetes. Diabetes Obes Metab 2016; 18: 24-33.
24. Butterfield WJH. Summary of results of the Bedford diabetes survey. Proc Roy Soc Med 1964; 57: 196-200.
25. Mooy JM, Grootenhuis PA, de Vries H, Kostense PJ, Popp-Snijders C, Bouter LM, et al. Intra-individual variation of glucose, specific insulin and proinsulin concentrations measured by two oral glucose tolerance tests in a general Caucasian population: the Hoorn Study. Diabetologia 1996; 39: 298-305.
26. Olefsky JM, Reaven GM. Insulin and glucose responses to identical oral glucose tolerance tests performed forty-eight hours apart. Diabetes 1974; 23: 449-53.
27. Szathmary EJ. The impact of low carbohydrate consumption on glucose tolerance, insulin concentration and insulin response to glucose challenge in Dogrib Indians. Med Anthropol 1989; 11: 329-50.
28. Kaneko T, Wang PY, Tawata M, Sato A. Low carbohydrate intake before oral glucose-tolerance tests. Lancet 1998; 352: 289.
29. Trenchard PM, Jennings RD. Diurnal variation in glucose tolerance and its reversal by lengthened fasting. Br Med J 1974; 2: 640-2.
30. Toeller M, Knussmann R. Reproducibility of oral glucose tolerance tests with three different loads. Diabetologia 1973; 9: 102-7.
31. Gordon BA, Fraser SF, Bird SR, Benson AC. Reproducibility of multiple repeated oral glucose tolerance tests. Diabetes Res Clin Pract 2011; 94: e78-82.
32. Kramer CK, Vuksan V, Choi H, Zinman B, Retnakaran R. Emerging parameters of the insulin and glucose response on the oral glucose tolerance test: reproducibility and implications for glucose homeostasis in individuals with and without diabetes. Diabetes Res Clin Pract 2014; 105: 88-95.

การพัฒนาสูตรเครื่องดื่มกลูโคส 75 กรัม รสมะนาว สำหรับทดสอบ OGTT ผลทดสอบความสามารถในการทำซ้ำและการยอมรับ

ภวินท์พล โชติวรรณวิรัช, ยศพล เตียวจิตต์เจริญ, วิน ภาคสุข, สิริเนตร กิตติยาวงศ์, กฤดิ์ชนา หุตะแพทย์, สุนทรี นาคะเสถียร, สมิง เก่าเจริญ, เทพ หิมะทองคำ

ภูมิหลัง: การตรวจความทนต่อน้ำตาล the oral glucose tolerance test (OGTT) เป็นวิธีการทดสอบที่สามารถใช้ในการคัดกรองและวินิจฉัย ผู้มีความผิดปกติของการควบคุมน้ำตาลทั้ง IFG, IGT และเบาหวาน แต่ไม่ได้รับความนิยมแพร่หลายด้วยข้อจำกัดด้านความไม่สะดวกในขั้นตอนการตรวจ รสชาติของเครื่องดื่มกลูโคส 75 กรัมที่หวานมาก ตลอดจนความรู้สึกมวนท้องและคลื่นไส้หลังการทดสอบ ผู้นิพนธ์ได้พัฒนาเครื่องดื่มกลูโคส 75 กรัม รสมะนาวเพื่อแก้ไขปัญหาดังกล่าว

วัตถุประสงค์: เพื่อพัฒนาเครื่องดื่มสูตรมะนาวสำหรับใช้ทดสอบ OGTT และเพื่อทดสอบเปรียบเทียบระดับพลาสมากลูโคส ฮอร์โมนอินซูลินและค่าดัชนีชี้วัดที่ได้จากทดสอบ OGTT ด้วยเครื่องดื่มสูตรมะนาวและเครื่องดื่ม OGTT สูตรเดิมในกลุ่มตัวอย่างที่มีสุขภาพดี

วัสดุและวิธีการ: สูตรเครื่องดื่ม OGTT รสมะนาวได้ถูกพัฒนาขึ้นเพื่อแก้ไขปัญหาเรื่องรสชาติโดยการเติมกรดซิตริก 1,000 มิลลิกรัม กลิ่นมะนาว 0.03 กรัม ลงในสารละลายกลูโคส 75 กรัม และปรับปริมาตรน้ำให้ได้ 300 มิลลิลิตร การทดสอบความสามารถในการทำซ้ำเมื่อเทียบกับสูตรเครื่องดื่มมะนาวต้นฉบับทำในกลุ่มตัวอย่างที่มีสุขภาพดีจำนวน 30 คน โดยกลุ่มตัวอย่างจะถูกสุ่มให้ทำ OGTT ด้วยเครื่องดื่มสูตรเดิมและตามด้วยสูตรใหม่ภายหลัง 1 สัปดาห์ โดยการเก็บตัวอย่างเลือดในช่วงเวลา 0, 30, 60, 90 และ 120 นาที เพื่อใช้ในการหาระดับกลูโคสในพลาสมา และระดับฮอร์โมนอินซูลินที่ช่วงเวลา 0 และ 120 นาที และใช้คำนวณดัชนีชี้วัดสี่ชนิด ทดสอบความด้านประสาทสัมผัสด้วย 9-point Hedonic Scale หลังจากดื่มเครื่องดื่มกลูโคส 75 กรัม

ผลการศึกษา: กลุ่มตัวอย่างจำนวน 30 คน (เป็นผู้หญิง 15 คน) มีค่าเฉลี่ยอายุอยู่ที่ 33.2±7.5 ปี ค่าดัชนีมวลกายเฉลี่ยอยู่ที่ 22.9±3.5 จากการทดสอบไม่พบความแตกต่างทางสถิติของระดับพลาสมากลูโคสที่เวลา 0, 30, 60, 90, 120 นาที ระดับอินซูลินที่ 0 และ 120 นาที และดัชนีชี้วัดทั้งสี่ชนิดระหว่างเครื่องดื่ม OGTT สูตรดั้งเดิมและสูตรใหม่ คะแนนด้านความพึงพอใจโดยรวมของเครื่องดื่ม OGTT รสมะนาวนั้นสูงกว่าสูตรดั้งเดิมอย่างมีนัยทางสถิติ (7.1±1.8 vs. 4.7±2.0) โดยพบผู้ที่มีอาการคลื่นไส้เพียง 1 คน ภายหลังการทดสอบด้วยเครื่องดื่มทั้งสองสูตร

สรุป: เครื่องดื่ม OGTT รสมะนาวได้รับการยอมรับที่ดีกว่าจากกลุ่มตัวอย่างที่ทดสอบโดยไม่มีผลต่อระดับพลาสมากลูโคสและค่าอื่น ๆ ที่ได้จากการทดสอบ OGTT เมื่อเปรียบเทียบกับสูตรดั้งเดิม