THE GLYCEMIC INDEX OF MIXED MEAL: PEANUT BUTTER AND JAM SANDWICH AND GUAVA

FONG KWONG SHIO

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Saya ~~Fong~~ FONG KWONG SHIO

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Fong Kwong Shio

BN09110148

CERTIFICATION

NAME	:	**FONG KWONG SHIO**
MATRIC NO.	:	**BN09110148**
TITLE	:	**THE GLYCEMIC INDEX OF MIXED MEAL: PEANUT BUTTER AND JAM SANDWICH AND GUAVA**
DEGREE	:	**BACHELOR OF FOOD SCIENCE WITH HONORS IN FOOD SCIENCE AND NUTRITION**
VIVA DATE	:	**5 JULY 2013**

CERTIFIED BY

SIGNATURE

1. **SUPERVISOR**
   PN. RAMLAH GEORGE @ MOHD ROSLI

2. **EXAMINER 1**
   DR. YASMIN OOI BENG HOUI

3. **EXAMINER 2**
   DR. HASMADI MAMAT

4. **DEAN**
   PROF. MADYA DR. SHARIFUDIN MD. SHAARANI

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ABSTRACT

The glycemic index (GI) of peanut butter and jam sandwich with guava was investigated among healthy subjects. Ten subjects (5 males, 5 females; BMI 21.3 ± 1.35 kg/ m^2) consumed a reference meal of 50 g glucose twice and one test meal (peanut butter and jam sandwich with one serving of guava) after a 12 hour overnight fast. Capillary blood samples were taken at time 0 (fasting), 15, 30, 45, 60, 90, and 120 min after the consumption of test or reference meal. The mean GI value of the test meal was calculated. iAUC of the test meal was 176.1 ± 69.79 mmol· min/ L, which was not significantly different from the iAUC of reference meal 212.1 ± 68.15 mmol· min/ L ($p>0.05$). The GI of the test meal was 86 ± 29.90, categorized as high GI. The GI measured was 19.4% higher than the GI predicted, which was 72. The difference of GI was 14 units.

ABSTRAK

INDEKS GLISEMIK DALAM MAKANAN CAMPURAN: ROTI MENTEGA KACANG DAN JAM SERTA JAMBU BATU

Indeks glisemik (GI) roti mentega kacang dan jam serta jambu batu telah dikaji dalam kalangan subjek yang sihat. Sepuluh subjek (5 lelaki, 5 perempuan; BMI 21.3 ± 1.35 kg/ m^2) mengambil makanan rujukan iaitu 50 g glukosa sebanyak dua kali dan makanan ujian (roti mentega kacang dan jam serta jambu batu) selepas 12 jam berpuasa. Sampel darah kapilari diambil pada masa 0, 15, 30, 60, 90 dan 120 minit selepas bermula makan. Min indeks glisemik makanan ujian telah dikira. iAUC makanan ujian adalah 176.1 ± 69.79 mmol· min/ L, yang mana tidak signifikan dengan iAUC makanan rujukan 212.1 ± 68.15 mmol· min/ L ($p>0.05$). Indeks glisemik makanan ujian adalah 86 ± 29.90, dikategorikan sebagai indeks glisemik tinggi. Indeks glisemik yang didapati melalui kajian ini adalah 19.4% lebih tinggi daripada yang dijangkakan, iaitu 72. Perbezaan indeks glisemik adalah sebanyak 14 unit.

LIST OF CONTENTS

LIST OF TABLES

LIST OF DIAGRAM

LIST OF ABBREVIATION

AACC	American Association of Cereal Chemists
ADA	American Dietetic Association
ATP	adenosine triphosphate
ANOVA	analysis of variance
BMI	body mass index
CDC	Centers for Disease Control and Prevention
CCK	cholecystokinin
CHD	coronary heart disease
CI	confidence interval
CV	coefficient of variation
DM	diabetes mellitus
DNA	deoxyribonucleic acid
et al.	et alii (and others)
FAD	flavine adenine dinucleotide
FAO	Food and Agriculture Organization
g	grams
GI	glycemic index
GL	glycemic load
GLP-1	glucagon-like-peptide-1
H	hydrogen
HDL-C	high-density lipoprotein cholesterol
iAUC	incremental area under the curve
IDDM	insulin-dependent diabetes mellitus
kcal	kilocalorie
kg	kilogram
kJ	kilojoule
LDL-C	LDL cholesterol
m	meter

LIST OF ABBREVIATION

(continued)

min	minute
ml	milliliter
MOH	Ministry of Health, Malaysia
mmol/ L	milimoles per liter
NAD^+	nicotineamide adenine dinucleotide
NEFA	non-esterified fatty acid
NIDDM	non insulin-dependent diabetes mellitus
RNA	ribonucleic acid
SD	standard deviation
SEM	standard error of mean
TC	total cholesterol
WHO	World Health Organization

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.0 Introduction

The most important food source of energy is carbohydrates, which comprise about forty to eighty percent of total food energy intake depending on factors such as environment, culture and economic status. People who are in the lower economic level often have high carbohydrate diets as those foods are most often the least expensive. Rice, the primary staple food in many countries, is one excellent example (FAO/ WHO, 1998). Besides providing energy, carbohydrates have other physiological effects such as controlling blood glucose and insulin metabolism, effects on satiety or gastric emptying, protein glycosylation, cholesterol and triglyceride metabolism, effects on large bowel microflora and fermentation (FAO/ WHO, 1998).

Carbohydrates are divided into three main groups: sugars, oligosaccharides and polysaccharides. Each of the groups is subdivided based on monosaccharide composition of the individual carbohydrates. The energy value of dietary carbohydrate is four kcal/ g (17 kJ/ g). Absorbed carbohydrates result in elevation of the blood glucose concentration. The factors that affect the extent and duration of the blood glucose elevation include gastric emptying and the rate of hydrolysis and diffusion of hydrolysis products in the small intestine (FAO/ WHO, 1998).

The glycemic index (GI) is the classification of different types of foods that contains carbohydrates according to their effect on blood glucose raising potential. The glycemic response induced by the test food is compared to a standard food, consumed by the same subject. Both the test food and standard food should contain the same amount of available carbohydrate. Available carbohydrate is defined as total carbohydrate minus dietary fiber (Wolever *et al.*, 2008). The GI value of a test food is

expressed as a percentage of the standard, determined by the blood glucose area after consumption. Low GI foods are those that are digested and absorbed slowly and lead to a low glycemic response. In contrast, high GI foods are digested and absorbed rapidly, resulting in a high glycemic response. Thus, low GI foods are found to have positive effects on risk factors for certain chronic diseases (Brouns *et al.*, 2005).

Bread is a staple in many parts of the world and also one of the contributing sources of carbohydrate in the Malaysian diet. White bread has a GI value of 70 (Foster-Powell *et al.*, 2002), which is classified as a high GI food (Brand-Miller *et al.*, 2003). In Malaysia, bread is usually eaten with kaya and butter (*roti kahwin)*, peanut butter with or without jam, and jam. Besides that, bread is also eaten toasted or prepared as French toast, or served as sandwiches with fillings such as chicken, corned beef, tuna, or ham.

The GI of peanut butter sandwich has been tested in individuals with either non insulin-dependent diabetes mellitus (NIDDM) or insulin-dependent diabetes mellitus (IDDM). The GI of peanut butter sandwich, with glucose as reference food, in the NIDDM and IDDM groups were 51 and 67 respectively. The difference may be due to the prolonged glucose tolerance test in IDDM and the raised blood glucose levels still seen at 3 hours. It was also possible that the different responses were due to different somatotype of the IDDM and NIDDM (Jenkins *et al.*, 1984). Though there are GI data on peanut butter sandwich, there is no study done to determine the glycemic index of peanut butter and jam sandwich eaten with guava.

Peanut butter sandwich has a GI of 59, categorized as medium GI (Foster-Powell, 2002). Chen *et al.* (2010) reported the GI of jam and peanut butter toast was 72. Bread has a GI of 70, categorized as high GI. Strawberry jam is a low GI food, with a GI value of 51 (Foster-Powell *et al.*, 2002). Peanut butter has a GI of 23, categorized as low GI (Aston *et al.*, 2010). Guava is a high GI food, with a GI value of 78 (Premananth *et al.*, 2011). The interesting question is what would the GI of peanut

butter and jam sandwich if eaten with guava, as bread and strawberry jam has high GIs, peanut butter has low GI, guava has high GI but is rich in fiber, which has a glycemic lowering effect (Jenkins *et al.*, 1989; Potter *et al.*, 1981).

Although it is suggested that the GI of mixed meals can be predicted by summing up the GI of each food item in the mixed meal (Wolever and Jenkins, 1986; Chew *et al.*, 1988), it is also known that the meal GI could be different from the predicted GI value due to many factors that are known to influence GI of foods such as fat and protein (Welch *et al.*, 1987), food structure, degree of processing, cooking time, acidity, physical entrapment and soluble fiber (Kirpitch and Maryniuk, 2011). According to FAO/ WHO (1998), the blood glucose response to foods is influenced by a number of factors which includes amount of carbohydrate, nature of the monosaccharide components, nature of starch, cooking or food processing and other food components. Examples of other food components are fat and protein, dietary fiber, antinutrients and organic acids.

Moghaddam *et al.* (2006) concluded that, across the range of zero to 30 g, both protein and fat reduced the glycemic response elicited by oral glucose in normal subjects. Protein had a 2 to 3 times larger effect than fat. It was hypothesized that fat reduces glucose responses via glucagon-like-peptide-1 (GLP-1) mediated effects on gastric emptying whereas protein reduces glucose responses due to amino-acid mediated effects on insulin secretion.

Fruits are good sources of dietary fiber (MOH, 2010) and it is known that they are rich in micronutrients (Barakatun *et al.*, 2005). The consumption of foods that contain dietary fiber provides micronutrients and nonnutritive components such as antioxidants and phytoestrogens which give additional health benefits (ADA, 2003). According to the Malaysian Dietary Guidelines (2010), one serving of guava (111 g) has higher dietary fiber (7.5 g per 100 g) compared to one serving of fruits such as apple, banana, grape, mandarin orange, mango, oranges, papaya, pear, pineapple, prune, starfruit and watermelon. The total dietary fiber, starch, non-cellulosic

polysaccharides, cellulose and lignin in 100 g of edible portion of guava is 5.2, 0.55, 2.5, 1.4 and 1.2 respectively (Candlish *et al.*, 1987). The total dietary fiber, non-cellulosic polysaccharides, cellulose and lignin of 100 g of guava reported by Osman (1990) was 2.9, 1.1, 0.5 and 1.3 respectively. Non-cellulosic polysaccharides encompass pectins (d-galacturonans) and hemicelluloses (d-xylans, d-glucans, d-mannans). Soluble fiber has been shown to lower glycemic response (Fairchild *et al.*, 1996; Ellis *et al.*, 1991; Chuang *et al.*, 1992; Garcia *et al.*, 2007).

Consumption of viscous fibers may delay the gastric emptying of ingested foods into the small intestine, and may contribute to weight control by creating a sensation of fullness. Delayed gastric emptying may also reduce postpandrial blood glucose concentrations and potentially have a beneficial effect on insulin sensitivity (ADA, 2002). The beneficial physiological effects of dietary fiber include blood glucose attenuation, laxation, and blood cholesterol attenuation (AACC, 2000).

1.1 Objective

The objective of this study is to:

1. determine the glycemic index of peanut butter and jam sandwich eaten with guava, and
2. make a comparison of the GI value of the meal GI (measured in the laboratory) to the predicted GI value (calculated meal GI which assigns GI value to the food components of a mixed meal based on published data).

1.2 Importance of Study

The study will provide data for GI value of a mixed meal that includes peanut butter and jam sandwich and one serving of guava (111 g), which will be useful for individuals that may require this data for the purpose of meal planning and determination of dietary glycemic index. The measured GI of the test meal that includes peanut butter and jam sandwich and one serving of guava will be used to compare with the predicted GI value derived through calculation (Wolever and Jenkins,

1986) which involves combing the GI of each of the food ingredients obtained from the International Table of Glycemic Index and Glycemic Load Values (Atkinson *et al.*, 2008).

CHAPTER 2

LITERTURE REVIEW

2.1 Carbohydrates

Carbohydrates are organic compounds which include sugars, glycogen, starches and cellulose, with the basic structure of $C_x(H_2O)_y$. The most important types of carbohydrates in foods include sugars, dextrins, starches, celluloses, hemicelluloses, pectins and certain gums. Chemically, they only contain the elements of carbon, hydrogen and oxygen (Potter and Hotchkiss, 1998).

Carbohydrates can be classified according to their degree of polymerization and divided into three principal groups which are sugars, oligosaccharides and polysaccharides. The groups can then be subdivided based on the monosaccharide composition of the individual carbohydrates (FAO/ WHO, 1998). Sugar comprise of monosaccharides, disaccharides and polyols, also known as sugar alcohols. Oligosaccharides include malto-oligosaccharides, galactosides and fructo-oligosaccharides. Polysaccharides can be divided into starch and non-starch polysaccharides which include cellulose, hemicelluloses and pectin (FAO/ WHO, 1998). Monosaccharides and disaccharides are termed simple sugars whereas polysaccharides are known as complex carbohydrates (Tortora and Derrickson, 2010).

Sugars are simple carbohydrates which form ring structures. The six carbon sugar glucose is one of the simplest carbohydrates (FAO/ WHO, 1998). Monosaccharides are the building blocks of carbohydrates, which main function is to provide chemical energy for generating the ATP that fuels metabolic reactions. Ribose and deoxyribose are monosaccharides used to make ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) (Tortora and Derrickson, 2010). The arrangement of the carbon, hydrogen and oxygen atoms in the ring affects the solubility, sweetness, and

rates of fermentation by microorganisms and other properties (Potter and Hotchkiss, 1998).

Disaccharides are simple sugars consisting of two monosaccharide joined by a covalent bond. During the formation of a disaccharide molecule from two monosaccharide molecules, a molecule of water is removed, and thus, the reaction is called dehydration synthesis (Tortora and Derrickson, 2010). Maltose, sucrose and lactose are examples of disaccharides. Inversely, by addition of a water molecule, known as hydrolysis reaction, disaccharides can by split into monosaccharides. Each of the disaccharides also has difference in solubility, sweetness, susceptibility to fermentation and other properties (Potter and Hotchkiss, 1998).

Polysaccharides are formed by linkage of larger number of glucose units in polymers. They are large, complex carbohydrates that contain tens or hundreds of monosaccharides joined through dehydration synthesis reactions. Like disaccharides, polysaccharides can be broken down into monosaccharides through hydrolysis reactions. Amylase, an example of polysaccharide, is an important component of plant starches. Cellulose is a chain of glucose units linked together in a slightly different way. Starches in plants and cellulose in plant cell walls are polysaccharides made up of glucose units (Tortora and Derrickson, 2010). Hence, simple sugars are the building blocks of derivatives such as polysaccharides, disaccharides, dextrins, starches, celluloses, hemicelluloses, pectins and gums. These derivatives can be broken down or hydrolyzed into smaller units including their simple sugars which can be accomplished with acid or by specific enzymes (Potter and Hotchkiss, 1998).

In the human body, the main polysaccharide is glycogen which is made entirely of glucose units joined together in branching chains. Glycogen is stored in liver cells and skeletal muscles, which can be broken down into glucose if energy needed by the body is high. If the energy needed by the body is low, glucose can be used to make glycogen. Humans cannot digest cellulose but is utilized to provide bulk to help move

feces through the large intestine. The difference between simple sugars and complex sugars is that polysaccharides are usually neither soluble in water not sweet (Tortora and Hotchkiss, 2010).

Oxidation of carbohydrates provides energy where glucose in the blood is a ready source of energy for animals. Yeast and other microorganisms can ferment carbohydrates which result in carbon dioxide, alcohol, organic acids and other compounds (Potter and Hotchkiss, 1998).

2.2 Glycemic Index

The glycemic index is defined by the Food and Agriculture Organization of the United Nations and World Health Organization as "the incremental area under the blood glucose response curve for a 50 g carbohydrate portion of a test food expressed as a percent of the response to the same amount of carbohydrate from a standard food taken by the same subject (Wolever *et al.* 1991).

The glycemic index (GI) is the classification of different types of foods that contains carbohydrates according to their effect on blood glucose raising potential. The glycemic response induced by the test food is compared to a standard food, consumed by the same subject. Both the test food and standard food should contain the same amount of available carbohydrate (Jenkins *et al.*, 2002). Besides glucose, other reference food choices include white bread, rice, potato, or some other local foods because of the large part consumed by these foods in the local carbohydrate intake (Brouns *et al.*, 2005). The GI value of a test food is expressed as a percentage of the standard, determined by the blood glucose area after consumption (Jenkins *et al.*, 2002). The GI ranking of food is ≤55 considered low GI, ≥70 is high GI and in between, which is 56 to 69, is considered medium GI food (Brand-Miller *et al.*, 2003).

To be of clinical utility, it was proposed by Coulston *et al.* (1984) and Hollenbeck *et al.* (1986) that GI should fulfill four criteria: (1) consistency of calues for the same food across space and time, (2) application to individual subjects, (3) application to mixed meals, and (4) demonstration of clinically significant therapeutic improvements by practical dietary changes.

Low GI foods are those that are digested and absorbed slowly and lead to a low glycemic response. In contrast, high GI foods are digested and absorbed rapidly, resulting in a high glycemic response. High glycemic response leads to high glycemic demand which contributes to carbohydrate oxidation causing decreased fatty acid oxidation (Jenkins *et al.*, 2002; Wolfe, 1998). Brand-Miller (2003) reported association between high GI foods with lower satiety and reduced access to fats as fuel, resulting in increased total energy intake. Thus, low GI foods are found to have positive effects on risk factors for certain chronic diseases (Brouns *et al.*, 2005).

Jenkins *et al.* (1981) reported that high carbohydrate foods with the lowest glycemic index which include oatmeal porridge, spaghetti, buckwheat, yam, sweet potato and dried leguminous seeds were those generally eaten by the poor in Western counter countries or the inhabitants of large parts of Africa and Asia.

2.2.1 The Use of Glycemic Index

The GI concept was originally designed for people with diabetes as a guide to food selection, advice being given to select foods with a low GI (Jenkins *et al.*, 1983). FAO/ WHO (1998) recommended that GI of foods to be considered together with information about food composition in guiding food choices. Lower GI foods are considered beneficial due to the lower glycemic response after ingestion, compared with high GI food. In addition to playing a role in the treatment of diabetes, low GI diets are recommended for the prevention of chronic diseases including diabetes, obesity, cancer and heart disease and in the treatment of cardiovascular risk factors, especially dyslipidemia (Jenkins *et al.*, 2002).

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