INVESTIGATION OF SELECTED FOODS ADDED WITH FENUGREEK THAT CONTROLS POSTPRANDIAL BLOOD GLUCOSE IN HEALTHY VOLUNTEERS

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INVESTIGATION OF SELECTED FOODS ADDED WITH FENUGREEK THAT CONTROLS POSTPRANDIAL BLOOD GLUCOSE IN HEALTHY VOLUNTEERS

by

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LIST OF SYMBOLS AND ABBREVIATIONS

mg	milligram
min	minute
ml	millilitre
mmol/l	millimole per litre
mm x hr	millimetre times hour
mmHg	millimetre of mercury
β	beta
g	gram
hr	hour
kcal/100 g	kilocalorie per one hundred gram
kg	kilogram
w/v	weight per volume
ADA	American Dietetic Association
ANOVA	Analysis of variance
BMI	Body Mass Index
CHD	Coronary Heart Disease
CV	Coefficient of Variation
DBP	Diastolic Blood Pressure
DF	Dietary Fibre
FAO	Food and Agriculture Organization
FBG	Fasting Blood Glucose
FOS	Fructooligosaccharides

FR	Fried Rice
FRFG	Fried Rice with Fenugreek
GI	Glycemic Index
GOD	Glucose Oxidase
HbA1c	glycosylated haemoglobin
HDL-C	High Density Lipoprotein Cholesterol
IAUC	Incremental area under the curve
IDF	Insoluble Dietary Fibre
LDL-C	Low-Density Lipoprotein Cholesterol
NHMS	National Health and Morbidity Survey
PAP	Phenol + Aminophenazone
PPG	Post prandial plasma glucose
RS	Resistant starch
RGR	Relative glucose response
SBP	Systolic Blood Pressure
SDF	Soluble Dietary Fibre
SEM	Standard Error of Mean
SIAUC	Satiety incremental area under the curve
SPSS	Statistical Package for the Social Sciences
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus
TC	Total Cholesterol
TDF	Total Dietary Fibre
TG	Triglyceride

WB	White Bread
WBFG	White Bread with Fenugreek
WHO	World Health Organisation

PENYIASATAN KE ATAS MAKANAN TERPILIH DITAMBAH DENGAN HALBA YANG MENGAWAL GLUKOSA DARAH POSPRANDIAL DALAM SUKARELAWAN SIHAT

ABSTRAK

Bukti yang semakin meningkat menunjukkan bahawa makanan berfungsi boleh memberi manfaat kepada mereka yang mengidap penyakit kronik seperti kencing manis, obesiti, penyakit kardiovaskular dan kanser. Kajian awal klinikal terhadap haiwan dan manusia mencadangkan potensi ciri-ciri hipoglisemik halba apabila diambil secara oral. Kajian ini dilakukan untuk menentukan komposisi kimia dalam halba, menyiasat kesan penambahan halba terhadap plasma glukosa selepas makan (PPG) dan tahap kenyang dalam kalangan individu berlebihan berat badan dan obes. Kandungan galaktomanan dalam makanan ujian dan keupayaan serbuk halba dalam menurunkan respons glisemik dan indeks glisemik (GI) apabila dimasukkan dalam roti dan capati juga dikaji. Semasa fasa pertama percubaan rawak, kajian keratan rentas terkawal terhadap 14 subjek yang berlebihan berat badan telah dikaji pada waktu pagi selepas berpuasa semalaman pada empat sesi ujian yang berasingan. Respons Glisemia terhadap pengambilan 50g karbohidrat roti putih dan jem dengan atau tanpa 5.5 g halba dan nasi goreng dengan atau tanpa 5.5 g halba telah ditentukan lebih 2 jam. Titik akhir utama adalah peningkatan kawasan di bawah lengkungan graf plasma tindak balas glukosa (IAUC). Dalam fasa kedua kajian ini 10 subjek yang sihat (5 lelaki, 5 wanita) telah diberikan 50 g larutan gula (makanan rujukan, dua kali); roti (0% dan 10% serbuk biji halba); dan capati (0% dan 10% serbuk biji halba) pada 6 sesi yang berbeza. Satu titis sampel darah daripada kapilari telah dikumpulkan pada 0, 15, 30, 45, 60, 90, dan 120 minit selepas mula makan. Tahap kesedapan makanan ujian dinilai menggunakan skala Likert. Keputusan menunjukkan serbuk biji halba mengandungi protein (32.5%), karbohidrat (46.4%), jumlah keseluruhan serat dietari (39.6%), serat dietari terlarut (SDF) (23.8%) dan serat dietari tidak terlarut (IDF) (15.8%). Penambahan halba untuk kedua-dua makanan mengurangkan IAUC berbanding makanan tanpa halba: roti putih dan jem, 180±22 berbanding 271±23 mmol × min/L (P=0.001); nasi goreng, 176±20 berbanding 249±25mmol × min/L (P=0.001). Halba juga secara signifikan mengurangkan kawasan di bawah lengkung kenyang bagi roti putih dengan jem (134±27 berbanding 232±33mm × jam, P=0.01) dan nasi goreng (280±37 berbanding 379±36mm × jam, P=0.01). Sebaliknya kawasan tambahan di bawah nilai keluk glukosa (AUC) roti dan capati dengan 10% halba (138±17 mmol x min/L; 121±16 mmol x min/L) adalah jauh lebih rendah berbanding dengan 0% roti halba dan capati (227±15 mmol x min/L; 174±14 mmol x min/L, P=<0.01). Penambahan 10% serbuk biji halba mengurangkan GI roti dalam julat 51±7-82±5 (P<0.01) dan kepada GI capati dalam julat 43±5-63±4 (P<0.01). Sebagai tambahan, kandungan galaktomanan dalam capati dan roti yang ditambah dengan halba masing-masing adalah 1.54±0.02% dan 3.06± 0.03 %. Adalah disimpulkan bahawa halba menurunkan respons PPG dengan ketara dan meningkatkan tempoh kenyang dalam kalangan individu berlebihan berat badan dan obes. Di samping itu, kajian ini menunjukkan bahawa penggantian 10% tepung gandum dengan serbuk biji halba mengurangkan tindak balas glisemik dan GI roti dan capati dengan ketara.

INVESTIGATION OF SELECTED FOODS ADDED WITH FENUGREEK THAT CONTROLS POSTPRANDIAL BLOOD GLUCOSE IN HEALTHY VOLUNTEERS

ABSTRACT

Increasing evidence suggests that functional foods may benefit those with chronic diseases such as diabetes, obesity, cardiovascular disease and cancer. Preliminary animal and human trials suggest possible hypoglycemic properties of fenugreek when taken orally. The purpose of this study was to determine the chemical composition of fenugreek, to investigate the effects of fenugreek on postprandial plasma glucose (PPG) and satiety among overweight and obese individuals. Galactomannan content of the test foods and the ability of fenugreek seed in reducing glycemic response and glycemic index (GI) when added into buns and flatbreads were also investigated. During the first phase of this randomized controlled crossover trial, 14 overweight or obese subjects were studied in the morning after overnight fasts on four separate occasions. Glycemic responses elicited by 50 g carbohydrate portions of white bread and jam with or without 5.5 g of fenugreek and fried rice with or without 5.5 g fenugreek were determined over 2 h. The main endpoint was the incremental area under the plasma glucose response curve (IAUC). In the second phase of this study 10 healthy human subjects (5 men, 5 women) were given 50 g glucose (reference food, twice); buns (0% and 10% fenugreek seed powder); and flatbreads (0% and 10% fenugreek seed powder) on 6 different occasions. Finger prick capillary blood samples were collected at 0, 15, 30, 45, 60, 90, and 120 minutes after the start of the meal. The palatability of the test meals were scored using Likert scales. Results revealed that fenugreek seed powder contained considerable levels of protein (32.5%), carbohydrate (46.4%), total dietary fibre (TDF) (39.6%), soluble dietary fibre (SDF) (23.8%) and insoluble dietary fibre (IDF) (15.8%). Adding fenugreek to both foods significantly reduced the IAUC compared to the food alone: white bread and jam, 180±22 versus 271±23 mmol × min/L (*P*=0.001); fried rice, 176±20 versus 249±25mmol × min/L (*P*=0.001). Fenugreek also significantly reduced the area under the satiety curve for white bread with jam (134±27 versus 232±33mm × hr, *P*=0.01) and fried rice (280±37 versus 379±36mm× hr, *P*=0.01). On the other hand, the incremental areas under the glucose curve value (IAUC) of buns and flatbreads with 10% fenugreek (138±17 mmol x min/L; 121±16 mmol x min/L) were significantly lower than those of 0% fenugreek bun and flatbreads (227±15 mmol x min/L; 174±14 mmol x min/L, P= < 0.01). Addition of 10% fenugreek seed powder reduced the GI of buns from 82±5 to 51±7 (P<0.01) and to the GI of flatbread from 63±4 to 43±5 (P<0.01). Furthermore the galactomannan content of fenugreek added flatbreads and buns were 1.54±0.02% and 3.06±0.03 % respectively. It is concluded that fenugreek significantly decreased the PPG response and increased satiety among overweight and obese individuals. In addition, this study demonstrated that by replacing 10% of refined wheat flour with fenugreek seed powder significantly reduces the glycemic response and the GI of buns and flatbreads.

CHAPTER 1

INTRODUCTION

1.1 Background and Problem Statements

Adequate nutrition is crucial for the prevention of chronic disease such as obesity, cardiovascular disease and diabetes. In 2001, chronic disease contributed to 60% of reported deaths and 46% of the global disease burden, and this latter figure is expected to increase to 57% by the year 2020. Obesity is of prime concern, not least because of the rate at which the prevalence is increasing, but also because its reach extends across the globe (WHO/FAO, 2003). It's been reported that over 1.4 billion adults globally were overweight and of these greater than 500 million were obese. It is predicted that 2.3 billion adults around the world will be overweight and that at least 700 million will be obese by 2015 (WHO, 2013; Nguyen and El-Serag, 2010). This increasing tendency of obesity is seen in most countries including Malaysia, where the prevalence of overweight and obesity is about 29% and 14%, respectively (Khambalia and Seen, 2010). The major reason for this obesity epidemic is excess energy intake and decreased energy expenditure (Kant and Graubard, 2006; Prentice and Jebb, 1995). In addition it was noted that an estimated 43% of the Malaysian population have abdominal obesity (Zhang *et al*, 2010).

On the other hand, the prevalence of chronic diseases especially diabetes mellitus is increasing. Epidemiological studies have predicted that there will be an increase in the number of people with diabetes from the present number of over 150 million to 300 million or more by the year 2025 (King *et a.l*, 1998; Shaw *et al.*, 2010). According to the International Diabetes Institute, Malaysia ranks fourth in Asia with highest number of patients with diabetes (Hasimah *et al.*, 2014). The IV (NHMS) conducted by the Malaysian Ministry of Health in 2011, showed that there was a 31% rise in prevalence of diabetes mellitus among adults aged 18 or older within a period of 5 years, which is an increase from 11.6% (2006 NHMS III) to 15.2%. The latest National Health and Morbidity Survey (NHMS V, 2015) revealed that 3.5 million (17.5%) of Malaysian adults (18 years old and above) are suffering from diabetes mellitus. Furthermore it was found that among the diagnosed population with diabetes mellitus, just 22% have achieved the treatment target of HbA1c level < 7.0%, which is due to poor adherence to the intervention guidelines (Mafauzy *et al.*, 2011). Diabetes is a significant healthcare burden in Malaysia. In one prior study it was noted that treatment of diabetes and its complications accounted for 16% of the Malaysian healthcare budget (2.4 billion Malaysian Ringgits) with the majority of resources being used to treat diabetes complications. Serious complications of poorly treated diabetes included blindness, acute myocardial infarction, kidney failure and lower limb amputations (Zhang *et al.*, 2010).

The prevalence of diabetes among Malaysian adults is projected to increase further mainly because of rapid urbanization, physical inactivity and poor eating habits (Chinnappan *et al*., 2017). Hence there is a need to control the prevalence rate of obesity and other chronic diseases by implementing suitable prevention strategies. One such strategy would be, to enable the Malaysian population to select healthy foods.

Foods generally provide taste, aroma and nutritive value, but current research studies are focusing to explore if foods can provide additional physiological benefits, which can reduce the risk of getting chronic disease or else to improve health. Researchers are now considering the properties of whole foods rather than single compounds to be effective against certain diseases. The American Dietetic Association (ADA) recommends that the best nutritional strategy for promoting health and reducing the risk of chronic disease is to obtain adequate nutrients from a variety of foods (Davis and Finley, 2003). As a result of these research findings, the term 'functional foods' had emerged. Functional foods are foods promoted for health benefits beyond meeting nutritional needs of growth and maintenance (Litov, 1998). These foods aim to maintain health, improve well-being, and create the conditions for reducing risk of disease (Haesman and Mellentin 2001). They may delay or decrease the risk of chronic diseases like diabetes, heart disease and cancer thus increasing the life span of individuals.

Functional foods may be specific natural foods with a high or low content of a specific ingredient or they may be designed foods where certain components have been added or removed (Kalbe *et al.*, 2003). As a result of increasing interest in improving health in a convenient manner (Jong *et al*., 2003), the general public have become more concerned about the food they eat (Gil *et al*., 2000). Therefore, the field of nutrition and diet is rapidly growing and the food manufacturers are focused on developing products with additional nutritional benefits (Litov, 1998). Presently, food industries are developing products that would help control weight, improve general health, prevent aging and lower the risk of degenerative chronic diseases including diabetes, coronary heart disease and cancer. Few examples of functional foods already on the market are breads, beverages, snack foods, cereal grains and milk products. Health-promoting compounds like essential fatty acids, probiotics, prebiotics, lycopene and lutein have been used in a number of food products such as yoghurts, cheese, bread, sausages and cereal bars (Kalbe *et al*., 2003).

Fenugreek, *Trigonellafoenum-graecum* is one of the ancient medicinal plants from the family Leguminosae. The Malay name for fenugreek is *halba.* In Malaysia fenugreek is added as condiment in curries, *Nasi dagang* (Trading Rice) and snacks like *Puttu halba* (steamed fenugreek cake). Fenugreek seeds are composed of 45-60% carbohydrates, out of which 45.4% is dietary fibre (32% insoluble and 13.3% soluble, which is mostly galactomannan), and the gum is composed of galactose and mannose. Protein content in fenugreek seeds is about 20-30%. Lysine and tryptophan are the two major amino acids present in it. Other constituents include small amount of oils (5-10%), a small amount of pyridine alkaloids (mostly trigonelline), a few flavonoids, free amino acids, sapogenins, vitamins and volatile oils (Wani and Kumar, 2016).

Constituents in fenugreek that are thought to be responsible for its hypoglycemic effects include the testa and endosperm of the defatted seeds called the A subfraction, the 4-hydroxyisoleucine and the fibre (Yoshikawa et *al.*, 1997). Earlier studies have reported that the saponins in the seeds are converted into sapogenins in the gastrointestinal tract which is responsible for the lipid reducing effect. Preliminary animal and human trials have shown that fenugreek seed powder has the ability to reduce blood glucose and cholesterol levels (Ribes *et al.*, 1984; 1986). However there were no clinical nutritional studies done in Malaysia to determine the ability of fenugreek seeds in reducing the post prandial blood glucose or other possible benefits.

A study done by Tee (1999) has reported that Malaysians consume excess energy-dense foods which are high in fats, oils and refined carbohydrates, but low in complex carbohydrates. It was observed that Malaysians prefer westernized foods such as bread or toast with butter or margarine and jam or kaya (coconut egg jam). Sweetened creamer milk was the most commonly consumed milk, while fruits and vegetables were not commonly eaten. Malaysians mostly eat rice and wheat based foods as the main meal accompanied with meat/shrimps/fish/egg and less vegetables. Some of the common foods that are popular among the Malaysian population are bakery products and flatbreads (Howden *et al*., 1993). Hence flatbreads and buns can be an effective vehicle to carry the functional nutrients to human health.

As the prevalence of obesity in Malaysia is on the rise, fenugreek the functional food that contain the above mentioned health advantages can be studied and used to develop novel foods aimed to prevent chronic disease in the community. The background to this research project was emphasized on the ability of fenugreek added foods that can increase satiety and decrease post prandial blood glucose among overweight/obese or healthy individuals and to develop foods with a low glycemic index (GI) value. This research was the first of its kind in Malaysia and one of a few international studies to evaluate the effects of a functional food in decreasing hunger and lowering the post prandial blood glucose among human subjects. Previous research studies done elsewhere, have been conducted with isolated or defatted or extracted fenugreek experimental foods (Madar *et al*., 1988; Bordia *et al*., 1997; Sharma, 1986; Sharma *et al*., 1996). In contrast, untreated fenugreek seed powder was used in this study.

1.2 Rationale and Significance of the Study

Over weight and obesity in Malaysia has become an issue of great concern. In spite of various measures taken to control and prevent overweight/obesity, the prevalence is on the rise. Nutrition has been demonstrated to play an essential role in the prevention and treatment of obesity. Growing evidence suggest that fibre rich foods such as whole grains, cereals, pulses, nuts, fruits and vegetables can control excess energy intake thereby reducing the rate of weight gain. However, poor selection of foods by the Malaysian population can be one of the main causes for the rise in obesity epidemic. Hence popular foods among the Malaysian population can be an effective agent to incorporate functional food ingredients that can able to reduce postprandial blood glucose and increase satiety. As buns and flatbreads are some of popular foods in Malaysia (Howden *et al*., 1993), fenugreek seed powder can be incorporated in buns and flatbreads to produce health benefits. In addition fenugreek seeds are cheap and are easily available in the Malaysian food market. Fenugreek seeds mainly contain 45-60% carbohydrates, most of which is a mucilaginous fibre which is 30% soluble and 20% insoluble fibre. Fibre in the diet is important to increase satiety and reduce post prandial blood glucose because fibre delays digestion and absorption of food.

There were no previous studies done in Malaysia to determine the effects of fenugreek seed powder on post prandial glucose response or satiety among overweight or obese individuals. Furthermore, there are no studies done to develop a low GI food added with fenugreek seed powder. Hence the present study was focused to evaluate the effect of fenugreek incorporated foods in reducing the post prandial blood glucose, increasing the satiety among overweight/obese individuals and to develop low GI buns and flatbreads incorporated with fenugreek seed powder.

1.3 Research Objectives

1.3.1 General Objectives

1. To evaluate the post prandial blood glucose response in over weight/obese and healthy subjects after the ingestion of foods added with fenugreek.

1.3.2 Specific Objectives

1. To determine the proximate composition of the study foods
2. To determine the effects of fenugreek on satiety among overweight and obese individuals
3. To develop food products such as buns and flatbreads added with fenugreek
4. To determine the chemical composition of the developed food products
5. To determine the galactomannan content of the study foods
6. To determine the GI values of the developed food products

1.4 Research Flow Chart

The research flow chart which divided into 2 phases is shown below:

Phase 1

Proximate analysis of fenugreek seed powder and the study foods

Selection of overweight and obese subjects (n=16)

- Each subject was tested with Control food 1 (White Bread with Jam) and Control Food 2 (plain rice)
- Blood samples were collected at 0, 15, 30, 45, 60, 90 and 120 minutes after starting to eat.
- Satiety and Palatability score of each subject was evaluated

- Each subject was tested with Test food 1 (White Bread with fenugreek and Jam) and test food 2 (Fried Rice with fenugreek)
- Blood samples were collected at 0, 15, 30 , 45, 60, 90 and 120 minutes after starting to eat
- Satiety and Palatability score of each subject was evaluated

- Blood samples were taken into 1.5ml eppendorf tubes containing fluoride oxalate and quickly centrifuged to obtain plasma, which was stored at -20° C prior to analysis of glucose.
- Blood glucose was analyzed using an auto analyzer which uses the glucose oxidase method

Calculation of area under the curve and GI

Results and data analysis

Phase 2

Proximate analysis and galactomannan estimation of the study foods

↓

Selection of healthy subjects (n=13)

↓

- Accuracy check for the glucometer was performed
- Each subject was tested with glucose (reference food) twice Control food 1 (Bun) and Control Food 2 (Flatbread)
- Blood samples were collected at 0, 15, 30 , 45, 60, 90 and 120 min after starting to eat
- Palatability score of each subject was evaluated

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- Each subject was tested with Test food 1 (Bun with fenugreek) and Test Food 2 (Flatbread with fenugreek)
- Blood samples were collected at 0, 15, 30 , 45, 60, 90 and 120 minutes after starting to eat.
- Palatability score of each subject was evaluated

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- Finger prick capillary blood samples were analyzed for plasma glucose using a glucometer

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Calculation of area under the curve and GI

↓

Results and data analysis

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Thesis writing, Publications and Presentations

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of functional foods

There are numerous definitions regarding functional foods which includes “foods that may provide health benefits beyond basic nutrition; foods that encompass potentially helpful products, including any modified food or food ingredient that may provide a health benefit beyond that of the traditional nutrient it contains; food similar in appearance to conventional food that is intended to be consumed as part of a normal diet, but has been modified to sub serve physiologic roles beyond the provision of simple nutrient requirements” (Frewer *et al*., 2003). According to The Institute of Medicine of the National Academy of Sciences, functional foods are those in which the concentrations of one or more ingredients have been altered to enhance their health promoting properties (ADA Reports, 2004).

There is no standard definition of functional foods (ADA Reports, 2004) but the term functional foods is used to describe a series of novel foods under development, which are designed to provide some benefit beyond nutrition to the person consuming them (Frewer *et al*., 2003). These include food products aimed at people who have chronic disease, and foods aimed at preventing the development of such diseases within the general public. According to the American Dietetic Association, whole natural foods such as fruits and vegetables represent the simplest form of functional foods and, the term functional foods does not classify foods as good or bad. Variety of foods can be included in moderation into a healthful eating plan (ADA Reports, 2004).

2.2 Classification of functional foods

Various studies have shown that numerous substances can be used as functional food components. Although additional research is necessary to validate efficacy and establish appropriate dietary levels, researchers have identified functional food components that may provide health benefits. Foods may be developed to promote the expression of specific metabolites, reducing or preventing common diseases that afflict consumers with a specific genotype. Consumers might select functional foods and tailor their diets to meet changing health goals and different requirements at different ages. Table 2.1 shows the classification of functional foods based on the class and component that occurs naturally in the food item and its possible health benefits (International Food Information Council (IFIC), 2011).

Table 2.1: Classification of functional foods with sources and health benefits

Source: International Food Information Council (IFIC, 2011)

Class/Components	Source*	Potential Benefit
CAROTENOIDS		
Beta-carotene	carrots, pumpkin, sweet potatoes, cantaloupe, spinach, tomatoes	neutralizes free radicals which may damage cells; bolsters cellular antioxidant defenses; can be made into vitamin A in the body
Lutein, Zeaxanthin	kale, collards, spinach, corn, eggs, citrus fruits, asparagus, carrots, broccoli	supports maintenance of eye health
Lycopene	tomatoes and processed tomato products, watermelon, red/pink grapefruit	supports maintenance of prostate health
DIETARY(functional and total) FIBER		
Insoluble fiber	wheat bran, corn bran, fruit skins	supports maintenance of digestive health; may reduce the risk of some types of cancer
Beta glucan**	oat bran, oatmeal, oat flour, barley, rye	may reduce risk of coronary heart disease (CHD)
Soluble fiber**	psyllium seed husk, peas, beans, apples, citrus fruits	may reduce risk of CHD and some types of cancer
Whole grains**	cereal grains, whole wheat bread, oatmeal, brown rice	may reduce risk of CHD and some types of cancers; supports maintenance of healthy blood glucose levels

Table 2.1: Continued

Class/Components	Source*	Potential Benefit
FATTY ACIDS		
Monounsaturated fatty acids (MUFAs)**	tree nuts, olive oil, canola oil	may reduce risk of CHD
Polyunsaturated fatty acids (PUFAs) – Omega-3 fatty acids—ALA	walnuts, flaxseeds, flaxseed oil	supports maintenance of heart and eye health; supports maintenance of mental function
PUFAs – Omega-3 fatty acids—DHA/EPA**	salmon, tuna, marine and other fish oils	may reduce risk of CHD; supports maintenance of eye health and mental function
Conjugated linoleic acid (CLA)	beef and lamb; some cheese	supports maintenance of desirable body composition and immune health
FLAVONOIDS		
Anthocyanins – Cyanidin, Pelargonidin, Delphinidin, Malvidin	berries, cherries, red grapes	bolster cellular antioxidant defenses; supports maintenance of healthy brain function
Flavanols – Catechins, Epicatechins, Epigallocatechin	tea, cocoa, chocolate, apples, grapes	supports maintenance of heart health
Procyanidins and Proanthocyanidins	cranberries, cocoa, apples, strawberries, grapes, red wine, peanuts, cinnamon, tea, chocolate	supports maintenance of urinary tract health and heart health
Flavanones – Hesperetin, Naringenin	citrus fruits	neutralizes free radicals which may damage cells; bolster cellular antioxidant defenses
Flavonols – Quercetin, Kaempferol, Isorhamnetin, Myricetin	onions, apples, tea, broccoli	neutralizes free radicals which may damage cells; bolster cellular antioxidant defenses

Table 2.1: Continued

Class/Components	Source*	Potential Benefit
ISOTHIOCYANATES		
Sulforaphane	cauliflower, broccoli, broccoli sprouts, cabbage, kale, horseradish	may enhance detoxificatio of undesirable compound bolsters cellular antioxidar defenses
MINERALS		
Calcium**	sardines, spinach, yogurt, low-fat dairy products, fortified foods and beverages	may reduce the risk of osteoporosis
Magnesium	spinach, pumpkin seeds, whole grain breads and cereals, halibut, almonds, brazil nuts, beans	supports maintenance of normal muscle and nerve function, immune health and bone health
Potassium**	potatoes, low-fat dairy products, whole grain breads and cereals, citrus juices, beans, banana, leafy greens	may reduce the risk of higl blood pressure and stroke, in combination with a low sodium diet
Selenium	fish, red meat, whole grains, garlic, liver, eggs	neutralizes free radicals which may damage cells; supports maintenance of immune and prostate health
PHENOLIC ACIDS		
Caffeic acid, Ferulic acid	apples, pears, citrus fruits, some vegetables, whole grains, coffee	bolsters cellular antioxidan defenses; supports maintenance of eye and heart health
PLANT STANOLS/STEROLS		
Free Stanols/Sterols**	corn, soy, wheat, fortified foods and beverages	may reduce risk of CHD
Stanol/Sterol esters**	stanol ester dietary supplements, fortified foods and beverages, including table spreads	may reduce risk of CHD

Table 2.1: Continued

Class/Components	Source*	Potential Benefit
POLYOLS		
Sugar alcohols – Xylitol, Sorbitol, Mannitol, Lactitol**	some chewing gums and other food applications	may reduce risk of dental caries
PREBIOTICS		
Inulin, Fructo-oligosaccharides (FOS), Polydextrose	whole grains, onions, some fruits, garlic, honey, leeks, banana, fortified foods and beverages	supports maintenance of digestive health; supports calcium absorption
PROBIOTICS		
Yeast, *Lactobacilli, Bifidobacteria* and other specific strains of beneficial bacteria	certain yogurts and other cultured dairy and non-dairy applications	supports maintenance of digestive and immune health; benefits are strain-specific
PHYTOESTROGENS		
Isoflavones – Daidzein, Genistein	soybeans and soy-based foods	supports maintenance of bone and immune health, and healthy brain function for women, supports menopausal health
Lignans	flax seeds, rye, some vegetables, seeds and nuts, lentils, triticale, broccoli, cauliflower, carrot	support maintenance of heart and immune health
SOY PROTEIN		
Soy Protein**	soybeans and soy-based foods like milk, yogurt, cheese and tofu	may reduce risk of CHD

Table 2.1: Continued

Class/Components	Source*	Potential Benefit
SULFIDES/THIOLS		
Diallyl sulfide, Allyl methyl trisulfide	garlic, onions, leeks, scallions	may enhance detoxification of undesirable compounds; supports maintenance of heart, immune and digestive health
Dithiolthiones	cruciferous vegetables	may enhance detoxification of undesirable compounds; supports maintenance of healthy immune function
VITAMINS		
A* **	organ meats, milk, eggs, carrots, sweet potato, spinach	supports maintenance of eye, immune and bone health; contributes to cell integrity
Thiamin (Vitamin B1)	lentils, peas, brown or enriched white rice, pistachios and certain fortified breakfast cereals	supports maintenance of mental function; helps regulate metabolism
Riboflavin (Vitamin B2)	lean meats, eggs, green leafy vegetables, dairy products and certain fortified breakfast cereals	supports cell growth; helps regulate metabolism
Niacin (Vitamin B3)	dairy products, poultry, fish, nuts, eggs and certain fortified breakfast cereals	supports cell growth; helps regulate metabolism
Pantothenic acid (Vitamin B5)	sweet potato, organ meats, lobster, soybeans, lentils and certain fortified breakfast cereals	helps regulate metabolism and hormone synthesis

Table 2.1: Continued

Class/Components	Source*	Potential Benefit
VITAMINS (continued)		
Pyridoxine (Vitamin B6)	beans, nuts, legumes, fish, meat, whole grains and certain fortified breakfast cereals	supports maintenance of immune health; helps regulate metabolism
Folate or folic acid (Vitamin B9)**	beans, legumes, citrus fruits, green leafy vegetables and fortified breads, cereals, pasta, rice	may reduce a woman's risk of having a child with a brain or spinal cord defect; supports maintenance of immune health
B12 (Cobalamin)	eggs, meat, poultry, milk and certain fortified breakfast cereals	supports maintenance of mental function; helps regulate metabolism and supports blood cell formation
Biotin	liver, salmon, dairy, eggs, oysters and certain fortified breakfast cereals	helps regulate metabolism and hormone synthesis
C	guava, sweet red/green pepper, kiwi, citrus fruit, strawberries, fortified foods and beverages	neutralizes free radicals which may damage cells; supports maintenance of bone and immune health
D**	sunlight, fish, fortified foods such as yogurts or cereals, and beverages, including milk and juices	may reduce the risk of osteoporosis; helps regulate calcium and phosphorus; supports immune health; helps support cell growth
E	sunflower seeds, almonds, hazelnuts, turnip greens, fortified foods and beverages	neutralizes free radicals, which may damage cells; supports maintenance of immune and heart health

2.3 Consumers perception of functional foods

In recent years, consumers have become more health conscious and carefully choose foods that can prevent themselves from getting chronic diseases (Hassan, 2008). The changes in eating habits have significant effects on consumer perception towards food products. This attitude change among the consumers has led the ministry of health and commercial food manufacturers to provide consumers with healthy food products. Such efforts include dissemination of nutrition information of the food product, nationwide health programmes and health policies. These activities have increased the health awareness among the society. This interest in healthy living has gained momentum not only in western or other Asian countries, but also in Malaysia (Ahmad, 1996).

Malaysia consists of multi-ethnic groups (Malay, Chinese, Indian and indigenous groups), each group has its preferred functional food, most of which are available in the market (Ahmad, 1996). Some of the functional foods available in the Malaysian food market claim to boost vitality reverse ageing or cure and prevent specific diseases. Some of the local foods which have been linked for boosting vitality and preventing aging, cancer, diabetes, and hypertension are *mengkudu/noni* juice (*Morinda citrifolia*) (Nandhasri *et al*., 2005 and Wang *et al*., 2002), petai (*Parkia speciosa*) (Wong *et al*., 2006), pegaga (*Centella asiatica*) and tongkat ali (*Eurycoma longifolia*) (Hamzah *et al*., 2003).

Functional foods that are believed to have antioxidant effects and prevent cancer include ginseng, soybean (*Glycine max*) and hawthorn fruit (Yi *et al*., 1999) green tea (Fujiki *et al*., 1996) and mushrooms (Chang, 1996). In addition, turmeric (*Curcuma longa*) is believed to have phytochemical and antioxidant properties that help suppress multiple myeloma and blood cancer (Krishnaswamy, 1996), while cumin or jeera (*Cuminum cyminum*) is used in Ayurvedic medicine for the treatment of diarrhoea and jaundice (Iyer *et al.,* 2009). However there are no studies done on functionality of fenugreek.

According to IFIC, 2013, 63% of consumers believe that functional foods will provide health benefits and have confidence they could make the necessary changes to integrate functional foods into their diet. It was found that consumers prefer to include a functional food during breakfast or snack time (IFIC, 2013). There was a positive attitude regarding the use of vitamin and supplement among consumers. Consumers who eat functional foods are more likely to be favourable towards the idea of getting health benefits (IFIC, 2013). Changes in eating habits among the consumers have altered the demand for food products and food related nutrition information. In recent times, consumers expect more detailed, accurate and easy to understand information on food labels. Food marketers and mass media through various communication channels, play a major role in providing accurate information about the nutritional and functionality of food products to the consumers. This has influenced consumer tastes, food product preferences as well as information seeking and purchase behaviours. Consumer knowledge about functional foods is an important factor that influences the acceptance and decision-making regarding the food products (Verbeke, 2005).

2.4 Characteristics of functional foods for weight management

Functional foods for weight management should have the ability to induce satiety, reduce appetite and reduce post prandial blood glucose. Reduction in energy intake may be obtained by increasing satiety with low-density satisfying foods, and rheological modification of foods and by reduced energy absorption in the gut. Satiety and appetite regulation is a complex interaction of neural and hormonal interactions. Food components that modulate intestinal or peripheral satiety peptides, hypothalamic neuropeptides and central nervous system (CNS) appetite transmitters are the agents for weight regulation via reducing food intake (Wynne *et al*., 2005). Dietary fibre induces satiety by increasing gastric load, and emptying time, which may increase cholecystokinin and reduce ghrelin (Serrano *et al*., 2012). Intestinal lipase inhibitors obstruct fat digestion and absorption, and thereby possess applications in the management of obesity. Food sources with low GI values and those that are fibres are the most effective in promoting satiety and weight loss because they cause the least rise in blood glucose and insulin and take longer to digest and to be absorbed than carbohydrates with high GI values (Ludwig, 2000).

2.4.1 Carbohydrates

Carbohydrate forms the major portion of a meal, comprising 40-75% of the daily energy intake. Plants and milk products are the major sources of dietary carbohydrates (FAO/WHO, 1998; Cummings, 2007). Carbohydrates are organic molecules which consist of carbon, hydrogen, and oxygen. According to chemistry, dietary carbohydrate can be classified into sugars, oligosaccharides, and polysaccharides. Sugars are made up of monosaccharides (such as glucose, fructose, or galactose), disaccharides (such as sucrose, lactose, or maltose), and sugar alcohols (polyols, such as xylitol and sorbitol). Oligosaccharides are made up of maltodextrin and inulin (FAO/WHO, 1998; Cummings, 2007). Polysaccharides can be classified into starch and non-starch polysaccharides. Starches are polymers of glucose, which are either branched (amylopectin) or non-branched (amylose). Non-starch polysaccharide includes cellulose, hemicellulose, and pectin. The physiological effects of carbohydrates are dependent, to their chemical composition, physical properties such as water solubility, gel formation, crystallization state, association with proteins or fats, and complex structures of the plant cell wall (FAO/WHO, 1998; Cummings, 2007).

The physiology and utilization of carbohydrates in the gastrointestinal tract depends on the rate and extent of digestion and absorption, which in addition is affected, by meal and food properties of carbohydrate. With relation to their physiological or nutritional function carbohydrates are further classified as available and unavailable carbohydrates, glycemic carbohydrates, dietary fibre and resistant starch (FAO/WHO, 1998; Cummings, 2007). Available carbohydrates are those that are hydrolyzed by the intestinal enzymes to monosaccharides, absorbed in the small intestine and get into the conduits of carbohydrate metabolism. Unavailable carbohydrates are not hydrolyzed by the intestinal enzymes, instead are fermented in the large intestine. Carbohydrate that yields glucose when metabolised is referred to glycemic carbohydrate. Most mono and disaccharides, some oligosaccharides (maltodextrins), and rapidly or slowly digested starches are glycemic carbohydrate (FAO/WHO, 1998; Cummings, 2007).

Non-starch polysaccharides and resistant starch are considered to be non-glycemic carbohydrates. Resistant starch is defined as "starch and starch degradation products not absorbed in the small intestine of healthy humans". The main forms of resistant starch are physically enclosed starch, e.g. within intact cell structures (RS_1), some raw starch granules (RS_2) and retrograded amylose (RS_3) (Englyst et al, 1992; 1990).

2.4.1(a) Dietary fibre

Dietary fibre is "that portion of food which is derived from cellular walls of plants which is digested very poorly by human beings". Based on this hypothesis relation between fibre and health was developed. Dietary fibre mainly comprised of cellulose, hemicellulose, pectin and lignin (Wolever, 2006). Based on the method of analysis, dietary fibre has also been defined. According to the American Association of Cereal Chemists (AACC 2000), dietary fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibres promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation (DeVries, 2003). According to the Malaysian dietary guidelines (NCCFN, 1999) the daily recommended intake level of dietary fibre is 20 to 30 g. Dietary fibre is mainly found in plants and is very significant for human health. Dietary fibre can be classified into soluble and insoluble. The difference between soluble and insoluble fibres is based on the chemical properties of the fibre sources and analytical methods rather than composition or physiological responses (Roberfroid, 1993). Two main physicochemical properties of fibre, viscosity and fermentability, have been recognized as producing beneficial physiological responses (James *et al.*, 2009). Soluble polysaccharides such as gums, pectins, and β-glucans are viscous dietary fibres which can thicken when mixed with fluids. The degree of thickening when exposed to fluids is associated with the chemical composition and concentration of the polysaccharide. Earlier studies have shown that viscous fibres can reduce post prandial blood glucose and cholesterol concentrations, prolongs gastric emptying, and slows transit time through the small intestine (Schneeman, 2001; Malkki, 2001). Fermentability of the insoluble fibre is associated with large bowel function.

The microflora in the large bowel ferments the fibre to short chain fatty acids. Partially fermented fibre sources improve bowel health by promoting laxation, reduce transit time, and increase stool weight (Schneeman, 2001).