CHARACTERISATION AND SENSORY EVALUATION OF FORMULATED LOW GLYCEMIC INDEX BISCUITS FROM *Baccaurea angulata* POMACE

BY

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ABSTRACT

The addition of fruits fiber in bakery products such as biscuit has been shown to improve blood glucose response. *Bacaurea angulata* is one of the underutilized fruit, which may have some potential benefits to health. The effect of two different ways of drying, which are hot air drying and freeze drying on chemical properties of *B.angulata* was examined. The chemical analysis includes proximate analysis, antioxidant properties and dietary fiber composition. Four different amount of hot air dried *B.angulata* pomace (0 %, 10 %, 20 % and 30 %) were incorporated in the biscuit formulations substituting wheat flour. Shortening content was reduced to 40 %, 30 % and 20 % of the weight flour. The effects of supplementation of hot air dried *B.angulata* pomace on physical qualities as well as sensory properties of sixteen biscuits were determined. Four formulations with the highest overall acceptance score were selected for further analysis on chemical properties and blood glucose response. There were full fat control biscuit (FFC), full fat with 10 % pomace biscuit (FF10), full fat with 20 % pomace biscuit (FF20) and 40 % fat with 10 % pomace biscuit (RF10). Blood glucose response was assessed on twenty healthy non-diabetic subjects, where they were required to consume reference food (glucose drink) and four test biscuits after an overnight fasting in different sessions with at least one day gap. Each test meals contained 50g available carbohydrate. Blood samples were collected from finger-pricks in fasted subjects before each test (0 min) and at 15, 30, 45, 60, 90 and 120 minutes after consumption of reference or test biscuits. The GI was calculated as ratio of incremental areas under curve (IAUC) of test biscuits with IAUC of reference food. Hot air dried pomace contained significantly higher moisture and lignin in comparison to the freeze-dried pomace. In contrast, freeze-dried pomace showed significantly higher total ash, cellulose and resistant starch. There were no significant differences in total, insoluble, soluble dietary fiber and total fructan content with different types of drying. Freeze-dried pomace also sustained better antioxidant activity showed by significantly lower IC_{50} value of DPPH and ABTS, 39.78±0.69 mg/ml and 4.98±0.39 mg/ml respectively in comparison to the hot air dried pomace. The physical and sensory properties of pomace fortified biscuits were significantly affected by fat and pomace level, where FF10 biscuits showed the best preferences among consumers. However, further chemical studies suggested greater nutritional values in FF20 biscuit, where it contained the highest total dietary fiber (6.65±2.90 g/100g) and resistant starch (0.4±0.14 g/100g) although not significantly different from FFC biscuit. FF20 biscuit also contained significantly higher antioxidant properties, DPPH (0.76±0.29 mg TE/g) and ABTS (3.69±0.15 mg TE/g) in comparison to other type of biscuits. All four tested biscuit types, including the FFC biscuit, showed low GI ranging from 44 to 54. Therefore, fortification of biscuits with *B.angulata* pomace was suitable to produce low GI food.

ملخص البحث

باكاوريا أنقولاتا هي أحد الفواكه النادر استعمالها، والتي من المحتمل أن يكون لها بعض الفوائد الصحية . في هذا البحث تم فحص الأثر الناتج للخصائص الكيميائية عن أسلوبين مختلفتين للتجفيف، هما التجفيف بالهواء الساخن والتجفيف بالتجميد. تم استخدام أربع كميات مختلفة من الهواء الساخن لتجفيف الباكاوريا أنقولاتا، وهي (0% و 10% و 20%) ثم أضيفت إلى وصفات طحين البسكويت المصنوعة من دقيق القمح. تم خفض محتوى المواد المضافة إلى 40% و 30% و 20% من وزن الطحين، وتم تحديد آثار الباكاوريا أنقولاتا المجفف بالهواء الساخن على الصفات الفيزيائية والخصائص الحسية. تم اختيار أربعة عينات للمركب، وفقاً لنقاط الإستحسان العالية، لمزيد من التحاليل على الخواص الكيميائية واستجابة الدم للسكر. كانت أنواع البسكويت تتكون من البسكويت المنتظم الكامل الدسم (FFC) ، والبسكويت الكامل الدسم بـ10% من الثفل (FF10)، و البسكويت الكامل الدسم بـ20% من الثفل (FF20)، والبسكويت بدسم ـ40% وبدسم بـ10% من الثفل (RF10) . الثفل المجفف بالهواء الساخن احتوى على كميات عالية من الرطوبة واللجنين مقارنة بالثفل المجفف بالتجميد. وفي المقابل، أظهر الثفل المجفف بالتجميد كمية عالية من الرماد الكلي والسليلوز والنشا المقاوم. الثفل المجفف بالتجميد أظهر أيضاً نشاطاً مضاداً للأكسدة بشكل متواصل والذي أثبت من خلالها قيمة IC_{50} لاختبار DPPH و ABTS المنخفضة جداً، بمعدل 39.78±0.69 ملغ/مل و 4.98±0.39 ملغ/مل كلٌ على حده مقارنة بالثفل المجفف بالهواء الساخن. تأثرت الخواص الفيزيائية والحسية للبسكويت المدعم بالثفل بشكل كبير بسبب الدهون ومستوى الثفل، حيث كان البسكويت FF10 الأفضل في معدلات الإستحسان بين المستهلكين. مع ذلك، اقترحت الدراسات الكيميائية الإضافية لأن القيم الغذائية كانت عالية في البسكويت FF20، حيث أنها احتوت على أعلى مجموع للألياف الغذائية (6.65±2.29 غم/100غم) وأعلى نسبة من النشا مقاوم (0.4±0.14 غم/100غم) على الرغم من أن هذا ليس مختلفاً عن بسكويت FFC بشكل ذي أهمية. احتوى البسكويت FF20 أيضاً بشكل ملحوظ على خصائص مضادة للأكسدة، DPPH (0.76±0.29 TE / مغ) بالمقارنة مع الأنواع الأخرى من البسكويت. كل أنواع البسكويت الأربعة المختبرة، بما في ذلك بسكويت FFC ، أظهرت معدلات GI تراوحت ما بين 44 إلى 54 . و لذلك، فإن تقوية البسكويت بثفل الباكاوريا أنقولاتا كان مناسباً لإنتاج أغذية ذي معدل GI منخفض .

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Nutrition Sciences.

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DECLARATION

I hereby declare that this thesis is the result of my own investigation, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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This is dedicated to the Almighty God, my beloved family and to all the researchers who are passionately making efforts by day and night figuring out the Pandora box.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

ABTS	[2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid)]
ADF	Acid detergent fiber
ADL	Acid detergent lignin
AE	Ascorbic acid equivalent
ANOVA	Analysis of variance
ARIC	Atherosclerosis Risk in Community
AUC	Area under curve
BMI	Body Mass Index
CHD	Coronary heart disease
CI	Confidence Interval
C-peptide	Connecting peptide
CVD	Cardiovascular disease
DP	Degree of polymerisation
DPPH	2,2-diphenyl-1-picrylhydrazyl
EPIC-NL	European Prospective Investigation into Cancer and Nutrition-Netherlands
FAO	Food and Agriculture Organisation
FF10	Full fat with 10% fiber biscuit
FF20	Full fat with 20% fiber biscuit
FFA	Free fatty acids
FFC	Full fat control biscuit
FFQ	Food Frequency Questionnaire
FOS	Fructooligosaccharides
GAE	Gallic acid equivalent
GI	Glycemic Index
GIP	Glucose-dependent insulinotropic polypeptide
GL	Glycemic Load
GLP-1	Glucagon-like-peptide-1
GLUT-4	Glucose transporter type 4
HbA1c	Glycosylated haemoglobin
HDL-C	High density lipoprotein cholesterol
HGI-LC	High GI combined with low carbohydrate
HPLC	High performance liquid chromatography
HR	Hazard Ratio
hs-CRP	High sensitivity serum C-reactive protein
IC_{50}	Half maximal inhibitory concentration
IDF	International Diabetes Federation
IFG	Impaired Fasting Glucose
IGT	Impaired Glucose Tolerance
LDL-C	Low density lipoprotein cholesterol
LGI-HC	Low GI combined with high carbohydrate
LGI-LC	Low GI combined with low carbohydrate
MANS	Malaysian Adult Nutrition Survey
NDF	Natural detergent fiber
NHMS	National Health and Morbidity Survey

NIDDM	Non-insulin dependent diabetes mellitus
NSP	Non-starch polysaccharides
OR	Odd Ratio
r^2	Correlation coefficient
RF10	40% fat with 10% fiber biscuit
ROS	Reactive oxygen species
RR	Relative Risk
SCFA	Short chain fatty acids
SD	Standard Deviation
TE	Trolox equivalent
WHO	World Health Organisation
WHR	Waist-to-Hip ratio
WMD	Weighted Mean Difference

CHAPTER ONE

INTRODUCTION

1.1 THE ERA OF DIABETES EPIDEMIC

Diabetes along with other non-communicable diseases such as cardiovascular disease and obesity has become an epidemic in our modern era. In fact, diabetes contributed 2.6 % of world's death cause in 2011 (World Health Organisation, 2014), and the fourth or fifth leading causes of death in high income countries (Sicree, Shaw, & Zimmet, 2009). The numbers of people who suffer with diabetes have constantly been estimated to increase in several epidemiological studies (King, Aubert, & Herman, 1998; Wild, Roglic, Green, Sicree, & King, 2004). The most current global estimates data by International Diabetes Federation (IDF) reported that 552 million people will have diabetes by 2030 in comparison to 366 million people in 2011 (Whiting, Guariguata, Weil, & Shaw, 2011). This is the highest estimate number that has been estimated since 1998. The developing countries with high population, such as China, India and Indonesia, are in the top ten countries with people aged 20-79 years with diabetes (Whiting et al., 2011). In fact, more than 60 % of diabetes statistic comes from Asian countries since it is the most populous region in the world (Chan et al., 2009; Ramachandran, Snehalatha, Shetty, & Nanditha, 2012). Asians are also more prone to diabetes risk at lower body mass index (BMI) and waist circumference in comparison to the Western society. Besides, working age adults from 40 to 60 years is the majority group of people with diabetes in low and middle income countries (Whiting et al., 2011). This adds greater indirect costs to the countries due to disability, work loss and premature mortality.

Meanwhile, National Health and Morbidity Surveys (NHMS) in Malaysia have constantly reported the rising trend of diabetes prevalence, which started from NHMS I in 1986. The diabetes prevalence was reported to be 6.3 % among adults above 35 years old (Letchuman et al., 2010). This statistic was followed by an 80 % increase in 2006 (NHMS III) among adults above 30 years old (Letchuman et al., 2010). The recent NHMS 2011 found that 15.2 % of adults above 18 years old have diabetes (Institute for Public Health (IPH), 2011) in comparison to 11.6 % in NHMS III. On top of that, NHMS III result on diabetes number has already reached the projected prevalence for year 2025 estimated by the International Diabetes Federation (IDF) (King et al., 1998). The diabetes prevalence in Malaysia is at an alarming rate, where there were no signs of slowing down in the near future.

One of the main reasons of diabetes is that Malaysians consume carbohydrate rich diet such as rice, noodles and bread as daily diet. Most of this carbohydrate rich diet is rich in high glycemic index (GI). Even though Malaysian Food Pyramid recommends public to take 4 to 8 servings per day, but it does not highlight the importance of carbohydrate quality. GI was first introduced by Jenkins and colleagues in 1980's where it measures the blood glucose response of carbohydrate in food (Jenkins et al., 1981). Consuming high GI foods could cause adverse effects to the health. A recent meta-analysis showed a significant relationship between high consumption of white rice with diabetes within Chinese and Japanese populations (Hu, Pan, Malik, & Sun, 2012). Moreover, high GI food is also associated with the risk of cardiovascular disease and obesity, especially among women (Beulens et al., 2007; Dong, Zhang, Wang, & Qin, 2012; Youn et al., 2012). Facts from these studies support the alarming rate of chronic disease occurrences in Malaysia. Therefore, real actions are needed in tackling these health issues immediately.

Accordingly, functional foods can be the alternative way of healthy eating among Malaysians. As a developing country, people lead a busy lifestyle which make them prefer convenient and yet healthy foods. Many nutritionists have realised this need and come out with variety functional food products. Bakery goods, especially biscuits, have been used as carriers for fiber and polyphenol in fruits. Some examples of these fruits are apple, orange and mango (Ajila, Leelavathi, & Prasada Rao, 2008; Kohajdová, Karovičová, Jurasová, & Kukurová, 2011; Romero-Lopez, Osorio-Diaz, Bello-Perez, Tovar, & Bernardino-Nicanor, 2011). Biscuits enriched with fiber proved to be low in GI (Marangoni & Poli, 2008; Trinidad et al., 2006). Furthermore, low GI foods have been consistently reported to improve blood glucose regulation especially in diabetes patients (Riccardi, Rivellese, & Giacco, 2008). Low GI and low fat foods were also reported to decrease total cholesterol and low density lipoprotein cholesterol (LDL-C) at four weeks in hypercholesterolemia adults (Shikany et al., 2010). Hence, exotic fruits like *Baccaurea angulata* with potential health benefits can be utilized to develop a novel low GI enriched biscuit.

1.2 PURPOSE OF THIS STUDY

This study aims to produce low GI food from biscuit fortified with *B.angulata* pomace. Biscuit has been known to be one of most consumed bakery products, which require specific attributes and qualities for consumer acceptability. The supplementation of *B.angulata* pomace has been assumed to improve nutritional values as well reducing the GI in the common biscuit types. Therefore, the specific objectives to be determined in this study are listed as below;-

1. To determine nutrient composition and antioxidant properties of pomace from *Belimbing dayak* with two different drying techniques.

2. To determine nutrient composition and antioxidant properties of biscuits formulated with dried *Belimbing dayak* pomace powder.
3. To determine the acceptability and physical properties of biscuit formulated with dried *Belimbing dayak* pomace powder
4. To determine the GI value of formulated biscuit from dried *Belimbing dayak* pomace powder.

CHAPTER TWO

LITERATURE REVIEW

2.1 THE DETRIMENTAL EFFECT OF INSULIN RESISTANCE

Diabetes is undoubtedly may lead to premature mortality and morbidity among the sufferers. The occurrence of diabetes is as the result of abnormal function of insulin in regulating blood glucose level, which is either caused by inadequate production (Type I) or ineffective insulin (Type II). In addition to diabetes, pre-diabetes condition termed as Impaired Glucose Tolerance (IGT) or Impaired Fasting Glucose (IFG) is known to cause earlier onset of cardiovascular diseases and diabetes itself (Zimmet, Alberti, & Shaw, 2001). High rate of IGT cases in Asia region reflect the progression of diabetes, as it indicates the transition from normal to diabetic condition (Sicree, Shaw, & Zimmet, 2010). All causes mortality and cardiovascular mortality are highly associated with IGT, where the risk is greater with higher fasting blood glucose mainly within the range of 110 to 125 mg/dl (Wen, Cheng, Tsai, Hsu, & Wang, 2005). Asia Pacific Cohort Study Eight reported the hazard ratio values for each complication related to diabetes, which are 2.93 for renal disease, 1.21 for cancer, 1.52 for respiratory infections, 1.98 for all infections or inflammatory disease, 1.56 for all non-cardiovascular disease and 1.68 for all-cause mortality (Lee et al., 2007). As a consequence, diabetes sufferers might also face increasing burden of disability and health cost. However, diabetes and each complication related to it can be prevented even for individual with IGT with a few changes in daily routine lifestyle and eating habit.

2.2 THE HEALTH BENEFITS OF LOW GI FOOD

Rapid economic growth in Asia is the key factor in diet transition among the society, mostly in urban area. Majority of people are changing towards energy dense and rich in fats diet also known as 'westernization' which has taken place globally including Malaysia. Readily available and plenty of calorie dense foods at low cost rapidly stimulate the diet transition in Asia. Hu (2011) has highlighted three major changes that have taken place in Asian traditional diet pattern, which are 1) majority of the society is consuming refined grain such as polished rice instead of coarse grain, 2) higher income groups consume less cereals and 3) all income groups consume more fat with the lower income groups have higher energy intake than the higher income groups.

Traditional diets of Asian countries are mostly consisted of polished white rice and refined wheat. Even though rice intake among Malaysian has been reported decreasing, cereal maintained as the main source of calorie where the intake was 20% more than developed countries (Sheng, Shamsudin, Mohamed, Abdullah, & Radam, 2008). Rice has been listed as the top ten daily consumed foods with 97% of Malaysians consume rice twice daily (Norimah et al., 2008). Other Asian countries such as India also have high intake of carbohydrate with 60% to 67% as source of energy (Misra, Khurana, Isharwal, & Bhardwaj, 2009). However, refined cereals have high glycemic index (GI) and glycemic load (GL) values that are highly associated with diabetes risk. High intake of white rice was found to be associated with diabetes risk in comparison to brown rice, which has the protective effect (Hu, 2011).

2.2.1 The Definition of Glycemic Index

Jenkins and his colleagues were the first to recognise the importance of carbohydrate quality in the daily diet and introduced the GI concept in 1981 (Jenkins et al., 1981). High carbohydrate diet especially refined cereals may cause increase in blood glucose concentration, which is also known as glycemic response. Constant rising of blood glucose level from high carbohydrate intake will lead to insulin resistance or diabetes type II where insulin is ineffective in regulating blood glucose level (Zimmet et al., 2001). GI is the ranking of the carbohydrate containing food based on the postprandial glycemic response in comparison to a reference food; (i.e. white bread or glucose) (Jenkins et al., 2002). GI is determined from the incremental area under the blood glucose response curve of 50 g available carbohydrate relative to a similar amount of available carbohydrate in the reference food. The ranking of GI consist of three levels, which are low ≤ 55, medium 56-69 and high ≥ 70. Meanwhile, GL is used in complement to GI that indicates the amount of carbohydrate in the food. GL is calculated by multiplication of GI with the amount of carbohydrate contains in a portion size of the food (Monro & Shaw, 2008).

Blood glucose level in human is a tightly regulated homeostatic metabolic system, which is highly affected by high carbohydrate intake. Carbohydrate must be converted into glucose by a series of enzymes and hormones beginning from the mouth and end up in the liver. Glucose can either be stored as glycogen or triglycerides in the liver by glucagon. But, most of the times glucose is metabolized into energy in the muscle by insulin (Aronoff, Berkowitz, Shreiner, & Want, 2004). High GI diet causes the blood glucose level rapidly shoot up after the ingestion of carbohydrate food, which will return rapidly to the normal level by homeostatic mechanism. As a consequence, human body will be in the hyperglycemia and hypoglycemia state with high GI diet.

Frequent hyperglycemia state in metabolic system will lead to hyperinsulinemia condition as well as an increase in oxidative stress level (Ludwig, 2002). Hyperinsulinemia might produce insulin resistance, which is associated with type 2 diabetes, while high level of oxidative stress level is related to cardiovascular disease. Besides, hypoglycemia state will trigger frequent hunger feeling in human, which might cause obesity (Ludwig, 2002). However, low GI diet could overcome this problem by producing a gradual rise and slow drop of blood glucose after carbohydrate intake and thus, preventing hyperglycemia and hypoglycemia state in the metabolic system.

2.2.2 The Pros and Cons of Low and High GI Foods

2.2.2.1 Observational Studies

Numerous studies have been conducted, which are mostly in the form of observational studies. However, results on the association between GI or GL diet with health benefits so far have been mixed. Early large prospective cohort studies by Nurse's Health Study I and Health Professional Follow Up Study reported that both quality and quantity of carbohydrate were positively associated with diabetes risk among women (Hu et al., 2001; Salmerón, Manson, et al., 1997) as well as in non-insulin dependent diabetes (NIDDM) men (Salmerón, Ascherio, et al., 1997). In contrast, no association was found between GI and diabetes risk in Iowa Women's Health Study during six years of follow up among 35,988 post-menopausal women (Meyer et al., 2000) and the Atherosclerosis Risk in Community (ARIC) in African American and whites (Stevens et al., 2002).

Nevertheless, majority of the current evidences are in support of GI and GL diet as one of main diabetes risk factors. The Melbourne Collaborative Cohort Study reported that the odd ratios (OR) for every 10 unit increase in GI was 1.39 without adjustment for body mass index (BMI) and waist-to-hip ratio (WHR) (Hodge, English, O'Dea, & Giles, 2004). The relationship was however, only significantly positive in