Nutritional Composition and Palatability Evaluation of Some Selected Commercially Available Local Brown Rice in Kelantan Prepared By Different Types of Cooking Methods

Thesis submitted in partial fulfilment for the

Degree of Bachelor of Science (Honour) in Nutrition

CHAN CHIEW TING

School of Health Sciences

Universiti Sains Malaysia

Health Campus

16150, Kubang Kerian, Kelantan

Malaysia

JUNE 2013

ABSTRAK

Kini, sebanyak 2.2 juta ton nasi putih diambil oleh rakyat Malaysia setiap tahun. Pengambilan nasi putih yang tinggi adalah berkaitan dengan penyakit kencing manis (T2DM), dislipidemia, strok ischemik dan penyakit kardiovaskular. Beras perang merupakan makanan bijirin yang mengandungi nilai nutrisi yang tinggi. Kajian mendapati penggantian nasi putih dengan makanan bijirin penuh termasuk nasi perang dikaitkan dengan pengurangan risiko T2DM, tahap insulin dan tahap glukosa. Walau bagaimanapun, pengambilan nasi perang adalah rendah di Malaysia kerana sifat-sifat sensori dan tekstur yang tidak disukai. Kajian ini telah dijalankan untuk menentukan komposisi pemakanan dan tahap kesedapan bagi 3 jenis beras perang yang disediakan dengan 3 kaedah masak berbeza. Sampel beras dimasak dengan kaedah mendidih, mereneh atau mengukus. Sampel-sampel ini kemudiannya dianalisis untuk menentukan nilai kelembapan, abu, lemak kasar, protein kasar, dan karbohidrat. Penilaian deria dan analisis profil tekstur telah dijalankan untuk menilai tahap kesedapan nasi perang. Nasi perang mengandungi sebanyak 72.82% -78.38% kelembapan, 1.42% -2.65% lemak, 0.47% -1.44% abu, 8.05% -9.31% protein, dan 2.67% -4.79% jumlah serat (kaedah mengukus). Nilai pemakanan nasi perang adalah lebih tinggi daripada nasi putih (0.03% -0.08% lemak, 0.11% -0.15% abu, 6.63% - 6.75% protein, 0.15% jumlah serat) ($p < 0.05$) kecuali nilai karbohidrat (10.04% - 14.94 %) adalah lebih rendah daripada nasi putih (17.75% -28.2%) ($p < 0.05$). Berbanding dengan nasi perang yang dididih (75.37% -78.38% kelembapan, 0.82% - 1.21% abu, 8.61% -9.31% protein, 1.42% -2.15% lemak, 10.04% -12.69% karbohidrat), nasi perang yang dikukus mengandungi nilai kelembapan (72.82% - 73.68%) yang lebih rendah, kandungan abu (1.11% -1.36%) dan protein (8.05% -

8.92%) yang setanding, tetapi kandungan lemak (2.34% -2.65%) dan karbohidrat (13.47% -14.94%) yang lebih tinggi. Kaedah memasak seperti tempoh memasak, suhu memasak, nisbah air dengan beras (W/R) serta komposisi kimia beras seperti kanji, nilai kelembapan dan protein menyumbang kepada kepelbagaian tekstur nasi. Berbanding dengan kaedah mendidih, kaedah mengukus menghasilkan tekstur nasi perang R3 (10.77kg vs 4.22kg) dan R4 (11.53kg vs 4.62kg) yang lebih keras, R2 dan R3 (1.18kg/s vs-0.56kg/s) yang kurang melekit (1.16kg/s vs-0.71kg/s), R2 yang lebih kohesif (5.27kg vs 4.64kg) manakala R4 yang kurang kohesif (3.77kg vs 5.0kg). Kekerasan yang optimum, tahap kohesif dan kelekitan yang rendah serta nilai jelikitan yang tinggi membolehkan R2 dan R3 yang dikukus mencapai skor tekstur yang lebih tinggi (4.02 dan 3.86) daripada nasi yang dididih ($p < 0.05$). Sampel R3 dan R4 yang dikukus lebih keras dan kurang melekit mendapat skor tinggi dan ketara dalam atribut rupa ($p < 0.05$) berbanding dengan sampel beras yang dididih. Walau bagaimanapun, hanya R3 yang dikukus (4.28) mempunyai tahap penerimaan yang lebih tinggi daripada R3 yang dididih (3.28) ($p < 0.05$). Tahap penerimaan panel terhadap R4 yang direneh, R3 dan R4 yang dikukus adalah setanding dengan nasi putih ($p > 0.05$). Secara ringkasnya, jenis kaedah memasak, komposisi kimia dan jenis beras memberi kesan terhadap sifat tekstur dan sensori nasi perang. Kaedah mengukus dan mereneh disarankan untuk memasak beras perang. Beras perang yang sederhana keras dan tinggi serat (R3) diikuti beras perang yang keras dan tinggi serat (R4) disaran sebagai makanan ruji alternatif untuk menggantikan beras putih kerana mengandungi komposisi makanan yang tinggi dan setanding enak dengan beras putih.

ABSTRACT

Presently, about 2.2 million tons of white rice is consumed by Malaysians every year. Such high white rice intake is associated with type-2 diabetes mellitus (T2DM), dyslipidemia, ischemic stroke and cardiovascular diseases. Brown rice is high nutritional value whole grain. Substituting whole grains including brown rice to white rice is associated with decrease in the risk of T2DM, lowered insulin level and postprandial glucose level. However, brown rice intake is low in Malaysia due to undesirable sensory and texture properties. The present study were conducted to determine nutritional composition and palatability levels of 3 types of brown rice varieties prepared with 3 different cooking methods. Rice samples were either cooked by boiling, simmering or steaming methods and analyzed for moisture, ash, crude fat, crude protein, and carbohydrate content. Sensory evaluation and texture profile analyses were also conducted to assess palatability level of cooked brown rice. Cooked brown rice had 72.82%-78.38% of moisture, 1.42%-2.65% of fat, 0.47%-1.44% of ash, 8.05%-9.31% of protein, and 2.67%-4.79% of total dietary fiber (steaming method). These nutritional values were higher than cooked white rice (0.03%-0.08% of fat, 0.11%-0.15% of ash, 6.63%-6.75% of protein, 0.15% of total dietary fiber) ($p<0.05$) except carbohydrate (10.04%-14.94%) which was lower than cooked white rice (17.75%-28.2%). As compared to boiled brown rice (75.37%-78.38% of moisture, 0.82%-1.21% of ash, 8.61%-9.31% of protein, 1.42%-2.15% of fat, 10.04%-12.69% of carbohydrate), steamed brown rice contained lower water level (72.82%-73.68%), comparable concentration of ash (1.11%-1.36%) and protein (8.05%-8.92%) but higher fat (2.34%-2.65%) and carbohydrate (13.47%-14.94%) content. Recent studies reported rice variety, cooking properties such as cooking duration, cooking temperature, water uptake (W/R) ratio as well as chemical composition of rice like starch, water level and protein contributed to diversity of cooked rice texture. As compared to boiling method, steam cooking produced firmer gelatinized rice of R3 (10.77kg vs 4.22kg) and R4 (11.53kg vs 4.62kg), less sticky R2 (-1.16kg/s vs -0.71kg/s) and R3 (-1.18kg/s vs -0.56kg/s), more cohesive R2 (5.27kg vs 4.64kg) but less cohesive R4 (3.77kg vs 5.0kg). Optimum hard, less cohesive, less sticky and gummier properties of steamed R2 and R3 achieved significantly higher texture score (4.02 and 3.86) than the boiled one in sensory test ($p<0.05$). Firmer and less sticky steamed R3 and R4 obtained significant high score in appearance attribute ($p<0.05$) compared with boiled one. However, only steamed R3 (4.28) was appeared to be overall preferred than boiled R3 (3.28) ($p<0.05$). In sensory evaluation, simmered R4, steamed R3 and R4 were comparable to white rice ($p>0.05$) in which white rice was highly accepted by panelists. In summary, different types of cooking methods, chemical composition of rice and rice varieties affected texture and sensory properties of cooked brown rice. Steaming and simmering techniques are recommended methods in cooking brown rice. Medium hard and high fiber brown rice (R3) followed by hard and high fiber brown rice (R4) are recommended as an alternative staple food to replace white rice as they contain higher nutritional composition and comparably palatable as white rice.

DECLARATION

I hereby declare that the work presented in this thesis is to the best of my knowledge and original, except for the citations and quotations which have been acknowledged. I also declare that this thesis is not submitted for any other degree or award neither in University Sains Malaysia nor other institutions.

Chan Chiew Ting

Date: 4th July, 2013

I certify that Ms. Chan Chiew Ting has conducted a study entitled "Nutritional Composition and Palatability Evaluation of Some Selected Commercially Available Local Brown Rice in Kelantan Prepared by Different Types of Cooking Methods" as final year project in nutrition under my supervision. She had complied with the relevant rules, requirements, procedures and policy in conducting her study and completed writing her thesis. I am satisfied with her work and have no objection for her thesis to be examined by the appointed examiners by the School of Health Science, University Sains Malaysia.

Thank you.

____

Supervisor

Associated Professor Dr. Wan Rosli bin Wan Ishak

Date: July 4, 2013

ACKNOWLEDGEMENT

I am always grateful to Associated Professor Dr. Wan Rosli Wan Ishak for accepting to be my supervisor of this final year project. His guidance and inspiration has been much appreciated. Valuable discussions and views had been given throughout the project and thesis writing.

In addition, I wish to thank to laboratory officers at nutrition lab and food preparation lab for assistances throughout the project. The project required a lot of laboratory works and numerous difficulties had been faced. Fortunately, with their valuable views, discussions and helps, data was collected successfully and much more time had been saved.

My special gratitude to staffs at Unit Pengurusan Makmal Sains (UPMS) who provided chemicals and tools that I required throughout the project. With their wise opinions and assistances, problems were eased. I also greatly thanked to UNIPEQ UKM, Bangi as samples were send there for total dietary fiber analysis so that I could complete my data for the whole project successfully.

Besides that, I am very much appreciated to postgraduates, Mrs. Nurhanan Binti Abdul Rahman, Miss Che Anis Jauharah Che Mohd Zin, Mr. Shazwan, and Miss Ng Sze Han. I thank to them for being enduring me all the time throughout this project. Special gratitude to my colleagues and friends, Miss Shazwani binti Magini, Miss Chow Yuh Nien, Miss Lim Siok Ling, Miss Ng Ai Ping, Miss Lim Yoke Har, Miss Kum Choi Sine, Miss Chi Yuen Yee, Miss Chan Xin Yi, Miss Ng Shi Yin and Mr.

Wong Yeng Wei for their untiring effort in assisting me throughout sample preparation and sensory evaluation.

Final year project required continuous trials and errors. Therefore, patience, commitment, dedication and hard work were very much needed to conduct the project. I learned that research and development (R&D) work is challenging. Yet, outcome from research project will be an achievement in R&D field. Without all guidance and aids that I gained from everyone, I could not make it.

TABLE OF CONTENT

LIST OF TABLE

LIST OF SYMBOL, ABBREVIATION AND ACRONYMN

Abbreviations	Meanings
%	Percentage
<	Less Than
>	More Than
≥	At Least
°C	Degree Celsius
µg	Microgram
µL	Microlitre
AACC	American Association of Cereal Chemists
ANOVA	Analyses of Variances
AOAC	Association of Official Analytical Chemists
BMI	Body Mass Index
CVDs	Cardiovascular Diseases
FAO	Food and Agricultural Organization
GABA	Gamma Amino Butyric Acid
GI	Glycemic Index
GL	Glycemic Load
g	Gram
HDL-C	High Density Lipoprotein Cholesterol
HMG-Co A	3-hydroxy-3-methyl-glutaryl-Coenyzme A
HPLC	High Performance Liquid Chromatography
HSD	Honestly Significant Difference
IDF	Insoluble Dietary Fiber
kg	Kilogram

kg/s	Kilogram per second
LDL-C	Low Density Lipoprotein Cholesterol
MANS	Malaysian Adults Nutrition Survey
MD	Milling Degree
mg	Milligram
mL	Millilitre
mm/sec	Millimeter per second
NHMS III	National Health and Morbidity Survey III
R&D	Research and Development
RBO	Rice Bran Oil
SDF	Soluble Dietary Fiber
SPSS	Statistical Package for Social Science
TC	Total Cholesterol
TDF	Total Dietary Fiber
TPA	Texture Profile Analysis
T2DM	Type 2 Diabetes Mellitus
vs	Versus
v/v	Volume per Volume
WC	Waist circumference
WHO	World Health Organization
WHR	Waist Hip Ratio
WUR	Water Uptake Ratio
W/R	Water-to-rice
w/w	Weight per Weight

CHAPTER 1: INTRODUCTION

1.1. Background

Archeological evidence showed that at the early 9000 years ago, human in China had already known the way to harvest and cultivate rice species *Oryza sativa* in the middle Yangtze and upper Huao rivers (Liu, *et al.*, 2007). Until now, *Oryza sativa* becomes one of the rice species that is globally grown and consumed in many parts of the world including South East Asian Countries. The subspecies of *O.sativa* which are primarily cultivated are *Oryza sativa L. indica* and *Oryza sativa L. japonica* (because both types are able to resist to different climatic conditions) (Maclean, *et al.*, 2002). *Indica* rice is commonly consumed in India, Southern China, and the lowland areas of Southeast Asia while *Japonica* rice is consumed in Southeast Asia, northern China, Japan and United State (Hiemori, Koh and Mitchell, 2009).

In Malaysia, the word '*nasi*' is local language used for cooked rice. For the last 10 years, domestic rice production contributed to 77% of total domestic consumption in Malaysia while the remaining 23% were imported from international market. About 2.2 million tons of rice is consumed by Malaysians every year (Abdullahi, Zainalabidin and Ismail, 2011). Rice consumption per capita among Malaysia consumers increased 10.5 kg from 2006 to 2010 (Hoh, 2011).

Rice grain is a seed of *Oryza* plant. Rice grain consists of caryopsis (the true fruit) that covered with hard siliceous hull (Juliano and Bechtel, 1985). The main components of rice grain are hull, seed coat, nucellus, aleurone, endosperm and germ. Brown rice consists of seed coat, nucellus and germ which are rich in protein, lipid, vitamins and minerals, only the hull is removed.

White rice is polished rice or processed rice which is converted from brown rice after a complete milling and hulling. The core nutrient component remained in white rice is starch, most nutrients have been removed and damaged by those processes (Rosniyana, Rukunudin and Norin, 2006). Hence, white rice is also a refined carbohydrate food. Some beneficial nutrients like magnesium (Huxley, *et al.*, 2009) and dietary fiber, (Montonen, *et al.*, 2003) which are protective against type 2 diabetes mellitus (T2DM) are normally removed during milling and polishing (Nanri, *et al.*, 2010). Therefore, it has been suggested a positive association between white rice intake and T2DM (Hu, *et al.*, 2012; Liang, Lee and Binns, 2010; Nanri, *et al.*, 2010; Song, *et al.*, 2012; Villegas, *et al.*, 2007).

More studies were also conducted and found out positive association between white rice intake and other metabolic diseases like dyslipidemia (Song, *et al.*, 2012), ischemic stroke (Liang, Lee and Binns, 2010) in Japanese (Nanri, *et al.*, 2010), Korean (Song, *et al.*, 2012), Chinese (Liang, Lee and Binns, 2010; Villegas, *et al.*, 2007) and, Western population (Hu, *et al.*, 2012).

Brown rice has been reported having therapeutic effects like hypocholesterolemia, improvement of low density lipoprotein cholesterol (LDL-C) level and preventing T2DM (Lai, *et al.*, 2012; Most, *et al.*, 2005; Sun, *et al.*, 2010) because of its constituents. Yet, rice consumers prefer white rice instead of brown rice because of its texture, taste, colour, price, tradition, brand preference, refusal to change previous dietary habits and availability (Zhang, *et al.*, 2010).

Cooking is a processing step to make rice grain desirable to be consumed. It also affects nutritional value of food depending on temperature and time (Gokoglu, Yerlikaya and Cengiz, 2004). However, there is lack of information available in literature regarding the effect of different cooking methods on nutritional composition of brown rice for consumption. Hence, this study investigated the effect of selected common practice of domestic rice cooking, namely boiling, steaming and simmering towards nutrition composition and palatability of brown rice.

1.2. Problem Statement

Non communicable diseases such as cardiovascular diseases (CVDs), T2DM are increasing in worldwide nowadays. High intake of white rice which is a refined carbohydrate food (Nanri, *et al.*, 2010) has been associated with the prevalence of CVDs (Ma, *et al.*, 2006) and T2DM (Hu, *et al.*, 2012).

CVDs are the leading cause of total death on Malaysia. Malaysian Ministry of Health's annual report 2007 stated that pulmonary and heart diseases were responsible for 16.5% of total death in Malaysia. These diseases were ranked as the first of principal cause of death in Malaysia (Mininsry of Health Malaysia, 2007). Statistical report by year 2008 indicated that 12.9% of 124875 total deaths in Malaysia were due to ischemic heart disease (Jabatan Perangkaan Malaysia, 2010).

Prevalence of diabetes in Malaysia is increasing. National Health and Morbidity Survey (NHMS) III 2006 stated that the prevalence of diabetes in Malaysia population aged 30 and above was 14.9%. For younger age group between 18 years old to 30 years old, prevalence of diabetes was 2.4%. NHMS III results showed that by year 2006 Malaysia had already reached the projected prevalence for year 2025 (Letchuman, *et al.*, 2010). World Health Organization (FAO/WHO) predicts by 2030, Malaysia would have 2.48 million people with diabetes (Ministry of Health Malaysia, Malaysia Society of Ophthalmology and Academy of Medicine Malaysia, 2011).

Many studies found out that brown rice consists of dietary fiber, essential fatty acids, vitamins which exhibit health benefit (Lai, *et al.*, 2012; Most, *et al.*, 2005; Sun, *et al.*, 2010). It will be great for rice consumers if brown rice substituted for white rice. However, Malaysian population favors on white rice instead of brown rice. Factors that affect consumers to purchase brown rice are quality, appearance, availability, texture, aroma, and price (Abdullahi, Zainalabidin and Ismail, 2011). A better cooking treatment may enhance flavour, texture, and palatability of brown rice, and retain nutrients of brown rice.

1.3. Research Objectives

1.3.1. General Objective:

To determine nutritional composition and palatability levels of brown rice prepared with different types of cooking methods.

1.3.2. Specific Objective:

1. To determine nutritional composition of 3 cooked brown rice varieties prepared with 3 types of cooking techniques.
2. To investigate sensory and texture attributes of 3 cooked brown rice varieties prepared with 3 types of cooking techniques.

1.4. Research Question

1. What are the differences in nutrient content of 3 selected commercially available brown rice?
2. What are the differences in palatability levels of the 3 cooked brown rice varieties?
3. What are the differences in nutrient content of brown rice in 3 types of cooking methods?
4. What are the differences in palatability levels of brown rice in 3 types of cooking methods?
5. Why is brown rice better than white rice in term of nutritional value?

1.5. Hypotheses

1.5.1. Null Hypotheses (N_0)

There is no difference of proximate composition, texture profile and sensory evaluation in brown rice prepared with different types of cooking methods.

1.5.2. Alternate Hypotheses (N_A)

There are significant differences of proximate composition, texture profile, and sensory evaluation in brown rice prepared with different types of cooking methods.

1.6. Significance of Study

This study was conducted in order to investigate the nutritional changes of brown rice prepared with different type of cooking methods. It developed the best method for cooking brown rice. Best cooking method is able to enhance palatability levels of cooked brown rice, preserve soluble nutrients and minimizing nutrient loss during cooking.

This study promoted substitution of brown rice for white rice as staple food in Malaysia. It could reduce health circumstance caused by high intake of white rice.

This study determined nutritional composition of some selected locally available brown rice in Kelantan, Malaysia. This study could be source of database for local brown rice research projects in future time. It would then contribute to the deployment of studies on brown rice. It also would be a potential interest in development of brown rice based functional food in Malaysia. The study also provided informative and scientific data for educators to educate and raise the awareness of people about health benefits of brown rice.

CHAPTER 2: LITERATURE REVIEW

2.1. Consumption of Rice in Malaysia

Rice is the predominant type of rice most commonly consumed worldwide. (FAO, 2004b). More than half of world's population consumes rice as their staple food as well as in Malaysia, Japan, China and India (FAO, 2004b; Karim, *et al.*, 2003; Miller, Prakash and Decker, 2002; Norimah, *et al.*, 2008; Shenga, *et al.*, 2008). One third of world's population relies on rice as one of the important crops besides corn and wheat. Champagne and his colleagues stated that 90% rice production and consumption is in Asian countries like China, India, Indonesia, Bangladesh, Vietnam and Japan (Champagne, *et al.*, 2004).

Rice provides main source of calorie intake for Malaysian consumers (Abdullahi, Zainalabidin and Ismail, 2011). It is commonly consumed "white". 27% dietary calorie intake and 20% of dietary protein intake in developing countries like Malaysia are contributed by rice. Food and Agricultural Organization (FAO) stated that more than 2 billions of Asian gets 60 to 70% of daily energy supply from rice and rice products. Meanwhile, a billion Asian households depend on rice systems for their major source of employment and livelihood (FAO, 2004b).

Rice consumption is high in Malaysia population. About 2.2 million tons of rice is consumed by Malaysians every year (Abdullahi, Zainalabidin and Ismail, 2011). Few studies had been done on rice consumption trends and projections in Malaysia. Malaysian Adults Nutrition Survey (MANS) that was conducted to evaluate food consumption in Malaysian adults showed that 97% of Malaysians consume about 2

½ plates of rice (white rice) everyday on average (Karim, *et al.*, 2003; Norimah, *et al.*, 2008).

Hoh's study (2011) stated that rice consumption per capita among Malaysia consumers increased 10.5 kg from 2006 to 2010, exclude foreign workers and tourists (Hoh, 2011). Arshad and colleagues stated that total consumption of rice in Malaysia had multiplied from 2.7 million tons to 4 million tons in periods of 1985 to 2009.

However, from 1990 to 2008, rice consumption per capita in Malaysia dropped from 87 kg to 79 kg. It might because of increased income per capital, change in food preference and dietary pattern (Arshad, *et al.*, 2011). Western fast food outlets and local hawkers with wheat based food like '*roti canai*' and increasing of Malaysian rice consumers' health conscious might contribute to a decline of rice consumption per capita. It was projected that rice will be replaced by alternative foods like breads, noodles, meats and cereal products (Abdullahi, Zainalabidin and Ismail, 2011).

2.2. White Rice

White rice is the predominant type of rice most commonly consumed worldwide, especially in Asia (FAO, 2004b). White rice is milled rice and is also known as refined carbohydrate food which is produced by a series of mechanical process. Rice milling processing includes cleaning to remove foreign subjects; hulling to rubs off husks; whitening to eliminate bran layers from endosperm; polishing in order to smoothen and brighten surface of rice grains; grading which separating milled rice from broken rice, whole grain rice and head grain rice; sorting to remove rice defects (Abbas, *et al.*, 2011).

The nature and composition of rice bran depends on the milling degree (MD), contamination with husk and the degree of parboiling for parboiled rice. Rice can be categorized according to different MDs (Abbas, *et al.*, 2011).

2.3. Nutritional Composition of White Rice

Predominant nutrient of white rice is carbohydrate which is mainly contributed by starchy endosperm. Deficient of nutrients in white rice due to milling process is substantial which indicates 40-47% extraction of whole rice grain. It is expected 80% of thiamin is removed during milling whereas 29% of protein, 79% of the fat, 84% thiamin and 67% of iron are eliminated during polishing. Different MD varies amount of nutrient loss (Abbas, *et al.*, 2011).

In terms of food preparation, removal of pericarp and bran layer aids in diffusion of water soluble nutrients from aleurone layers into cooking water. Hence, there is significant inadequacy of hydrophilic vitamins and minerals in cooked white rice (Abbas, *et al.*, 2011).

White rice consumers basically ingest food product which nutrients are seriously depleted. Nutritional value of polished rice can be improved by techniques such as plant breeding, increasing micronutrient content of the grain through genetic modification and improving rice fortification techniques (Kennedy, Burlingame and

Nguyen, 2002). The best-known genetic-modifying rice product is "golden rice", which contains synthetic carotenoids (FAO, 2004a).

Some beneficial nutrients like magnesium (Huxley, *et al.*, 2009), dietary fiber (Montonen, *et al.*, 2003) which are protective against T2DM are removed (Nanri, *et al.*, 2010). Therefore, it has been suggested the association between white rice intake and T2DM (Villegas, *et al.*, 2007), (Hu, *et al.*, 2012; Liang, Lee and Binns, 2010; Nanri, *et al.*, 2010; Song, *et al.*, 2012).

2.4. Brown Rice

Plenty of researches had been done on brown rice in the United States (Sun, *et al.*, 2010), Japan (Tran, *et al.*, 2004), China (Jiang, *et al.*, 2008), Korea (Han and Lim, 2009), Brazil (Heinemann, *et al.*, 2005), and Malaysia (Norzaleha, *et al.*, 2011; Rosniyana, Rukunudin and Norin, 2006; Shahin, *et al.*, 2009). Aspects of brown rice that had been studied are therapeutic effect, texture properties, sensory properties, digestive properties, chemical composition, nutrition contents like gamma amino butyric acid (GABA), crude protein, amino acid, phenolic compounds and minerals, antioxidant capacity, physicochemical properties and cooking characteristics of brown rice (Han and Lim, 2009; Heinemann, *et al.*, 2005; Jiang, *et al.*, 2008; Norzaleha, *et al.*, 2011; Rosniyana, Rukunudin and Norin, 2006; Shahin, *et al.*, 2009; Sun, *et al.*, 2010; Tran, *et al.*, 2004; Zhang, *et al.*, 2010).

Unlike white rice, brown rice is unpolished rice grain which is covered with bran layer. The nutritious bran layer which consists of pericarp, seed coat, nucellus, aleurone layer, and germ, contributes to 3% to 8% of the rice grain. Brown rice is produced after eliminating husk through dehulling process. The husk is removed by a rubber roll huller before separating mixture that comprising brown rice and paddy by a paddy separator (Rosniyana, Rukunudin and Norin, 2006).

The bran layer of brown rice contributes to a light tan color, nutlike flavor and chewy texture (Islam, Shams-Ud-Din and Haque, 2011). Therefore, brown rice can be distinguished by nutty flavour, chewiness, short shelf-life and high nutritional value.

The main difference between brown rice and white rice is milling degree. Full milling or complete whitening removes outer bran layer of rice grain and produces white rice. Bran layer is high in dietary fiber, vitamins and minerals. It results significant nutrient loss and only carbohydrate remained within white rice (Rosniyana, Rukunudin and Norin, 2006).

2.5. Nutritional Composition of Brown Rice

With the presence of germ and outer layer, brown rice is richer in nutrients like essential fatty acids, proteins, dietary fibers, vitamins such as thiamine, riboflavin, pyridoxine, tocopherol, minerals like potassium, magnesium, calcium, sodium, zinc, iron, manganese, copper than in the starchy endosperm (Abbas, *et al.*, 2011; Jiang, *et al.*, 2008). The B-vitamins, potent antioxidant compounds and α-tocopherol are concentrated in the bran layers with the embryo accounting for more than 95% of total tocopherols (Norzaleha, *et al.*, 2011; Rosniyana, Rukunudin and Norin, 2006).

As compared to white rice, brown rice has higher free sugar, amino acid contents, peak viscosity, amylase activity, protease activity, less amylose content, water uptake ratio (WUR), and α-glucosidase activity (Tran, *et al.*, 2004).

Food and Agricultural Organization (FAO) (FAO, 2004a) stated that 100g of brown rice contains 7.9 g of protein, 2.2 mg of iron, 0.5 mg of zinc and 2.8 g of fiber. A study showed a wide variation of zinc (2.1 - 39.4 μg/g) and iron (5.1 - 441.5 μg/g) content among 220 rice varieties (Brar, *et al.*, 2011).

Brown rice is known to have higher lipid content than white rice (Abbas, *et al.*, 2011). Therefore, brown rice could not be stored in longer period to prevent rancidity caused by lipolysis. Lipolysis of lipids occurred in outer bran layer of brown rice and produced free fatty acids which resulted in deterioration and off-flavor of brown rice (Zhou, *et al.*, 2002).

Nevertheless, a previous study revealed lipolysis in milled rice was comparable to brown rice after 10 months of room temperature storage. It was reported that lipid compounds of milled rice was lipolyzed by hydrolysis and oxidation during storage. The rate of lipolysis of milled rice was faster and stronger than brown rice after 10 months storage. The authors explained caryopsis coat of brown rice offered protection against environmental and physical effects to reduce and inhibit lipolysis (Tran, *et al.*, 2004).

Rice bran oil extracted from brown rice may contain more than 80% of unsaturated fatty acid like oleic acid, linoleic acid and palmitic acid depending on rice variety (Frei and Becker, 2004). Rice bran also contains potent antioxidant compounds like oryzanols, tocopherols and tocotrienols which are benefit to health (Llyod, Siebenmorgen and Beers, 2000).

2.6. Health Benefit of Brown Rice

A community based study suggested an inverse association between whole grains food intake and metabolic risk factors (body mass intake, BMI, waist-hip-ratio (WHR), total cholesterol, LDL-C level, fasting glucose, and fasting insulin). Subjects who followed whole grains diet were likely to have healthy lifestyle such as physically active, intake of multivitamin and less smoking. Whole grains consumption was found to be related with fasting insulin concentration, body weight, fat distribution. Hence, McKeown and colleagues (2002) proposed that whole grains diet which was rich in dietary fiber and other micronutrient like magnesium enable to protect against metabolic diseases like T2DM, CVDs (McKeown, *et al.*, 2002). Brown rice is an excellent example of whole grain food due to attached outer bran and germ (Sun, *et al.*, 2010).

Another study observed the risk of T2DM was slightly reduced by consumption of brown rice among western population. This study showed replacement of 50g white rice per day for similar amount of brown rice significantly reduces risk of developing T2DM. The authors observed the reduction risk was associated with bran content of brown rice but not germ content and compared the effect of substitution of 50g whole grain per day for same amount of white rice on T2DM and obtained positive result. Greater reduction risk of T2DM in subjects was found (Sun, *et al.*, 2010).

The variation of rice grain structure results in wide range of glycemic index (GI) (Gokoglu, Yerlikaya and Cengiz) value. In general, brown rice and white rice have moderate GI values which are 55±5 and 64±7 respectively (Foster-Powell, Holt and Brand-Miller, 2002). It is difficult to determine the effectiveness of replacement of brown rice for white rice on postprandial glucose response.

In other study, a randomized control trial observed that isocaloric substitution of whole grain for white rice significantly lowered insulin level and postprandial glucose level. The whole grain diet was comprised of small amount of white rice, 66.6% of brown rice and barley as well as 22.2% legume powder (Jang, *et al.*, 2001).

Association of refined grains consumption with insulin resistance and the metabolic syndrome was evaluated among an urban population in Chennai, Southern India. This cross sectional study observed lower high-density lipoprotein cholesterol (HDL-C) level, higher waist circumference (Sun, *et al.*), blood pressure, serum triglyceride concentration, and insulin resistance were related to high intake of refined grain (Radhikaa, *et al.*, 2009).

Rice bran oil (RBO) which presents in outermost layer of brown rice, was reported to have cholesterol-lowering effect because of its unsaponifiable components. RBO is rich in γ-oryzanol that is a ferulate ester of triterpene alcohols and tocotrienols in which made up by β- and γ-tocotrienols (Sugano and Tsuji, 1997). There was a study which proposed mechanism of cholesterol lowering effect by RBO. The researchers observed that γ-tocotrienols inhibited 3-hydroxy-3-methyl-glutaryl-coenzyme A (HMG-CoA) reductase, the rate-limiting enzyme in endogenous cholesterol synthesis and thereby reduced cholesterol level (Kerckhoffs, *et al.*, 2002).

Hypocholesterolemic effect was postulated caused by cholesterol-structure-similar sterol, β-sitosterol which inhibited cholesterol absorption in small intestine (Most, *et al.*, 2005). Some dietary interventions with RBO-containing food consumption found out a significant decline of total cholesterol (TC) level and LDL-C level in diabetic patients, and normolipidemic subjects (Lai, *et al.*, 2012; Vissers, *et al.*, 2000).

Other trace elements in brown rice like potassium was reported involving in body metabolism, muscle growth and cardio activity. Meanwhile, manganese was reported to be involved in activity of normal functioning of the brain and nerves while copper plays a role in enzyme production for normal body function (Jiang, *et al.*, 2008).

2.7. Dietary Fibers and Its Roles

The main components of dietary fiber are derived from the cell walls of plant-origin food. It includes cellulose, hemicellulose and pectin (the non-starch polysaccharides). Even though lignin is a non-carbohydrate component of the cell wall, it is also categorized as dietary fiber (NCCFN, 2005). According to American Association of Cereal Chemists (AACC), dietary fiber is defined as 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 fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances (waxes, cutin, and suberin) which exhibit beneficial physiological effects such as laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation (Dietary Fiber Definition Committee, 2001).

Food sources of dietary fiber are fruits, vegetables and whole grains products. There are more than 3% dietary fiber present in nuts, legumes and high fiber grain which composed of pectin, hemicelluloses and cellulose.

Brown rice consists of more insoluble dietary fiber than soluble dietary fiber. Li and colleagues (2002) found 2.89g/100g of insoluble fiber and 0.44g/100g of soluble fiber in cooked long grain brown rice. Total dietary fiber (TDF) of the brown rice was 3.33g. It was considered a good source of dietary fiber as its TDF more than 1g/100g. (Li, Andrewsw and Pehrssonw, 2002).

According to Malaysian Dietary Guidelines (NCCFN, 1999), 20-30 g of dietary fiber per day is recommended for all age groups. It is recommended that TDF intake of more than 25 g per day whereas non-starch polysaccharides intake is recommended to be more than 20 g per day for the prevention of diet related chronic diseases (FAO/WHO, 2004). Malaysian Dietary Guidelines also recommended whole grains products should be half of the total daily carbohydrate intake.

Dietary fiber has been recognized to exhibit beneficial effects in health and disease. It is resistant to digestion and absorption in human body and pass through the small intestine until the large intestine to carry out fermentation. Fermentation in large intestine gives positive impact to physiological health (NCCFN, 2005).

There are countless benefits from dietary fiber diet such as increasing fecal bulk, reducing transit time of fecal material through the large intestine, increasing frequency of defecation, improving regularity of defecation, reducing hardness of stools, lowering colonic pH, encouraging intestinal microflora growth and change in intestinal microflora species distributions (Dietary Fiber Definition Committee, 2001).

2.8. Factors That Affect the Selection of Rice by Consumers

A recent study on Malaysian's demand for rice found that consumers would select regular or normal rice as their staple food rather than fragrant or brown rice (Hanis, *et al.*, 2012). Survey that was conducted in Klang Valley stated that rice consumers purchased rice based on quality of rice, availability, price (price indicates rice quality), flavor, aroma and whiteness (Abdullahi, Zainalabidin and Ismail, 2011). It is supported by a survey which observed Malaysian rice consumers preferred high quality varieties of rice as per capita income increased (Yeah, 2008).

A study also observed that Malay community was concerned about price changes in rice. The Malay community was expected to increase rice consumption when per capita income rise (Shenga, *et al.*, 2008).

Zhang and colleagues (2010) conducted a study on awareness and acceptance of brown rice among Chinese population. They indicated that several factors of low brown rice consumption were texture, taste, colour, price, tradition, brand preference, refusal to change previous dietary habits and availability. However, the willingness to change increased after brown rice substitution trial and acknowledgement of its nutritional value (Zhang, *et al.*, 2010). Thus, more comprehensive investigation on brown rice chemical composition and nutritional value should be conducted in Malaysia to convince rice consumers increasing their brown rice intake.

2.9. Association between White Rice and Non-Communicable Diseases

White rice has been a major staple in many countries worldwide. It was suggested an association between rice consumption and non-communicable diseases like T2DM (Hu, *et al.*, 2012) and CVDs (Ma, *et al.*, 2006). Some studies observed high dietary glycemic load (GL) and GI were positively associated with T2DM and several metabolic risk factors in Japanese female and Indian population. Many studies done on metabolic risk factors were insulin resistance, high fasting glucose, high serum triglyceride, and low HDL-C level (Murakami, *et al.*, 2006; Radhikaa, *et al.*, 2009; Villegas, *et al.*, 2007).

In terms of GL and GI, white rice is categorized as high GI food (Villegas, *et al.*, 2007). According to international table of GI and GL values 2008, GI of white rice was 64±7 (Foster-Powell, Holt and Brand-Miller, 2002). Basically, GI represents degree of food producing a high peak in postprandial blood glucose and overall blood glucose response during the first 2 hour after consumption compared to reference food (Jenkins, *et al.*, 1981).

The GI measures carbohydrate quality of a serving of food whereas GL of food indicates the carbohydrate quantity of particular serving food and GI value of the food. High GL indicates greater elevation in blood glucose and in the insulinogenic effect of the food (Foster-Powell, Holt and Brand-Miller, 2002).

Recent meta-analysis of prospective cohort study showed a positive association between white rice intake and increased risk of developing T2DM. It was more significant in Asian compared to western rice consumers. Together with a dose-response analysis, it expected that risk of T2DM increased about 11% with each serving of white rice per day (Hu, *et al.*, 2012).

The result was consistent with another large-scale population-based cohort study in Japanese women and men. In the study, subjects who consumed ≥300 g rice per day increased risk of developing T2DM 1.8-fold greater than subjects who consumed less than 200 g rice per day (Villegas, *et al.*, 2007).

Nanri and colleagues (2010) observed a high intake of rice was associated with low intakes of dietary factors that linked to lower risk of T2DM like decaffeinated coffee, magnesium and calcium. Hence, they suggested white rice consumption might independently affect development of T2DM (Nanri, *et al.*, 2010).

High intake of white rice was also found to be associated with increased risk of dyslipidemia in Korea population (Song, *et al.*, 2012). A study stated long-term high refined carbohydrate intake is associated with an increased risk of hyperlipidemia. It was found that there is an inverse association between high refined carbohydrate intake and TC, LDL-C and HDL-C. Moreover, GI was found to be related with high serum triacylglycerol level while GL is associated with TC and LDL-C levels. High triacylglycerol and low HDL-C are risk factors of coronary heart disease, T2DM and metabolic syndrome (Ma, *et al.*, 2006).

Established risk factors for stroke were found to be diabetes and hyperlipidemia. Thus, increased white rice consumption might be related to ischemic stroke (Liang, Lee and Binns, 2010).

2.10. Cooking Methods for Rice

Cooking had been reported to increase water content of rice from 15% to 65%, and change gelatinization of starch. Rice becomes softer due to water absorption into rice after starch crystallization and formation of bond between starch and water molecules (Kasai, *et al.*, 2005). This phenomena is known as complete starch gelatinization which involves change in physical, chemical, and nutrition properties of starch as well as diffusion of water and heat, swelling, rheological behaviour, viscosity, susceptibility to enzymatic digestion and deformation of original starch products (Bhattacharyya, *et al.*, 2004).

Therefore, cooking enhances digestibility of starch, wholesomeness, and texture of rice. Different cooking methods present different heat transfer characteristics and cause difference in the rate of digestion and quality of cooked rice. Studies stated that quality of cooked rice could be determined by textural profile and sensory evaluation (Kim, Eun and Rhee, 1998; Kim, *et al.*, 1987; Kim and Kim, 1998).

The preference of rice texture and cooking methods varies in different countries. For example, western rice consumers favour in long grain, light, fluffy or slightly dry fully cooked rice. On the other hand, Indian community would like to select medium grain, fluffy, light and fully cooked rice. Generally, Asians cook rice in measured water while western people prefer boiling technique (Juliano, 1982).

Cooking duration, temperature and water-to-rice (W/R) ratio affect texture of cooked rice (Tribeni-Das, *et al.*, 2006). It is supported by a recent study which proved moisture content of rice cooked in excess water was higher than rice cooked in optimal water (Yahyaa, Fryera and Bakalis, 2011).

Interestingly, cooking times and W/R ratio of rice cooking treatments were inconsistence. Some cooking duration was depended on the variety and type of rice and conditions for each individual study. The most basic rice cooking methods are excess method (rice cooked in large amount of water and drained) and oriental method (rice cooked in measured amount of water until all water is absorbed by rice) (Crowhurst and Creed, 2001). In addition, oriental method includes both simmering and steaming techniques.

Steaming is one type of cooking method generally used in some countries especially China to cook rice. There has been 3000 years of history for Chinese to use steamers (Bin and et al, 2011). Both bamboo steamer and electric metal steamer are two common basic utensils used for steaming rice (Li, 2003).

In a sealed, moist environment, steaming cooks or softens food in an even temperature without exposing food to dry and intense heat by using natural convection heat (liquid or steam) which is migrating in air. Food doesn't contact with heat source (Bin and et al, 2011). Steamed glutinous rice served with meat in bamboo joint is one of the traditional dishes in Malaysia (Li, 2003).

Steaming retains most of food nutrients because the nutrients are avoided against leaching away into the water (Bin and et al, 2011). Steaming and boiling reduce starch as sugar is highly soluble in water but retain total dietary fiber (Kumar and Aalbersberg, 2006). It is also common in East Coast of Malaysia especially in Kelantan state. Steamed rice or known as '*Nasi Kukus*' is consumed by Kelantan local people accompanied with savoury fried chicken, beef, squid curry, *ulam* (Malay term for raw vegetables) or other Malay dishes.

Excess method, which is boiling, is food cooking treatment at 100°C and a combination of leaching and chemical destruction (Alajaji and El-Adawy, 2006). It is widely used in rural areas and some institutions like hostels, prisons, hospitals, commercial canteens, religious places, schools, hotels, etc (Singhal, *et al.*, 2012). For other food like legumes, boiling reduces amount of fat, ash and vitamin B complex (thiamin, riboflavin, niacin, pyridoxine) and influences composition, anti-nutritional factors, flatulence factors of legumes because food is cooked in water and thereby nutrients leach into the cooking water (Alajaji and El-Adawy, 2006). Appearance of food is also distorted as excess water is absorbed (Tan, *et al.*, 2011).

In table of nutrient-retention factors, excess method retains 75% of thiamin, 90% of riboflavin; oriental method retains 80% of thiamin and 90% of riboflavin (Nutrient Data Laboratory, *et al.*, 2007).

2.11. Sensory Profile of Rice

Positive relationship between acceptability and preference of Ghana's consumers and the sensory rice attributes such as stickiness, rice odour, creamy flavour, sweet taste, uniform appearance whitish and yellow was reported previously (Tomlins, *et al.*, 2005). In another test, rice that was highly preferred by people was white, with pleasant aroma, pleasant taste, less tenderness, cook moist and did not become hard upon cooling (Shabbir, Anjum and Nawaz, 2008). Factors of low brown rice consumption are texture, taste, colour, refusal to change previous dietary habits, availability price, tradition, and brand preference. In fact, preference of rice consumers on rice can be assessed by sensory properties like odour, flavour, aroma, taste, appearance, tenderness or firmness, springiness, chewiness, adhesiveness and cohesiveness etc (Mohapatra and Bal, 2006; Shabbir, Anjum and Nawaz, 2008; Tomlins, *et al.*, 2005).

A preliminary study showed that sweet taste was the main positive flavour attribute that prominent varieties grown and traded to and within Southeast Asia whereas some important textural attributes that distinguished cooked rice were springiness, stickiness, roughness and slickness of the surface of the grain (Champagne, *et al.*, 2010). Sensory evaluation and texture profile analysis are common tests to evaluate sensory properties of brown rice (Daomukda, *et al.*, 2011; Ebuehi, Ikanone and Nwamadi, 2004; Heinemann, Behrens and Lanfer-Marquez, 2006; Mohapatra and Bal, 2006).

CHAPTER 3: MATERIALS AND METHODS

3.1. Research Design

This study was an experimental study which consisted of a control group and 3 experimental groups. The control sample was commonly consumed local white rice while the experimental samples were commercially available unpolished local brown rice from different varieties. This study compared proximate composition, dietary fiber content, texture profile and sensory acceptability of brown rice after cooking by different techniques.

3.2. Sample Collection

Four samples of long grain *indica*-type rice (*Oryza sativa L*) (1kg each) in which three sample of brown rice and a sample of white rice were purchased from Giant Hypermarket and Pasar Siti Khadijah in Kota Bharu, Kelantan. The identity of *indica* variety was confirmed by the supplier companies. Rice sample was categorized based on dietary fiber content and texture. R1 was local white rice favoured by local rice consumers, served as control. Table 3.1. shows different varieties of the selected rice samples.