PHYSICOCHEMICAL CHARACTERISTICS OF DIFFERENT RICE VARIETIES FOUND IN SABAH

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DECLARATION

I hereby declare that this dissertation is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

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ABSTRACT

Five different rice varieties found in Sabah (White rice, Red rice, Black rice, Brown rice and Aroma rice) were evaluated for physicochemical characteristics. The relationships between different characteristics were determined using Pearson correlation. Different varieties showed significantly variations in their physicochemical characteristics. Thousand grains weight, length–breadth (L/B) ratio, and moisture content varied between 15.30 g to 20.90 g, 2.18 to 3.33, and 12.30% to 16.40%, respectively among the various varieties. Minimum cooking time, water uptake ratio, gruel solid loss, and elongation ratio were found within 21.97 min to 47.20 min, 2.30 g g^{-1} to 3.51 g g^{-1}, 6.02% to 13.62% and 1.25 to 1.65 respectively. Brown rice showed a lower elongation ratio and water uptake ratio, and a higher cooking time than the other rice varieties. The water uptake and elongation ratio of rice kernels showed negative correlation with cooking time, with a correlation coefficient of -0.960 and -0.900 respectively ($P \leq 0.05$). Starch content, starch swelling power (SSP), and amylose content (AC) of studied rice varieties varied between 33.73% to 64.98%, 9.31 g g^{-1} to 13.01 g g^{-1} and 10.83% to 14.93% respectively. Protein, phosphorus (P), sodium (Na), potassium (K), magnesium (mg) and copper (Cu) contents ranged from 13.13% to 24.60%, 19.95 mg/100 g to 27.60 mg/100 g, 74.98 mg/100 g to 627.17 mg/100 g, 68.40 mg/100 g to 126.73 mg/100 g and 0.57 mg/100 g to 1.63 mg/100 g, respectively among different rice varieties. The highest contents of these elements were observed in Red rice, Black rice and Brown rice. The result obtained showed that the traditional rice (Red rice, Black rice and Brown rice) found in Sabah had the better physicochemical characteristics and higher nutritional value as compare to cultivated White rice and Aroma rice.

CIRI-CIRI FIZIKOKIMIA BAGI VARIETI BERAS BERLAINAN YANG DITEMUI DI SABAH

ABSTRAK

Lima jenis varieti bera berlainan yang ditemui di Sabah (Beras putih, Beras Merah, Beras Hitam, Beras Coklat Dan Beras Wangi) telah dinilai dari segi ciri-ciri fizikokimia. Hubungan antara ciri-ciri yang berbeza ditentukan dengan menggunakan korelasi Pearson. Varieti yang berbeza menunjukkan variasi yang signifikan dalam fizikokimia mereka. Berat seribu bijih, nisbah panjang lebar (P/L), dan kelembapan di antara pelbagai jenis beras adalah berbeza antara 15.30 g hingga 20.90 g, 2.18 hingga 3.33 dan 12.30% hingga 16.40% masing-masing. Minima masa memasak, nisbah serapan air, kehilangan bubur padat, dan nisbah elongasi berbeza antara 21.97 minit hingga 47.20 minit, 2.30 g g^{-1} hingga 3.51 g g^{-1}, 6.02% hingga 13.62% dan 1.25 hingga 1.65 masing-masing. Beras Coklat menunjukkkan nisbah pemanjangan dan nisbah serapan air yang lebih rendah, dan minima masa memasak yang lebih tinggi berbanding dengan jenis beras yang lain. Nisbah serapan air dan nisbah pemanjangan beras berkorelasi negatif dengan masa memasak, dengan pekali korelasi -0.900 dan -0.960 masing-masing ($P \leq 0.05$). Kandungan kanji, daya pembengkakan kanji, dan kandungan amilosa berbeza antara 33.73% hingga 64.98%, 9.31 hingga 13.01 g g^{-1} dan 10.83% hingga 14.93% masing-masing. Kandungan protin, fosforus, natrium, kalium, magnesium dan kuprum adalah 13.13% hinnga 24.60%, 19.95 mg/100 g hingga 27.60 mg/100 g, 74.98 mg/100 g hingga 627.17 mg/100 g, 68.40 mg/100 g hingga 126.73 mg/100 g dan 0.57 mg/100 g hingga 1.63 mg/100 g masing-masing. Beras Merah, Beras Hitam dan Beras Coklat mempunyai kandungan mineral yang lebih tinggi berbanding dengan beras yang lain. Keputusan yang diperolehi menunjukkan bahawa beras tradisional (Beras Merah, Beras Hitam dan Beras Coklat) yang ditemui di Sabah memiliki sifat fizikokimia yang lebih baik dan nilai gizi yang lebih tinggi berbanding dengan Beras Putih dan Beras Aroma.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

AC	Amylose content
ANOVA	Analysis of variance
DOM	Degree of milling
FAO	Food and Agriculture Organization
GT	Gelatinous temperature
HRY	Head rice yield
IRRI	International Rice Research Institute
L/B	Length/Breadth
MC	Moisture content
SSP	Starch swelling power
TGW	Thousand grain weight
USDA	United State Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Foreword

Rice (*Oryza sativa L.*) has been the major staple food in the world, especially Asian countries since ancient time. Generally, rice is unique due to the whole grain is eaten exclusively by human in contrast with other cereal grains such as wheat, barley and sorghum. It feeds more than one third of the world's population by supplying high value of carbohydrate and consisting of more than 50% of the human's daily calories intake (Anjum *et al.,* 2007).

Rice is very rich in carbohydrate. Although rice has a relatively low in protein content but still sufficient to sustain the daily needs for an adult. Moreover, rice can help to overcome malnutrition problem with small amounts of minerals. Minerals present in rice like potassium, manganese, iron and zinc play an important role in body regulatory functions (FAO, 2004). Besides just being as food, rice has the potential to alleviate poverty and hunger twice as compare to other agricultural products.

Among the cereals, rice has a great diversity with more than 120,000 different varieties (IRRI, 2008). All the varieties can be grouped into two sub-species: Japonica and Indica (Khush *et al.,* 2000). Even though there are many rice varieties to be found in the market, the preferences varied from one country to another depending on the consumer preference or the preference in the market. Some of them will prefer milled-white rice while other likes brown rice or Aroma rice. Some country will have great demand on long-grain rice while other prefers short-grain rice.

Like other countries, rice is also important for Malaysian. Rice plays a crucial cultural role in Malaysia beyond providing nourishment. For thousands of years, it has shaped the cultures, economies and diets of many regions in Malaysia. It plays an important role as the essence of Malaysian life. In Malaysia, each ethnic cuisine has developed individual use of rice. For example, rice is cooked as desserts which known as "kuih-muih" for Malayan. Other than that, rice is ground into flour for making "kuih bakul" by Chinese during celebration of Chinese New Year. Rice wine is produced by Kadazan and Dusun ethnics through fermentation. These unique cultures of rice usage in Malaysia have been kept until today from one generation to another generation.

Government has put huge effort in increasing the rice production to fulfill the local demand. Even so, it is unable to meet the huge demand and has to import from neighboring countries such as Thailand, Vietnam and Philippine. But, rice production in Malaysia is indeed gradually increasing from 2,169,000 tonnes in year 2000 to 2,354,000 tonnes in year 2008 (USDA, 2009). Rice produced in Malaysia varies significantly especially traditional rice in Sabah. Traditional rices in Sabah market show variations in colour such as white, brown, red and black. Traditional rices in Sabah have largely contributed in the rice market but they have not yet been documented. Therefore, it is important to have a proper study and research on these rice varieties.

Generally, rice in Sabah is grown by farmers in small farm size of one hectare or less. Certified rice seeds approved by the government normally are a luxury item that is beyond the farmer's financial ability and what they can afford is the traditional seeds that sold in the market or seeds they collected during harvesting. Due to small scale of cultivation, these rice seeds have not yet been proven on their eating and cooking quality. However, we cannot deny their quality since they still have a foothold in this competitive market. This proved that the quality of those traditional varieties are accepted and preferred by the local consumers. Therefore, the traditional rice varieties should own a chance to prove their quality.

With the rapid economic growth in Malaysia, consumers are becoming wiser in their choice of quality of rice. The quality of rice becomes the choice determinant factor. Many countries become self-sufficiency in rice production during this few ten years and starting involve in global market. The competitiveness of rice export among these countries becomes more drastic and again verifies the importance of rice quality. Therefore, it is necessary to understand the factors contributing to the quality of rice in order to meet the requirement of consumer.

There are many varieties of rice and each type has its own characteristics. Unlike other cereals, rice is consumed as a whole grain. Therefore, the physical appearance of rice such as size, shape and colour are of utmost importance. However, quality of rice does not only involve the physical appearance, rather it encompasses both the chemical and cooking properties. In conclusion, physicochemical characteristics of rice are the determinant factor. This fact has been proved from previous studies and researches (Singh *et al.*, 2003; Singh *et al.*, 2005; Yadav *et al.*, 2007). Present study is designed to access the physicochemical characteristics of Sabah varieties to better understanding for the consumers and world exporters.

1.2 Justification

Determination for rice quality is one of the common problems faced by the consumer (end users) especially during the purchasing of rice. Consumers basically purchase their rice based on basic visual observation which show low awareness on rice quality. Lacking of understanding regarding the essential factors which determined the rice quality cause the consumers to make the wrong judgment and end up buying low quality of rice. Therefore, this study may lend a hand to consumer by providing them some rice quality indicator's recommendation. With comprehend on those quality indicators, consumer welfare can be satisfied easily by consuming high quality of rice.

Nowadays, low quality rice still can be found easily in local market. This phenomenon is caused by the lacking of rice quality measurement and standard to monitor the quality assurance and food security of rice production. Variation in rice quality might be due to the lacking of inspection and supervision under the standard quality assurance system. Therefore, a locally suited quality control system should be established based on the results in this study. Consequently, all the rice produced which undergoes the strict regulation can be an assurance of the quality.

Traditional rice varieties which place a foothold in the local market of Sabah and serve the capability in accomplishing consumer satisfaction for rice quality but they are still not been documented so far by government. Therefore, this study help to discover the physicochemical characteristics of those rice varieties in term of verifying their quality and set foot on the way to be certified by government. As certified rice, the rice will earn more attention from government that they will strive to ensure the success of the rice production in Malaysia.

Traditional rice in Sabah is usually grown by farmer in small scale basis. Those rice varieties only been recognized by local people in the particular rural local market. Traditional rice production will remains unchanged due to the similar demand in the market. This is the time to publish and recommend the traditional rice in Sabah to other places as well as other countries. Once the rice varieties have been certified for their quality, then it can be market nationally or globally where the consumers had higher awareness on rice quality. The increasing demand on traditional Sabah's rice will increase farmers' income and profits as the rice production and yield is getting higher. On the other hand, Malaysia will become famous in international trade by supplying high quality of rice.

1.3 Objective

The objective of this study is to study the physicochemical characteristics of rice varieties found in Sabah.

1.4 Hypothesis

H_0: There are no differences in physicochemical characteristics among the rice varieties.

H_1: There are differences in physicochemical characteristics among the rice varieties.

CHAPTER 2

LITERATURE REVIEW

2.1 Rice

Rice plant (*Oryza sativa L.)* belongs to the tribe Oryzae under the sub-family Pooideae in the grass family Gramineae (Poaeae) (Khush *et al.,* 2000; Sparks, 2004). Rice is one of the most essential cereals and commercially more than two thousand varieties of rice are grown throughout the world (Deepa *et al.,* 2008). Rice is well-off genetic diversity by thousands of varieties grown throughout the world. In its natural un-milled state rice comes in many different colours, including brown, red, purple and even black. These colourful rice varieties are often prized for their health assets (FAO, 2004).

Rice is one of the leading food crops of the world and is a staple food of around one-half of the world population (Singh *et al.,* 2005; Yu *et al.,* 2010). Rice is the major staple food for 17 countries in Asia and the Pacific, nine countries in North and South America and eight countries in Africa. Rice supplies 20% of the world's dietary energy and 30% of the dietary energy for the Asian countries such as Malaysia, Indonesia, Philippines and China (FAO, 2004).

2.2 Types of Rice

The genus Oryza has two cultivated and twenty-one wild species. The cultivated rice, *Oryza Sativa* is grown all over the world. While for the African cultivated rice, *Oryza glaberrima* is grown in West Africa on a small scale. From its subtropical origins rice is now available between 55°N in China and 36°S in Chile. It is able to grown under diverse environmental conditions such as irrigated, rain-fed lowland, rain-fed upland and flood prone ecosystems. Besides that, human selection and rice adaptation to diverse environmental conditions has resulted in numerous varieties. Moreover, cultivation and farmer selection for centuries under varied growing conditions has then resulted in a myriad of rice varieties. It is estimated that about 120,000 distinct rice varieties exist in the world after removing duplicates. About 80,000 of them are preserved in Genetic Resources Center of International Rice Research Institute (IRRI). China has about 40,000 varieties and India about 25,000 varieties in the gene banks. And other countries have the rest collections (Khush, 1997).

Oryza sativa varieties can be separated into two subspecies, the indica and japonica. Their origin showed as the result of selection by human in the process of domestication and selection of the wild rice under different environmental conditions. From the time 40 years ago, indica and japonica rice were considered by most rice scientists to be the most ecogeographic races. As hybridization between the groups continues, perhaps even that distinction will disappear, because of any of the identifying japonica and indica characteristics can be relocated in either direction through crossing and selection (Robert, 1979; Virmani, 1994).

2.2.1 Indica and Japonica

The indica rice varieties grown throughout the tropics, exhibit little tolerance to cold temperatures and respond in grain yield only to low applications of fertilizer. It is considerable drought tolerance and resistance to insect and disease attack. In general, the grains of indicas are medium-long to long, and medium to high content of amylose, causing the cooked rice to be dry and fluffy and to show little disintegration during cooked (Robert, 1979; Khush *et al.,* 2000).

Japonica rice varieties grow throughout the temperate countries such as Japan, Italy, Portugal and Spain. They are generally resistant to water-lodging and are more nitrogen responsive in their yield. Japonica has lower disease and insect resistance as compared to indica type. Generally, the grain is shorter and wider in its size and shape. The amylose content of the Japonica is lower, and this will result the rice stickier and glossier during cooking. The grains tend to disintegrate if boiled in too long period of time (Robert, 1979; Khush *et al.,* 2000).

The differences between indica and japonica were studied by Toriyama *et al.* (2005). Cooked indica rice is generally hard but not sticky. However, Japanese people are more favor on japonica cooked rice because of its moderate elasticity and stickiness. It is normally said that hardness and stickiness of cooked rice are influenced by the amylase content in rice. Japonica rice has lower amylose content and moderate elasticity and stickiness.

2.3 Rice in Malaysia

Rice (*Oryza sativa L.*) or nasi is the basic food of Malaysia and the most important source of employment and income of the rural population. As Asian rice demand is projected to increase by 30% in 2010, a sustainable approach of rice production has become important. In order to fulfill the rice demand for the growing population and with the target rice self-sufficiency of 65%, the government has to increase its rice productivity (Najim *et al.,* 2007). Currently, the self-sufficiency level of rice in Malaysia is about 75% (Vaghefi *et al.,* 2011).

Grain elongation, amylose content and aroma are key determinants of high quality rice varieties (Golam *et al.,* 2004). There is an increasing demand for quality rice in domestic markets. Almost all aromatic rice is imported, of which the majority are from Thailand and India. Many of our traditional rice varieties have aroma but there was only little effort to utilize the trait from such varieties. Malaysian rice breeders have already started to breed for high quality rice, where grain elongation, amylose content and aroma are major components in the special high quality breeding programme (Mohamad *et al.,* 2008).

Worldwide, there are more than 120,000 different rice varieties (IRRI, 2008), although only small number offers quality acceptable to be grown commercially in Malaysia. The rice germplasm collection at the Rice Genebank (Malaysia) stands at 11,470 registered accessions (Mustapha, 2007).

2.4 Nutritional Value

Rice has been considered as the best staple food among all cereal groups. It is a starchy staple food, which gives a large portion of dietary energy for around 90% of Asia population. White and brown rice contains about 90% and 75 to 85% carbohydrates, respectively. It has higher digestibility, biological value and protein efficiency ratio owning to presence of higher concentration (~ 4%) of lysine. Minerals like magnesium, phosphorus and calcium are present along with some traces of iron, zinc, copper and manganese. Mineral components were significantly higher in brown rice as compared to white rice (Shabbir *et al.,* 2008).

Many minerals are vital for body normal metabolic functions and are necessary components in a balanced diet. Calcium, phosphorus, sodium, potassium, and magnesium are required in large quantities and iron, copper, manganese, and zinc in smaller amounts. However, the ability of plants to assimilate minerals may vary with regard to variety and environmental conditions (Swain *et al.*, 1977; Fink *et al.,* 2008).

In addition to being a rich source of dietary energy, rice is a good source of thiamine, riboflavin and niacin. Unmilled rice contains a significant amount of dietary fiber. The amino acid profile of rice shows that it is high in glutamic and aspartic acid, while lysine is the limiting amino acid (FAO, 2004).

2.5 Rice Quality

Grain quality includes not only the traditional physical and visual properties of the rice grain but also cooked rice texture as indexed by apparent amylase content, alkali spreading value (index of gelatinization temperature), gel consistency, actual texture measurement of cooked grain, and protein content (nutritional value). Texture measurement is proceed primarily to verify the classification of amylose, but instrument methods are not sensitive enough to differentiate cooked rice within the same amylose type, as do sensory evaluation and processing (IRRI, 1991).

In many regions of the world, rice is the most important part of the human diet, so the consumer's daily bowl of rice needs to be safe and of good quality. In 1995, the Codex Alimentarius Commission agreed to adopt safety and quality criteria for the rice that is produced for human consumption (Codex Standard for Rice). These standards for rice are accepted by the World Trade Organization (WTO), so the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) take care to ensure that they have a sound scientific basis (FAO, 2004).

Grain quality in rice is very difficult to define with precision as preferences for quality vary from country to country. Few people realize its complexity and the various quality components involved. The concept of quality varies according to the preparations for which grains are to be used. Although some of the quality characteristics desired by growers, millers, and consumers may be the same, each may place different emphasis on various quality characteristics. For instance, the miller's basis of quality is dependent upon total recovery and the proportion of head rice and brokens on milling. Consumers base their concept of quality on grain appearance, grain size and shape, behavior upon cooking, and the taste, tenderness, and flavor of cooked rice (Graham, 2002).

Rice quality is considered to have two general aspects. First are the milling, cooking, and processing qualities, which refer to suitability of the grain for a particular end-use. The second aspect is the physical quality, which means cleanliness, soundness, and being free from foreign materials. Usually, physical quality and milling, cooking, and processing qualities are interrelated in that certain market grades of rice are more suitable than others for consumer products (Toriyama *et al.*, 2005).

Rice forms an integral part of the culinary tradition for many cultures. Different cultures have different preferences regarding the taste, texture, colour and stickiness of the rice varieties that they consume. For example, dry flaky rice is eaten in South Asia and the Middle East; moist sticky rice in Japan, Taiwan Province of China, the Republic of Korea, Egypt and northern China; and red rice in parts of southern India. Many countries have signature rice recipes, such as sushi, fried rice, curry, paella, risotto, pancit, and beans with rice. There are also many sweets and candies made from rice (FAO, 2004).

Rice has a great diversity in its genetic background, amylose content, grain shape, and cooking quality. Varietal properties such as grain size, shape, thousand-kernel weight, hardness and bulk density affect the grain quality (Yadav *et al.,* 2007). The cooking quality of rice is determined on the basis of the variety and its physicochemical properties, but mainly the amylose content (Sujatha *et al.,* 2004). Shabbir *et al.* (2008) also had same conclusion on rice quality. The consumers are interested in to get rice of good cooking and eating quality. These characteristics are largely depending on the physico-chemical properties of starch, which make up 90% of milled rice. Other important characteristics like apparent amylose content (AC), water absorption ratio, volume expansion ratio and final starch gelatinization temperature (GT) collectively determine cooking and eating qualities of rice.

2.6 Physicochemical Characteristics of Rice

2.6.1 Appearance

Rice grain colour, size and shape are important criteria to understand the physical properties of rice (Deepa *et al.,* 2008). As rice is consumed and processed in whole kernel form, the physical attributes of the intact endosperm are the foremost importance for its market price all the time. The uniformity in physical dimensions of rice, such as length, breadth, shape and weight, also affect its market value (Virmani, 1994).

The appearance of rice is the focus point of consumers. Rice grain appearance depends on the size and shape of the grain and translucency and chalkiness of the grain. The physical dimensions of rice grains are very take seriously to those engaged in the many facets of the rice industry. Rice varieties objectively classified into grain-type categories based upon two physical parameters: length and shape. Length is a measure of the rice grain in its greatest dimension. Grain size and shape can be visually classified, and more exact measurements are needed for a more critical comparison of varieties (Graham, 2002).

2.6.1.1 Size and Shape

Grain size and shape are the first criteria that breeders consider in for the rice quality to develop new varieties for release for commercial production (Graham, 2002). Rice grain size and shape are important to consumers. This is because they determine the physical appearance and affect the cooking quality of the rice grain. In addition, rice size is important in the evolution of cereal crops because people tended to select for large seed size during the early domestication (Li *et al.,* 2004).

Rice varieties may be objectively classified into grain-type categories based on two physical parameters, the length and shape. Length is a measure of the rice kernel in its greatest dimension. While shape is determined by the length: width ratio (Khush *et al.,* 2000). Methods for measuring rice grains include of using photographic enlargers to magnify grains or simply measuring with a ruler the thickness, width and length of several rice grains placed in adjacent positions for particular measurements. Even though it will consumer longer period of time, probably it is the simplest methods for thickness, width and length determination (Luh, 1991).

The rice varieties can be classified as short grain varieties (L/B ratio less than 2.0), medium grain varieties (L/B ration less than 3.0) and long grain varieties (L/B more than 3.0) (Graham, 2002). While according to USDA (2005), rice is primarily classified according to its grain shape. The category known as long grain contains milled rice that is around three times longer than it is wide. The rice with 2.1 to 2.9 times longer than it is wide is medium grain rice. The short grain is less than two times longer than it is wide (USDA, 2005).

Preferences for grain size and shape differ from one group of consumers to another. Some of them favor short bold grains, some prefer medium-long grains, and others highly prize long slender grains. Generally, long grains are preferred in the Indian subcontinent, but, in Southeast Asia, they are more preferred on medium to medium-long rice. In temperate areas, short-grain varieties are their choice. However, there is a strong demand for long-grain rice on the international market (Graham, 2002).

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