QUALITY EVALUATION OF LOCALLY GROWN AND IMPORTED RICE IN MALAYSIA

By

RACHEL THOMAS A/P THARMABALAN

Thesis submitted in fulfilment of the requirements for the degree of Master of Science

January 2014

ACKNOWLEDGEMENTS

First and foremost, I would like to thank God for seeing me through my entire project and writing of this research. Without his grace and mercy, I would have not been able to have completed it. I would also like to express my heartfelt gratitude to my supervisor, Prof Madya. Dr. Rajeev Bhat, whose guidance in providing and generating ideas and knowledge has helped and encouraged me during the course of this research and writing of this thesis. I would also like to thank my co-supervisor Pn. Wan Nadiah for her precious contributions and support throughout my research. I would like to acknowledge the Institute of Postgraduate Studies for the funding of USM Graduate Assistant.

I would like to extend my appreciation to all the lecturers, staff and laboratory assistants for their help throughout my project.

Finally, I would like to express my eternal appreciation and heartfelt gratitude to my family especially my parents for their continuous support, understanding and love showered on me. I could not have done anything without them.

Rachel Thomas a/p Tharmabalan

January 2014

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

PAGE

LIST OF ABBREVIATIONS

AABA	α-Aminobutyric acid
AACC	American Association of Cereal Chemist
ABTS	2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid)
ADA	American Dietetic Association
AOAC	Association of Official Analytical Chemist
APC	Aerobic plate count
Aw	Water activity
BF_3	Boron trifluoride
BV	Breakdown viscosity
CFU	Colony forming unit
cP	Centipoise
$CuSO_4$	Copper sulphate
DPPH	1,1-diphenyl 2-picrylhydrazyl
EA	Emulsion activity
EFSA	European Food Safety Authority
ES	Emulsion Stability
FAME	Fatty acid methy esters
FAO	Food and Agriculture Organization
FC	Folin-Ciocalteu
$FeCl_3.6H_2O$	Ferric chloride
FRAP	Ferric reducing antioxidant potential
FV	Final Viscosity
GAE	Gallic acid equivalent
GC-FID	Gas chromatography- Flame ionization detector

GI	Glycaemic index
GRAS	Generally recognized as safe
H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
IDF	Insoluble dietary fibre
IRRI	International Rice Research Institute
KOH	Potassium hydroxide
L/B	Length to breadth
LGC	Least gelation capacity
MUFA	Monounsaturated Fatty Acid
MW	Molecular weight
N_2	Nitrogen
Na_2SO_4	Sodium sulphate
NaOH	Sodium hydroxide
OAC	Oil absorption capacity
PUFA	Polyunsaturated Fatty Acid
PV	Peak viscosity
QE	Quercetin
SDF	Soluble dietary fibre
SFA	Saturated Fatty Acid
TDF	Total dietary fibre
TEAC	Trolox-Equivalent Antioxidant Capacity
TPTZ	2,4,6-Tris(2-pyridyl)-1,3,5-triazine
TS	Total starch
US FDA	United States Food and Drug Administration

USDA	United States Department of Agriculture
UV	Ultraviolet
WAC	Water absorption capacity
WHO	World Health Organization

PENILAIAN KUALITI BERAS TEMPATAN DAN IMPORT DI MALAYSIA

ABSTRAK

Dalam kajian ini, enam varieti beras yang dipasarkan di Pulau Pinang, Malaysia (tempatan dan diimport) telah dinilai untuk komposisi proksimat, serta sifat-sifat fisiko-kimia, masakan, berfungsi dan antioksida. Antara pelbagai jenis beras yang dikaji, berat 1000 kernel adalah dalam julat 16.97-19.43 g, nisbah panjang / lebar (l / b) adalah antara 2.09-3.75, manakala ketumpatan pukal berada antara 0.81-0.86 g / ml. Secara keseluruhan, variety beras hitam mempunyai kandungan protein tertinggi (8.16%) dan kandungan lemak yang terendah (0.07%) dibandingkan dengan varieti lain. Antara semua varieti beras yang disiasat, jumlah asid lemak tepu dan kandungan asid lemak tak tepu adalah tertinggi dalam beras hitam (5.89%). Ciri-ciri berfungsi dan pempesan beras tempatan dan beras import menunjukkan perbezaan yang signifikan dalam kapasiti penyerapan air (3.82-10.86 ml/g), kapasiti penyerapan minyak (2.18-6.37 ml/g) pH (6.07-6.45) dan a_w (0.62-0.68), Aktiviti mengemulsi (5.48%) dan kestabilan (98.3%), serta kapasiti berbuih (3.98%) adalah tertinggi dalam beras pulut. Perbezaan yang ketara diperhatikan dalam parameter pempesan kanji beras terutama di waktu puncak, kelikatan puncak, kelikatan akhir dan 'setback'. Keputusan juga menunjukkan masa memasak minimum antara 10-31.67 min., adalah berkait negatif dengan kandungan amilosa ($r = -0,97$; $P \leq 0.01$). dengan beras perang mengambil masa yang paling lama. Korelasi positif turut didapati untuk kandungan amilosa dan nisbah l / b berhubung dengan pemanjangan nasi. Ciri memasak dan fizikokimia beras amat bergantung

pada kandungan amilosa. Aktiviti-aktiviti antioksidan yang telah ditentukan dengan menggunakan pelarut pengekstrak yang berbeza (100% metanol, etanol 100% dan air/air) menunjukkan ekstrak metanol menghasilkan kandungan fenolik (26.27-60.4 mg GAE/100g), FRAP (0.98-8.42 mM Fe (II) / g) dan kandungan antosianin (0.6067-116.33 mg cyanidin-3-glukosida Eq/10 g). tertinggi bagi semua sampel Keputusan aktiviti scavenging ABTS radikal kation^{+} aktiviti berada dalam julat 1.24-6.87 mM/100g TEAC untuk semua sampel beras. Mi beras (koay teow atau beras mi rata) disediakan dari Bario; telah dibandingkan dengan mi beras yang disediakan dari beras Basmati. Keputusan menunjukkan kekuatan tegangan dan modulus keanjalan mi beras berkurang dengan penyimpanan dan beras Basmati menunjukkan nilai terendah bagi kedua-dua parameter yang dianalisis (24.11 kPa dan 7.89 kPa, masing-masing). Kerugian memasak mi beras meningkat dengan storan dalam kedua-dua jenis beras dengan beras Basmati menunjukkan julat yang lebih tinggi 5.9-7.14%. Dengan mengambil kira kualiti mikrob, hitungan plat aerob serta hitungan yis dan mould, meningkat dengan ketara semasa penyimpanan. Kesimpulannya, tesis ini menunjukkan pelbagai ciri kedua-dua beras tempatan dan import di Malaysia. Selain itu, menyediakan maklumat yang mencukupi mengenai kualiti beras yang dimakan oleh penduduk tempatan adalah berguna bagi para pengguna yang mementingkan kesihatan.

QUALITY EVALUATION OF LOCALLY GROWN AND IMPORTED RICE IN MALAYSIA

ABSTRACT

In the present study, six different rice varieties marketed in Penang, Malaysia (locally grown and imported) were evaluated for proximate composition, physicochemical, cooking, functional and antioxidant properties. Among the various rice varieties investigated, 1000 kernel weight varied between 16.97-19.43 g, length/breadth (l/b) ratio was between 2.09-3.75, while bulk density varied between 0.81-0.86 g/ml. Overall, 'Black rice' variety had the highest protein content (8.16%) with lowest fat content (0.07%). Among the rice varieties, the total saturated and unsaturated fatty acid content was highest in black rice (5.89%). The functional and pasting properties of rice varieties showed significant difference in water absorption capacity (3.82-10.86 ml/g), oil absorption capacity (2.18-6.37 ml/g) with pH and a_w varying between 6.07-6.45 and 0.62-0.68, respectively. Emulsifying activity (5.48%) and stability (98.3%), as well as foaming capacities (3.98%) were highest in glutinous rice. Significant differences were observed in pasting parameters of rice starch especially in relevance to the peak time, peak viscosity, final viscosity and setback temperature. Results also showed minimum cooking time to range between 10 to 31.67 min., and is be negatively correlated with amylose content ($r = -0.97$; $P \leq 0.01$) with brown rice taking the longest time to cooked. Positive correlation was also recorded for both amylose content and l/b ratio in relation to elongation of cooked rice. These results highlight cooking and physiochemical properties of rice to be strongly dependent on their amylose content. Antioxidant activities determined

using different extracting solvents (100% methanol, 100% ethanol and aqueous/water) showed methanolic extract exhibiting total phenolics (26.27- 60.4 mg GAE/100g), ferric reducing antioxidant potential (0.98-8.42 mM Fe (II)/g) and anthocyanins contents (0.6067-116.33 mg cyanidin-3-glucoside Eq/100g) to be the highest among all samples. The results of $ABTS^{+}$ scavenging activity were in the range from 1.24-6.87 TEAC mM/100g among all rice samples. Rice noodles (koay teow or flat rice noodles) prepared from Bario rice, was compared with rice noodles prepared from Basmati rice. Results showed tensile strength and elasticity modulus of rice noodles to decrease on storage with Basmati rice showing the lowest value for both the parameters analyzed (24.11 kPa and 7.89 kPa, respectively). The cooking loss of rice noodles increased on storage in both rice varieties with Basmati rice showing higher range of 5.9-7.14%. With regard to microbial quality, aerobic plate count as well as yeast and mould counts increased significantly during storage. In conclusion, this thesis showed the various qualities of both locally and imported rice found in Malaysia. Providing adequate information on the quality of rice consumed by local population is important and useful for health conscious consumers.

CHAPTER 1

INTRODUCTION

1.1 Background

Rice (*Oryza sativa L.*) is one of the predominant staple foods for more than half of the world's population, and is consumed as whole grains after cooking (Singh *et al*., 2005; Cai *et al*., 2011). In the normal Asian diet, rice contributes over 40 to 80% of the calorie intake (Bhattacharjee *et al*., 2002). Rice is normally grown in continents like Asia, Africa and America. Depending on the geographical location, consumer preference varies based on the different varieties of rice (Azabagaoglum and Gaytancioglu, 2009; Musa *et al*., 2011).

Variations in composition and cooking quality of rice mainly depend on the genetic as well as surrounding environmental factors where they are grown (Giri and Vijaya Laxmi, 2000; Singh *et al*., 2005). Rice grain quality is reported to be influenced by the physicochemical characteristics that determine the cooking behaviour as well as the cooked rice texture (Bocevska *et al*., 2009; Moongngarm, 2010). Additionally, amylose content which can vary based on the variety, can also highly influence cooking and eating qualities of rice (Juliano, 1972; Bhattacharjee *et al*., 2002). It is also expected to be useful for minimizing fuel consumption while cooking, as the time required for cooking rice is determined. However in Malaysia, limited information is available on the quality parameters of both local and imported rice varieties.

Evaluating the nutritional qualities of rice grain has been given high priority, as it is the major cereal consumed in most of the developing countries (Tan *et al*.,

1999; FAO, 2004; Jiang *et al*., 2005). As the demands for rice continuously grow due to the increase in population, the safety aspect of rice needs to be determined (Wogu *et al*., 2011). Grain quality needs to be preserved when it comes to long term storage, hence microbiological counts should be considered. Standards have also been established by various bodies (Food Standards Australia and New Zealand, 2008) regarding the safe limits of microbial population in rice grains.

Determining the functional properties such as water and oil absorption capacities, emulsifying activity and stability, and foaming capacity of rice are highly significant as this properties can help in deciding whether the grains have promising usage in the food ingredient industry or not (Theerakulkait *et al*., 2006; Marerat *et al*., 2011). The processing capability and characteristic of the final product is strongly influenced by the functional properties of rice (Perdon *et al*., 2001). Rice starch is made out of two main polymers which are amylose and amylopectin which is most abundant in the endosperm. The ability of starch to gelatinize and form a viscous substance consisting of leached amylose and broken up starch granules is known as pasting (Manaois, 2009). In addition, determining the pasting properties is essential as it can aid in deciding the cooking stability, water-binding capacity and baking quality of starch (PBIP, 1995).

As functional and pasting properties tends to play a pivotal role in determining the quality of a rice based food product, it is highly essential to provide details on these parameters (water absorption capacity, oil absorption capacity, foaming capacity, least gelation concentration, emulsifying activity and stability and pasting properties) especially for the locally grown rice varieties. Additionally, since

consumers' acceptance is very important in choosing the right variety of rice when quality criteria are set, it is also important to identify and provide details on the positive aspects of local rice grain varieties.

Apart from that, there has been an escalating interest in research of natural antioxidants present in cereals, fruits and vegetables as consumer preference and awareness of the health benefits of antioxidants has been made known. The health benefits and nutritional quality of pigmented rice have been acknowledged centuries ago and is beneficial in lowering the development of chronic diseases which is associated with one's diet (Gunaratne *et al*., 2013). The beneficial effects have been related to the phenolic phytochemicals which possessed antioxidant activity. Flavonoids and phenolic acids are the frequently found phenolic compounds in whole grains (Al-Farsi and Lee, 2008). Therefore eating adequate proportions of rice is advised as it not only gives nutritional but health benefits too.

Today, consumers' expectation and demand has increased tremendously for healthy and nutritious food of traditional origin. In addition, consumers are constantly looking for novel food products wherein local produce (cereals, grains, legumes, etc) are incorporated. This has spurred food manufactures to explore and formulate new food products (with improved taste, texture and appearance) based on the local traditional knowledge available.

Rice noodles are traditionally prepared popular dish, broadly consumed in most of the South-East Asian Countries (Juliano and Hicks, 1996; Fiedler, 2009). The main ingredients for rice noodles are rice and water, mixed at appropriate concentrations. Rice noodles have a very smooth texture, soft mouth feel and are

white in colour. It is reported that adequate functional and cooking properties are essential to produce a high quality rice/starch based noodle (Chen *et al*., 2003; Cui, 2005; Purwani *et al*., 2006). As the quality of noodles (cooked or uncooked) are generally assessed by its physical (colour and texture), cooking and sensory qualities, it is highly imperative to provide these details when developing a noodle from an unreported rice variety.

1.2 Objectives

The general objectives of this research were to evaluate the quality parameters of locally grown and imported rice varieties in Malaysia. These parameters could provide vital information in identifying 'superior quality of rice' based on its physical, chemical, nutritional, microbial, functional, cooking and antioxidant properties. The specific objectives in this study were:

1. To evaluate the physicochemical of locally grown and imported rice varieties in Malaysia.
2. To determine and compare the nutritional and microbial qualities of the different rice varieties.
3. To determine the functional and cooking properties of locally grown and imported rice varieties in Malaysia.
4. To determine the antioxidant compounds from rice and their activities.
5. To produce flat rice noodles from the selected/best rice variety.

CHAPTER 2

LITERATURE REVIEW

2.1 Significance of Rice

Rice is an important cereal crop in Asia where 90% of its production and consumption originates (Hossain and Narciso, 2004). Rice can be cultivated in many different countries as long as it has a proper water source as it requires sufficient water for irrigation. Thus, rice is grown in every single continent except for Artic and Antartica.

2.1.1 Rice Grain Structure

The basic structure of rice grain can be divided into the hull (husk), bran and endosperm. The hull consists of a lemma, a palea, an awn (tail), a rachilla (grain stem and two sterile lemmas. The hull is made out of 40% crude fiber (including fiber lignin and cellulose) around 20% of the five-carbon sugars (mainly hemicelluloses) (World granary, 2011). The other 20% consists of small amount of crude protein, crude fat, and other organic compounds.

The bran is found underneath the husk and it consists of the pericarp、tegmen, aleurone layer, outer endosperm, inner endosperm and germ (Houston, 1972; FAO, 1992a). The pericarp consists of three fibrous layers of protein, cellulose and hemicellulose. The tegmen is next and inner to the pericarp

which consists of two piled tissues with arrays of fatty materials. The aleurone layer is the next layer under the tegmen. It envelopes the starchy endosperm and the embryo. In Japan, the aluerone layer is often not removed however in many other countries all bran layers are removed to give very highly polished rice (IRRI, 2011).

The endosperm contains the starch content and compromises mostly complex carbohydrates (77%). some proteins (6%), fat (0.9%) and traces of vitamins and minerals (FAO, 1992a; IRRI 2011). The embryo is the reproductive organ of the grain and it is rich in protein and fat. The germ is the life source of rice and it is rich in saturated fats, vitamin B and E (World granary, 2011).

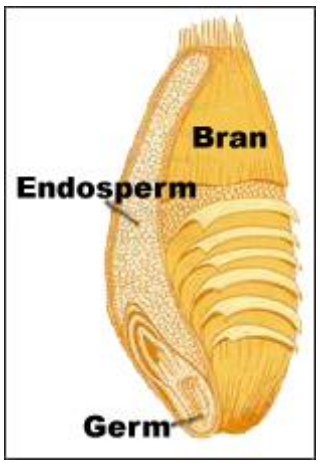

Figure 2.1 Rice grain structure
(adapted from: Teck Seng Rice mill, 2005)

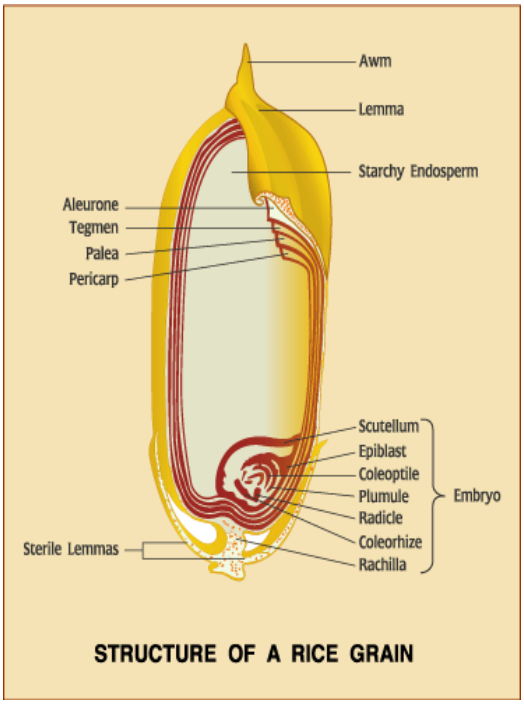

Figure 2.2 Whole rice grain structure
(adapted from: American Institute
for Cancer Research, 2007

2.1.2 Rice Production and Processing

The major rice producing countries are China, India and Indonesia, whereas the biggest exporters of rice are Thailand and Vietnam (IRRI, 2009). Thailand and Vietnam exports over 16 million tonnes of rice yearly (IRRI, 2009). The global production of rice is expected to increase to about 730 million tonnes in the year 2013 (FAO, 2013). America exports more rice, as rice consumption there is significantly lower compared to Asia. There are more than 120000 varieties of rice available worldwide, some of which are consumed only where they are grown and others are well known around the world (USA Rice Federation, 2007). *Oryza sativa,* is the more commonly cultivated species around the world and *Oryza glaberrima*, is more popularly grown in different parts of West Africa (IRRI, 2012).

The first step in rice production is the selection of a suitable variety of rice to grow that would suit the environment which it will be grown. Apart from that, the seeds selected have to have the highest possible quality in order to achieve successful rice production in terms of yield potential. Good quality seed can increase yields by 5-20%. The extent of this increase is directly proportional to the quality of seed that is being sown (IRRI, 2010).

Good seed is pure, full and uniform in size and free of weed seeds, seed-borne diseases, pathogens, insects, or other matter (IRRI, 2010). After which the seed is established in a separate nursery area where they are grown for 20-80 days before they are transplanted into the field (IRRI, 2013). The pre germinated seeds are then transferred to the wet bed. The rice is then allowed to grow and mature for about 30-45 days (depending on the variety) before it is harvested (Uprety, 2005).

Paddy which is also known as rough rice, consists of the whole rice kernel with the layers still intact. The first step in obtaining rice is harvesting of the mature paddy. Harvesting activities include cutting, stacking, threshing, cleaning, and hauling (Afzalinia *et al.,* 2002). In order to maximize grain yield, quality and decrease grain damage, good harvesting methods need to be employed. It is then followed by drying which is considered to be the most critical operation as it reduces the moisture content of rice grains to a safe level. Hence, making it suitable for storage as well as improves grain quality and minimize losses (IRRI, 2013).

After which, the paddy is cleaned to remove all impurities and foreign objects like stones, dust, soil particles, and weed seeds. The husk is then removed from clean paddy to obtain brown rice. The rice is then ready to undergo the milling process which removes the bran layer, thus converting it to white rice. White rice then undergoes the polishing process to improve its appearance by removing the remaining bran particles and by polishing the exterior of the milled kernel.

Rice milling process always creates some broken kernels which must be separated out together with the head rice based on the different lengths (IRRI, 2011). This process is known as grading. Once that is complete, rice is sorted to remove discolored, yellow and immature grains in order to add value to rice. Finally, the last step in rice processing is packing. The finished product is packed and stored to be delivered to valued customers.

2.1.3 Rice Consumption and Pricing

The major rice consumers in the world are China. India, Indonesia and Bangladesh (IRRI, 2007). However in terms of per capita basis, Brunei has the highest average rice consumption with 245 kilogram per person yearly whereas China and India consumes about 50% of the total world's consumption. Over the past decade, rice consumption has started to decrease in China and India as the population started consuming other food products and changing their diet patterns into a more western orientated meal. On the other hand, rice consumption in Europe and America has started to increase significantly over the past decade (IRRI, 2009). Various factors are said to influence rice consumption such as economic growth and urbanization (Abdullah *et al*., 2005). The consumption of rice is set to increase over the next couple of years as the world's population continue to grow, particularly in Asian countries. Among the various of rice consumed, white rice is most popular followed by brown rice, red, purple or black rice (Nanri *et al.,* 2010; Sompong *et al.,* 2011).

Rice traded internationally is one of the most misrepresented commodity stock market. This is due to the fact that there is a very low percentage of rice traded internationally. Being the staple food, there is a strong attachment for both consumers and producers in terms of ensuring financial and food security. The rice market has been identified as thin, inconsistent, disconnected and seriously distorted (Narayanan and Gulati, 2002).

Malaysia relies heavily on rice imports compared to other countries. Major exporters of rice to Malaysia are Thailand and Vietnam. As Malaysia has not been able

to meet the increasing needs for rice, plans have been put in place to ensure that Malaysia becomes independent and less reliant on imported rice. Policies have been implemented regarding rice as it plays a part in the national economy, contributes job opportunity and involvement of foreign exchange due to trading (Dano and Samonte, 2005). Subsidies, taxes and buffer stocks help control the inconsistent price of rice in the world market (Vengedesalam *et al*., 2011).

Foreign rice sold in Malaysia is more expensive than locally grown rice. A price check in the local hypermarkets showed that the price of imported rice such as Basmati, glutinous and black rice was 20-30% more expensive than locally grown rice. This is because of the import quotas imposed by various rice bodies in Malaysia. Back in the 1960's an average Malaysian typically spends about 21.5 % of their salary on rice (Ani, 1968). That is no longer the case as the average household income of Malaysians has increased in recent years. However the amount spend on rice by Malaysians are still relatively high compared to other countries such as the United States as rice sold there is almost half the price of what it is here (Musa *et al*., 2011).

2.1.4 Rice Varieties in Malaysia

Milled rice that has had its outer layers which consists of the husk, bran, and germ removed is called white rice. White rice is one of the most popular types of rice and is the staple foods in countries like Japan, Malaysia and China because it has a smooth flavour and is believed to balance well with intense and subtle locally prepared sauces or curries. White rice undergoes a polishing process which eventually leads to a white, shiny and vivid grain. Polishing is also done to avoid oil found on the outer layers of the grain from going bad, thus preventing spoilage (Montilla *et al*., 2006). White rice is believed to have long storage life and this can be extended even further if the grains are stored in air-tight containers. Consumers generally favour polish rice over unpolished rice (Babu *et al*., 2009).

Many vital nutrients are removed during the polishing process. Rice which has undergone polishing loses about 90 % of vitamin B6, 80 % of vitamin B1, 79% of fat, 67% of iron, vitamin B3 and 29% of its protein content (Abbas *et al*., 2011; Babu *et al*., 2009). Hence it is usually recommended that milled and polished white rice be enriched with vitamins B1, B3 and iron to avoid nutrient deficiencies.

Unmilled or brown rice consists of the whole kernel with its bran layer still intact. The distinct characteristic feature differentiating brown from white rice is not only the colour but also in the milling process. Generally, for brown rice, the hull is removed but with retention of bran and the germ. Brown rice is more nutritious, richer in fibre, has a mild ‘nutty’ flavour and is traditionally believed to be more ‘chewy’ than white rice. It has a shorter shelf life because of the oil present in the germ which causes it to get rancid and develop a bitter taste easily. Brown rice is not

as appealing as white rice because of its poor cooking and eating attributes (Das *et al*., 2008). Therefore, the consumption of brown rice is still relatively low, despite it being highly nutritious (Chung *et al*., 2012a). Brown rice is generally not an allergenic food as it does not contain any oxalates and purines.

Bario rice (White) is considered to be an exotic variety with a unique taste and cooking quality. Bario rice is grown at high altitudes (above 1000 m sea level) and has a high market value as it is considered to be an organic produce, with no usage of chemical fertilizers or pesticides during its cultivation (Kevin *et al.*, 2007; NST, 2012). Planting Bario rice is a very labour intensive process as it is planted and harvested without any aid of equipments and machines. Traditional methods are used for harvesting. Cooked grain has a soft texture with a mild and delicate aroma, and is longer compared to raw rice grain. The yield for Bario rice has been declining over the past decade as farmers prefer to venture into other businesses which are more lucrative. This is because the Bario rice can only be harvested once a year and it takes 6 months to grow hence making it less profitable (Naeg, 2012, Yap , 2012).

Black rice popularly known as forbidden rice, is an unmilled rice. Since the black husks are not removed, it has increased nutritional value and is considered as a heirloom variety of rice cultivated in Asia. This rice is rich in fibre and iron. Black rice is highly popular for preparing noodles, exotic desserts and sushi. Even though it is referred to as 'black rice', the colour of black rice is in fact 'deep purple to burgundy' owing to its high anthocyanin content (Xia *et al*., 2006). The colour becomes more apparent after the rice has undergone the cooking and soaking process. Black rice is slightly sweet, has an unique taste with a nut like flavour. It is

highly nutritious and is claimed to be the new super-food in the market (Daily Mail, 2010).

The cooking time of black rice is relatively high; however it can be shortened if it is soaked first. Similar to brown rice, even the black rice undergoes spoilage easily and has a short storage life. It has been reported that consumption of black rice can lead to the prevention of cancer, heart problems, atherosclerosis, and infectious diseases (Barron, 2010).

Glutinous rice (popularly known as sweet rice, origin of Thailand and Laos) is particularly preferred owing to its sticky and dense texture obtained on cooking. In addition, this rice does not contain any gluten (Wanchana *et al*., 2003). Glutinous rice is commonly used in stabilizing sauces and gravies due to its low amylose content that renders them more versatile particularly when frozen foods are considered (Juliano and Hicks, 1996). Apart from making sweet delicacies or desserts, this rice is also used by some of the Asian communities to prepare sushi and rice crackers.

There are two kinds of glutinous rice which are the white type and the black type. Milled glutinous rice is white, and it may be polished to remove the germ whereas unmilled glutinous rice can range in colour from light brown to a mix between purple and black. There was a decline in the cultivation of glutinous rice for a brief period of time due to changes in rice cultivation technique. However in the twentieth century its popularity increased again (Wanchana *et al*., 2003).

Basmati rice is characterized by its long and slender grain. This rice is cultivated mainly in India and Pakistan and possess an exquisite aroma that can be is associated with the aging process (reduction in moisture content) (Wass, 2011). Compared to most of the rice varieties, Basmati rice has good cooking properties,

soft texture, distinct scent, and good cooked elongation ratio (Bligh, 2000; Arora *et al*., 2007). Basmati rice is recommended for people suffering from diabetes as it is known to have a lower glycaemic index (British Dietetic Association, 2011). The slow releasing carbohydrates, helps limit the appetite (Jacob, 2011).

2.1.5 Problems in Rice Production

Paddy fields are the typical feature of rice farming in East, South and Southeast Asian countries. There are many problems associated with rice cultivation due to natural forces such as flash floods which then causes the paddy to drown hence forcing an increase in price, due to the supply and demand reaction (Lawrence, 2008). Drought seasons can also cause paddy fields to dry up and lower its yield. Rice is grown in many third world countries; henceforth farmers tend to use varieties which produce a lower yield and traditional methods due to the lack of awareness and funds. Rice producing countries such as India struggle with labour issues, abuse of insecticides and pesticides, scarcity of land and many other issues which vary from place to place (The Independent, 2011).

In order to increase harvest, rice is planted three times a year as compared to one huge harvest. There are many downsides associated with it as soil nutrients will be completely lost. This is because; crop rotation to replenish the soil with nutrients will no longer be practiced. Nutrients such as phosphorus, nitrogen and potassium will then be supplied by using large amounts of synthetic fertilizers to make the soil whole again. Many different organisms such as nitrogen-fixing algae, humus building agents, organisms which ward of rice pests have been identified for rice crops. Abuse of

various chemicals such as insecticides, herbicides, fertilizers has also decreased and destroyed most of these beneficial parasites and predators. Aquatic animals such as fish, frogs and many others are also affected as the water source becomes contaminated and polluted.

Certain methods have been proposed to reduce the environmental impacts cause by using large doses of fertilizers. This includes rotating crops with legumes to improve, increase and meet nitrogen requirements. Using rainy season crops and mixing it with other crops during drought season will reduce methane discharge, boost soil characteristics and obstruct growth of rice pests (Rao *et al*., 2006).

Looking from another perspective, the three fold increase in rice pricing in 2008 is not due to environmental forces but caused by the soaring increase of global oil prices which affects and increases the transportation and production cost of rice (Lawrence, 2008). Compared to other staple foods, very few countries export rice and it is usually grown for domestic consumption. Hence it is a very unpredictable crop due to the small trading market. Some rice producing countries like India, Vietnam and a few others have restricted rice exports to help combat soaring prices and inflations (Lawrence, 2008). China and India are the biggest consumers and producers of rice, which accounts for more than half of the total crop production (Khoso and Raza, 2008).

Figure 2.3 Paddy ready for harvest (adapted from: Yap, 2012)

Figure 2.4 Paddy field in Bario (adapted from: Yap, 2012)

2.2 Rice Quality

Rice quality is a compound of physical and chemical attributes which is used by a particular user for a distinct application (IRRI, 1980; Bhonsle and Krishnan, 2010). Being the major grain consumed and grown around the world, rice quality plays an important role to both consumers and rice breeders. High quality rice is more sought after worldwide Rice breeders have to develop various rice varieties to meet the demands of different international markets. There are many factors which determine the quality of rice such as its visible presentation, taste, composition and nutrition (Das *et al*., 2008). In order to improve grain quality, variety, crop management and post production has to be taken into consideration.

Based on milled rice standards in Malaysia, grade B1, which is considered the best, should contain a minimum of 95% head rice, 3% broken, 2% brewers and

there should be no red streaked grains present (Hashifah and Rohani, 1985; Afsar *et al.,* 2001). There are all together 13 grades of milled rice in Malaysia and visual manifestation is a key factor in determing the price of rice. In the Philippines, premium rice should contain less than 95% head rice, 4.9% brokens, 0.1% brewers and less than 1% for red streaked grains. In Malaysia, there should be no foreign material found in premium rice. Head rice is rice kernels which remains as a whole rice (75% or more) after milling (IRRI, 1985; Cooper and Siebenmorgen, 2005). Brewer rice is less than half the size but more than a quarter long of a full rice kernel. This happens because it has been removed from a larger milled rice kernel. Red streaked grains are milled rice kernels which still has a small portion of the bran adhering on to its surface. It is a common defect found in rice grains. The moisture content for premium rice should be equal or less than 14%.

Table 2.1 Specifications and grading requirements of A grade rice (Long grain rice)

	GRADE			
Grading Factors	**A1** Malaysian Long Super	**A2** Malaysian Long 10%	**A3** Malaysian Long 25%	**A4** Malaysian Long 45%
Head rice (minimum %)	95.00	80.00	65.00	40.00
Brokens (maximum %)	3.00	10.00	10.00	10.00
Brewers (maximum %)	2.00	10.00	25.00	45.00

		Defectives		
Damaged grains (maximum %)	0.50	2.00	4.00	4.00
Contrasting Lengths (maximum %)	2.00	6.00	10.00	10.00
Chalky and immature grains (maximum %)	2.00	7.00	10.00	10.00
Red grains (maximum %)	0.00	0.20	0.30	0.30
Foreign matter (maximum %)	0.00	0.15	0.20	0.20
Moisture content (maximum %)	14.00	14.00	14.00	14.00

(Adapted from: Afsar *et al.*, 2001)

2.3 Physicochemical Properties of Rice

There are many factors which contribute to the physicochemical quality of rice such as the milling degree, foreign material, head rice, chalkiness and a few others (IRRI, 1985). Foreign material such as stones, weed, soil, gravel, mud lumps are some of the common material found in rough rice. All these contribute to the market price of packaged milled rice. Brown rice kernel with the bran eliminated is a known dimension for milling degree. Milling degree has a strong influence on a few

feature qualities of rice such as nutritional, chemical, cooking, eating and physiochemical properties (Payakapol *et al*., 2011). The market cost and consumer acceptance of milled rice strongly depends on its usual manifestation (Rickman, 2002). The corresponding ease during the milling process to remove the bran from rice kernels is controlled by various factors such as moisture content, temperature and kernel exterior profile (Cooper and Siebenmorgan, 2005).

After rough rice undergoes milling, rice kernels which maintains 75-80% of its length is known as head rice and the remainder 20-25% is known as broken rice. The combination of head rice and broken rice makes out total milled rice. Chalkiness is described when the milled rice kernel is murky rather than being translucent. It diminishes the visible manifestation and cooking character of milled rice and is considered as a defective characteristic (Bautista *et al*., 2009). Chalky grains are more fragile and tend to break easily during milling as it has a lower density when compared to whole translucent kernels (Del Rosario *et al*., 1968; Lisle *et al*., 2000).

Rice grains can be classified according to the length and width and is used as an international standard to characterize the rice appearance, configuration and origin based on species (Rice Quality, 2012). Rice grains are generally characterized by its length into three categories which are short, medium and long. In terms of length and width, all samples must be consistent. The facts about dimensions and density of the grain can be evaluated from grain weight.

Based on the Codex Alimentarius (1995a) for rice, long grain rice has a length/width ratio of 3.0 or more with a kernel length of 6.0 mm or more and is also classified as slender. Medium grain rice has a length/width ratio of 2.0-2.9 with a

kernel length of 5.2 mm or more but less than 6.0 mm and short grain has a length/width ratio of 2.0 or less with a kernel length of less than 5.2mm. Short grain rice is usually classified as bold based on its length to width ratio. Long grain rice are usually fluffy and slender, an example being Basmati rice while short grain rice are plump and round and generally cooks sticky due to the higher starch content present. Grain quality appraisal is based on kernel shape and length to breadth ratio (Bisne and Sarawgi, 2008). Consumer acceptance varies from region to region. Long grain rice is preferred by Southeast Asians and South Asians whereas short grain rice is much preferred by the Japanese and Koreans (Suwannaporn and Linnemann, 2008).

The other physicochemical properties of rice such as gelatinization temperature and amylose content play essential roles in influencing the cooking and eating quality of rice (Pandey *et al*., 2012). Gelatinization temperature determines the time required to cook rice and is measured using the alkali spreading value. It is also the temperature where the starch granules began to swell irreversibly in hot water. Intermediate gelatinization temperature is preferred which is within the range of (70-74^{o}C) as compared to low gelatinization temperature (55 to 69.5°C) and high gelatinization temperature (74.5 to 80°C). The cooking quality of rice is affected by gelatinization temperature due to the time it takes to cook from its core to the surface (Juliano, 1993).

Rice is made out of two main polymers which are amylose and amylopectin. Based on its amylose content, rice starch could be divided into non-waxy rice starch (1.64% of amylose) and waxy rice starch (above 21-30%) (Jiranuntakul *et al*., 2011). The cooking and eating quality of rice is single-handedly controlled by its amylose

content which is directly associated with water absorption, volume augmentation and compactness of cooked rice (Juliano *et al*., 1965; Asghar *et al*., 2012). High amylose content rice (25-30%) tends to cook fluffier, absorbs more water and hardens upon cooling compared to other amylose content groups (Frei and Becker, 2003). On the other hand, low amylose content rice tends to cook moist and sticky. It breaks apart and divides upon cooling. Hence rice with intermediate amylose content (20 -25%) which corresponds to high cooking quality is much more sought after as it remains soft after cooling. (Suwansri and Meullenet, 2004; Ong *et al*., 2012). The variation in starch content in rice is mainly due to environment and genetic factors

2.4 Nutritional Quality

2.4.1 Proximate Composition

With the augmentation in world's population, the need for potential nutritional sources from plant origin has tremendously increased (Friedman and Brandon, 2001; Bhat and Karim, 2009; Abbas *et al*., 2011). Among the various nutritional contents, protein quality, minerals and fatty acids content assume importance owing to their health benefits.

Rice is a wholesome grain that fulfils majority of the recommended daily dietary requirements set by food authorities. Rice grain encompasses rich amounts of carbohydrate, fibre, protein, fat and minerals. Carbohydrate (nearly 75-85%) in rice grain provides most of the calories associated. Protein is the second highest constituents found in rice and are considered to be of good quality as it has eight of the essential amino acids. The eight amino acids detected in rice are histidine, thereonine, valine, methionine, lysine, isoleucine, leucine and phenylalanine. Whereas, minerals like iron, copper, zinc, calcium, magnesium, phosphorus and manganese are also found in adequate amounts in rice (Yousaf, 1992; Parengam *et al*., 2010). In addition, sufficient amounts of dietary fibre can also be found in rice grains (Aune *et al*., 2011). Table 2.1 shows the proximate composition of rough rice and milling fraction at 14% moisture content.

Protein is an essential constituent in a healthy diet as it helps repair and maintain cells, tissues and muscles in the body. Rice protein is easier to digest when compared to other proteins obtained from vegan sources. Rice does not increase cholesterol levels at all and has a very small percentage of fat. The American Heart Association (1988) states that rice bran oil have a higher percentage of unsaturated fat which does not increase

blood cholesterol levels. Rice bran oil has been said to prevent cholesterol synthesis and reduce serum cholesterol levels in different animal models (Wilson *et al*., 2002).

Table 2.2 **Proximate composition of rough rice and its milling fractions**

Rice Fraction	**Crude Protein (g N X 5.95)**	**Crude Fat (g)**	**Crude Fibre (g)**	**Crude Ash (g)**	**Available Carbohydrates (g)**
Rough Rice	5.8-7.7	1.5-2.3	7.2-10.4	2.9-5.2	64-73
Brown Rice	7.1-8.3	1.6-2.8	0.6-1.0	1.0-1.5	73-87
Milled Rice	6.3-7.1	0.3-0.5	0.2-0.5	0.3-0.8	77-89
Rice Bran	11.3-14.9	15.0-19.7	7.0-11.4	6.6-9.9	34-62
Rice Hull	2.0-2.8	0.3-0.8	34.5-45.9	13.2-21.0	22-34

(adapted from: Juliano, 1985)

2.4.2 Dietary Fibre

Dietary fibre is the food fraction which cannot be enzymatically degraded within the human alimentary digestive tract. The main components are cellulose and lignin, but it can also contain hemicelluloses, pectins, gums and other carbohydrates, which are not hydrolysed by human digestive enzymes (Spiller, 2001; Yoon *et al*., 2008). Total dietary fibre (TDF) is the portion which still remains after elimination of plant cell walls using either an acid or alkali solution (Wiliams and Olmstead,

1935; FAO, 1998a). TDF is important in the calculation for caloric reduction of food products which contained fibre.

Dietary fibre can be separated into two groups which are insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) based on their dispersibility in water. Both fractions, IDF and SDF have nutritional significance (Ronsivalli and Viera, 1992; Ramulu and Rao, 2003). Soluble fibre is known for its hypocholesterolemic effects whereas insoluble fibre is known for its role in reducing the risk of colon cancer (Sudha *et al*., 2007). In terms of the effects on dietary and functional needs, the ratio of soluble to insoluble dietary fibre plays a crucial role (Figuerola *et al*., 2005). The food industry has primarily agreed that the SDF/IDF ratio used in the manufacturing of food ingredients should be approximately 1:2 (Jaime *et al*., 2002; Figuerola *et al*., 2005).

Dietary guidelines advise a minimum daily intake of 25 g of dietary fibre and this corresponds to 12.5 g dietary fibre per 100 calories consumed (Marlett *et al*., 2002). Dietary fibre is normally found in food such as vegetables and fruits or introduced in the food such as bread products to improve their nutritional properties. Fibre incorporation, in frequently consumed food, could help to overcome the fibre deficit (Fernandez-Gines *et al*., 2003). One cup of brown rice provides 4 g of fibre (Jensen *et al*., 2004).

Rice bran is one of the richest in dietary fibre. It is commonly used in various health foods and can be a substitute in bakery products and breakfast cereals (Garcia *et al*., 2012, Dakhara *et al*., 2012). Food rich in fibre may reduce the levels of total cholesterol and low density lipoproteins found in plasma, which is associated to a greater decrease and excretion of bile acids (Gallaher *et al*., 1992; Katan *et al*., 2003). Regarding food carbohydrates, dietary fibre plays an important role as