COOKING QUALITY OF UPLAND BROWN RICE GROWN IN KOTA BELUD

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

CROP PRODUCTION PROGRAMME
SCHOOL OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH
2013

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL: COOKING QUALITY OF UPLAND BROWN RICE GROWN IN KOTA BELUD

IJAZAH: IJAZAH SARJANA MUDA SAINS PERTANIAN DENGAN KEPUJIAN

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ACKNOWLEDGEMENT

This dissertation would not been possible without the guidance and help from several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study. First and foremost, I would like to express my sincere gratitude to my supervisor, Prof. Madya Dr. Harpal S. Saini who was abundantly helpful and offered invaluable assistance, support and guidance. I gratefully thank all the lecturers in School of Sustainable Agriculture (SSA) especially Miss Chee Fong Tyng for her support and critical comment on this thesis. I am also much indebted to Dr. Abdul Rahim Awang for his support during my early preparation of field sampling. I would also like to convey appreciations to SSA for providing laboratory facilities and to Encik Panjiman Saidi, for his guidance during my laboratory experiments. Special thanks to families of Puan Rubisa Kindagong, Encik Salimun Kindayop, Puan Rahani binti Labi and Encik Jahim Singkui for willing to cooperate in providing sample for this study. I gratefully acknowledge Mr. Marcus Logiau for his assistance during the process of sample collection for this study. I would also like to thank both my parents. Above all and most needed, they provided me with unwavering encouragement and support in various ways. Last but not least, it is a pleasure to pay tribute to all my fellow friends for their constructive comments on this dissertation.

ABSTRACT

Some cooking characteristics corresponding to seven varieties of upland rice cultivated in Kota Belud were investigated. Gelatinization temperature (GT), amylose content (AC) and gel consistency (GC) were determined. Physical characteristics of the grain were also classified. Cooking behaviour such as cooking time, water uptake, grain elongation, volume expansion and aroma were also evaluated. The results show that variations among varieties studied exists in all cooking quality characteristics except for GT and aroma. Good correlation was found between gel consistency and amylose content ($r= -0.565$, $p<0.01$), volume expansion and amylose content ($r= 0.375$, $p<0.05$) and between water uptake and amylose content ($r= 0.554$, $p<0.00$). Surprisingly, no association can be noted for gelatinization temperature and amylose content. An interesting observation recorded was that grain length and shape seems to be related with aroma. Tambunan variety was concluded to have the most desirable trait for home cooking quality by having medium-size grain, good aroma, intermediate AC and soft texture.

KUALITI MASAKAN BERAS BUKIT YANG DITANAM DI KOTA BELUD

ABSTRAK

Beberapa ciri-ciri masakan padi huma yang ditanam di Kota Belud telah dikaji. Suhu penggelatinan, kandungan amilosa dan konsistensi gel tujuh varieti padi huma telah dikenalpasti. Ciri-ciri fizikal bijian juga telah diklasifikasikan. Ciri-ciri masakan seperti masa memasak, pengambilan air, pemanjangan bijirin, pengembangan isi padu dan aroma juga dinilai. Hasil kajian menunjukkan bahawa wujud variasi di kalangan varieti padi huma yang dikaji dalam semua ciri-ciri kualiti masakan kecuali untuk penggelatinan dan aroma. Korelasi yang baik telah dibuktikan antara gel konsistensi dan kandungan amilosa ($r= -0.565$, $p<0.01$), pengembangan isi padu dan kandungan amilosa ($r= 0.375$, $p<0.05$) dan antara pengambilan air dan kandungan amilosa ($r= 0.554$, $p<0.00$). Walaubagaimanapun, korelasi untuk penggelatinan dan kandungan amilosa tidak ditemui. Satu pemerhatian yang menarik yang dapat diperhatikan adalah bahawa panjang dan bentuk bijian seolah-olah berkaitan dengan aroma. Varieti Tambunan disimpulkan mempunyai sifat yang paling dikehendaki untuk kualiti masakan di rumah di mana varieti tersebut mempunyai panjang bijian yang sederhana, aroma yang baik, kandungan amilosa yang sederhana dan tekstur yang lembut.

TABLE OF CONTENTS

Content **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

AC	Amylose content
ANOVA	Analysis of Variance
ASV	Alkali Spread Value
BCI	Better Crop International
BE	Branching Enzyme
CGIAR	Consultative Group on International Agriculture Research
CPSS	Centre for Public Studies
DAP	Diammonium phosphate
EARWG	East Asia Rice Working Group
FAO	Food and Agriculture Organization
GC	Gel consistency
GE	Grain elongation
GT	Gelatinization temperature
IRRI	International Rice Research Institute
ISSA	International Service for the Acquisition of Agri-Biotech Application Seasiacentre
IWMI	International Water Management Institute
JAFFC	Joint Action Forum on Food Crisis
KI	Potassium Iodide
KOH	Potassium Hydroxide
L/B	Length/breadth
NaOH	Sodium Hydroxide
SSA	School of Sustainable Agriculture
UNCT	United Nation Country Team
WU	Water uptake

LIST OF FORMULAE

CHAPTER 1
BACKGROUND

1.1 Introduction

As a staple food of Malaysia, paddy production has always been given priority in the country. Endless efforts by the government are often seen through the continuous determination in sketching of new strategies to improve the paddy production. Either by introducing new cultivation technology or improved varieties, the aim is to satisfy the domestic food self-sufficiency level. However, scarcity of flat arable land in Malaysia restricts the activity of paddy cultivation. The Food and Agriculture Organization of the United Nations (FAO) reports that the size of land suitable for rice production in Asia is disappearing due to the pressure from industrialization and urbanisation. Quantity and quality of water available for rice growing is also expected to decline for the same reason. The nature of upland rice which is adapted on hill-side and not irrigated can serve as a possible solution for both land and water constraint issue. Upland rice can be defined as rice crop that are grown in unbunded fields and depends on rainfall for its water requirements (Atlin *et al.*, 2006).

Upland rice contributes to a total of 11% of global rice production and cultivated on an estimated area of 14 million hectares (ha). In Malaysia, upland rice cultivation covers a total of 165,888 ha of land mostly in Sabah and Sarawak (Sohrabi *et al.*, 2012). Upland rice cultivation and fruit farming were the main agriculture activities in Sabah carried out by the Murut and Dusun before Sabah Land Development Board started to commercialize Oil palm plantation in 1968. Slash and burn technique is the most common method used in traditional upland rice production in Sabah. Slash and burn is a farming method in which farmers search for unexploited land for new cultivation and abandoned the land once it is no longer fertile.

The abandoned land is left to reclaim by natural vegetation or can be referred as fallow period which may took 8 years to recover. However, due to increased population pressure which can suffocate the rice supply, lengthy fallow periods are no longer feasible and upland rice cultivation become a threat to soil environment (BCI, 2002). According to the Department of Environment (1996), sheet erosion is high when fallow periods are reduced or when the ground is left bare between row crops.

Production of upland rice system is always low compared to those cultivated on irrigated lowland areas. Inappropriate farming practices of upland rice have also raised environmental problems. This puts the significance of upland rice only in their contribution to food security. Nevertheless, upland rice can still be a good alternative for rice production in overcoming land and clean water shortage in Malaysia. Upland rice also has many good and market-demand quality characteristics that can be commercialized such as good fragrance and long grains (Hanafi *et al.,* 2009). Quality of the grain should be considered in terms of consumer preference to ensure economic return for its production. Consumer preference on quality attributes of rice will determine the kind of rice that sells. Grain quality is evaluated not only by its chemical and physical characteristics, but also its appearance after cooking (Garcia *et al.*, 2011).

1.2 Justification

Meeting demand for quality food has become increasingly important as people nowadays are more wary in purchasing proper product and tend to be more selective in their preference. For rice, the quality in terms of consumer preference is judged based on its properties after cooking. Research conducted by Garcia *et al.* (2011) and Danbaba *et al.* (2011) suggest that consumers nowadays are very concerned with cooking quality and favours specific quality traits of rice for home cooking. Cooking quality can also contribute to price differential (Gonzales *et al.*, 2004). This can be used as leverage in trade negotiation and enhance the market network of the rice. Thus, the value of rice grain may increase when cooking quality is evaluated as one of the quality assessment.

Farmland availability in Malaysia is declining resulting from the rapid urbanisation and conversion of agricultural land to industrial land (JAFFC, 2008). Rice production may halt because of this complication. Upland rice can tackle this land scarcity problem if it is done sustainably. Upland rice plays an important role in enhancing rice production and refining knowledge of upland rice is therefore beneficial.

However, there is very little documentation on upland rice production characteristics in Malaysia which is important if any effort on improving upland rice production is to be initiated. This research thus intended to gather information about upland rice and its cooking properties from the consumer viewpoint.

1.3 Problem Statement

For countries such as Africa and Latin America which predominantly practices upland culture for its rice production (IRRI, 1984), researches carried out for upland rice is unceasing. In Malaysia particularly in Sabah, upland rice productions are only conducted on a small scale and mostly intended for household use only. Upland rice has not been commercialized due to its low and unstable yield. According to Hanafi *et al.* (2009), poor management of upland rice cultivation contributed to its low yield production. Therefore, the importance for upland rice research is often neglected. Lack of interest to study upland rice characteristics causes knowledge paucity of the local upland rice properties. Consequently, creating market access for upland rice become troublesome. Hence, investigation on the properties especially those which have an interest with consumer preference are important so that upland rice too can compete in the market.

1.4 Objective

The objective of this research is to compare the cooking quality of upland brown rice varieties grown in Kota Belud.

1.5 Hypothesis

H_0: There is no significant difference in cooking quality of upland brown rice varieties grown in Kota Belud.

H_1: There is a significant difference in cooking quality of upland brown rice varieties grown in Kota Belud.

CHAPTER 2
LITERATURE REVIEW

2.1 World Upland Rice Production

According to IRRI, the term "upland rice" has been loosely used to designate any rice strain of *Oryza sativa* or *Oryza glaberrima* which suited for upland culture. It also refers to rice grown on both flat and sloping fields that are not bunded, which were prepared and seeded under dry condition and depends on rainfall for moisture (IRRI, 1975).

Upland rice is mainly grown in Africa, Asia and Latin America (Table 2.1). Yield potential for upland rice varieties are comparably low and highly variable as it is more subjected to environmental stress. The uplands culture has a major share of poor and food insecurity people where poverty is often highly correlated in upland areas which have little access to markets (CGIAR Science Council, 2006). Upland rice thus is typically grown traditionally by poor farmer on poor soil with uncertain rainfall distribution except in some parts of Latin America that employ partly mechanized upland rice (Gupta and Toole, 1986).

Table 2.1: Estimated upland rice area and production in the world

Region	Area (thousand ha)	Production (thousand tan)	Yield (t/ha)
Africa	2047	1023	0.5
Asia	11593	11593	1.00
Latin America	6724	8820	1.10
World	20364	21436	1.05

Source:IRRI (1975)

2.2 Upland Rice in Asian Countries

Upland culture is considered an important system of growing rice in Asia although not majorly applied. Upland rice accounts for 13% of the total area of rice grown in Asia. Production is the most in India with 6 million ha, followed by Indonesia with 1.1 million ha and Thailand with 0.96 million ha. Malaysia on the other hand only plants 91,000 ha of upland rice (Gupta and Toole, 1986).

Upland rice in Asia plays an important role in agriculture land use, increasing rice production and base for food security for the poor. However, upland cultures in many countries in Asia are under pressure because of the high population growth which stirs the problem of natural resource degradation. Since slash and burn is mainly adopted in Asian upland rice production, declining yield productivity due to natural resource degradation leads to further encroachment into forest areas and increasing cultivation of marginal lands (CGIAR Science Council, 2006). Continuous activity of unsustainable clearing of forests for upland farming will cause soil to loss nutrient and may cause permanent damage. As a result, the land becomes unproductive and unable to sustain good crop yield (IWMI, 2010).

Yield potential of upland rice remains stagnant at around 1 tan per ha because of the numerous constraints caused by environmental diversity. Environmental factors such as rainfall distribution and soil characteristics prominently affect the development of upland rice. Average rainfall in Asia ranges between 600-3000 mm which is sufficient for growing upland rice. Most Asian upland rice is grown at low elevations (usually not exceeding 1000 m) where temperatures during the monsoon season range from 24 to 26°C. Upland rice is predominantly planted where slope exceed 8% and mostly have low fertility. In Southeast Asia, Orthic Acrisols are the most important upland rice soil of which having poor organic matter content, poor chemical composition, strongly acid and weathered (IRRI, 1984).

2.3 Upland Rice in Sabah

Upland rice cultivation in Sabah is found mainly on the interior part of the state such as in the districts of Pitas, Ranau and Kota Belud which carried out by the indigenous communities. There are at least 128 varieties of upland rice native to Sabah and a farmer may maintain 3-5 varieties of traditional upland rice inherited from their ancestor (EARWG). In Sabah, the state government offers special incentives granted by the federal government for upland rice farmers to encourage upland rice production. Incentives are given in the form of fertilizer and pesticide where registered farmers will receive 25 kg of fertilizers and 4 L of pesticide each month (New Sabah Times, 2008).

2.3.1 Pitas

Both lowland and upland rice is cultivated in Pitas with a production area of 3000 ha and 1500 ha respectively. Simple tool such as hoe is mainly used in the cultivation of upland rice in Pitas. Machinery is only used by farmers who can afford it. There are at least six (6) varieties commonly planted in Pitas which mostly have a maturity period of 4-5 months. Upland rice varieties that can be found in Pitas are Solung, Taring, Gapur, Linjauan, Tadong and Gampat. Solung variety is most preferred by farmers in Pitas because of its aroma properties and ability to produce higher yield. Planting season for upland rice starts on October until January and its yield may reach up to 1.5 tan per ha. Upland rice in Pitas is planted by farmers who are relatively financially fortunate and thus are cultivate only for household use and not for selling (Linsin bin Udian, Penyelaras Subsidi Padi).

2.3.2 Ranau

Upland rice activity is the highest in Ranau. It is conducted mainly by the Dusun communities. Farmers in Ranau have started to engage with permanent cultivation to replace the traditional shifting cultivation system although the traditional way is still practice by a small population of farmers in Ranau. In shifting cultivation, farmer will move to another location once the current land becomes unfertile. Rice is usually intercropped with other short-term crop to maximize output and assists in weed control. In permanent cultivation, growing of upland rice is carried out on the same land but with a rest period. Rest period allows the maintenance of soil health as well as preventing exhausting of natural land resources.

Upland rice is highly supported in Sabah where subsidy is given to farmers to encourage upland rice planting. Subsidies given to Ranau farmers are in the form of pesticide, sprayer and fertilizer. The subsidy inspires Ranau farmers to start planting their own rice where the number of farmers involved in upland rice planting was found to increase significantly. The yield of upland rice also can be seen rising gradually with the support of subsidy (Table 2.2).

Ranau has also taken an initial step in introducing upland rice in the local market. Upland rice has good quality properties which makes them worthy to be sold at a higher price. In Ranau, upland rice is sold at RM10 to RM15 per kg. The nutty flavoured brown upland rice is currently very famous among tourist in Nabalu, a small town in Ranau. However, the sale trade of the upland rice is confined to that particular town only because of its small scale cultivation area (Oswald John Masital, Pegawai Pertanian Ranau).

Table 2.2: Subsidies distribution and corresponding yield for upland rice in Ranau

Year	Production Area (ha)	Number of farmers	Subsidy distributed	Yield (metric ton/ha)
2006	250.10	193	987 kg DAP fertilizer.	1.765
2007	56.66	80	None	2.733
2008	469.61	431	531.54 of DAP fertilizer	2.571
2009	2111.49	1554	None	2.474
2010	2719.64	1900	1554 sprayer, 41340 L herbicide, 31005 L pesticide, 6216 L foliar fertilizer	3.097
2011	1800.44	1259	1730 kg DAP fertilizer, 110 sprayer, 3146 L herbicide, 3146 L pesticide, 630 L foliar fertilizer	Not assessed

Source: Department of Agriculture (Ranau)

2.3.3 Kota Belud

Kota Belud (KB) is one of the important centres of rice production. Paddy seed production and R&D centre has been developed in KB making KB among the Sabah's leading district in rice production. KB preliminary aim for upland rice is at a targeted production area of 197 ha but has reached 218.66 ha so far in 2010. Another 465 ha of potentially suitable land for further expansion of upland rice in KB have also been identified.

A total of 222 farmers in KB dominated by the Dusuns are involved in upland rice farming (Table 2.3) with an individual yield of 1.2 to 1.6 tan per ha. Upland rice in KB has an average yield of 1.3 tan per ha when computed as a whole. Farmers in KB practised shifting cultivation for upland rice production where forest is cleared and left to dry naturally and then burned following the dry season. Upland rice is mainly planted on hillside, some on flat land using dry cultivation system starting on June and harvested between November to January. A number of lands used for upland rice planting are often converted to other cash crop (mostly rubber) because of the differential economy value of the crop that alters the penchant of farmers in KB.

Table 2.3: Total number of farmers according to village (2010)

Village	Number of farmers	Land area (ha)
Lasau Lama	2	1.62
Nahaba	3	3.24
Pirasan	3	2.43
Melangkap Baru	5	5.28
Terintidon	6	6.48
Melangkap Tomis	7	11.13
Dudar	8	6.29
Purak ogis	9	6.04
Melangkap Nariou	10	11.74
Kaung	10	7.00
Bungliu	11	6.48
Lingkubang	13	42.87
Bubuk/Bungliu	15	10.32
Melangkap Tiong	15	12.55
Sayap	20	22.67
Kiau Bersatu	23	12.84
Tambatuon	25	21.07
Bundu Paka	37	28.61
	Total = 222	Total = 218.66

Source: Department of Agriculture (Kota Belud)

Upland rice from KB is sold at a price ranging between RM5 to RM7 per kg mainly at the roadside stall along the way from Ranau to Kota Belud. However, most farmers only sell their upland rice when there is a surplus because of the obvious low yield potential that cannot guarantee good economic return. Weakening interest on cultivating upland rice because of its poor yielding properties makes promoting of the crop becomes a perturbing dilemma. Labour is the primary problem in cultivating upland rice since it is more subjected to environmental stress and thus need more attention for care. Inadequate infrastructure such as access road and no farm grants further debilitate the position of the upland rice. Nevertheless, it is undeniable that upland rice also has notable quality characteristics such as its aroma properties which may be able to attract buyers.

The Department of Agriculture of KB attempted to save the continuity of upland rice production by allocating subsidies and incentives to farmers. Similar to Ranau, KB also distribute subsidy to upland rice farmers in the form of fertilizer, pesticide, sprayer and herbicide. Foliar fertilizer, herbicide, pesticide and sprayer was given in the year 2009 and 2010 while only DAP fertilizer is given in 2012 with a rate of 4.45 kg per acre. A total of 80 farmers from 13 different villages are eligible for incentive or subsidy grant in 2010 (Table 2.4). Extension service according to 2L (latihan dan lawatan) program, carried out by the extension technician is also provided to support farmers. (Muneh Sikin, Pegawai Pertanian daerah Kota Belud).

Table 2.4: Total number of farmers who received subsidy according to village (2010)

Village	Number of farmers	Land production area (acre)
Kodoku Peturu	1	2
Melangkap Tiong	2	5
Dudar	4	17
Melangkap Nariou	4	12
Rosok	4	10
Purak Ogis	4	13
Melangkap Tomis	5	23
Kiau Bersatu	6	13
Bundu Paka	6	25
Bubuk Bungaliu	8	20
Tambatuon	9	34
Siudon Bungaliu	9	23
Sayap	10	29

Source: Department of Agriculture (Kota Belud)

2.4 Upland Rice Environment

Different environment condition than that of lowland production contributes to its variability in grain yields. Upland rice has less grain to straw ratio because of the intense environmental stress caused by the variation of rainfall distribution, temperature and soil characteristics. Yields in upland rice production are often low because of these environmental restrictions.

2.4.1 Rainfall

Water availability is always uncertain in upland rice cultivation because the production depends on rainfall for its moisture requirement. Distribution of rainfall is thus very crucial in the cultivation of upland rice and it is obligatory to plant upland rice during rainy season. Area with low rainfall is not suitable for growing upland rice as moisture stress can reduce the rice yield. Moisture stress is identified as the primary limiting factors of paddy growth and yield under upland condition (IRRI, 1975). Water shortage affects crop yield by reducing photosynthesis activity and lessening the ability of root-soil interface for nutrient uptake (Ceesay, 2004). Moisture stress can also alter the composition of the rice grain. Both research conducted by Jianchang, *et al.* (2001) and Wang *et al.* (2006) suggest that at water deficits condition, sucrose-phosphate synthase (SPS) activity increases. SPS is the plant enzyme that controls the biosynthesis of sucrose where it is regulated by metabolites and reversible protein phosphorylation. SPS is activated in response to osmotic stress which results in fast hydrolysis of starch. Thus, starch content in rice decreases (Huber and Huber, 1996).

2.4.2 Temperature

Elevation above sea level is a major determinant for temperature. Since upland rice is cultivated at hilly areas, temperature changes will affect the yield production of upland rice especially when influenced by varying rainfall and solar radiation. Temperature will drop at higher altitude. Effects of low temperature vary with the crop growth stage but is the most damaging during panicle initiation, meiosis and pollen development (Gupta and Toole, 1986). Therefore, exposure to low temperature during these stages can severely affect the productivity of the rice.

Temperature can affect the plant growth, physiological condition and as well as gene expression. Environment temperature tends to drop at high altitude of upland rice cultivation. Nisar *et al.* (2008) stated that paddy which were subjected to low temperature during grain filling have higher amylose content. Expression of waxy gene in rice endosperm accelerates at low temperature which causes amylose content to increase (Takayumi *et al.*, 1995). This is supported by a research conducted by Hiro and Yoshio (1998) which stated that the levels of *Waxy* gene transcript and *Waxy* protein increases at cool temperature. They also found that the amylose content in mature seeds increase along with the amount of *Waxy* protein at cool temperature. The effect of temperature on amylose content is more apparent and occurs 5-15 days after heading. This is when synthesis of endosperm starch in rice is active. Therefore, upland rice that is grown on elevated areas with low temperature will most likely to have higher amount of amylose.

Lower temperature does not just amend the synthesis of amylose but affect the amylopectin content as well by altering branching enzyme (BE) activity. At lower temperature, relative activity of BE-II to BE-I activity increases. BE-I produce fewer branced glucans of amylose while BE-II produced highly branched glucans of amylopectin. This leads to an increase in the proportion of shorter chain and subsequently increases the crystallinity and molecular order of the starch which resulted in higher gelatinization temperature (Takayuki *et al.*, 2009).

2.4.3 Soil Characteristics

Soil is a very important factor in determining yield of upland rice. Most upland rice areas in Asia possess a low soil pH of 4.5-5.8. Type of soil which upland rice is to be planted is very important as soil texture can affect the moisture status. Soil texture is very important particularly in upland rice fields since there are no bunds in the field to hold moisture. Clayey soil is not suitable for upland rice cultivation because it restricts root growth. Sandy soil will allow easy root penetration but it has low water holding capacities and poor nutrient retention ability. Medium textured soil surface is more preferable as less water is loss (IRRI, 1975; Gupta and Toole, 1986). Hanafi *et al.* (2009) identified that most upland rice soil in Malaysia is sandy clay loam (70%) texture, followed by sandy loam (24%) and clay loam (6%) textures. Higher clay content in soil influences the mean percentage of water content and the available water capacity and thus is more preferable in upland culture due to the importance of moisture retention.

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