



UNIVERSITI PUTRA MALAYSIA

**EFFECTS OF DIFFERENT COOKING METHODS AND STORAGE
CONDITIONS ON THE RICE STARCH DIGESTIBILITY**

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CONDITIONS ON THE RICE STARCH DIGESTIBILITY**

By

YOGESHINI A/P RAMAKRISHNAN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirements for the Degree of Master of Science**

November 2009

DEDICATION

This work is dedicated to my husband Kalidasan and all family members who had given me constant encouragement and support.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairperson: Sharifah Kharidah Syed Muhammad, PhD

Faculty: Food Science and Technology

Seven types of rice with different levels of amylose were selected to study the effect of different cooking methods, chilling and freezing on the digestibility of their starches. An *in vitro* enzymatic starch digestion method was applied in order to estimate the expected glycemic index (GI) *in vivo* based on the kinetics of starch hydrolysis *in vitro*. First, samples were cooked with different cooking methods to investigate the effect of cooking on the starch digestibility; second, samples were steamed and stored at temperatures of 4 and -20°C in order to simulate certain storage conditions of cooked rice. The results indicated significant differences in terms of starch digestibility or GI of the seven types of

rice studied and the digestibility of their starches were further affected by different cooking methods. These differences can be attributed to the formation of resistant starch (RS). Steaming increased the RS formation in each type of rice. Cooking the rice with excess water, combi oven and rice cooker contributed only to small changes in the formation of RS. The proximate compositions of the rice before and after cooking were similar for all cooking methods. The amylose content of rice has an obvious impact on the rice starch digestibility due to its positive correlation with formation of RS. Starch hydrolysis was found to be rapid and complete for the waxy and low amylose rice rather than for the intermediate and high amylose rice. Chilling of steamed rice promoted the formation of RS more than freezing. The GI ranged between 68 and 98 for steamed rice and between 63 and 82 for chilled and frozen rice. Storing steamed rice at 4°C and -20°C gradually increased the formation of RS and reduced the estimated GI for all the seven types of rice. A high decrease in starch hydrolysis after chilling and freezing was found among the waxy rice. Thermal properties of rice that have undergone steaming, chilling and freezing showed a shift of the gelatinization temperature to a higher value. The pasting properties of steamed and chilled or frozen rice samples showed increased pasting temperatures and decreased peak viscosity compared to those of raw rice. The raw rice starches had the characteristic A-type crystalline pattern, with diffraction peaks at 15.2, 17.2, 17.9 and 23.2° (2 θ). The steaming, chilling and freezing treatment on rice caused weak peak formation at 16° and 20° (2 θ) representing crystalline B-type and V-amylose-lipid complexes. Steaming, chilling and freezing of rice had reduced the relative crystallinity (RC) value.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

KESAN DARIPADA PELBAGAI KAEDAH MEMASAK DAN KEADAAN PENYIMPANAN TERHADAP KEBOLEHHADAMAN KANJI BERAS

Oleh

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Tujuh jenis beras dengan tahap amilosa yang berbeza telah dipilih untuk dikaji terhadap kesan pelbagai kaedah memasak, penyejukan dan penyejukbekuan ke atas kebolehhadaman kanjinya. Kaedah penghadaman kanji secara enzim *in vitro* telah diaplikasi untuk menganggarkan indeks glisemik (GI) *in vivo* berdasarkan kinetik hidrolisis kanji *in vitro*. Pertama, sampel telah dimasak dengan pelbagai kaedah memasak yang berbeza untuk mengenalpasti kesan memasak ke atas kebolehhadaman kanji; kedua, sampel telah dikukus dan disimpan pada suhu 4°C dan -20°C untuk mensimulasi sesetengah kaedah penyimpanan nasi. Keputusan menunjukkan perbezaan yang ketara dari segi penghadaman kanji atau GI tujuh jenis beras yang dikaji dan kebolehhadaman

kanji tersebut, dipengaruhi oleh kaedah memasak. Perbezaan ini adalah disebabkan oleh pembentukan kanji rintang (RS). Pengukusan meningkatkan pembentukan RS pada setiap jenis beras. Memasak nasi dengan air yang berlebihan, ketuhar kombi dan periuk nasi menyumbang pada perubahan yang kecil dalam pembentukan kanji rintang. Komposisi proksimat nasi sebelum dan selepas memasak adalah hampir sama untuk semua kaedah memasak. Kandungan amilosa beras mempunyai impak yang ketara ke atas kebolehadaman kanji beras disebabkan oleh korelasi positifnya dengan kanji rintang. Hidrolisis kanji didapati cepat dan lengkap untuk beras pulut dan beras rendah amilosa berbanding dengan beras pertengahan dan tinggi amilosa. Penyejukan nasi menyebabkan pembentukan kanji rintang yang lebih banyak berbanding dengan penyejukan. Nilai GI adalah di antara 65 dan 98 untuk nasi yang dikukus dan di antara 63 dan 82 untuk nasi yang disejuk dan disejukbekukan. Penyimpanan nasi pada suhu 4°C dan -20°C meningkatkan pembentukan RS secara berperingkat dan mengurangkan GI anggaran untuk kesemua tujuh jenis beras. Penurunan yang tinggi dalam penghadaman kanji selepas penyejukan dan penyejukanbekuan didapati berlaku pada beras pulut. Ciri terma beras yang telah dikukus, disejuk and disejukbeku menunjukkan perubahan suhu pengelatinan ke nilai yang lebih tinggi. Sifat pempesan sampel nasi yang dikukus dan disejuk atau disejukbekukan menunjukkan peningkatan pada suhu pempesan dan penurunan puncak kelikatan berbanding dengan sampel beras. Kanji beras mempunyai ciri pembentukan penghabluran jenis A dengan puncak pembelauan pada 15.2, 17.2, 17.9 and 23.2° (2θ). Rawatan seperti pengukusan beras, penyejukan dan penyejukanbekuan nasi menyebabkan pembentukan puncak yang lemah pada 16° dan 20° (2θ) mewakili

penghabluran jenis B and kompleks V-amilosa-lipid. Pengukusan, penyejukan dan penyejukbekuan telah menurunkan nilai penghabluran relatif (RC).

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I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

YOGESHINI A/P RAMAKRISHNAN

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TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL	ix
DECLARATION	xi
LIST OF TABLES	xv
LIST OF FIGURES	xvi
LIST OF ABBREVIATIONS	xvii
CHAPTER	
1 INTRODUCTION	1
2 LITERATURE REVIEW	
2.1 Rice	4
2.2 Structure and form of rice starch	7
2.2.1 Amylose	8
2.2.2 Amylopectin	9
2.2.3 Macrostructure of the starch granules	11
2.3 Functional properties of starch	14
2.3.1 Glass transition	15
2.3.2 Swelling power and solubility	15
2.3.3 Starch crystallinity	16
2.4 Effect of cooking on starch	18
2.4.1 The starch granule and its modification during cooking	18
2.4.2 Gelatinization of starch	19
2.4.3 Retrogradation of rice starch	21
2.4.4 Protein-starch and lipid-starch complexes	22
2.4.5 Food processing, digestibility of starch fraction and glycemic responses	23
2.5 Starch digestibility	24
2.5.1 Glycemic index	27
2.5.2 Resistant starch	30
2.6 Factors influence the formation of resistant starch	33
2.6.1 Crystallinity of starch	33
2.6.2 Granular structure	34
2.6.3 Amylose : amylopectin ratio	34
2.6.4 Retrogradation of amylose	35
2.6.5 Influence of amylose chain length	36
2.6.6 Heat and moisture	37

	2.6.7	Processing conditions	37
	2.6.8	Storage conditions	38
3		EFFECT OF DIFFERENT COOKING METHODS ON RICE STARCH DIGESTIBILITY	39
	3.1	Introduction	39
	3.2	Materials and Methods	41
	3.2.1	Cooking in a steamer	41
	3.2.2	Cooking in excess boiling water	42
	3.2.3	Cooking in an electric rice cooker	43
	3.2.4	Cooking in a combi oven	43
	3.2.5	Sample powder preparation	44
	3.2.6	Proximate composition determination	44
	3.2.7	Amylose content determination	45
	3.2.8	Total starch (TS) determination	46
	3.2.9	Resistant starch (RS) determination	47
	3.2.10	<i>In vitro</i> kinetics of starch digestion and GI determination	49
	3.2.11	Statistical analysis	50
	3.3	Results and Discussion	51
	3.3.1	Hydration behavior of rice at ambient conditions	51
	3.3.2	End point of cooking in excess water	52
	3.3.3	Proximate composition	53
	3.3.4	Amylose content	54
	3.3.5	Total starch	57
	3.3.6	Effect of cooking on the resistant starch content	57
	3.3.7	Effect of cooking on the <i>in vitro</i> starch digestibility	60
	3.4	Conclusions	65
4		EFFECT OF STORAGE CONDITIONS ON RICE STARCH DIGESTIBILITY	66
	4.1	Introduction	66
	4.2	Materials and Methods	68
	4.2.1	Sample powder preparation	69
	4.2.2	Proximate composition determination	70
	4.2.3	Amylose content determination	70
	4.2.4	Total starch (TS) determination	71
	4.2.5	Resistant starch (RS) determination	71
	4.2.6	<i>In vitro</i> kinetics of starch digestion and GI determination	71
	4.2.7	Statistical analysis	71
	4.3	Results and Discussion	72
	4.3.1	Proximate composition	72

4.3.2	Amylose content	76
4.3.3	Total starch	78
4.3.4	Effect of chilling and freezing on the resistant starch content	80
4.3.5	Effect of chilling and freezing on the <i>in vitro</i> starch digestibility	82
4.4	Conclusions	84
5	CORRELATION OF RICE STARCH DIGESTIBILITY WITH RETROGRADATION AND CRYSTALLINITY	85
5.1	Introduction	85
5.2	Materials and Methods	87
5.2.1	Sample powder preparation	87
5.2.2	Pasting properties	87
5.2.3	Thermal properties	88
5.2.4	X-ray diffraction	89
5.2.5	Statistical analysis	89
5.3	Results and Discussion	90
5.3.1	Correlation of rice starch digestibility with amylose content	90
5.3.2	Correlation of rice starch digestibility with pasting properties	92
5.3.3	Correlation of rice starch digestibility with thermal properties	96
5.3.4	Correlation of rice starch digestibility with crystallinity	100
5.4	Conclusions	103
6	SUMMARY, GENERAL CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH	104
	REFERENCE	106
	APPENDICES	115
	BIODATA OF STUDENT	120

LIST OF TABLES

Table		Page
1	Prevalence and mean frequency of the top 10 daily consumed food in Malaysia	5
2	Classification of types of resistant starch (RS), food sources, and factors affecting their resistance to digestion in the colon	32
3	End point of cooking in excess water	52
4	Proximate composition of rice	55
5	Amylose, total starch and resistant starch content of rice	56
6	Recommended daily intake of dietary fibre for adults	59
7	Hydrolysis index (HI) and estimated glycemic index (GI) of rice	61
8	Pearson's correlation coefficients for the relationship between starch digestibility with pasting properties, thermal properties and crystallinity of steamed, chilled and frozen cooked rice	91
9	Pasting properties of the raw, steamed, chilled and frozen rice	95
10	Thermal properties and crystallinity of raw, steamed, chilled and frozen rice	98
11	Proximate compositions of raw, steamed, chilled and frozen rice	115
12	Total starch (TS) and resistant starch (RS) content of raw, steamed, chilled and frozen rice	116
13	Amylose content and GI of raw, steamed, chilled and frozen rice	117

LIST OF FIGURES

Figure		Page
1	Structure of rice grain	6
2	Amylose molecule	9
3	Amylopectin molecule	10
4	Schematic view of the structure of a starch granule, with alternating amorphous and semi-crystalline zones constituting the growth rings	12
5	Cluster structure showing linear chains of amylopectin. The C chain has the only free reducing group in the molecule	17
6	Influence of hydrothermic processing on physical starch characteristics	20
7	Schematic representation of a complex of amylose with two monopalmitin molecules.	27
8	Moisture uptake in rice grains during soaking	52
9	<i>In vitro</i> starch hydrolysis rate of rice cooked using (a) steaming method (b) excess water (c) rice cooker (d) combi oven	63
10	Effect of chilling on the (a) protein, (b) fat and (c) ash contents of steamed rice	73
11	Effect of freezing on the (a) protein, (b) fat and (c) ash contents of steamed rice	75
12	Effect of (a) chilling and (b) freezing on the amylose contents of steamed rice	77
13	Effect of (a) chilling and (b) freezing on the total starch contents of steamed rice	79
14	Effect of (a) chilling and (b) freezing on the resistant starch contents of steamed rice	81
15	Effect of (a) chilling and (b) freezing on the glycemic index of steamed rice	83
16	RVA pasting curves of the (a) raw, (b) steamed, (c) chilled and (d) frozen rice	93
17	DSC thermograms of (a) raw and (b) steamed rice	99
18	X-ray diffractograms of (a) raw and (b) steamed rice	102
19	Appearance of (a) raw rice, (b) steamed, (c) chilled or (d) frozen steamed rice	118

LIST OF ABBREVIATIONS

T _g	Glass transition temperature
RS	Resistant starch
TS	Total starch
DS	Digestible starch
GT	Gelatinization temperature
DSC	Differential scanning calorimetry
XRD	X-ray diffractogram
ΔT	Temperature range over which gelatinisation occurs
GL	Glycemic load
GI	Glycemic index
NSP	Non-starch polysaccharides
DP _n	Degree of polymerization
μm	Micrometer
g	Gram
hr	Hour
L	Liter
°C	Degree celsius
ml	Milliliter
mg	Milligram
nm	Nanometer
M	Molarity



min	Minute
HI	Hydrolysis index
ΔH	The enthalpy of gelatinization
Tc	Conclusion temperatures
To	Onset of gelatinisation in excess water
RC	Relative crystallinity



CHAPTER 1

INTRODUCTION

Differences in nutritional properties among starchy foods are intriguing. Elucidating the role of starch qualities in nutrition requires a greater understanding of how the physicochemical characteristics of food relate to their physiological properties. The rate and extent of starch digestion is influenced by many intrinsic food factors. Starch consists of two glucose polymers, amylose and amylopectin. The physical arrangement of amylose and amylopectin in food and their interrelation with other food components (proteins, fibres, lipids, etc.) determine the physicochemical and functional properties of starch and its susceptibility to amylolytic enzymes, and thus its bioavailability.

Hydrothermic food processing (i.e. panification, pastification, extrusion cooking, etc.) has a major impact on starch availability (Bornet, 1993). The arrangement of starch components changes continuously under the influence of hydrothermic parameters during both food processing and storage conditions. Starch availability is influenced by its digestibility and is characterised by high glycemic index and low resistant starch formation.



The glycemic index (GI) is a measure of the effects of carbohydrates on blood sugar levels. Resistant starch (RS) is starch that escapes digestion in the small intestine of healthy individuals. Resistant starch is considered the third type of dietary fiber, as it can deliver some of the benefits of insoluble fiber and some of the benefits of soluble fiber. The food processes that lead to gelatinised, highly viscous and soluble starches result in high glycemic index food (Colonna *et al.*, 1992). Food processes that limit the swelling of starch result in low glycemic index foods. The amount and quality of the resistant starch in food can also be modulated by hydrothermic processing and four different resistant starch fractions have been identified in cereal products (Bornet, 1993).

Low glycemic index and high resistant starch diets have been known to have health benefits. Various studies have demonstrated the beneficial effect of high-carbohydrate-low-glycemic index diets on insulin secretion in supporting β -cell function. Meanwhile, resistant starch can act as a fermentation substrate in the colon, similar to non-starch carbohydrates, with positive implications for the prevention of colon cancer and hypolipidemia (Englyst *et al.*, 2003).

Rice is the staple food for more than half of the world's population. An approximately 90% of the world's rice is produced and consumed in Asia. As the primary dietary source of carbohydrate in these population, rice plays an important role in meeting

energy requirement and nutrient intake. Milled rice is composed of 90% starch. The rice starch digestibility and thus nutritional properties can, therefore, be modified by hydrothermic processing and storage conditions. The simplest form of hydrothermic processing of rice that can be performed in homes is by boiling. Rice can be cooked by boiling in excess water or in a rice cooker, and by steaming. The food service industry often cooks its rice using a combi oven.

Since there is an increase in popularity of ready meal, storage conditions play an important role to develop products with chilled or frozen cooked rice. Storing the cooked rice at a low temperature contributes to starch retrogradation. Retrogradation of starch is a term used for the changes that occur in gelatinized starch from an initially amorphous state to a more ordered or crystalline state. The impacts of different cooking methods and storage conditions on rice starch digestibility, however, have not been evaluated. Therefore, the objective of the study reported here was to determine the cooking method and storage condition that will reduce glycemic index and increase resistant starch content of rice. The specific objectives of the study are;

1. To determine the effect of different cooking methods on formation of resistant starch and reduction of glycemic index in rice
2. To determine the effect of chilling and freezing on formation of resistant starch and reduction of glycemic index in rice
3. To evaluate the correlation of crystallization and retrogradation on rice starch digestibility

CHAPTER 2

LITERATURE REVIEW

2.1 Rice

Rice is one of the most important cereals in the world. Most people in Asia, tropical and subtropical countries use rice as a major staple food. As much as 80% of the daily caloric intake of people in the Asian countries is derived from rice. A small amount of the rice crop is used to make ingredients for processed foods and as feed, but the bulk is consumed as cooked rice. Cooked rice is consumed by 97% of Malaysian twice daily and the average amount eaten was 2½ plates per day (Table 1). Rice grains (Figure 1) are naturally surrounded by a loose, inedible husk. To obtain white rice, the embryo and several layers of bran are removed by milling to improve palatability and keeping qualities. Milling, however, results in a disproportionate loss of lipid, protein, fibre, reducing sugars and total sugars, ash and minor components including vitamins, free amino acids and free fatty acids (Park *et al.*, 2001). On the other hand, an available carbohydrate, mainly starch, is high in milled rice at about 90% of the dry matter. Protein and lipid content are also significant in the milled rice.

Table 1: Prevalence and mean frequency of the top 10 daily consumed food in Malaysia

Type of food	Prevalence who answered daily consumption (%)	Mean frequency per day	Total amount consumed daily
Cooked rice	97.15	2.0	2½ plates (294.06g)
Marine fish	40.78	1.61	1½ medium (100.27g)
Green leafy vegetable	39.89	1.47	1 cup (93.26g)
Sweetened condensed milk	35.55	1.57	3 teaspoons (50.93g)
Powdered milk	17.13	1.41	3 teaspoons (20.61g)
Bread	17.11	1.24	3 slices (96.48g)
Biscuit	16.30	1.25	5 pieces (55.66g)
Local “kuih”	16.30	1.25	2 pieces (62.27g)
Chicken egg	12.06	1.15	1 whole medium (71.84g)
“Ikan bilis”	11.94	1.24	2 teaspoons (15.45g)

(Source: Malaysia’s Health 2006, Malaysian Ministry of Health)

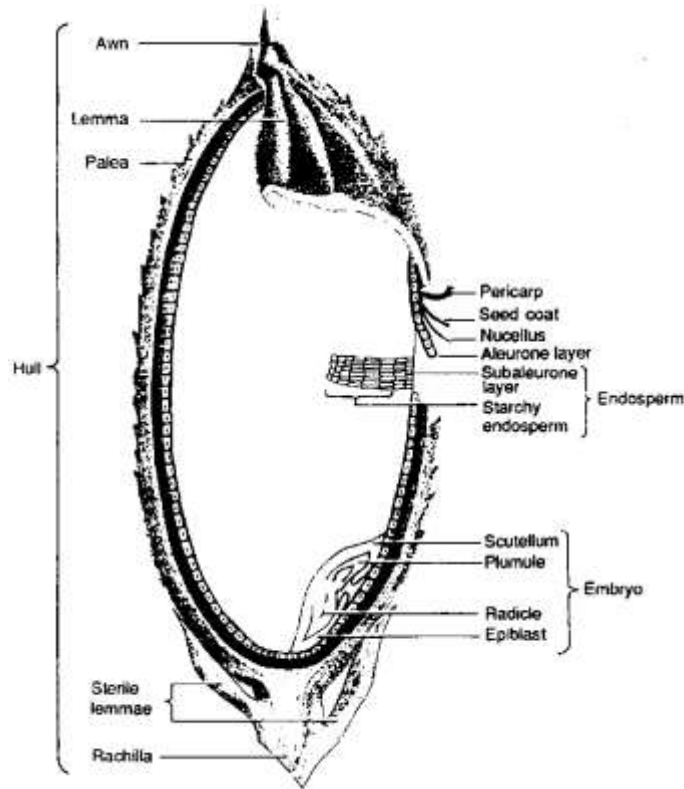


Figure 1. Structure of rice grain
(Source: Juliano, 1984)

There are many methods to cook the rice but most methods are subtle variation of two basic techniques: (i) cooking in large amounts of water, and drained (and sometimes rinsed) – commonly referred to as the Excess or American method; or (ii) cooking rinsed rice in a measured amount (often twice the volume of rice) of water which is absorbed into the rice – commonly known as the Pilaf or Oriental method (Daniel *et al.*, 2001). Besides these cooking methods, the rice is also commonly cooked or prepared at home by steaming using a steamer. The food service industry or catering professionals prefer to use a combi oven to cook the rice as they prepare cooked rice in a very large quantity. The cooking methods that are performed in homes or at catering industries are