UNIVERSITI PUTRA MALAYSIA

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

YOGESHINI A/P RAMAKRISHNAN

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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

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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° (2θ). The steaming, chilling and freezing treatment on rice caused weak peak formation at 16° and 20° (2θ) 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

YOGESHINI A/P RAMAKRISHNAN

November 2009

Pengerusi: Sharifah Kharidah Syed Muhammad, PhD

Fakulti: Sains and Teknologi Makanan

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 kebolehhadaman 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. Penyejukkan nasi menyebabkan pembentukkan kanji rintang yang lebih banyak berbanding dengan penyejukbekuan. 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 pembentukkan RS secara berperingkat dan mengurangkan GI anggaran untuk kesemua tujuh jenis beras. Penurunan yang tinggi dalam penghadaman kanji selepas penyejukkan dan penyejukbekuan didapati berlaku pada beras pulut. Ciri terma beras yang telah dikukus, disejuk and disejukbeku menunjukkan pengubahan 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, penyejukkan dan penyejukbekuan 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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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Sharifah Kharidah Syed Muhammad, PhD
Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairperson)

Jamilah Bakar, PhD
Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

Roselina Karim, PhD
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

_____
HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 February 2010

DECLARATION

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.

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YOGESHINI A/P RAMAKRISHNAN

Date: 10 March 2010

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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
DPn	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 ß-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)

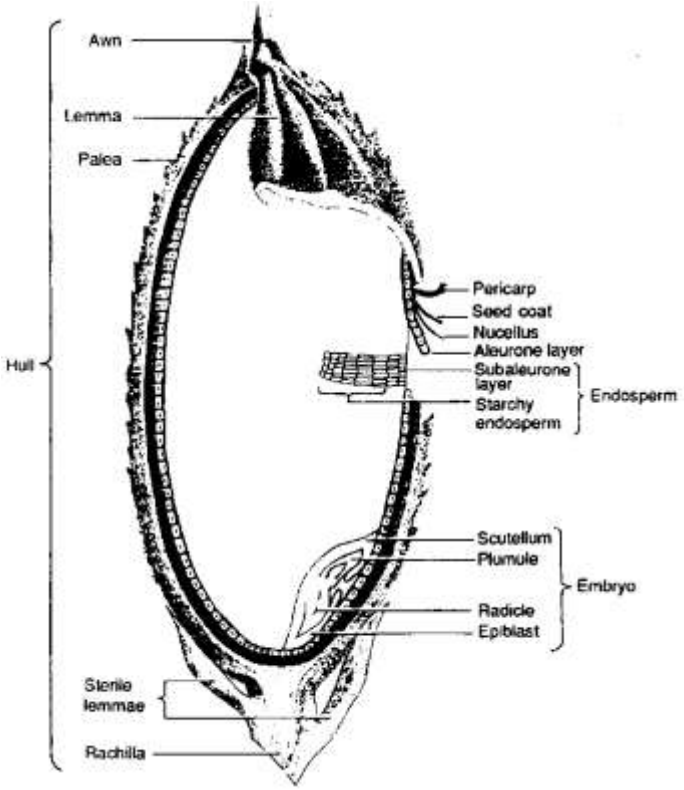

Figure 1. Structure of rice grain
(Source: Juliano, 1984)

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