REFERENCES

Thai references

บัณฑิต ลีฬหรัตนรักษ์. 2548. ความสัมพันธ์ระหว่างองค์ประกอบทางเคมีและสารหอม 2-แอซีติล-1-ไพรโรลีนและการเปลี่ยนแปลงของสมบัติเพสติ้งของข้าวพันธุ์ขาวดอกมะลิ 105 ระหว่างการเก็บรักษา. วิทยานิพนธ์ปริญญามหาบัณฑิต. ภาควิชาเทคโนโลยีทางอาหาร คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย.

รวิศรา อิ่มภาประเสริฐ. 2549. ผลของการอบแห้งด้วยเทคนิคฟลูอิไดเซชันร่วมกับเทมเปอริ่ง และอุณหภูมิในการเก็บต่อปริมาณ 2AP และคุณภาพการสีของข้าวขาวดอกมะลิ 105 *Oryza sativa* L.. วิทยานิพนธ์ปริญญามหาบัณฑิต. ภาควิชาเทคโนโลยีทางอาหาร คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย.

English references

AOAC. 1995. Official Methods of Analysis. 16th ed. Washington D.C.: The Association of the Official Analytical Chemists.

Bhadeshia, H. K. D. H. 2007. Differential scanning calorimetry [Online]. Available from: www.msm.cam.ac.uk/phase-trans/2002/Thermal2.pdf [2008, January 18]

Biliaderis, C. G., Maurice, T. J., and Vose, J. R. 1980. Starch gelatinization phenomena studied by differential scanning calorimetry. Journal of Food Science 45: 1669-1674.

Borompichaichartkul, C., Wiset, L., Impaprasert, R., and Waedalor, I. 2005. Effects of combination of high temperature and intermittent drying on volatile compounds and other quality attributes of Thai fragrant rice. In A. B. Datta, K. M. Kundu, and A. G. P. Sinha (eds), Proceedings of the 4th Asia Pacific Drying Conference, pp 1166-1176. India.

Brooker, D. B., Bakker-arkema, F. W., and Hall, C. W. 1975. Drying Cereal Grains. 2nd ed. Connecticut: AVI Publishing Company.

Buttery, R. G., Ling, L. C., Juliano, B. O., and Turnbaugh, J. G. 1983. Cooked rice aroma and 2-acetyl-1-pyrroline. Journal of Agricultural and Food Chemistry 31: 823-826.

Buttery, R. G., Ling, L. C., and Mon, T. R. 1986. Quantitative analysis of 2-acetyl-1-pyrroline in rice. Journal of Agricultural and Food Chemistry 34: 112-114.

Buttery, R. G., Turnbaugh, J. G., and Ling, L. C. 1988. Contribution of volatiles to rice aroma. Journal of Agricultural and Food Chemistry 36: 1006-1009.

Carrapiso, A. I., Jurado, A., Timon, M. L., and Garcia, C. 2002. Odor-active compounds of Iberian hams with different aroma characteristics. Journal of Agricultural and Food Chemistry 50: 6453-6458.

Childs, N. 2007. Outlook for U.S. agricultural trade [Online]. Available from: http://www.fas.usda.gov/cmp/outlook/2007/Nov-07/AES-11-30-2007.pdf [2008, Febuary 26]

Chrastil, J. 1990. Protein-starch interactions in rice grains: Influence of storage on oryzenin and starch. Journal of Agricultural and Food Chemistry 38: 1804-1809.

Chrastil, J., and Zarins, Z. M. 1992. Influence of storage on peptide subunit composition of rice oryzenin. Journal of Agricultural and Food Chemistry 40: 927-930.

Daud, W. R. W. 2005. Fluidized bed dryers-recent advances. In A. B. Datta, K. M. Kundu, and G. P. Sinha (eds), Proceedings of the 4th Asia Pacific Drying Conference, pp 228-241. India.

Department of Foreign Trade. 2007. Import-Export records [Online]. Available from: http://www.dft.moc.go.th/level3.asp?level2=29 [2008, Febuary, 26]

Dhaliwal, Y. S., Sekhon, K. S., and Nagi, H. P. S. 1991. Enzymatic activities and rheological properties of stored rice. Cereal Chemistry 68: 18-21.

Eliasson, A. 2003. Utilization of thermal properties for understanding baking and staling process. In G. Kaletunç, and K. J. Breslauer (eds), Characterization of Cereals and Flours: Properties, Analysis and Application, pp. 65-116. New York: CRC Press.

Fennema, O. R. 1996. Food Chemistry. 2nd ed. New York: Marcel Dekker.

Gay, F., Mestres, C., Hien, P. P., aguerre, M. L., and Ringuet, J. 2006. Development of semi-quantitative methods to analyse rice aroma. Proceedings of International Workshop on Biotechnology in Agriculture, pp 178-181. Veitnam.

Grimm, C. C., Bergman, C., Delgado, J. T., and Bryant, R. 2001. Screening for 2-Acetyl-1-pyrroline in the headspace of rice using SPME/GC-MS. Journal of Agricultural and Food Chemistry 49: 245-249.

Grist, D. H. 1986. Rice. 6th ed. Singapore: Longman Group Limited.

Hamaker, B. R., and Griffin, V. K. 1993. Effect of disulfide bond-containing protein on rice starch gelatinization and pasting. Cereal Chemistry 70: 377-380.

Hofmann, T., and Schieberle, P. 1998. 2-oxopropanal, hydroxy-2-propanone, and 1-pyrroline-important intermediates in the generation of the roast-smelling food flavor compounds 2-acetyl-1pyrroline and 2-acetyltetrahydropyridine. Journal of Agricultural and Food Chemistry 46: 2270-2277.

Hood. F. L. 1982. Current concepts of starch structure. In D. R. Lineback, and G. E. Inglett (eds), Food Carbohydrate, pp. 237-269. Connecticut: AVI Publishing Company.

Imoudu, P. B., and Olufayo, A. A. 2000. The effect of sun-drying on milling yield and quality of rice. Bioresource Technology 74: 267-269.

Inprasit, C., and Noomhorm, A. 2001. Effect of drying air temperature and grain temperature of different types of drying and operation on rice quality. Drying Technology 19: 389-404.

International Rice Research Institute. 2006. Sun drying [Online]. Available from: http://www.knowledgebank.irri.org/Drying/Drying_lesson06.htm [2008, May 1]

Jaisut, D., Prachayawarakorn, S., Varanyanond, W., Tungtrakul, P., and Soponronnarit, S. 2008. Effects of drying temperature and tempering time on starch digestibility of brown fragrant rice. Journal of Food Engineering 86: 251-258.

Ju, Z. Y., Hettiarachchy, N. S., and Rath, N. 2001. Extraction, denaturation and hydrophobic properties of rice flour proteins. Journal of Food Science 66: 229-232.

Juliano, B. O. 1981. A simplified assay for milled-rice amylose. Cereal Science Today 16: 334-340, 360.

Juliano, B. O. 1985a. Production and utilization of rice. In B. O. Juliano (eds), Rice: Chemistry and Technology, pp. 1-16. Minnesota: The American Association of Cereal Chemists.

Juliano, B. O. 1985b. Polysaccharides, proteins and lipids of rice. In B. O. Juliano (eds), Rice: Chemistry and Technology, pp. 59-174. Minnesota: The American Association of Cereal Chemists.

Juliano, B. O. 1985c. Criteria and tests for rice grain qualities. In B. O. Juliano (ed), Rice: Chemistry and Technology, pp. 443-523. Minnesota: The American Association of Cereal Chemists.

Juliano, B. O., and Bechtel, D. B. 1985. The rice grain and its gross composition. In B. O. Juliano (ed), Rice: Chemistry and Technology, pp. 17-58. Minnesota: The American Association of Cereal Chemists.

Keetels, C. J. A. M., Vilet, T. V., and Walstra, P. 1996. Gelation and retrogradation of concentrated starch systems: 1. gelation. Food Hydrocolloids 10: 343-353.

Le Bail, P., Bizot, H., Ollivon, M., Keller, G., Bourgaux, C., and Buléon, A. 1999. Monitoring the crystallization of amylose-lipid complexes during maize starch melting by synchroton X-ray diffraction. Biopolymers 50: 99-110.

Maga, J. A. 1984. Rice product volatiles: a review. Journal of Agricultural and Food Chemistry 32: 964-970.

Mahatheeranont, S., Keawsa-ard, S., and Dumri, K. 2001. Quantification of the rice aroma compound, 2-acetyl-1-pyrroline, in uncooked Khao Dawk Mali 105 brown rice. Journal of Agricultural and Food Chemistry 49: 773-779.

Marshall, W. E. 1994. Starch gelatinization in brown and milled rice: a study using differential scanning calorimetry. In W. E. Marshall, and J. I. Wadsworth (eds), Rice Science and Technology, pp. 205-227. New York: Marcel Dekker.

Martin, M., and Fitzgerald, A. 2002. Proteins in rice grains influence cooking properties. Journal of Cereal Science 36: 285-294.

Moritaka, S., and Yasumatsu, K. 1972. Studies on cereals. X. The effect of sulfhydryl groups on storage deterioration of milled rice. Eiyo To Shokuryo 25: 59–62, cited in, Juliano, B. O. 1985c. Criteria and tests for rice grain qualities. In B. O. Juliano (eds), Rice: Chemistry and Technology, pp. 443-523. Minnesota: The American Association of Cereal Chemists.

Morrison, W. R. 1995. Starch lipids and how they relate to starch granule structure and functionality. Cereal Foods World 40: 437-446.

Oka, H. I. 1991. Genetic diversity of wild and cultivated rice. In G. S. Khush, and G. H. Toenniessen (eds), Rice Biotechnology, pp. 55-81. Oxford: The Alden Press.

Ong, M. H., and Blanshard, J. M. V. 1995. Texture determinants of cooked, parboiled rice. II: Physicochemical properties and leaching behaviour of rice. Journal of Cereal Science 21: 261-269.

Paull, J. 2006. The farm as organism: the foundational idea of organic agriculture. Journal of Bio-Dynamics Tasmania 83: 14-18.

Pearce, M., Marks, B., and Meullenet, J. 2001. Effects of postharvest parameters on functional changes during rough rice storage. Cereal Chemistry 78: 354-357.

Reid, D. S. 2002. Use, misuse and abuse of experimental approaches to studies. In H. Levine (eds), Amorphous Food and Pharmaceutical Systems, pp. 325-337.

Reid, D. S., Hsu, J., and Kerr, W. 1993. Calorimetry. In J. M. V. Blanshard, and P. J. Lillford (eds), The Glassy State in Foods, pp. 123-132. Loughborough: Nottingham University Press.

Rordprapat, W., Nathakaranakule, A., Tia, W., and Soponronnarit, S. 2005. Comparative study of fluidized bed paddy drying using hot air and superheated steam. Journal of Food Engineering 71: 28–36.

Schieberle, P. 1991. Primary Odorants in Popcorn. Journal of Agricultural and Food Chemistry 39: 1141-1144.

Schoch, T. J. 1964. Swelling power and solubility of granular starches. In R. L. Whistler, R. J. Smith, and J. N. Bemiller (eds), Method in Carbohydrates Chemistry, pp. 534-544. New York: Academic Press.

Shin, M. G., Yoon, S. H., Rhee, J. S., and Kwon, T. 1986. Correlation between oxidative deterioration of unsaturated lipid and n-hexanal during storage of brown rice. Journal of Food Science 51: 460-463.

Soponronnarit, S. 1999. Fluidised-Bed Paddy Drying. Science Asia 25: 51-56.

Soponronnarit, S., and Prachayawarakorn, S. 1994. Optimum strategy for fluidized bed paddy drying. Drying Technology 12: 1667-1686.

Soponronnarit, S., Chiawwet, M., Prachayawarakorn, S., Tungtrakul, P., and Taechapairoj, C. 2008. Comparative study of physicochemical properties of accelerated and naturally aged rice. Journal of Food Engineering 85: 268-276.

Sowbhagya, C. M., and Bhattacharya, K. R. 1976. Lipid autoxidation in rice. Journal of Food Science 41: 1018-1023.

Sowbhagya, C. M., and Bhattacharya, K. R. 2001. Changes in pasting behaviour of rice during ageing. Journal of Cereal Science 34: 115-124.

Sriseadka, T., Wongpornchai, S., and Kitsawatpaiboon, P. 2006. Rapid method for quantitative analysis of the aroma impact compound, 2-acetyl-1-pyrroline, in fragrant rice using automated headspace gas chromatography. Journal of Agricultural and Food Chemistry 54: 8183-8189.

Steeneken, P. A. M. 1989. Rheological properties of aqueous suspensions of swollen starch granules. Carbohydrate Polymers 11: 23-42.

Sunthonvit, N., Srzednicki, G., and Craske, J. 2003. Effects of high temperature drying on the flavour components in Thai fragrant rice varieties. In V. K. Jindal, A. Noomhorm, and I. Ahmad (eds), Proceedings of the 3rd Asia-Pacific Drying Conference, pp 249-258.

Suttajit, M. 1999. 'Vegetarianism is the Way' an unforgettable visual, cultural and gastronomic experience: free radicals, antioxidants and Health [Online]. Available from: http://www.ivu.org/congress/thai99/ [2006, October 23]

Tang, S., Hettiarachchy, N. S., Ju, Z., and Cnossen, A. 2002. Surface hydrophobicity and protein cross-linking in rice subjected to varying drying and tempering conditions. Journal of Food Science 67: 2930-2933.

Teo, C. H., Karim, A. A., Cheah, P. B., Norziah, M. H., and Seow, C. C. 2000. On the roles of protein and starch in the aging of non-waxy rice four. Food Chemistry 69: 229-236.

Thai Meteorological Department. 2008. Daily weather summary in Bangkok from January 2007 to March 2008.

Thomas, D. J., and Atwell, W. A. 1999. Starches. Minnesota: American Association of Cereal Chemists.

Tirawanichakul, S., Prachayawarakorn, S., Tungtrakul, P., Varanyanond, W., and Soponronnarit, S. 2004. Effect of fluidized bed drying temperature on various quality attributes of paddy. Drying Technology 22: 1731-1754.

Tulyathan, V., and Leeharatanaluk, B. 2007. Changes in quality of rice (*Oryza sativa* L.) cv. Khao Dawk MaLi 105 during storage. Journal of Food Biochemistry 31: 415-425.

Tulyathan, V., Srisupattarawanich, N., and Suwanagul, A. 2008. Effect of rice flour coating on 2-acetyl-1-pyrroline and n-hexanal in brown rice cv. Jao Hom Supanburi during storage. Postharvest Biology and Technology 47: 367–372.

Unnikrishnan, K. R., and Bhattacharya, K. R. 1995. Changes in properties of parboiled rice during ageing. Journal of Food Science and Technology 32: 17–21, cited in Sowbhagya, C. M., and Bhattacharya, K. R. 2001. Changes in pasting behaviour of rice during ageing. Journal of Cereal Science 34: 115-124.

USDA. 2006. National nutrient database for standard reference [Online]. Available from: http://www.nal.usda.gov/fnic/foodcomp/cgi-bin/list-nut-edit.pt [2007, March 15]

USDA. 2007. Rice area, yield and production [Online]. Available from: http://www.fas.usda.gov/psdonline/psdgetreport.aspx?hidReportRetrievalName=BV S&hidReportRetrievalID=893&hidReportRetrievalTemplateID=1 [2008, March 2]

Walstra, P. 2003. Physical Chemistry of Foods. New York: Marcel Dekker.

Wang, C., and Damodaran, S. 1990. Thermal gelation of globular Protein: Weight-average molecular weight dependence of gel strength. Journal of Agricultural and Food Chemistry 38: 1157-1164.

Whistler, R. L., and Daniel J. R. 1984. Molecular structure of starch. In R. L. Whistler, J. N. Bemiller, and P. Eugene (eds), Starch: Chemistry and Technology, pp. 153-183. Florida: Academic Press.

Wiset, L., Srzednicki, G., and Driscoll, R. H. 2003. Effects of high temperature drying on physico-chemical properties of rice. In V. K. Jindal, A. Noomhorm, and I. Ahmad (eds), Proceedings of the 3rd Asia Pacific Drying Conference, pp 261-269.

Wongpornchai, S., Dumri, K., Jongkaewwattana, S., and Siri, B. 2004. Effects of drying methods and storage time on the aroma and milling quality of rice (*Oryza sativa* L.) cv. Khao Dawk Mali 105. Food Chemistry 87: 407-414.

Wongpornchai, S., Sriseadka, T., and Choonvisase, S. 2003. Identification and quantitation of the rice aroma compound, 2-acetyl-1-pyrroline, in Bread flowers (*Vallaris glabra* Ktze). Journal of Agricultural and Food Chemistry 51: 457-462.

Yoshihashi, T. 2002. Quantitative analysis on 2-acetyl-1-pyrroline of an aromatic rice by stable isotope dilution method and model studies on its formation during cooking. Journal of Food Science 67: 619-622.

Yoshihashi, T., Huong, N. T. T., and Inatomi, H. 2002. Precursors of 2-acetyl-1-pyrroline, a potent flavor compound of an aromatic rice variety. Journal of Agricultural and Food Chemistry 50: 2001-2004.

Yoshihashi, T., Huong, N. T. T., Surojanametakul, V., Tungtrakul, P., and Varanyahond, W. 2005. Effect of storage conditions on 2-acetyl-1-pyrroline content in aromatic rice variety, Khao Dawk Mali 105. Journal of Food Science 70: s34-s37.

Zhou, M., Robards, K., Glennie-Holmes, M., and Helliwell, S. 1998. Structure and pasting properties of oat starch. Cereal Chemistry 75: 273-281.

Zhou, Z., Robards, K., Helliwell, S., and Blanchard, C. 2002a. Composition and functional properties of rice. International Journal of Food Science and Technology 37: 849-868.

Zhou, Z., Robards, K., Helliwell, S., and Blanchard, C. 2002b. Ageing of stored rice: changes in chemical and physical attributes. Journal of Cereal Science 35: 65-78.

Zhou, Z., Robardsa, K., Helliwella, S., and Blanchard, C. 2003. Effect of rice storage on pasting properties of rice flour. Food Research International 36: 625-634.

Zobel, H. F. 1984. Gelatinization of starch and mechanical properties of starch pasted. In R. L. Whistler, J. N. Bemiller, and P. Eugene (eds), Starch: Chemistry and Technology, pp. 285-305. Florida: Academic Press.

APPENDICES

APPENDIX A

ANALYTICAL METHODS

A.1 Moisture content analysis, AOAC Official Methods 925.09B (AOAC, 1995)

Equipments and apparatus

1. Hot air oven (WTB Binder, model 7200, Germany)
2. Aluminum pan
3. Desiccator

Determination

Two grams of sample, accurately weighed, were placed into a preweighed aluminum pan. The sample was heated at 130°C for 4 hours or until its constant weight was obtained. The sample was then transferred to a desiccator and weighed soon after its temperature reached room temperature. Moisture content of the sample was calculated from the following formula.

$$\text{Moisture content (\% wb)} = \frac{\text{weight of sample (g)} - \text{weight of dried sample (g)}}{\text{weight of sample (g)}} \times 100$$

A.2 Crude protein analysis, AOAC Official Methods 979.09 (AOAC, 1995)

Equipments and apparatus

1. Digestion unit (Buchi, model K-424, Switzerland)
2. Distillation unit (Buchi, model B-324, Switzerland)

Chemical reagents

1. conc. sulfuric acid (A.R. grade, J. T. Baker Neutrasorb, USA)
2. 0.1 N standard hydrochloric acid (A.R. grade, Ajax Finechem, Australia)
3. Sodium hydroxide (A.R. grade, Carlo Erba, France), 50% w/v solution
4. Boric acid (A.R. grade, Merck, Germany), 4% w/v solution was prepared
5. Selenium reagent mixture (A.R. grade, Merck, Germany)

6. Indicator (dissolved 0.125 g of methyl red (A.R. grade, Fisher Scientific, UK) and 0.0825 g of methylene blue (A.R. grade, Ajax Finechem, Australia) in 100 ml of 90% ethanol)

Determination

One gram of sample was placed into a digestion flask. Five grams of selenium mixture and 25 ml of sulfuric acid were added into the flask. In case of blank, one milliliter of distilled water was used instead of the sample. The flask was placed in an inclined position and heated gently until frothing ceased, approximately 30 minutes. The digested sample was placed into Buchi distillation unit and distilled with the following program.

- 50% (w/v) sodium hydroxide solution	60 ml
- 4% (w/v) boric acid	50 ml
- distilled water	50 ml
- distillation time	5 min

The distilled solution was titrated with 0.1 N hydrochloric acid until reaching the end point. Methyl red/methylene blue was used as an indicator. Crude protein was calculated from the following formula.

$$\% \text{ Nitrogen} = \frac{(V-B) \times N \times 1.4}{\text{weight of sample (g)}}$$

$$\text{Crude protein (\% db)} = \%\text{Nitrogen} \times 5.95$$

where V represents the volume of 0.1 N standard hydrochloric acid titrated with the sample (ml), B represents the volume of 0.1 N standard hydrochloric acid titrated with blank (ml), and N represents the exact concentration of standard hydrochloric acid (N).

A.3 Crude fat analysis, AOAC Official Methods 920.39C (AOAC, 1995)

Equipments and apparatus

1. Soxhlet (Gerhardt, model HC61, Germany)
2. Rotary evaporator (Eyela, model SB-651, Japan)

Chemical reagents

1. Petroleum ether (A.R. grade, Fisher Scientific, UK)

Determination

Two grams of dried sample, accurately weighed, were placed into a porous thimble. The thimble was placed into a Soxhlet apparatus and 250 ml of petroleum ether was added. Crude fat was extracted from the sample for 3 hours. The solvent was evaporated from the extraction using a rotary evaporator. The crude fat residue in the preweighed rounded-bottom flask was dried at $100\pm5^{\circ}C$ for 30 minutes or until its constant weight was obtained. The sample was then transferred to desiccator and weighed soon after its temperature reached room temperature. Crude fat was calculated from the following formula.

$$\text{Crude fat (\% db)} = \frac{\text{weight of crude fat residue (g)}}{\text{weight of sample (g)}} \times 100$$

A.4 Dietary fiber analysis, AOAC Official Methods 992.16 (AOAC, 1995)

The dietary fiber was examined using the enzymatic method, AOAC Official Methods 992.16 (AOAC, 1995), by Institute of Nutrition, Mahidol University.

A.5 Ash content analysis, AOAC Official Methods 923.03 (AOAC, 1995)

Equipments and apparatus

1. Muffle furnace (Fisher Scientific, model Isotemp, Germany)
2. Crucible
3. Hot plate
4. Desiccator

Determination

Three to five grams of sample, accurately weighed, were placed into a preweighed crucible. The sample was heated on a hot plate in a fume hood until the smoke ceased. The sample was then ignited in a furnace at 550°C until the gray ash turned white. The crucible was transferred to desiccator and weighed soon after its temperature reached room temperature. Ash content of the sample was calculated from the following formula.

$$\text{Ash content (\% wb)} = \frac{\text{weight of ash (g)}}{\text{weight of sample(g)}} \times 100$$

A.6 Calculation of carbohydrate content (AOAC, 1995)

The carbohydrate content was calculated from the following formula.

Carbohydrate content (%db) = 100 – (%protein + %lipid + %dietary fiber +%ash)

A.7 Amylose content analysis (Juliano, 1981)

Equipments and apparatus

1. Spectrophotometer (Genesys Spectronic® 20, USA)
2. Water bath (Heto Lab Equipment, model DT-1, Denmark)
3. Magnetic stirrer (Framo-Geratetechnik, model M21/1, Thaliand) and magnetic bar

Chemical reagents

1. 95% ethanol (A.R. grade, Liquor Distillery Organization Excise Department, Thailand)
2. Sodium hydroxide (A.R. grade, Carlo Erba, France), 1 N solution
3. Iodine solution (dissolved 0.2 g of iodine and 2.0 g of potassium iodide (A.R. grade, Fisher Scientific, UK) in 100 ml of distilled water)
4. Standard amylose from potatoes (A.R. grade, Fluka, USA)

Determination of amylose content in flour sample

One hundred milligrams of sample, accurately weighed, were placed into a dried 100 ml volumetric flask. One milliliter of ethanol was added into the flask. The solution was gently shaken and 9 ml of sodium hydroxide was subsequently added. The solution was then stirred on a magnetic stirrer for 10 minutes. The magnetic bar was taken out from the volumetric flask. The final volume of the sample solution was then adjusted with distilled water. This solution will be subsequently called "prepared sample solution".

To determine the amylose content of the sample, 70 ml of distilled water, 2 ml of acetic acid and 2 ml of iodine solution were added into 100 ml volumetric flask. Five milliliters of the prepared sample solution was then pipetted into this solution and the final volume of the solution was adjusted with distilled water. Blank was prepared by the same procedure using distilled water instead of the prepared sample solution. The solution was let stand for 10 minutes and the absorbance at 610 nm of the sample was subsequently measured by spectrophotometer. The amylose content of the sample was calculated from standard curve of amylose.

Preparation of standard curve of amylose

The amylose standard solution was prepared with the similar procedure as used for the preparation of the sample solution but using 0.0400 g of potato amylose instead of the sample. The standard solution was prepared in 100-milliliter flask. The serial dilution was prepared as listed in Table A.1. Final volume in each flask was adjusted to 100 ml with distilled water. The solution was let stand for 10 minutes and the absorbance at 610 nm was measured by spectrophotometer. The standard curve was created (Fig. A.1)

Table A.1 Preparation of standard amylose solution

Distilled water (ml)	Iodine solution (ml)	Acetic acid (ml)	Standard stock solution[A] (ml)	Amylose content[B] (mg)
70	2	0.4	1	0.4
70	2	0.8	2	0.8
70	2	1.2	3	1.2
70	2	1.6	4	1.6
70	2	2.0	5	2.0

[A] Standard stock solution was prepared by adding 0.0400 g of amylose, 1 ml of 95% ethanol and 9 ml of 1 N sodium hydroxide to 100-milliliter volumetric flask, stirred on magnetic stirrer for 10 minutes and the final volume was adjusted to 100 ml with distilled water.

[B] Final weight of potato amylose in 100 ml of standard solution

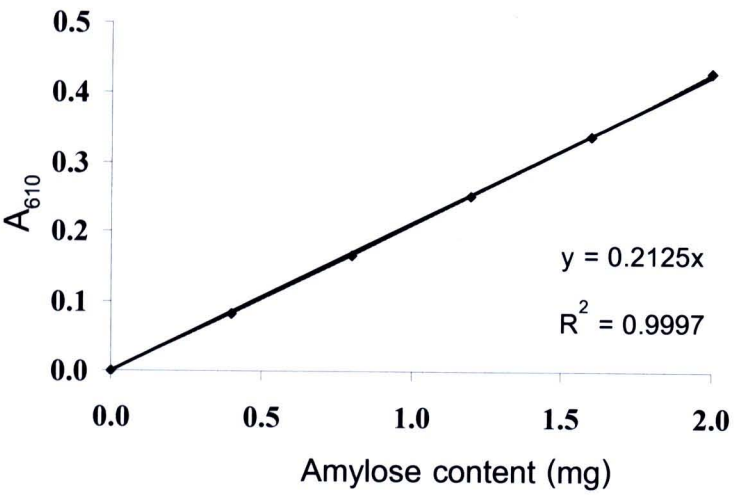

Figure A.1 Standard curve for the determination of amylose content

A.9 Thermal properties

Equipments and apparatus

1. DSC (Perkin-Elmer, model Diamond DSC, USA) equipped with an Intracooler unit (Perkin-Elmer, model 2P, USA) and nitrogen gas purge

2. 4-digit balance (Ohaus, model Explorer, Switzerland)

3. Aluminum volatile sample pan (Perkin-Elmer, kit number 0219-0062, USA)

Chemical reagents

1. 2-mercaptoethanol (A.R. grade, Bio Basic Inc., Canada)

Determination

A known weight of the rice flour was directly placed in a DSC volatile sample pan. Calculated amount of distilled water was added using the ratio of water to rice flour as 3:1 (w/w, db). The pan was hermetically sealed, reweighed and equilibrated overnight at room temperature before the experiment. The total weight of the sample in DSC pans was approximately 15 mg. An empty volatile sample pan was used as a reference. The sample and reference pan were scanned from 30°C to 85°C at a heating rate of 10°C /min. The DSC parameters, gelatinization temperature reported as T_p (°C), the range of gelatinization temperature (ΔT_g, °C) calculated by the difference between T_o and T_c, and ΔH_g (J/g) calculated from the area of the gelatinization peak from the DSC thermogram, were reported.

To determine effects of 2-mercaptoethanol treatment on thermal properties of the samples, solution of 0.5%v/v of 2-mercaptoethanol in distilled water was used instead of distilled water. The final concentration of 2-mercaptoethanol in the samples was 0.36% v/w.

A.10 Pasting properties

Equipments and apparatus

RVA (Newport Scientific, model Super 3, Australia)

Chemical reagents

1. 2-mercaptoethanol (A.R. grade, Bio Basic Inc., Canada)

Determination

Rice flour (3.000±0.010 g) was mixed with distilled water (25±0.010 ml) in a canister. The RVA temperature program started with holding at 50°C for 1 min, heating to 95°C with a heating rate of 12°C /min, holding at 95°C for 2.5 min, cooling at 50°C with a cooling rate of 12°C /min and then holding at 50°C for 1.5 min. PT, PV, BD and SB were automatically reported by the instrument.

To determine effects of 2-mercaptoethanol treatment on pasting properties of the samples, 100 µl of 2-mercaptoethanol was added into the sample suspension prior to immediate running of RVA analysis. The final concentration of 2-mercaptoethanol in the samples was 0.36% v/w.

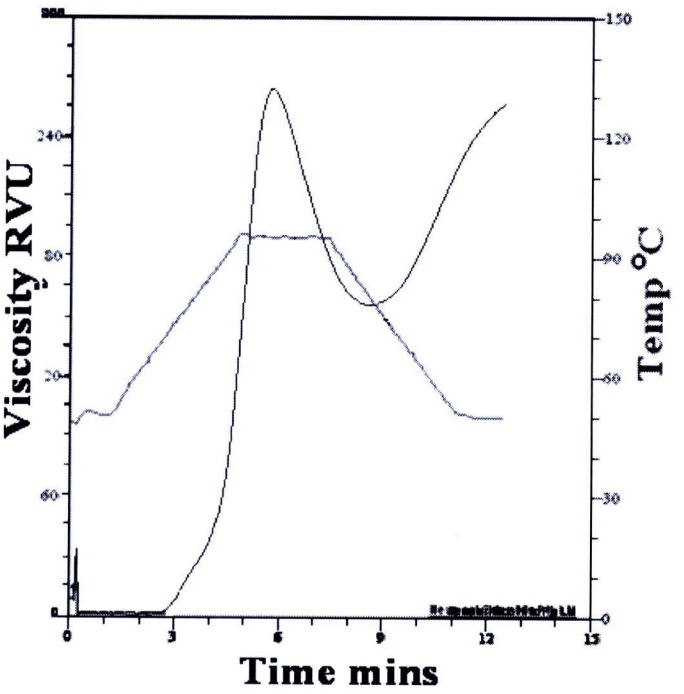

Figure A.2 RVA curve of fresh shade-dried hulled red jasmine rice

A.11 Swelling power (modified form Schoch, 1964)

Equipments and apparatus

1. Water bath (Heto Lab Equipment, model DT-1, Denmark)
2. Centrifuge (Thermo IEC, model IEC Multi-EF, USA)
3. Hot air oven (WTB Binder, model 7200, Germany)

Determination

Half grams of sample, accurately weighed, were placed into a preweighed centrifugal tube. Fifteen-milliliter of distilled water was then added and the sample was heated at 70°C and 90°C in a water bath for 30 minutes with continuous stirring. The sample was subsequently centrifuged at 6000×g for 30 minutes. The supernatant was gently poured into a preweighed porcelain pan and dried at 130°C. The porcelain pan

was transferred to desiccator and weighed soon after its temperature reached room temperature. The constant weight of the dried supernatant was measured and used to calculate for solubility of the sample. The precipitated paste was weighed and calculated for swelling power according to the following formula.

$$\% \text{ Solubility} = \frac{\text{weight of dried supernatant (g)}}{\text{weight of sample (g)}} \times 100$$

$$\text{Swelling power (g/g sample db)} = \frac{\text{weight of precipitated paste (g)}}{\text{sample weight (g) (100 - \% solubility)}} \times 100$$

APPENDIX B

FLUIDIZED BED DRYER

B.1 Calculation of the weight of paddy samples in each batch of FB drying

In this experiment, the drying chamber of the FB dryer was cylindrical with 20-centimeter diameter. Soponronnarit and Prachayawarakorn (1994) suggested that for the size of the cylindrical drying chamber, suitable height of sample in the chamber should be approximately 9.5 cm. Therefore, the volume of paddy samples in each batch was approximately 2,984 cm^3. The density of paddy samples containing the moisture content of 30% wb was approximately 0.60 g/cm^3. The amount of paddy samples loaded in FB dryer in each batch could be calculated from the following formula;

$$W = \rho \times V$$

where W represents the weight of paddy samples loaded in FB dryer in each batch (g), ρ represents the density of paddy samples (g/cm^3), and V represents the volume of drying chamber of FB dryer (cm^3) when the height of the samples was 9.5 cm.

Therefore, weight of the paddy samples was approximately 1,800 g in each batch.

B.2 Setting of air velocity

Before the operation, the FB dryer was switched on for 30 minutes. The temperature of the FB dryer was set at 35°C. To set air velocity, the samples were loaded into the chamber by the following procedure. Before sample loading, the fan motor was switched off. The samples were then loaded. Subsequently, the drying chamber was closed and the fan motor was switched on immediately. The fan motor was then adjusted until the air velocity reached 2.0 m/s. After that, the paddy samples were unloaded. During the setting of the air velocity, the temperature was maintained at 35°C.

B.3 Operation of FB dryer

Before the operation, the FB dryer should be switched on for 30 minutes. When the FB dryer was ready to operate, drying temperature was set at 115 °C. After the temperature was constant, a new batch of the samples was loaded into the chamber with the procedure previously mentioned in B.2. The samples were dried for 215 seconds to reduce the moisture of the samples to 18% wb. The samples were then unloaded and randomly collected to measure paddy temperature and moisture content immediately. The rest of the unloaded samples were placed into plastic baskets to shade dry.

B.4 Shutting down of the FB dryer

Before shutting down, the FB dryer should be cooled down and waited until the temperature reaches 35°C.

APPENDIX C

FIGURES OF HULLED RED JASMINE RICE SAMPLE

C.1 Raw and cooked hulled red jasmine rice

a b

Figure C.1 Raw (a) and cooked (b) freshly hulled red jasmine rice subjected to sun drying

C.2 Shade-dried hulled red jasmine rice packed in Nylon/LLDPE and OPP/AL/LLDPE pouch

a b

Figure C.2 Shade-dried hulled red jasmine rice packed in Nylon/LLDPE pouch (a) and OPP/AL/LLDPE pouch (b).

APPENDIX D

SENSORY ANALYSIS

D.1 Quantitative and Descriptive Analysis (QDA)

D.1.1 Panelists

A 8-member panel consisted of 5 females and 3 males with aged 23–30. All panelists were graduate students of Department of Food Technology, Faculty of Science, Chulalongkorn University.

D.1.2 Training the panelists

A training session was divided into 2 parts. In the first part, the panelists familiarized themselves with the cooked hulled rice and recognized characteristics and intensity of tested sensory attributes. The sensory attributes and their references are summarized in Table D.1. The second part was calibrating session. For each panelist, intensity rating of each attribute was calibrated using 10-point scale intensity rating (D.1.4). This 2-hour training session was performed twice before starting the actual evaluation.

D.1.3 Evaluation procedure

Five-gram portion of each cooked sample was served. Temperature of each served sample was approximately 40-50^{o}C. Each sample was coded with 3-digit number. Each panelist evaluated one sample at a time and marked their responses on a questionnaire with 10-point intensity scale (D.1.4). Panelists had to drink water to clean their mouth before evaluating a following sample.

Table D.1 Sensory attributes and reference standards

Sensory attribute	Standard	
	Intensity rating = 0	Intensity rating = 10
Fragrance	Cooked hulled red jasmine rice prepared from the sample which was shade dried, packed in Nylon/LLDPE pouch and stored at ambient temperature for 13 months	Cooked hulled rice prepared from commercial organic brown rice (Manufacturing date 12/02/08) which was purchased from local supermarket in March 2008.
Rancidity	Cooked hulled red jasmine rice prepared from the freshly shade-dried sample	Cooked hulled red jasmine rice prepared from the sample which was shade dried, packed in Nylon/LLDPE pouch and stored at ambient temperature for 13 months
Hardness	Cooked hulled rice prepared from commercial organic brown rice (Manufacturing date 12/02/08) which was purchased from local supermarket in March 2008.	Cooked hulled red jasmine rice prepared from the sample which was shade dried, packed in Nylon/LLDPE pouch and stored at ambient temperature for 13 months

D.1.5 Questionnaire for QDA

Sensory evaluation of cooked hulled red jasmine rice

Name.....Age.....Gender.....

3-digit sample code.....Date.....

Instructions Please evaluate the following attributes of each cooked hulled red jasmine rice sample. For each attribute, please check (✓) in the box representing the intensity level which was the most corresponded to your opinion.

1. Aroma

1.1 Fragrance

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

0 1 2 3 4 5 6 7 8 9 10

minimum intensity (no fragrance) — moderate intensity — maximum intensity (strong fragrance)

1.2 Rancidity

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

0 1 2 3 4 5 6 7 8 9 10

minimum intensity (no rancid aroma) — moderate intensity — maximum intensity (strong rancid aroma)

2. Hardness

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

0 1 2 3 4 5 6 7 8 9 10

minimum intensity (very soft) — moderate intensity — maximum intensity (very hard)

Suggestions.....

.....

Thank you for your participation ☺

D.2 Affective test

D.2.1 Panelists

A 34-member panel consisted of 21 females and 13 males with aged 11-43, all untrained. The panelists were students and staff of Chulalongkorn University. All panelists used to consume cooked hulled rice.

D.2.2 Evaluation procedure

Five-gram portion of each cooked sample was served. Temperature of each served sample was approximately 40-50°C. Each sample was coded with 3-digit number. Each consumer evaluated one sample at a time and marked their responses on a questionnaire with 5-point hedonic scale (D.2.3). Consumers had to drink water to clean their mouth before evaluating a following sample.

D.2.3 Questionnaire for affective test

การประเมินคุณภาพทางด้านประสาทสัมผัสของข้าวกล้องหอมมะลิแดง

เพศ.....**อายุ**.....**วันที่ทำแบบทดสอบ**.....

คำชี้แจง โปรดชิมตัวอย่างข้าวกล้องหอมมะลิแดงทีละตัวอย่าง แล้วให้คะแนนที่ตรงกับความรู้สึกของท่านมากที่สุดแก่ตัวอย่างในคุณภาพทางด้านประสาทสัมผัสตามที่ระบุในตาราง

1 = **ไม่ชอบมากที่สุด** 2 = **ไม่ชอบ** 3 = **เฉยๆ** 4 = **ชอบ** 5 = **ชอบมาก**

คุณภาพทาง ประสาทสัมผัส	**รหัสตัวอย่าง**		
สีของข้าวกล้องหุงสุก			
ความแข็งของข้าวกล้องหุงสุก			
กลิ่นของข้าวกล้องหุงสุก			
การยอมรับโดยรวม			

ข้อเสนอแนะ.....

.....

ขอบคุณมากค่ะ ☺

APPENDIX E

STATISTICAL ANALYSIS

Table E.1 The ANOVA table showing the effect of drying methods on moisture content and water activity of fresh hulled red jasmine rice at the 95% confidence

Dependent variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Moisture content	Between Groups	6.288	2	3.144	34.400	.000
	Within Groups	1.097	6	.091		
	Total	7.385	8			
Water activity	Between Groups	.009	2	.005	30.982	.001
	Within Groups	.001	6	.000		
	Total	.010	8			

Table E.2 The ANOVA table showing the effect of drying methods on thermal properties of fresh hulled red jasmine rice at the 95% confidence

Dependent variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Onset temperature (T_o)	Between Groups	3.396	2	1.698	116.028	.000
	Within Groups	.088	6	.015		
	Total	3.484	8			
Peak temperature (T_p)	Between Groups	1.473	2	.736	20.819	.002
	Within Groups	.212	6	.035		
	Total	1.685	8			
Range of gelatinization (ΔT_g)	Between Groups	.414	2	.207	10.076	.012
	Within Groups	.123	6	.021		
	Total	.537	8			
Enthalpy of gelatinization (ΔH_g)	Between Groups	1.960	2	.980	6.569	.031
	Within Groups	.895	6	.149		
	Total	2.855	8			

Table E.3 The ANOVA table showing the effect of drying methods on pasting properties of fresh hulled red jasmine rice at the 95% confidence

Dependent variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Pasting temperature (PT)	Between Groups	1.410	2	.705	.990	.400
	Within Groups	8.547	6	.712		
	Total	9.957	8			
Peak viscosity (PV)	Between Groups	5.579	2	2.790	.148	.864
	Within Groups	226.227	6	18.852		
	Total	231.806	8			
Breakdown (BD)	Between Groups	648.933	2	324.466	12.959	.001
	Within Groups	300.448	6	25.037		
	Total	949.380	8			
Setback (SB)	Between Groups	5.642	2	2.821	.698	.517
	Within Groups	48.492	6	4.041		
	Total	54.134	8			

Table E.4 The ANOVA table showing the effect of drying methods on swelling power of fresh hulled red jasmine rice at the 95% confidence

Dependent variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Swelling power at 70°C	Between Groups	1.182	2	.591	.315	.741
	Within Groups	11.266	6	1.878		
	Total	12.447	8			
Swelling power at 90°C	Between Groups	4.085	2	2.043	2.783	.115
	Within Groups	6.605	6	.734		
	Total	10.691	8			

Table E.5 The ANOVA table showing the effect of drying methods on color in Hunter L, a, b system of cooked hulled rice prepared from fresh hulled red jasmine rice at the 95% confidence

Dependent variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
L	Between Groups	8.621	2	4.310	1.144	.334
	Within Groups	101.740	27	3.768		
	Total	110.361	29			
A	Between Groups	7.921	2	3.961	16.578	.000
	Within Groups	6.450	27	.239		
	Total	14.372	29			
B	Between Groups	4.565	2	2.283	7.214	.003
	Within Groups	8.543	27	.316		
	Total	13.108	29			

Table E.6 The ANOVA table showing the effect of drying methods on fragrance aroma of cooked hulled rice prepared from fresh hulled red jasmine rice at the 95% confidence

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11.688(a)	9	1.299	1.360	.240
Intercept	595.021	1	595.021	623.030	.000
Panelist	6.146	7	.878	.919	.503
Drying method	5.542	2	2.771	2.901	.067
Error	36.292	38	.955		
Total	643.000	48			
Corrected Total	47.979	47			

a R Squared = .244 (Adjusted R Squared = .064)

Table E.7 The ANOVA table showing the effect of drying methods on rancidity of cooked hulled rice prepared from fresh hulled red jasmine rice at the 95% confidence

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	16.979(a)	9	1.887	2.240	.040
Intercept	130.021	1	130.021	154.400	.000
Panelist	8.813	7	1.259	1.495	.199
Drying method	8.167	2	4.083	4.849	.013
Error	32.000	38	.842		
Total	179.000	48			
Corrected Total	48.979	47			

a R Squared = .347 (Adjusted R Squared = .192)

Table E.8 The ANOVA table showing the effect of drying methods on hardness of cooked hulled rice prepared from fresh hulled red jasmine rice at the 95% confidence

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	26.521(a)	9	2.947	3.071	.007
Intercept	638.021	1	638.021	665.000	.000
Panelist	22.479	7	3.211	3.347	.007
Drying method	4.042	2	2.021	2.106	.136
Error	36.458	38	.959		
Total	701.000	48			
Corrected Total	62.979	47			

a R Squared = .421 (Adjusted R Squared = .284)

Table E.9 The ANOVA table showing the effect of storage condition on color in Hunter L, a, b system of cooked hulled rice prepared from sun-dried hulled red jasmine rice at the 95% confidence

Dependent variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
L	Between Groups	98.522	8	12.315	4.015	.000
	Within Groups	248.429	81	3.067		
	Total	346.951	89			
A	Between Groups	21.349	8	2.669	6.750	.000
	Within Groups	32.022	81	.395		
	Total	53.371	89			
B	Between Groups	10.305	8	1.288	4.126	.000
	Within Groups	25.286	81	.312		
	Total	35.592	89			

Table E.10 The ANOVA table showing the effect of storage condition on fragrance of cooked hulled rice prepared from sun-dried hulled red jasmine rice at the 95% confidence

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	64.667(a)	15	4.311	4.651	.000
Intercept	1834.694	1	1834.694	1979.460	.000
Panelist	6.861	7	.980	1.057	.395
Storage condition	57.806	8	7.226	7.796	.000
Error	118.639	128	.927		
Total	2018.000	144			
Corrected Total	183.306	143			

a R Squared = .353 (Adjusted R Squared = .277)

Table E.11 The ANOVA table showing the effect of storage condition on rancidity of cooked hulled rice prepared from sun-dried hulled red jasmine rice at the 95% confidence

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	343.243(a)	15	22.883	25.649	.000
Intercept	945.563	1	945.563	1059.876	.000
Panelist	11.493	7	1.642	1.840	.085
Storage condition	331.750	8	41.469	46.482	.000
Error	114.194	128	.892		
Total	1403.000	144			
Corrected Total	457.437	143			

a R Squared = .750 (Adjusted R Squared = .721)

Table E.12 The ANOVA table showing the effect of storage condition on hardness of cooked hulled rice prepared from sun-dried hulled red jasmine rice at the 95% confidence

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	199.903(a)	15	13.327	17.568	.000
Intercept	4225.000	1	4225.000	5569.675	.000
Panelist	15.778	7	2.254	2.971	.006
Storage condition	184.125	8	23.016	30.341	.000
Error	97.097	128	.759		
Total	4522.000	144			
Corrected Total	297.000	143			

a R Squared = .673 (Adjusted R Squared = .635)

Table E.13 The ANOVA table showing the effect of storage condition on consumers' preference in color, aroma and hardness of cooked hulled rice prepared from sun-dried hulled red jasmine rice packed in Nylon/LLDPE pouches at the 95% confidence

Dependent variable	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Color	Between Groups	2.020	2	1.010	1.573	.213
	Within Groups	63.559	99	.642		
	Total	65.578	101			
Aroma	Between Groups	.765	2	.382	.459	.633
	Within Groups	82.382	99	.832		
	Total	83.147	101			
Hardness	Between Groups	5.353	2	2.676	3.339	.040
	Within Groups	79.353	99	.802		
	Total	84.706	101			
Overall acceptance	Between Groups	3.314	2	1.657	2.496	.088
	Within Groups	65.706	99	.664		
	Total	69.020	101			

VITA

Ms. Yuwares Malila was born on July 23, 1982, in Bangkok. She obtained Bachelor of Science from Department of Food Technology, Faculty of Science, Chulalongkorn University with first class honor in 2005. Subsequently, she was working as a research assistant at Institute of Nutrition, Mahidol University for one year. In 2006, she enrolled in master degree program in Food Technology at Department of Food Technology, Faculty of Science, Chulalongkorn University. During master study, she was granted Chulalongkorn University Graduate Scholarship to Commemorate the 72nd Anniversary of His Majesty King Bhumibol Adulyadej from Graduate School of Chulalongkorn University. After achieving her master study, she was granted Full Science and Technology Scholarship by Royal Thai Government to pursue Ph.D. study in Food Chemistry program in USA.

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