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# A Study on Rice Milk Production

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## *Abstract*

*Various methods of rice milk production had been explored, including the method for enzymatic induction by germination of rice grain. The hydrolyses of rice starch by enzyme during germination and added enzyme from exogenous sources were compared. Sensory evaluations had led to the conclusion that the rice milk formulation added with enzyme from the exogenous sources produced a smoother mouth feel aftertaste sensation and obtained more preference by the majority of panelists.*

*Results obtained from the nutritive value analysis have shown that rice milk from this study provided higher carbohydrate and calcium contents than fresh milk. It was also found that cow milk contained higher total fat, cholesterol and protein contents than rice milk. Hence, rice milk could be used as a good nutrient source, especially when supplemented with protein.*

***Keywords:*** *Rice milk, rice beverage, rice product, cow-milk substitution product, food innovation, rice-product development.*

## Introduction

Thailand has been the number one exporter of rice for many years. The majority of the Thai population earned their living by growing rice. During the present economic crisis, income from the export of rice contributes to the earning of much needed foreign currency of the country. Unfortunately, the Thai exporters exported all the Thai rice in the form of unprocessed product, thus creating no benefit from any value addition. This problem leads to the disadvantage of Thai rice in the sense of the world market price fixing, the consequence of which is clearly reflected in the present price of rice. The Thai Government had justified the problem and tried to provide the solution by initiating a subsidized program to support the price of rice. Many people still in doubt whether such a solution will really do any good for the economy of the country as a whole.

On the other hand, the Thai Government also tried to encourage the farmers to raise dairy cows in order to provide sufficient amount of raw milk for the fresh drinking milk industry. But the industry has to face insufficient supply of raw milk consistently. Besides, the price of raw milk is far more expensive and the quality is not competitive with the imported powder milk. In practice, the UHT milk industry has depended on powder milk as a source of raw material supply instead of cow milk. This will eventually increase the problem for the whole milk production system. Another problem is to increase milk production; the Thai Government organized a dairy cow promotion organization that was responsible for the promotion of dairy cow raising of the farmers. But this organization had to face with a lot of management problems. At the end, the Government had no choice, but to turn over the management of this organization to a foreign firm.

To provide a solution to the problems mentioned above, the authors studied the method of utilizing rice as a raw material for the production of product that has similar nutritional value as cow milk for its substitution. It is predicted that such a product would receive a warm welcome from the Asian people as well as the American and European, especially those who have a problem of lactose intolerance. The success of this project would not only bring the price of the nutritious product down to an affordable level but also raise the price of Thai rice as well.

## Objective

The main objective of this study is to utilize rice as a raw material for the production of milk-substituted product that will benefit the majority of the population of the nation as a whole, especially for people that have problem with lactose intolerance. The consequence of this project should lead to an increase of value-added price for Thai rice.

Another objective of this study is to develop products that will benefit the nutritive consumption of the consumers of the low-income group.

## Literature Review

Although rice could survive as a perennial crop in the tropics or subtropics, it is considered a semi-aquatic annual plant. *Oryza sativa* L. and *0. glaberrima* Steud are the two cultivated species that can be grown in a wide range of water-soil regimes, from dry land on hilly slopes to a prolonged period of flooding in deep water.

Today, rice is grown in more than 100 countries, extending from 53$^{o}$ N latitude to 40$^{o}$ S, and from sea level to an altitude over 3,000 m. The production practices for rice in various countries vary from extremely primitive to highly mechanized operations. The crop has remarkable diversity because of its long history of cultivation and selection under diverse climatic and biotic environments, frequently in geographically separated areas (Hsich *et al.* 1982).

### Importance of Rice as Food

Although rice, wheat, and corn are the three most important cereals in the world, rice is the world's most important cereal for human consumption. As much as 80% of the daily caloric intake of people in these Asiatic countries is derived from rice. In the densely populated countries of Asia, especially Bangladesh, China, India, Indonesia, Iran, Japan, Korea, Pakistan, and Sri Lanka, rice is the most important staple food.

When the actual extraction rates of the cereals (the fraction of each grain utilized as food) are considered, rice is calculated to produce more food energy per hectare than the other cereals (Lu and Chang 1980). Total food protein production per hectare is also high for rice, second only to that for wheat. When the superior quality of rice protein is considered, the yield of utilizable protein is actually higher for rice than for wheat.

Rice is also consumed in the form of noodles, puffed rice, fermented sweet rice, and snack foods made by extrusion cooking (Mercier *et al.* 1989). It is used in making beer, rice wine, and vinegar. Some oriental desserts require the use of glutinous or sweet rice, which consists entirely of amylopectin in the starch, in contrast to the non-glutinous rice that contains both amylopectin and amylose (10-30%).

Rice oil extracted from the bran is rich in vitamin E and has received considerable attention from researchers as a potential source of oil for the developing countries. Up to the present, the use of rice oil has lagged behind its potential value because of activation of lipase and lipoxygenase enzymes during milling, which caused rancidity and development of off-flavor. Extrusion heating of rice bran immediately after milling to inactivate the enzymes has improved the stability of rice oil. As the new technology in oil extraction and refining becomes available to the developing countries, the consumption of rice oil should gradually increase production of cereal crops in the whole region (Luh 1980).

World rice production has increased by about 40% during the 1960s, and by about 30% during the 1970s (Herdt and Palacpac 1983). The yield per hectare increased by about 20% and the area harvested by about 10%. In Southeast Asia, rice production has increased by 30% during the 1960s and by nearly 35% during the 1970s. Increases in both the area harvested and the yield have contributed to the increased production.

**Rice in World Trade**

Rice traded on the world markets ranged between 11.8 and 12.7 mill.t per annum. The volume traded was 4.5% of the total production. Asia remains the largest rice-importing region, followed by Africa (over 3 mill.t during 1985-86), Europe (2 mill.t during 1980-84), and South America (1.6 mill.t in 1986) (IRRI 1987; FAO 1987, 1988, 1989).

Thailand remains the top rice-exporting country (2.8-4.8 mil.t/annum), followed by the US (2.3-3.1 mill.t); China (0.7-1.4 mill.t); Pakistan (0.7-1.3 mill.t); Myanmar and Italy (0.3-0.8 mill.t); and Australia, Uruguay, and Japan (0.1-0.7 mill.t).

Among the rice-importing countries, Indonesia ranks first (1973-83), followed by Saudi Arabia, Nigeria, the USSR, Senegal, and Cote d'voire. Brazil showed highly variable imports during the period. Saudi Arabia has been a major rice importer.

The international market price showed a rapid drop following the 1974 peak ($542/t for 5% broken Thai white rice) and remained stable during 1978-81. A sharp decline began in 1982 and continued until the second half of 1987, when the price of rice rallied. The average real price was slightly over $200/t in 1983 (FAO 1987, 1988, 1989).

During 1986-87, there was a surplus of rice on the world market, and the price was at an all-time low. The widespread drought of 1987 in South and Southeast Asia and the erratic monsoon weather of 1988 prevailing in Bangladesh, parts of India, and China reduced the reserve stocks to an all-time low, and the world price of rice rallied again.

**Utilization of Rice and Its By-Products**

Milled rice and parboiled rice are consumed mainly as boiled rice. Different rice varieties with specific amylose : amylopectin ratios are used in specific rice products. Waxy (glutinous) rice is the staple food in China, Lao PDR, and Thailand, and is usually prepared by steaming milled rice previously soaked in water. Waxy rice is used also in sweets and desserts. In the US, medium-grain low-amylose rice (of 12-20% amylose is used in making baby foods and breakfast cereals. Rice varieties in temperate countries (Japan, Korea, and northern China) have low amylose content. Intermediate-amylose (20-25%) varieties are used mainly for fermented rice cakes and in making canned soups. Intermediate-amylose rice is preferred over high-amylose rice in China, the Philippines, Indonesia, Thailand, Malaysia, and Vietnam. In the US, the short- and medium-grain varieties have low amylose content, while the long-grain varieties have intermediate-amylose content. High-amylose (>25%) rice is used for extruded rice noodles. Among high-amylose varieties of rice, soft-gel consistency is preferred to hard-gel consistency.

Many books on rice production have been published, e.g. by De Datta (1981), Luh (1980), and Yoshida (1981). Pillaiyar (1988) published the Rice Post-Production Manual, which deals largely with post-harvest operations. Juliano (1990) reviewed the literature on rice grain quality, with emphasis on problems and challenges. *But the literature of rice milk is completely lacking.*

**Lactose Intolerance**

Milk and other dairy products are a major source of nutrients in the American and European diets. Most important of these nutrients is calcium that is essential for the growth and repair of bones throughout life. In the middle and later years, a shortage of calcium may lead to thin, fragile bones that break easily (a symptom called osteoporosis). A concern for both children and adult with lactose intolerance is getting enough calcium in a diet that includes little or no milk. Unfortunately, milk can be the most important factor for the cause of lactose intolerance. Between 30 and 50 million Americans are lactose intolerant. Certain ethnic and racial populations are more widely affected than others. As many as 75% of all African-Americans and Native Americans and 90% of Asian-Americans are lactose intolerant. The condition is least common among persons of northern European descent.

Lactose intolerance is the inability to digest significant amounts of lactose, the predominant sugar of milk. This inability results from a shortage of the enzyme, lactase, which is normally produced by the cells that line the small intestine. Lactase breaks down milk sugar into simpler forms that can then be absorbed into the bloodstream. When there is not enough lactase to digest the amount of lactose consumed, the results, although not usually dangerous, may be very distressing. While not all persons deficient in lactase have symptoms, those who do are considered to be lactose intolerant.

Common symptoms of lactose intolerance include nausea, cramps, bloating, gas, and diarrhea, which begin about 30 min to 2 hrs after eating or drinking foods containing lactose. The severity of symptoms varies, depending on the amount of lactose each individual can tolerate.

Fortunately, lactose intolerance is relatively easy to treat. No treatment exists to improve the body's ability to produce lactase, but the symptoms can be controlled through the diet by not eating any food containing lactose. But the body still needs food that contains all of the nutrients found in regular milk. Therefore, the production of rice milk that maintains the nutritive value similar to regular milk certainly will receive a warm welcome by these consumers.

## Materials and Methods

### Rice

- Paddy, variety RD 1.

### Chemicals

- Soluble starch, ACS - for analysis, from Carlo Erba Reagenti.
- Maltose from Becton Dickinson Microbiology System, Cockeysville, USA.
- Potassium dihydrogen orthophosphate ($KH_2PO_4$) from Ajax Chemicals, Australia.
- Dipotassium hydrogen phosphate anhydrous, extra pure, from Merck, Darmstadt, Germany.
- Tris (hydroxymetyl)-aminomethane hydrochloride from Merck, Darmstadt, Germany.
- Calcium chloride dihydrate from Ajax Chemicals, Australia.
- 3,5-dinitrosalicylic acid from Sigma Chemical Co., USA.
- Sodium potassium tartrate from Sigma Chemical Co., USA.
- Sodium hydroxide, anhydrous pellets, from Carlo Erba Reagenti.
- α-amylase and β-amylase from Novo Nordisk.

### Equipment

- Centrifuge from HermLe, Germany.
- Spectrophotometer from Milton Roy Co., USA.
- Incubator from Jouan
- Refrigerator.
- Hot air oven from Memmert.
- Gas chromatography.
- HPLC.
- Atomic absorption.

### Method

***Rice Germination:*** 100 g of paddy was weighed and put into a 500 mL beaker. The paddy was washed for several times to reduce the chance of getting contaminanation. The paddy was soaked for 2 hrs, then germinated on plastic trays laid over with tissue paper. The paddy was then covered with two-layer cheesecloth. Water the trays and keep them at 24°C. Take the paddy samples from the tray on Days 1, 2, 3, 4, 5, 6, 7, and 8, respectively, for the enzyme activity test.

***Enzyme Extraction from Rice:*** 3 g of rice grains were sampled everyday for an 8-day interval. The grains were pounded into powder by using a mortar. The powder was put into a 100 mL beaker. 30 mL of 0.05 M Tris-HCl 0.02 M $CaCl_2$ buffer at pH 7.4 was put into the mortar. Then wash the mortar and the solution was poured into the beaker. Mix well by shaking the beaker for 30 second. Keep the solution in the refrigerator (4°C) for 3 hrs (shake the beaker every hour). After 3 hrs, shake well and leave the solution for 3 min, then pour the solution into a 250 mL beaker through a piece of cheesecloth. Add another 15 mL of the buffer. Mix the solution well and wait for 3 min, then pour the solution through same cheesecloth. Centrifuge the solution at 5000 rpm for 30 min and pour the supernatant into a color bottle. The supernatant was used for the detection of enzyme activity.

***α-Amylase Essay:***

*Enzyme activity:* The enzyme activity was determined by measuring the decreasing of the starch concentration. The method is commonly used for the determination of the saliva activity. α-amylase from saliva would react with 2% starch at 70°C (pH 6.8 controlled by phosphate buffer) for 3 min and then measured the optical density by spectrophotometer at OD 650 by using water as blank.

Preparation of substrate (2% starch): Weigh 1 g of starch and put into a 250 mL beaker, which contain 15 mL of distilled water. Mix well and add another 60 mL of distilled water and boil for 5 min. Cool down to room temperature and add distilled water until the final volume is 100 mL. This solution can be kept and used for at least one week.

Preparation of standard curve: Prepare 0, 1, 2, 3 and 5% starch solution. Boil the solutions at 70°C for 5 min. Cool down and add 5 mL of distilled water. Read the optical density by spectrophotometer at OD 540 nm by using water as blank. This standard curve can be used for the comparison of optical density and unit activity of enzyme.

*Measuring the enzyme activity by saccharifying method:* In this method enzyme activity was detected by measuring the reducing groups from hydrolyzing of soluble starch after reacted with 3,5-dinitrosalicylic acid (Bernfeld 1951). For α-amylase activity from the germinating rice was given that 1 unit is equal to the amount of enzyme that can change the substrate into reducing groups. This unit activity can be calculated from maltose which give 1 μmole of maltose/min at 37°C and the specific activity of enzyme is the amount of 1 unit activity/mg of protein.

Substrate Preparation (1% starch Solution): Put 1 g. of starch into a 250 mL beaker, which contained 15 mL of 0.02 M phosphate buffer at pH 7.0 in 0.01 M sodium chloride. Pour another 60 mL buffer, which has been boiled for 5 min and let cool down to room temperature. Then add buffer again until the final volume is 100 mL (the reagent can be kept in the refrigerator for a long time.)

Color reagent preparation: Weigh 1 g of 3,5-dinitrosalicylic acid, dissolve into 20 mL 2 N sodium hydroxide. Add 50 mL distilled water and use magnetic stir bar to help dissolve. Add 30 g of potassium nitrate and use magnetic bar to mix the solution well. Then add distilled water until the final volume is 100 mL. Pour into a color bottle. (The reagent can be kept for using for a long time.)

Standard curve of maltose: Prepare maltose at the concentrations 0, 0.1, 0.3, 0.5, 0.8, and 1.0 mg/mL. Take 1 mL of each concentration and added into 1 mL of 3,5-dinitrosalicylic acid. Boil for 5 min and cool down. Add 5 mL of distilled water. Read the optical density at OD 540 nm by spectrophotometer. Distilled water was used as blank. The standard curve of maltose was used for converting the value of optical density into unit activity of enzyme.

**Protein Determination of Bradford**

Protein determination by Bradford method was used to measure the change of Bradford reagent color at OD 595 nm by spectrophotometer. This method can be used together with maltose standard curve for converting the amount of protein to unit activity and specific activity.

***The Standard Curve of Bradford:*** Prepare protein BSA at 0, 0.005, 0.01, 0.03, 0.05, 0.07 and 0.1 mg/mL. Take 1 mL of each concentration, added into 5 mL of Bradford reagent, and leave for 5 min. Measure the optical density at OD 595 nm by spectrophotometer.

**Moisture Content Determination:** Moisture content determination was done by following the method published by AOAC (1990)

**Study on the Raw Materials Used for Rice Milk Making:**

***Procedure for Brewing Rice Beverage from Germinating Rice:*** Germinating rice on Day 7 was used. Water at different ratios was added to the rice. The mixture was blended in a blender and sieved to get rid of any larger particle. The liquid was used as substrate for the performing of wort mashing temperature programming. Heat the substrate to 49°C for 60 min (proteolytic activity), then increase temperature to 71°C for 90 min (amylolytic activity), and increase the heat to 77°C for 30 min (enzyme deactivation). Measure total soluble solid (°Brix) and then boil it. Add other ingredients such as sugar, salt, etc. and filter through a double layer of cheesecloth. Boil again. Add flavor and hot fill to bottle.

*Determination of the optimum ratio of boiled rice, variety RD 1, to water:* Boiled rice added with water was prepared for 4 treatments, which were 1:10, 1:8, 1:6 and 1:4. Using blender blended each treatment. Then, measure total soluble solid by using refractometer. Add 0.1 mL/L of α-amylase enzyme. Let stand for 1 hr. Gently boil and add 1.73 and 10.77 g of salt and skim milk powder, respectively. Adjust the total soluble solid to get 7°Brix by adding sugar. Stirred until the rice milk becomes uniform. Then filter it with cheesecloth. Pasteurize the rice milk and hot fill into glass bottle. Store in the refrigerator at 4°C for further sensory evaluation.

*Determination of the optimum ratio of germinating rice to water:* Three-day-old germinating rice was dried at 60°C for 4 hrs and gently roasted for 5 min. Four treatments of rice to water were 1:18, 1:16, 1:14 and 1:12. Each sample was blended, measured total soluble solid, and gently boiled. The rest of procedure was the same as above.

Each treatment of rice milk from boiled and germinating rice was tasted. Then the optimum ratio of boiled rice and germinating rice were compared to determine the acceptability and preference of the sample by the panelists.

**Study on the Optimum Ratio of Rice Milk Formula**

***The Best Concentration of Sugar:*** Sugar was added in 4 treatments, which were 0, 13.86, 27.72, 41.56 and 55.44 g/L of rice milk instead of adjusted according to the total soluble solid measurement.

***The Best Concentration of Salt:*** Five samples of rice milk were added with various amounts of salt, which were 0, 0.865, 1.73, 3.47, and 6.93 g/L of rice milk.

***The Best Concentration of Skim Milk Powder:*** Three samples of rice milk were added with various amounts of skim milk powder: 0, 10.77, and 28.72 g/L of rice milk.

***The Best Concentration of Vanilla Powder in Rice Milk:*** Three samples were added with 0, 1, and 2 teaspoons of vanilla powder. It was noticed that vanilla powder was added as the last ingredient before stirring and boiling.

***The Best Concentration of Cocoa Powder:*** Cocoa powder was added with various amounts as follows: 5.74, 11.48, 17.22, and 22.96 g/L of rice milk.

**Optimum Ratio of Ingredient in Rice Milk Formula**

Rice milk samples were compared by sensory evaluation. A 9-Point Hedonic Scale with 1 to 9 marks was used as tasting material. A total of 20 panelists were selected from the Biotechnology Faculty members and students. The panelists were informed and trained for the acceptable characteristics of the products before tasting and recommended for seven attributes, namaely: color, odor, taste, texture, mouth feel, aftertaste, and overall acceptance. Rice milk was tasted when it was cool. Significant difference of means in each attribute was analyzed by Duncan's New Multiple Range Test (DMRT) at significant level 0.05 %.

**Nutritive Values of Boiled Rice Milk Added and Without Added α-Amylase**

Nutritive values of boiled rice milk added and without added α-amylase at the rice to water ratio 1:6 were compared to germinating rice milk and roasted rice milk at the rice to water ratio 1:16

The following factors in the final products were determined:

- Calories by spectrometry (VIS) method
- Saturated fat by HPLC method
- Cholesterol by gas chromatography method
- Sodium by atomic absorption method
- Carbohydrate by diagnostic test
- Sugar by titrimetric method
- Protein by spectrophotometer
- Calcium by atomic absorption

## Result and Discussion

### Germination of Rice

The result of the experiments on rice grain germination at room temperature (32°C) is shown in Fig. 1.

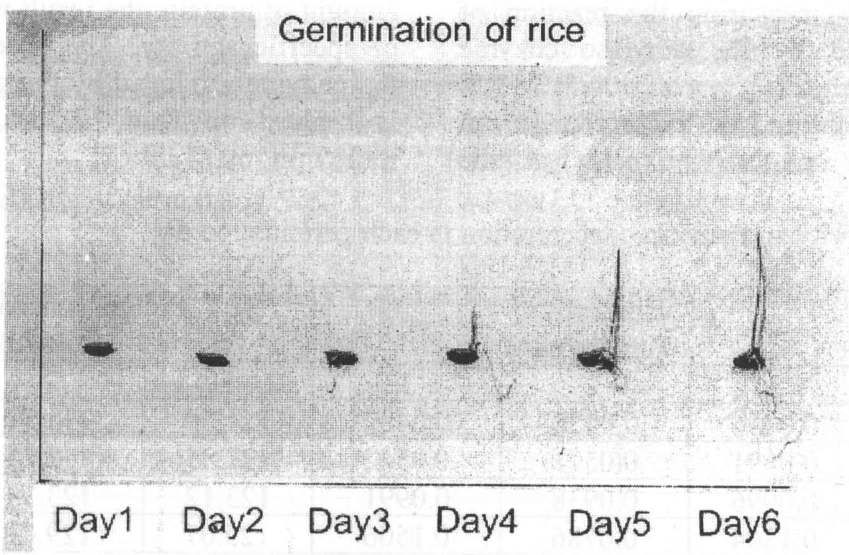
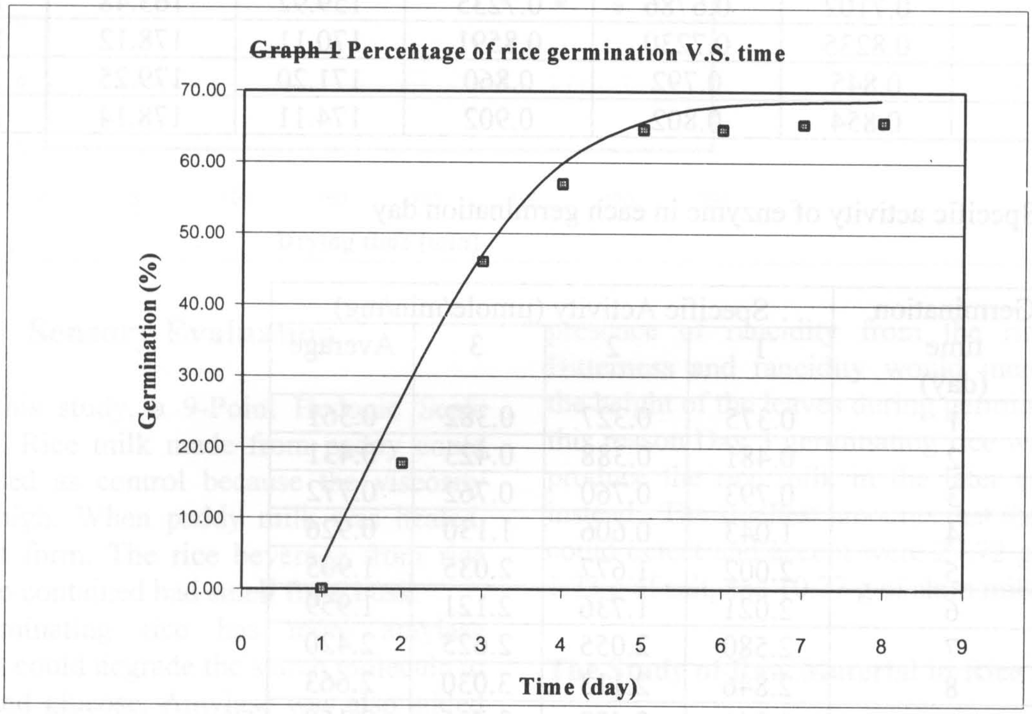



Fig. 1. The germination of paddy

The percentage of germination in each day was plotted in Graph 1. From the graph, it can be seen that the highest percentage of germination was obtained on Day 5 and then grew into the stationary phase on the following day.




### The Comparison of α-Amylase Activity at Different Days of Germination

The analysis of α-amylase activity by measuring the decreasing of the concentration of starch solution within limited times indicated that all the results had a wide range of error. Therefore, it was decided to change the analysis procedure to measure the α-amylase activity by saccharifying method.

Results from the experiments are shown in Tables 1 and 2. From Table 1, the average enzyme unit activity of the germinating rice was obtained by measuring the reaction of maltose produced by the amylase enzyme hydrolysis. Maltose reacts with 3,5-dinitrosalicylic acid and the color change can be detected by spectrophotometer at the wavelength of 540 nm. The amount of protein can be measured by Bradford method. When the value of unit activity was divided by the amount of protein, the result will be the value of specific activity. The specific activity of the enzyme produced by the germinating rice is highest on Day 12, which is 4.623 μ mole/min/mg (Table 2).

Table 1. Unit activity and protein concentration in each germination day

| Germination time (day) | Unit activity (μmole/min) 1 | 2 | 3 | Protein concentration (mg/ml) 1 | 2 | 3 |
|---|---|---|---|---|---|---|
| 1 | 0.0456 | 0.0438 | 0.0482 | 121.69 | 133.77 | 126.12 |
| 2 | 0.0591 | 0.0571 | 0.0542 | 122.85 | 147.25 | 128.23 |
| 3 | 0.0996 | 0.0938 | 0.0991 | 123.12 | 123.33 | 129.98 |
| 4 | 0.1304 | 0.0786 | 0.1506 | 125.07 | 129.71 | 133.15 |
| 5 | 0.2605 | 0.2571 | 0.2812 | 130.12 | 153.33 | 138.15 |
| 6 | 0.2768 | 0.2786 | 0.3071 | 136.96 | 160.44 | 144.78 |
| 7 | 0.3679 | 0.3250 | 0.3884 | 142.61 | 158.12 | 147.97 |
| 8 | 0.4102 | 0.3179 | 0.4523 | 144.12 | 150.44 | 149.27 |
| 9 | 0.4829 | 0.4030 | 0.5607 | 149.02 | 161.74 | 150.87 |
| 10 | 0.5132 | 0.3750 | 0.5990 | 151.09 | 153.19 | 151.22 |
| 11 | 0.7102 | 0.6786 | 0.7235 | 159.92 | 163.48 | 161.02 |
| 12 | 0.8235 | 0.7230 | 0.8591 | 170.11 | 178.12 | 172.93 |
| 13 | 0.845 | 0.792 | 0.860 | 171.20 | 179.25 | 184.63 |
| 14 | 0.854 | 0.802 | 0.902 | 174.11 | 178.14 | 192.94 |

Table 2. Specific activity of enzyme in each germination day

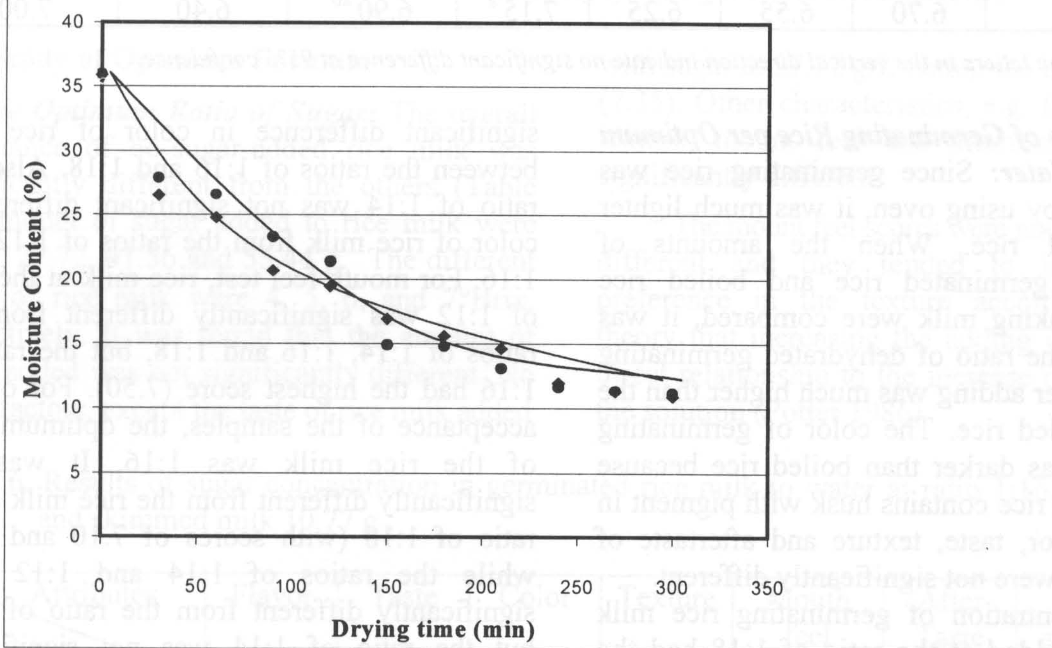
| Germination time (day) | Specific Activity (μmole/min/mg) 1 | 2 | 3 | Average |
|---|---|---|---|---|
| 1 | 0.375 | 0.327 | 0.382 | 0.361 |
| 2 | 0.481 | 0.388 | 0.423 | 0.431 |
| 3 | 0.793 | 0.760 | 0.762 | 0.772 |
| 4 | 1.043 | 0.606 | 1.130 | 0.926 |
| 5 | 2.002 | 1.677 | 2.035 | 1.905 |
| 6 | 2.021 | 1.736 | 2.121 | 1.959 |
| 7 | 2.580 | 2.055 | 2.625 | 2.420 |
| 8 | 2.846 | 2.113 | 3.030 | 2.663 |
| 9 | 3.241 | 2.492 | 3.716 | 3.150 |
| 10 | 3.397 | 2.448 | 3.961 | 3.269 |
| 11 | 4.441 | 4.151 | 4.493 | 4.362 |
| 12 | 4.841 | 4.059 | 4.968 | 4.623 |
| 13 | 4.936 | 4.418 | 4.658 | 4.620 |
| 14 | 4.905 | 4.502 | 4.675 | 4.618 |

**Drying of Germinated Rice at Day 7**

From the experiments it was found that germinating rice maintained its activity well at the moisture content between 12-14%. Therefore, experiments were further conducted to explore the optimum time and temperature for the drying of germinating rice in order to maximize the shelf life of germinated rice.

At 50°C, the time for drying germinating rice to 12-14% moisture was 220-250 min (Graph 2). At 60°C, the optimum time was 190-240 min (Graph 2). After drying, the rice samples were tested for their original activity and it was found that the activity of α-amylase enzyme still remained the some as before drying.

**Graph2** **The moisture content V.S. time at the drying temperature of 50 and 60 °C**




## Sensory Evaluation

In this study, a 9-Point Hedonic Scale was used. Rice milk made from paddy could not be used as control because the viscosity was too high. When paddy milk was heated, gel would form. The rice beverage from rice paddy also contained bad smell from husk.

Germinating rice has more amylase activity; it could degrade the starch molecule to maltose and glucose. Amylase was also added to boiled rice to compare the characteristic of rice milk made from germinating rice.

At the early stage of this study, germinating rice at Day 7 was used to produce the rice milk, but the panelists disliked the product since the taste was bitter, and the presence of rancidity from the rice leaves. Bitterness and rancidity would increase with the height of the leaves during germination. For this reason Day 3 germinating rice was used to produce the rice milk in the later experiment instead. The smallest amounts that the panelists could detect and accept were 27.72 g of sugar, 1.73 g of salt, and 10.77 g of skim milk powder.

**The Study of Raw Material in Rice Milk**

***Ratio of Boiled Rice to Water:*** Table 3 reveals that there was no significant difference at 95% level in the ratio of boiled rice to water because boiled rice was unsweetened with no color. When boiled rice was mixed with water, the flavor was very plain. So the panelists could not detect the difference, except in the samples at the ratios of 1:4 and 1:6 where significant difference was found because they had better texture than other samples. The ratio 1:6 had better mouth feel that was significantly different from the ratio of 1:10. From this result it was concluded that the proper ratio of boiled rice to water is 1:6.

Table 3. The result of boiled rice to the preference of panelists by adding sugar at 7°Brix, salt 1.73g and skim milk powder 10.77g

| Attributes / Rice:Water | Flavor | Taste | Color | Texture | Mouth feel | Aftertaste | Overall Acceptance |
|---|---|---|---|---|---|---|---|
| 1 :10 | 6.50 | 6.35 | 6.65 | 6.40[b] | 6.35[ab] | 6.50 | 6.50 |
| 1 : 8 | 6.20 | 6.05 | 6.37 | 6.55[b] | 6.65[a] | 6.25 | 6.75 |
| 1 : 6 | 6.30 | 6.20 | 6.45 | 7.25[a] | 7.30[b] | 6.30 | 7.20 |
| 1 : 4 | 6.70 | 6.55 | 6.25 | 7.15[a] | 6.90[ab] | 6.40 | 7.00 |

***Note:** The same letters in the vertical direction indicate no significant difference at 95% confidence.*

***The Ratio of Germinating Rice per Optimum Ratio of Water:*** Since germinating rice was dehydrated by using oven, it was much lighter than boiled rice. When the amounts of dehydrated germinated rice and boiled rice used for making milk were compared, it was found that the ratio of dehydrated germinating rice per water adding was much higher than the ratio of boiled rice. The color of germinating rice milk was darker than boiled rice because germinating rice contains husk with pigment in it. The flavor, taste, texture and aftertaste of this sample were not significantly different.

Concentration of germinating rice milk per water added at the ratio of 1:18 had the highest score (7.25) of color, but there was no significant difference in color of rice milk between the ratios of 1:16 and 1:18. Also, the ratio of 1:14 was not significant different in color of rice milk from the ratios of 1:12, and 1:16. For mouth feel test, rice milk at the ratio of 1:12 was significantly different from the ratios of 1:14, 1:16 and 1:18, but the ratio of 1:16 had the highest score (7.50). For overall acceptance of the samples, the optimum ratio of the rice milk was 1:16. It was not significantly different from the rice milk at the ratio of 1:18 (with scores of 7.10 and 7.40) while the ratios of 1:14 and 1:12 were significantly different from the ratio of 1:18; but the ratio of 1:14 was not significantly different from that of 1:12 (Table 4).

Table 4. Results of germinated rice concentration to the preference of panelists, when added sugar at 7 °Brix, salt 1.73 g and skimmed milk powder 10.77 g

| Attributes / Salt (g) | Flavor | Taste | Color | Texture | Mouth feel | After Taste | Overall acceptance |
|---|---|---|---|---|---|---|---|
| 0.00 | 7.00 | 6.45[b] | 7.10 | 7.15 | 7.30 | 7.35 | 6.25[ab] |
| 0.87 | 7.40 | 6.30[b] | 7.25 | 7.30 | 7.20 | 7.10 | 6.70[bc] |
| 1.73 | 7.05 | 7.40[a] | 6.35 | 7.15 | 6.90 | 6.85 | 7.65[d] |
| 3.47 | 6.80 | 6.25[b] | 6.55 | 7.35 | 7.05 | 7.00 | 7.10[c] |
| 6.93 | 6.95 | 5.20[c] | 6.40 | 7.60 | 6.85 | 7.05 | 5.90[a] |

***Note:** The same letters in the vertical direction indicate no significant difference at 95% confidence.*

When boiled rice milk at the ratio of 1:6 and germinating rice milk at the ratio of 1:16 were compared (Table 5), it was found that the panelists preferred germinated rice milk to boiled rice milk at flavor score of 7.05, texture 7.45, and overall acceptance 7.25. These values were higher than boiled rice milk and were significantly different. Color was the only one characteristic of boiled rice milk that had the higher score of 7.20 which was significantly different from germinated rice milk (6.00). The mouth feel and aftertaste of these two samples of rice milk were not significantly different.

Table 5. Comparison between preference of boiled rice milk at ratio 1:6 and germinated rice milk at ratio 1:16 which added sugar at 7°Brix, salt 1.73 g and skimmed milk powder 10.77 g

| Attributes / Rice (g) | Flavor | Taste | Color | Texture | Mouth feel | After Taste | Overall acceptance |
|---|---|---|---|---|---|---|---|
| Boiled | 6.40 [a] | 6.95 | 7.20 [a] | 6.60 [a] | 6.35 | 6.80 | 6.30 [a] |
| Germinated | 7.05 [b] | 7.35 | 6.00 [b] | 7.45 [a] | 6.58 | 6.85 | 7.25 [b] |

*Note: The same letters in the vertical direction indicate no significant difference at 95% confidence.*

**The Study of Optimum Formula**

***The Optimum Ratio of Sugar:*** The overall acceptance of no-sugar-added rice milk was significantly different from the others (Table 6). Amount of sugar added to rice milk were 13.86, 27.72, 41.56 and 55.44 g. The different °Brix of rice milk were 4, 5, 6, and 7°Brix, respectively. It was found that the amount of sugar added was not significantly different. No other factors, except the taste of rice milk added with sugar at 27.72 g/L obtain the highest score (7.35). Other characteristics, e.g. flavor, color, texture, mount feel and aftertaste were not significantly different.

The mount feel scores were not significantly different and they tended to increase the preference in the texture according to the theory that increasing the adding of sugar has direct relationship to the increase of texture of the solution (Potter 1986).

Table 6. Results of sugar concentration in germinated rice milk to water at ratio 1:16, salt 1.73 g and skimmed milk 10.77 g

| Attributes / Sugar (g) | Flavor | Taste | Color | Texture | Mouth feel | After Taste | Overall acceptance |
|---|---|---|---|---|---|---|---|
| 0.00 | 6.85 | 4.70 [a] | 6.45 | 6.90 | 6.65 | 6.80 | 5.95 [a] |
| 13.86 | 7.10 | 5.95 [b] | 6.70 | 7.20 | 6.70 | 6.50 | 6.75 [b] |
| 27.72 | 7.15 | 7.35 [c] | 6.45 | 7.25 | 7.05 | 6.65 | 7.00 [b] |
| 41.56 | 6.80 | 6.75 [d] | 6.60 | 7.05 | 6.80 | 6.40 | 7.15 [b] |
| 55.44 | 6.95 | 6.10 [b] | 6.65 | 7.45 | 6.95 | 6.60 | 6.80 [b] |

*Note: The same letters in the vertical direction indicate no significant difference at 95% confidence.*

**The Optimum Ratio of Salt**

Sodium chloride increases the sweetness of sugar (Amerine *et al.* 1965) and contributes to the iodine content in rice milk. From this study, it was found that the amount of 1.73 g of salt was found to be optimum because the taste and the overall acceptance scores obtained were the highest values which were significantly different (7.40 and 7.55) when compared to the other four samples (Table 7).

For overall acceptance, rice milk, in which 0.87, 3.47, and 0 g of salt were added, were not significantly different, which was the same as flavor, color, texture, mouth feel, and aftertaste.

**The Best Concentration of Skim Milk Powder**

The purposes of adding skim milk were to increase the creamy and milky body in the rice milk. This is because rice milk contains a

Table 7. Effect of salt concentration to rice milk characteristics at the ratio of 1:16 in the presence of 27.72 g of sugar and 10.77 g of skim milk

| Salt (g) \ Attributes | Odor | Taste | Color | Texture | Mouth feel | After Taste | Overall acceptance |
|---|---|---|---|---|---|---|---|
| 0.00 | 7.00 | 6.45[b] | 7.10 | 7.15 | 7.30 | 7.35 | 6.25[ab] |
| 0.87 | 7.40 | 6.30[b] | 7.25 | 7.30 | 7.20 | 7.10 | 6.70[bc] |
| 1.73 | 7.05 | 7.40[a] | 6.35 | 7.15 | 6.90 | 6.85 | 7.65[d] |
| 3.47 | 6.80 | 6.25[b] | 6.55 | 7.35 | 7.05 | 7.00 | 7.10[c] |
| 6.93 | 6.95 | 5.20[c] | 6.40 | 7.60 | 6.85 | 7.05 | 5.90[a] |

*Note: The same letters in the vertical direction indicate no significant difference at 95% confidence.*

lot of fat and protein (Vernam and Sutherland 1994) while rice contains mostly starch. The milk powder used in this study was a high calcium content formula. It was found that there was a significant difference between adding and no adding of skim milk. This is because most people preferred rice milk added with skim milk. However, there was no significant difference between adding 28.72 and 10.77 g of skim milk powder in odor, taste, texture, mouth feel, and overall acceptance. There was significant difference between adding 28.72 g of skim milk and without adding skim milk as shown in Table 8. Therefore, 10.77 g of skim milk powder was chosen to be the optimum ratio, because the less skim milk powder added, the lower lactose content occurred in the rice milk.

Table 8. Effect of skim milk concentration to rice milk at ratio 1:16 in the presence of 27.72 g of sugar, 1.73 g of salt and 10.77 g of skim milk powder

| Skim milk (g) \ Attributes | Odor | Taste | Color | Texture | Mouth feel | After Taste | Overall acceptance |
|---|---|---|---|---|---|---|---|
| 0.00 | 6.65[a] | 4.45[a] | 6.75 | 6.50[a] | 6.25[a] | 6.95 | 6.55[a] |
| 10.77 | 7.10[b] | 6.05[b] | 6.95 | 7.05[b] | 7.15[b] | 7.20 | 7.10[b] |
| 28.72 | 7.30[b] | 7.25[b] | 6.90 | 7.40[b] | 7.55[b] | 7.25 | 7.40[b] |

*Note: The same letters in the vertical direction indicate no significant difference at 95% confidence.*

**The Best Concentration of Vanilla Powder in Vanilla Flavor Rice Milk**

After the best formula for rice milk production was determined, vanilla and cocoa powder were added into the product. From Table 9, adding vanilla powder gave better flavor in the product and its odor, taste, and overall acceptance were clearly shown the significant difference than the sample without adding vanilla. However, the different concentration of vanilla powder did not show significant difference in color, texture, mouth feel, and aftertaste

**The Best Concentration of Cocoa Powder in Cocoa Flavor Rice Milk**

As shown in Table 10, the more cocoa powder added, the better taste of the product was. There was a significant difference in odor in all samples, but there was no significant

Table 9. Effect of vanilla concentration in rice milk products at ratio 1:16 in the presence of 27.72 g of sugar, 1.73 g of salt, and 10.77 g of skim milk powder

| Vanilla powder (g) \ Attributes | Odor | Taste | Color | Texture | Mouth feel | After Taste | Overall acceptance |
|---|---|---|---|---|---|---|---|
| 0 teaspoon | 6.50$^{a}$ | 6.80$^{a}$ | 6.35 | 6.85 | 7.10 | 7.05 | 6.65$^{a}$ |
| 1 teaspoon | 7.25$^{b}$ | 7.50$^{b}$ | 6.15 | 7.05 | 7.25 | 7.30 | 7.35$^{b}$ |
| 2 teaspoon | 7.30$^{b}$ | 7.65$^{b}$ | 6.45 | 7.35 | 7.45 | 7.20 | 7.50$^{b}$ |

***Note:*** *The same letters in the vertical direction indicate no significant difference at 95% confidence.*

difference in taste, color, and overall acceptance of 11.48 g and 17.22 g of cocoa. However, there were some significant differences in taste, color, and overall acceptance between sample added with 5.74 g and 22.96 g cocoa. Regarding the characteristics of mouth feel and aftertaste, the sample containing 5.74 g of cocoa showed significant difference among three samples. For the texture, there was no significant difference among the three samples, which were 5.74, 11.48, and 17.22 g of cocoa, but at 22.96 g of cocoa there was a significant difference. From the result, it is obvious that the best amount of cocoa in 1 L of rice milk is 22.96 g.

Table 10. Effect of various cocoas content in rice milk product on sensory evaluation

| Cocoa (g) \ Attributes | Odor | Taste | Color | Texture | Mouth feel | After Taste | Overall acceptance |
|---|---|---|---|---|---|---|---|
| 5.74 | 4.85 | 4.85 | 5.45 | 6.20 | 4.90 | 4.80 | 5.20 |
| 11.48 | 5.70 | 5.60 | 6.20 | 6.40 | 6.05 | 6.31 | 6.20 |
| 17.22 | 6.40 | 6.05 | 6.10 | 6.35 | 6.00 | 6.30 | 6.35 |
| 22.96 | 7.60 | 7.00 | 6.75 | 6.95 | 6.10 | 6.35 | 7.25 |

***Note:*** *The same letters in the vertical direction indicate no significant difference at 95% confidence.*

Table 11. Nutritive values of four rice milk samples

| Nutritive components | Rice:water ratio 1:6 | | Rice:water ratio 1:16 | | Cow's milk |
|---|---|---|---|---|---|
| | Germinated rice | Roasted rice after germination | Amylase-boiled rice | Non-enzyme boiled rice | |
| Calorie (Kcal) | 124 | 138 | 120 | 132 | - |
| Total fat (gram) | 0.63 | 0.58 | 0.67 | 0.75 | 3.34 |
| Saturated fat (gram) | 0 | 0 | 0 | 0 | - |
| Cholesterol (ppm) | 0 | 0 | 0 | 0 | 110-140 |
| Carbohydrate (gram) | 7.5 | 8.75 | 7.92 | 9.17 | 4.66 |
| Sugar (gram) | 2.5 | 3.33 | 2.92 | 3.75 | - |
| Protein (gram) | 0.42 | 0.50 | 0.46 | 0.42 | 3.29 |
| Calcium(%) | 1.50 | 1.60 | 1.60 | 1.70 | 0.2 |

## Nutritive Values of Boiled Rice Milk Added and Without Added α-Amylase

Nutritive values of boiled rice milk added and without added α-Amylase at the rice to water ratio 1:6 were compared to germinating rice milk and roasted rice milk at the rice to water ratio1:16. From Table 11, all of the rice milk samples had nearly the same nutritive values, especially calcium and protein contents. In addition, saturated fatty acid and cholesterol were not found in all samples.

By comparing the nutritive values of rice milk samples to cow milk, it can be seen that rice milk provides higher carbohydrate and calcium contents than fresh cow milk, while the latter contains higher total fat, cholesterol and protein contents. Hence, the rice milk can be used as a good nutrient source when supplemented with appropriate amount of protein.

## Suggestion

- For further study, the appropriate sources of raw material to provide higher protein content in this product should be explored.
- Other flavors should also be explored to test the preference of a wide variety of consumers.
- Roasted rice is a good source of raw material for rice-milk making because it contains a good source of aroma and flavor.
- Consumer acceptance and marketing survey should be studied before the marketing of this product.

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