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Acknowledgements

The Asia BioBusiness Project Team wishes to acknowledge the kind support of Kh Supachai Lorlowhakarn, (Director, NIA) and his staff for their competent support and excellent planning and organization of the two stakeholder workshops conducted as part of this study. The team is also grateful to Dr Gerard Barry (Head, Intellectual Property Office, International Rice Research Institute), Dr Leocadio S Sebastian (Executive Director of PhilRice), and Dr Randy Hautea (Global Coordinator / Director, ISAAA) and their respective colleagues for their valuable suggestions and support during the field visit in January 2006.

Executive Summary

Rice production has always played an integral part in Thai culture and society. Today, however, the rice industry is facing increasing competition at all stages of the production and value chains. Improved production practices round the world mean that markets have access to improved quality and lower prices. To compete successfully, Thailand must move quickly to adopt and utilize innovative production systems and technologies to improve yields and quality. But it must also seek to maximize value from the commodity by creating new products and utilizing previously unused waste components. Bulk export of rice does not maximize value for Thailand. Innovation, powered by a targeted research and development effort in combination with effective global marketing strategies, is the only way for Thailand to ensure value is created, *in situ*, from its strategically vital rice sector.

This study was undertaken to identify potential target areas where innovation can be put to work to create value. A primary finding is that innovation can contribute significantly to a value added proposition at all stages in the value chain. Whilst the largest margins are most likely to be created in processed / refined products, we have been conscious that innovation is needed along the entire value chain, especially at the farmer and primary processor levels. It is therefore important to ensure that benefits accrue to all of the players within the industry, from the farmer to the processor.

At the production level, Thailand's yields per hectare are amongst the lowest in the world - on a par with Bangladesh. There is a significant yield gap between potential and actual yields (from 10 to 60%) due to uneven adoption of technologies. Studies have demonstrated the impact of technology innovation in reducing this yield gap. Innovation cannot only be applied to, or thought as necessary, higher up the value chain. Significant improvement can be achieved through the adoption of new production practices.

Further downstream in the value chain, there are major opportunities for extraction of valuable components from the rice grain. Perhaps the most exciting opportunities are in creating products for the rapidly growing local and global wellness markets (valued at over US\$60 billion annually in the USA alone). We are already seeing energetic Thai companies enter this market aggressively, with products such as purified rice bran oil that is reported to reduce serum cholesterol. Individual phytochemicals have considerable potential for commercialization and exploitation e.g. oryzanol, phytosterols, ferulic acid, oligosaccharides, either alone or in combination with probiotics, etc. Rice starch has considerable versatility beyond its application as a food ingredient. A modified starch has been developed that is digested more slowly than regular starch, and is suitable for treatment of nighttime hypoglycemia in diabetics. It also has application in sports drinks. There are also a number of non-food, industrial and pharmaceutical applications, including its use as a tablet filler for the pharmaceutical industry. This last innovation potentially can reduce the need to import expensive fillers from overseas, and was recognized by the National Innovation Agency in its 2005 National Innovation Awards.

Various treatments of the whole rice grain can be used to create products that have added value at consumer level. Pre-cooked rice has of course been with us for many years, but other recently developed processes can also be employed to add ingredients and/or nutrients lost during regular processing, or that have a perceived health or utility e.g. Vitamin B through washing. Careful milling of the whole grain has been used to ensure that the germ (embryo) is not removed from the grain. Leaving the antioxidant-rich embryo intact in this way attracts a price premium among health-conscious consumers. Other

approaches have seen the creation of novel blends of rice with other seeds or ingredients e.g. sesame, millet, green tea. Many of these added ingredients have reported health benefits.

Waste products from the early stages of rice handling can be used in a number of applications including biofertilizers (husks), substrates for high value mushroom culture e.g. *Ganoderma* (Lin Zhi) (husks), power generation (husks), bicycle tyres (husks with resins) mulching mats (straw), building panels and roadside posts (straw incorporated with resins), fertilizers, charcoal, deodorizers, pest control agents (carbonized husks).

Innovation is not only required in the development of new products. It can also be applied to the marketing of new rice products and to the development of an identifiable Thai brand. A national brand could be considered which would certainly complement the “Kitchen of the World” initiative. However, ensuring recognition of a Thai brand will require major investment in brand-building in key high-value markets such as the EU, USA and Japan.

Clearly then, there is a growing realization in the rice sector that innovation must be put to work to enhance the competitiveness of the sector in the global marketplace. Already, some ambitious companies are adopting new technologies and methods to truly compete, but they are relatively few in number. It must be realized that innovation is not a reactive process; it must be an integral part of a company’s structure for it to survive. There must also be a sound understanding of intellectual property and its management and an efficient regulatory system to ensure that the maximum value of innovative thinking is captured.

Targets for Innovation (See Table 1)

There are opportunities at all stages of the value chain but the highest returns may result from extraction of phytochemicals from rice bran oil.

Business development opportunities also exist with increased incorporation of rice into baby food formulations. Much of the market is based on western tastes and formulations. Expansion of rice use in Asia-targeted baby foods has major potential. Formulations could be made with additions such as rice bran oil and vitamins extracted from rice. Marketing could emphasize the health aspects of the food rather than simply its flavour. The use of organic rice could also be applied to this sector.

Likewise, starches modified specifically for healthcare applications e.g. low glycemic index starches for diabetics, and for the weight control and sports nutrition markets have major global market potential.

While potential returns and value addition are assessed as medium for production of biodegradable food boxes made from rice husks, given the enormous market for food packaging, this technology may be rapidly adoption once formulation is completed. Such a project may also benefit from linkages with bioplastics programmes and potentially could play a major role in complementing NIA’s own biodegradable plastics programme.

Carbonized rice husks (CSH) could be the basis of several major initiatives. At present the technology is targeted at the farm level in the Philippines but it could easily be scaled up to industry level. Add-on facilities at the rice mills could lead to spin-off initiatives such as bio-fertilizer production.

Table 1: Summary of Opportunities for Commercialization of Innovative Rice Products

Product	Value Addition Potential*	Closeness to Commercialization	Market Potential**	Potential for returns
Gamma	Medium	Ready	Medium	Medium
Embryo rice	Medium	Ready	Medium	Medium
Organic five-grain rice blend	Medium	Ready	Low / medium	Medium
O-Rice	Medium	Ready	Low / medium	Medium
Modified starch	Medium / High	Ready	Medium / High	High
Baby foods	High	Ready	Medium / High	High
Stabilized rice bran	Low / medium	Ready	Medium / High	Low / medium
Tyres	Low / medium	Ready	Low / medium	Low / medium
Bio-organic fertilizer	Low	Ready	Low / medium	Low / medium
Carbonized rice husks (CRH)	Low	Ready	Low to medium	Low / medium
Biodegradable fast food meal box	Low	Ready	Medium	Medium
Rice bran oil	Medium	Ready	Low / medium	Medium / High
Paper production	Low	Ready	Low / medium	Low
Rice bran	Medium	Ready	Medium	Low / medium
Oryzanol	High	Ready	Medium / High	High
Probiotics	High	Ready	Medium / High	High
Phytosterols	High	Ready	Medium / High	High
Rice ingredients for Cosmetics	High	Ready	High	High
Rice ingredients for cosmeceuticals	High	Ready	High	High

*Relative to base ingredient

** Integration of factors e.g. competing products / size of products / time scale to gain value

Introduction and Description of Study

In 2003 Thailand produced 27 million tones of paddy on 10 million ha of land. As the world's biggest rice exporter, annual shipments are worth more than US\$2,000 million and reached 7.5 million tones in 2003. The main export markets are Indonesia, Nigeria, Iran, the United States and Singapore.

Thailand's success in the international rice trade is due to its high quality, long-grain white rice, which has a substantial price advantage over lower grades. This emphasis on grain quality is also the main reason for Thai farmers' limited adoption of modern, high-yielding rice varieties. However, as a result of this slow adoption rate, yields per hectare are amongst the lowest in the world- on a par with Bangladesh. The yield gap between potential and actual yields is also very variable (from 10 to 60%) due to uneven adoption of technologies. Studies have demonstrated the impact of technology innovation in reducing this yield gap.

Aside from agronomic improvements, innovation in processing is also needed. For the most part, rice is sold as a raw commodity, and only a small percentage of rice export earnings are derived from value-added downstream products. Innovation is needed to increase this percentage and bring a bigger share of income back to the farm.

Thailand is currently facing increasing competition on several fronts, both conventional and novel- conventional, from countries such as Vietnam, whose exports are rapidly catching up with Thailand, and novel, from countries such as China, which has deployed biotechnology to complement its conventional breeding programs, to produce hybrid rice yielding double that of current varieties. Thailand faces an even greater threat to its niche market, *homemade* fragrant rice, and in 2004 prevented an attempt by American scientists to develop its own varieties of Jasmine rice. Such an undertaking would have led to a permanent collapse in incomes for poor rice farmers in northeastern Thailand, probably with grievous social consequences. Thailand is still vulnerable to this threat today.

Compared with other rice producing countries, Thailand's rice economy has benefited relatively little from Green Revolution technologies, and there has been limited investment in downstream value added products. Thailand's rice sector could benefit enormously from a coherent rice innovation policy, which would focus on increasing productivity and water use efficiency, technology transfer for downstream processing, and promotion of high value specialties for international markets.

Project Objectives

This study is intended to identify innovative technologies, processes and products that could add value to Thailand's rice sector. These may be ready to adopt immediately, or in other cases might require further applied research and development to ensure adaptation to the Thai situation. The work aims to identify opportunities to achieve the following:

- Increased added value through innovative processed rice products for consumption (increased downstream products)
- Diversification of products and income by creating new industries
- New specialty markets (domestic and international)

- Increased farmer income through processing at community level
- New specialty varieties adapted to Thai conditions.

The team has taken a broad view of the constraints and challenges facing Thailand's rice industry, and has identified innovative products, technologies and processes that can provide added value and income. The analysis includes an examination of medicinal uses, nutritional supplements, high-value fine chemicals and derivatives, functional foods, probiotics, cosmetics, novel snack foods and branding opportunities.

Methodology

A benchmark technology audit was conducted by the team of international and Thailand-based experts to establish the current status of rice in Thailand, and at a global level, identify emerging technologies, products, processes and markets that may be relevant and applicable to the Thai context. Interviews were conducted with experts in Thailand and also with world experts at the International Rice Research Institute (IRRI) in Los Baños, Philippines, and other centres of excellence, to establish a consensus on threats and emerging opportunities in the rice sector. A summary of ongoing research currently being conducted in Thailand was also compiled. Finally, two workshops were conducted in Thailand and the outputs incorporated into this Final Report.

The Commodity and Innovation

The rice plant usually takes 3-6 months to complete its life cycle. In a tropical environment, a 120-day variety which is non-photoperiod-sensitive requires about 60 days for vegetative growth, with the reproductive and ripening periods each requiring 30 days.

After flowering, the rice grains undergo what are called the milky, dough, yellow-ripe and maturity stages before harvesting. The post-harvest processes involve the transfer of rice grains from the fields to the mills for de-hulling (dehusking) and polishing before storage and distribution.

The rice grain is called rough rice. It consists of an outer protective covering called husk or hull. The rice fruit is called caryopsis. The fruit skin (pericarp) of caryopsis is inseparably fused with the seed skin (testa). After dehulling, the rice fruit is commonly called brown rice, cargo rice, dehulled rice or dehusked rice.

In the milling and polishing processes, the pericarp, testa, germ, (embryo) and the aleurone layer which encloses the embryo of brown rice are removed; this fraction is known as rice bran. The core of the rice grains after polishing is called polished rice which consists of the endosperm containing mainly starch granules.

The Opportunity for Innovation

Innovative ideas and concepts can be applied to all the stages of the growth cycle and to the rice grain in its various forms. We shall see that novel products have been produced with all

the components of the grain but the creation of added value can also take place with modifications to the rice variety through genetics / breeding and also through technology being applied to the production system itself.

Agronomy and Genetics

Yields of rice in Thailand on a per hectare basis are low in comparison to many of the major rice producers. This can be improved through the adoption of more modern varieties and production technologies. The value of the adoption of such technologies may not sometimes be reflected in obvious changes to the bottom line but in terms of nutrition, health, quality of life and environmental sustainability they may represent significant steps forward. Further value addition can be achieved through more effective use of water conservation technologies, better use of pesticides and an integrated pest management strategy. Application of modern molecular biological techniques to the rice plant can also lead to significant benefits. These techniques may or may not include genetic modification. Research is targeting yield, disease, growth and harvesting characteristics, water stress, salinity, heat and cold tolerance.

Genetic modification (biotech crops) is a controversial technology for some people but more and more countries around the world are using it to improve crop production. In Europe, farmer groups have been lobbying for access to the technology to allow them to be competitive. Initial targets for this technology have been the creation of new varieties resistant to disease, or able to tolerate certain herbicides. In the near future crops including rice will be available that also have improved nutritional traits or can synthesize high value chemicals (bio-factories).

It is likely that China will commercialize GM rice within the next year, and some predict that once this occurs Vietnam will also rapidly adopt the technology. This will have particular impact on lower value rice production (non-Jasmine), increasing yields and quality. Thailand is already looking at how this technology can be applied to rice and must continue to do so to ensure competitiveness.

Both breeding aided by molecular selection techniques and traditional breeding are being used to address nutritional challenges that go beyond the simple provision of calories. In recent years there has been a growing awareness of malnutrition caused not by lack of calories but by a lack of micronutrients in the diet. Micronutrient malnutrition is caused by poor quality diets, characterized by high intakes of staple but low consumption of animal and fish products, fruits, legumes, and vegetables, which are rich sources of bioavailable minerals and vitamins. As such, most of the malnourished are those who cannot obtain these foods from their own production.

Even mild levels of micronutrient malnutrition may damage cognitive development, lower disease resistance in children, and reduce the likelihood that mothers survive childbirth. The cost of these deficiencies in terms of lives lost and quality of life are immense. Micronutrients include iron, zinc and vitamin A. Iron deficiency is of particular concern in Thailand.

Biofortification is the process of breeding food crops that are rich in bioavailable micronutrients. These crops fortify themselves- they load high levels of minerals and

vitamins in their seeds and roots, which are then harvested and eaten. Through biofortification, scientists can provide farmers with crop varieties that naturally reduce anemia, cognitive impairment, and other nutritionally related health problems, potentially in hundreds of millions of people.

Crops can be biofortified through traditional breeding aided by modern molecular techniques or by genetic engineering e.g. Golden Rice is enhanced through modern biotechnological techniques to synthesize beta-carotene, a precursor of vitamin A.

Treatments of the Whole Grain and Food Production

Conventionally processed rice products

Processed rice products may be derived from rough rice, brown rice, milled rice, cooked rice, broken, dry milled flour, wet milled flour or rice starch.

Rough rice is conventionally used for the production of popped rice, which is consumed as breakfast cereal. Another direct use of brown rice is for the preparation of parboiled rice. The parboiling process involves soaking rough rice in water, followed by boiling and steaming the steeped rice to gelatinize the starch. The parboiled rice is then dried before storage or milling.

The milled rice is conventionally used for the preparation of cooked rice or porridge. The broken rice can be wet-milled or dry-milled for the preparation of cakes, noodles, rice papers, rice wrappers, rice crackers, puddings, and muffins. After cooking, rice can be used for the production of miso, vinegar and wines (1).

Rice bran is conventionally used for the production of rice bran oil and livestock feeds. The husks are used as fuel, bedding, seedbed mediums, and charcoal briquettes. Rice straw is commonly used for composting, roofing materials, livestock feeds and a medium for growing straw mushroom.

Innovative Uses of Rice

Canned rice

There are two types of canned rice, namely dry-pack canned rice and wet-pack canned rice.

Dry-pack-canned rice such as rice breakfast cereals are produced by cooking a cereal slurry that is then dried, flaked and packed.

Wet-pack-canned rice is usually steamed for 30 minutes and sealed and sterilized at 112 °C for 80 minutes (2).

In Taiwan, wet-pack-canned rice are all sweetened and mixed with dried longans, red beans, peanuts, and oatmeal. Low amylose rice is used for dry-pack fried rice.

Before serving, the rice is heated in boiling water for 15 minutes, or the content is taken out and microwaved for 2 minutes.

Pre-cooked rice package

Pre-cooked rice packages are very popular in Taiwan. The package usually contains a Cantonese-style rice-congee made from low amylose milled rice brokens which are washed, ground and pre-cooked with 6 times the volume of water, drum-dried for 3 minutes with a steam pressure of 5Kg/cm² to remove excess moisture. The processed rice is then flaked, mixed with dried cooked meat, vegetables, salt, monosodium glutamate and other flavourings and finally packed in pouches.

The other pre-cooked rice package is known as guo-ba. It is prepared by cooking waxy rice in a rice cooker. The cooked rice is spread in a thin layer on perforated trays and baked over a flame until the rice layers become crunchy. The baked rice (guo-ba) is cut into square or rectangular blocks and then sun-dried to 12% moisture. The guo-ba is then further flavoured, deep-fried and repackaged as a ready-to-eat snack (3).

Pre-washed rice (rinse-free rice)

Some rice-consumers prefer pre-washed rice as it could be cooked directly without rinsing. Nutritionists believe that rinsing removes substantial quantity of soluble nutrients, especially Vitamin B complex, from the polished grains.

Pre-washed rice is prepared by spraying a mist of water particles with droplet size approximately 20 microns through a hollow shaft. High pressure air is generated during milling and polishing. The atomized water droplets remove loose bran and dirt adhering to the surface of polished rice, making the rice cleaner and more translucent.

Pre-washing is carried out in combination with a specially designed metallic roll-type refining machine. Water droplets are quickly evaporated from the grain surface after pre-washing. The washed grain is subsequently stored at a lower temperature than for regular milled rice (3).

Instant rice

Instant rice is also known as quick-cooking rice. It requires significantly less cooking time than raw milled rice which usually requires 15 to 25 minutes depending on cooking temperature. Instant rice only takes about 5 minutes to prepare before serving.

Recently, instant rice which is fully precooked with the addition of savoury ingredients has become highly popular among consumers in USA. One of the most well-known instant rice brands is Uncle Ben's Ready Rice from Hackettstown, New Jersey-based Masterfoods USA. The Ready Rice can just be placed into the microwave heater and after 90 seconds it is ready for the dinner plate.

Another type of instant rice is processed and marketed by Zatarain's in New Orleans. This company provides microwavable ready-to serve rice in 60 seconds. Products include red beans with rice and chicken as well as herb rice (3).

Asian Superior Foods Co Ltd of Thailand has also developed an instant rice. This product aims to compete with the instant Chinese noodle and other rice products.

The company's instant rice is priced at Bt30 per kilogram, compared with Chinese instant noodles costing between Bt40 and Bt50 per kilogram. The lower price and shorter cooking time are expected to attract market share.

At the outset, Asian Superior Foods products will be focused only on export markets, particularly in the US and South and Central America. The company has applied for US Food and Drug Administration approval for sale in the US market.

Nutrient-enriched rice

The purpose of rice enrichment and fortification is to restore to milled rice the levels of vitamin complex and minerals removed from the rough rice during milling. It is technically more difficult than enriching wheat flour since rice is consumed as whole grain.

Traditional methods of nutrients enrichment include parboiling, acid parboiling with 1% acetic acid, thiamine enrichment, coating, production of artificial rice, dibenzoyl thiamine enrichment and multi-nutrient enrichment by adding a nutrient-enriched premix.

The pre-mix is made by cooking milled rice in an acetic acid solution of the water soluble vitamins, e.g. thiamine, riboflavin, niacin, panthotenic acid and pyridoxine. Then it is steamed, dried, and coated with separate layers of vitamin E, calcium and iron, and then with a protective coating material and natural food colouring to prevent the loss of nutrients through washing (4).

Embryoed rice

Embryoed rice is also known as germ rice. It is produced by using gentle abrasive roll milling under very low pressure. This process leaves the embryo intact for more than 80% of the grains. Embryoed rice is rich in thiamine, riboflavin, tocopherol, calcium and linoleic acid. Recent studies indicated that rice embryo is rich in gamma-oryzanol, which is a powerful antioxidant. Health – conscious consumers are prepared to pay a premium for its high nutritional value.

As the shelf –life of embryoed rice is shorter than that of ordinary milled rice due to rancidity of lipids in the embryo, it is advisable to pack embryoed rice in small packages to enable the rice to be consumed within a month (3).

Gamma rice

Gamma rice is also known as GABA rice. It is specially-bred for its high level of γ -aminobutyric acid or GABA. The GABA content is 50-100 times higher than that of ordinary cultivars.

In China, it is reported that gamma rice can regulate blood pressure and is beneficial to people with hypertension.

A Chinese company (Sin-An Biotech Company) in Zhejiang Province has planted 667ha of gamma rice in Hainan Island in early 2005. Yield is estimated to be 4.5 tons/ha.

China has also discovered that pre-germination of brown rice through soaking at a pre-determined temperature will activate the process of nutrient transformation in the embryo. The GABA level in germinated brown rice is 5 times higher than that of polished rice and 3 times higher than that of ordinary brown rice (5).

Pearl rice

Pearl rice is prepared by mixing brown rice with barley in a ratio of 2:1. The mixed cereals are soaked in a specially prepared solution containing amino acids, spring onion, ginger and monosodium glutamate. The mixture is wet-milled to form a slurry. Moisture is removed from the slurry in the dehydration process. The gelatinous paste then goes through a granulation process, which shapes the substrate into pearl shaped granules. The final product is then steamed, dried, and packed for sale.

Pearl rice is mainly of the ready-to-eat type in which the rice starch provides texture-modifying properties, whilst brown rice imparts its own special flavour to the product. Among the important properties of pearl rice, is the ability to retain its texture and crispness while being eaten as breakfast cereals or snack foods (6).

Organic five-grain rice blend

A Taiwanese company, Seen-An, based in Chih Shang, Taitung, recently introduced an innovative multigrain cereal package. This organic five-grain rice blend is quickly gaining popularity among consumers who prefer “green” foods in Taiwan.

The five types of ingredients used in the cereal package include: organic rice, millet, Job’s Tear (*Coix lachryma jobi*), sesame and barnyard grass (*Echinochloa crus-galli*).

All the cereals used in the multi-grain package are grown on organic farms where good agricultural practices are stringently adopted to avoid contamination by pesticides and other agro-chemicals (7).

Slim rice

Slim rice is a novel health product recently introduced by Sante de Pharma Company in Malaysia. The main ingredients in Slim Rice are purple rice (*Oryza sativa* with anthocyanin), green tea (*Camellia sinensis*) and a type of Salacia (known as *Salacia reticula*).

According to the company, Slim Rice has a special fat reducing effect. Slim Rice is also reported to have the ability to detoxify the digestive system and has beneficial effects on strength and energy levels.

O-rice

In an excellent example of successful public-private sector partnership, the Phetchabun Innovation Company working with the Federation of Thai Industries, Kasetsart University and the National Innovation Agency, has developed a new, “healthy” rice.

Researchers have improved the process known as “orisation”. In this process husked rice is steeped in warm water before being steamed. This process ensures that all the nutrients are “locked” in the grain. The rice germ or embryo that contains all of the vitamins can be maintained completely, even through the polishing process.

This process also blocks the action of lipase which would otherwise cause oxidation of oils in the grain and cause a bad odour and rancidity.

Research at Kasetsart University has shown that O-rice has 10 times the nutritional value of milled rice. It is especially rich in vitamins B1 and B6 and contains triple the amount of magnesium when compared to white rice (8).

Udong noodles formulation changes

Asian Superior Foods Company has also changed the ingredients of its Thai Udon noodles. Instead of a more costly formulation of 100% wheat flour, up to 30 percent rice flour has been added but nevertheless maintaining the flavour and cooking characteristics. This new formulation reduces production costs and uses more local ingredients (8).

Modified rice starch with slower-digesting properties

The United States Department of Agriculture has developed a process which can modify rice starch to give it slower digesting qualities. This type of modified rice starch can be used to reduce the incidence of nighttime hypoglycemia (low blood sugar) among diabetics.

Heat and enzymes are used in the process of rice starch modification, which slows down the conversion of polysaccharide to glucose. Modified rice starch has fat-replacing properties and could be used in the preparation of fat-free yogurt or sour creams. It could also be combined with proteins and fats to make drinks that convert to glucose at a slower rate (9).

Stabilised rice bran

Rice bran contains hemicellulose which is effective in reducing the rate of dietary cholesterol absorption from the small intestine. However, a high degree of rancidity due to its oil fraction has always been a hindrance towards wider utilization of rice bran in the food industry.

Stabilised rice bran has been introduced recently in manufactured bakery products. The stabilization processes involve the inactivation of the enzyme lipase in full fat bran.

Stabilised rice bran can be incorporated into muffins and other cookies at levels of up to 20%. It is also consumed as an integrated component of breakfast cereals and snack foods.

Stabilised rice bran has hypocholesterolaemic properties (see later for more on rice bran) but only full fat rice bran lowers cholesterol level significantly. When it is used in combination with fish oil, it can lower plasma and hepatic triglyceride and hepatic lipogenesis, i.e. the formation and accumulation of fats in the liver **(10)**.

Fermented rice germ milk

Rice milk has been used as a substitute for animal milk and milk powder. It is usually prepared from puffed rice flour or wet-milled flour with sugar and peanut oil for flavouring. Generally speaking, brown rice gives a better quality milk than polished rice.

Japanese scientists have discovered the use of *Lactobacillus* to produce fermented rice germ milk. *Lactobacillus bulgaricus* and *Lactobacillus acidophilus* are used commercially to ferment milk into yogurt. The specially selected *Lactobacillus* species can also convert rice germ or embryo into a highly palatable and nutritious drink **(3, 9)**.

It is reported that fermented rice germ milk is gaining popularity in Japan and Taiwan.

Recombinant human lysozyme

A plant biotechnology company, Ventria of Sacramento, California, has developed a rice that incorporates recombinant human lysozyme which has bactericidal activity. The ultimate aim is to improve medical and nutritional quality of infant formulas and baby foods with rice flour or rice extract containing recombinant human lysozyme **(11)**.

Extending the Use of Rice, its Component Parts and Waste.

Besides its value for direct consumption of the grain as food, rice and its component parts are extensively used in non-food applications. With evolving technologies these applications are likely to be expanded and extended into new areas. The inedible parts that are discarded through the milling process, and the edible part can be transformed into some of the following products:

Rice husks

The rice hulls are inedible, but can be used in various non-food applications. They contain primarily cellulose, ash (mostly silica), pentosans, lignin, and trace amounts of protein and fat.

These are used as fuel and mulch, in abrasives, and in bedding and litter. Over 90% of the rice husks in Thailand are utilized in fuel for commercial rice mill steam generators. To increase the fuel's effectiveness, rice husks are burned and compressed into briquettes. If carbonized, these briquettes could become a high-quality charcoal (see below). The hulls are a light waste product, they are worth little and they take a lot of space, so nowhere is it economical to transport them.

Road surfaces

A waste product from rice has been used by Japanese scientists to produce surfacing materials for roads. Roads made using this method absorb noise better, drain faster and are less susceptible to extremes of temperature than traditional based road surfaces. The rice bran is mixed with resins and the result is a hard resilient material with many interesting properties. It is versatile, light, friction resistant and porous. Mixtures of the material can be added to asphalt and aggregate to make a long-lasting road surface. Tests suggest that the rice-bran-based surfaces can absorb around 25% more noise than aggregate and asphalt roads or surfaces with glass fibres added. This could make the surface popular in urban areas or on major roads close to residential estates (12).

Biodegradable fast food meal boxes

In Anhui Province of China, rice straw and husks are used for the manufacturing of biodegradable fast food meal boxes which are superior in quality compared with conventional polystyrene meal boxes. The biodegradable meal boxes are more tolerant to heat, acidity and alkalinity with no undesirable side effects. It is estimated that China consumed 10 billion fast food meal boxes annually, and the demand is expected to increase with rapid urbanization and industrialization.

A manufacturer in the Han-San district of An Hui Province currently has the capacity to produce 30 million biodegradable fast food meal boxes per annum. The raw materials comprise 530 tonnes dry straw and 240 tonnes moulding agent. The annual sales revenue is estimated at US\$ 880,000 (13).

Bio-organic fertilizers

A Malaysian company, Organi-Gro Limited Company pioneered the utilization of rice husks about 5 years ago. The ingredients used are finely ground rice husks, spent sugar molasses and a bio-plus activator (an organic complex made up of chelated trace elements, enzymes, growth enhancers and 23 types of micro-organisms.) In addition, rice bran, fishmeal, soy meal, copra meal and single cell proteins are also added into the mixture to accelerate the biodegradation process of the substrates.

The company has a production capacity of 3,600 tons of organic fertilizer per month. Field observations have shown that this bio-organic fertilizer used in combination with liquid lime has achieved some of the best recorded rice yields in the Muda rice area of Malaysia (14).

Substrates for Ganoderma culture

The medicinal properties of certain edible fungi have long been recognized. *Ganoderma lucidum* or Ling Zhi is one of the most well known medicinal fungi among the Chinese. Ganoderma, (classified under Class Basidiomycetes, Order Polyporales) produces a bracket or shelf-like-growth known as basidiocarp that is actually the fruiting structure of the fungus.

The medicinal value of Ganoderma comes from the organic germanium compounds in the basidiocarp. There are 2 major Ganoderma producers in Malaysia (DXN Limited Co, publicly-listed, and Gano-Excel Limited Co). These two companies use rice husks as the main substrate for Ganoderma culture (15).

Eco-friendly rice-straw mulching mat

Rice straw can be used to produce mulching mats that are compact, light, flexible, easy to handle and hence reduces transportation costs. When the straw mats receive adequate moisture, they mould easily to the terrain and conform to the shape of land surface on flat grounds or hill slopes. They are not easily dislodged by adverse weather condition. Rice straw can be reinforced with fibres from empty fruit bunches of oil palm, which further strengthens the mulching mat and enhances durability.

Rice straw mulching mat, being fully biodegradable, is also eco-friendly. The mat provides optimal porosity which allows water to percolate and be retained by the soil underneath. Straw mulching mat can provide adequate protection to the soil, making it less susceptible to erosion. In addition, the mat provides a gradual and sustained release of nutrients to grasses, ferns and shrubs growing on hill slopes, facilitating faster plant growth and better root anchorage (16).

Rice husk for power generation

Rice husk produced as a residue from the rice milling industry can be used as fuel. In a typical rice mill, electricity is required for milling and heat is needed for mechanical paddy drying as well as for parboiling. The silica-rich ash is a useful by-product and can be used as an insulator in the rough iron industry. Experiments are being conducted to refine silica ash as an alternative source of pure silica dioxide for computer chips.

According to Ban Heng Bee Rice Mill, the biggest rice mill in Malaysia, every ton of rough rice generates around 220kg of husk which, when used as fuel, is capable of producing an average of 100 KWh of electricity. The milling power needed for a ton of paddy ranges from 20 KWh for white rice production to 60 KWh for parboiling, leaving a surplus of 40 to 80 KWh for other purposes.

Ban Heng Bee Rice Mill commissioned the rice husk -fired Vyncke Cogeneration plant in 1998. In this Cogeneration (Cogen) project, saturated steam is produced in the rice husk fired boiler. The steam is fed onto a backpressure turbine to generate 500 KW electricity. The exhaust steam is used in a heat exchanger to produce hot water which is used for paddy drying operations.

The Vyncke Cogen Plant in Ban Heng Bee rice mill uses 8 tons of rice husk per hour. The ash produced is sold at RM 100-150 per ton. The ash is used for making fertilizer and salted eggs (17).

Building panels and roadside posts

The rice grower cooperative, working with polymer engineering researchers at RMIT University, Melbourne, have developed road-side posts, building panels and spacers for shipping steel by using rice husks, thermoplastic resins and nylon carpet offcuts. These

innovative products are registered as Husk-I-Bond which hold the promise of replacing many applications for timber products.

It was reported that in 2001, some 2,500 Husk-I-Bond roadside posts made from rice husks had been installed on Australian country roads (18).

Bicycle tyres

The Inoue Rubber Company Japan (with its Thai subsidiary) has developed a new tyre compound that incorporates rice husks throughout the tyre. The product is known as Rice Bran Ceramics (RBC). This newly developed concept combines rice husks with a thermosetting resin which is then superheated and ground to a powder. This powder is added to the tyre compound. This reportedly enhances traction and durability, and orients the small pieces of RBC randomly throughout the tyre tread. Each RBC grain contains needles that create a "micro-spike" (effectively poking into the road surface) and "micro-pores" which act as mini suction cups, and grip the surface in a second way.

Compared to other common rubber compound additives such as silica or carbon, RBC possesses a lower molecular weight thanks to its porous structure, and yields a lighter tyre.

Rice Bran Ceramic has a longer life span than regular rubber compounds. As the Rice Bran Ceramic is distributed throughout the rubber compound, the benefits do not diminish as the tread is worn down through normal use (19).

Carbonized rice hulls (CRH)

Rice hulls can be carbonized to generate an extra source of income. It is made from incomplete or partial combustion of rice hulls with a carbonizer which uses an easily constructed perforated oil drum as the ignition chamber. The process starts with igniting some combustible materials e.g. paper or chaff and then covering them with the ignition chamber. A mound of rice husk is then made outside the chamber and the draught force that pulls the smoke through the chimney continually draws air in and carbonizes the rice hull. Once the mound has turned completely black, the carbonized rice hull is transferred to 200-litre oil drums and sprinkled with water.

Carbonized rice hulls can be used to make charcoal briquettes, deodorizer or odour suppressant in animal pen and poultry houses. It can also be used as soil conditioner, water purifier, as well as a pest control agent, especially for the control of golden apple snails (20).

It should be emphasized that CRH differs from the white ash produced by burning rice hull. It is substantially superior in value to the white ash as it contains potassium, phosphorus, calcium, magnesium and other micronutrients needed for growing crops.

As a soil conditioner, the use of CRH provides the following:

- retains heat from sunlight, thus increasing soil and water temperature;
- high air permeability, thus, has the ability to replenish air in the soil;
- enhances water retention;
- sterile and pathogen-free;

- excellent host for beneficial microorganisms;
- excellent ingredient for bio-organic fertilizer; and
- reduces the population of golden apple snail in flooded rice fields.

This carbonizer can convert 1,585 liters of rice hull to at least 982 liters of CRH in four to five hours. Ten to 12 sacks of rice hull can produce four to five sacks of CRH.

Much of the production from this process is exported to Japan and used in organic production. CRH would be a useful complement to support the movement to organic agriculture in Thailand (21).

Paper production

There is a growing interest in using alternative fibre sources for paper making. The demand for paper in the business world has not fallen despite the advent of emails- the “paperless office” never materialized. Much of the interest is in using kenaf but rice husks and rice stalks also have significant potential as fibre sources. Already some small-scale production is taking place, but this could offer considerable value added at farm level in Thailand.

Fish feed

Rice bran is used to feed fish (catfish, sutchi, snakehead, giant fresh water prawn) not only in Thailand but also across Asia. Used either alone or in combination with other ingredients such as oil cakes. Rice bran is also used in formulated feeds in many countries in Asia. In subsistence farming, rice bran / wheat bran is the sole feed given to fish. No negative impacts of its use have been reported.

Rice bran has also been shown to increased production levels of zooplankton in estuarine water (22).

Biofuels and fermentation

There is considerable interest in using rice straw, rice bran oil etc. as fuel and as a feedstock for higher value chemical production including ethanol and enzymes.

Colusa Biomass Energy Corp of Colusa, California has patented a process for converting rice straw into ethanol. The company has partnered with Massachusetts company (Yet2.com) to help commercialize the company's technology, which is aimed at creating valuable biofuels from agricultural waste products. (Most of the rice straw has no commercial value). CBEC's technology can make an acre of waste rice straw into almost 1,200 litres of fuel ethanol and 400kg of high-grade silica for industry and can generate more than US\$ 890 of revenue from an acre of waste rice straw (23).

In addition to its use as a fermentation feedstock for industrial or beverage alcohol, there is considerable interest and targeted research for its use as a substrate for enzyme production. Many of these have applications in the pharmaceutical and food industries. Rice straw,

husk and bran have all been used to produce acid protease, lipase, alpha galactosidase, amylase, glutaminase, and glucoamylase (24).

Figure 1: The Rice Plant and its Utilization

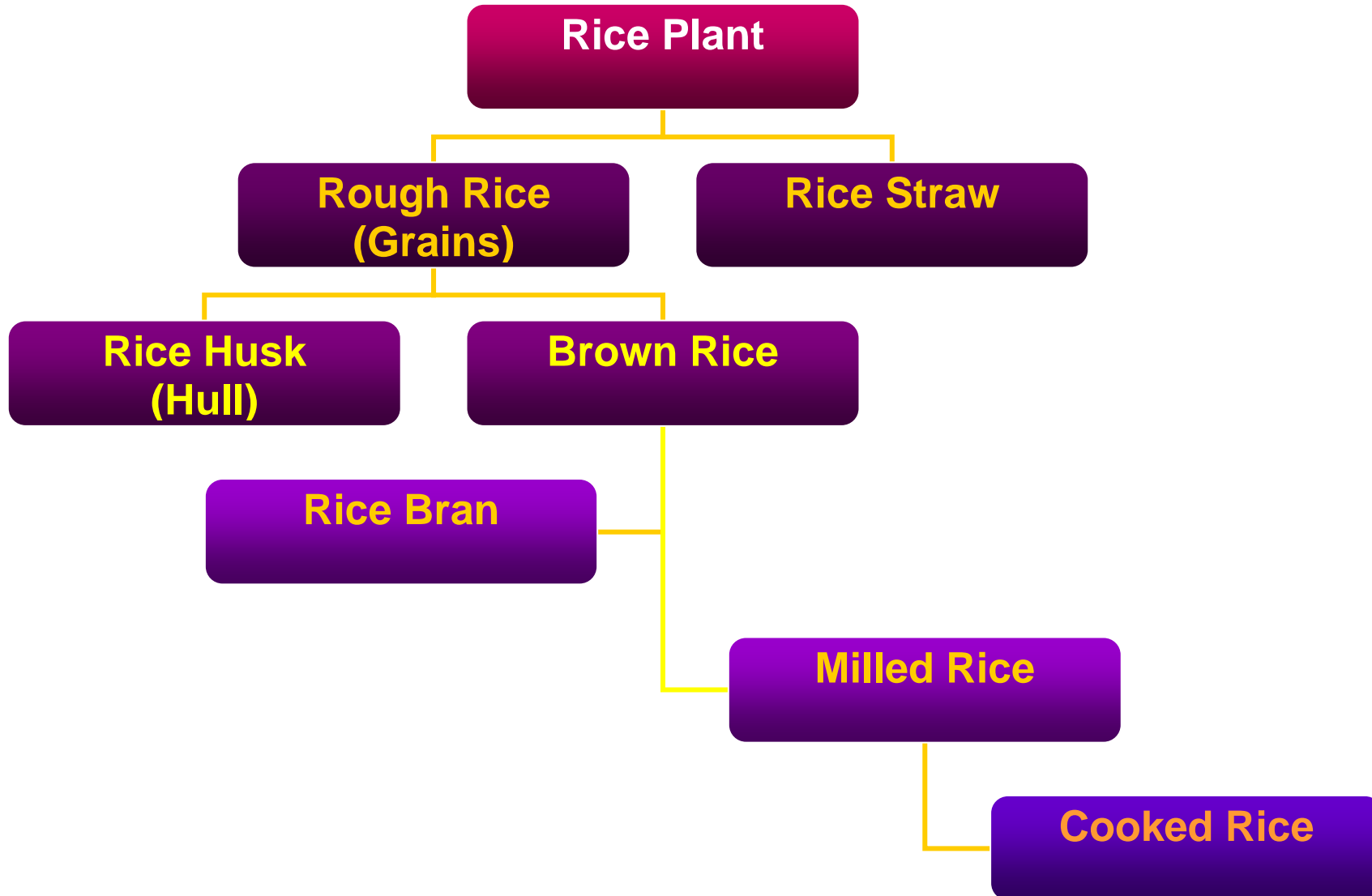
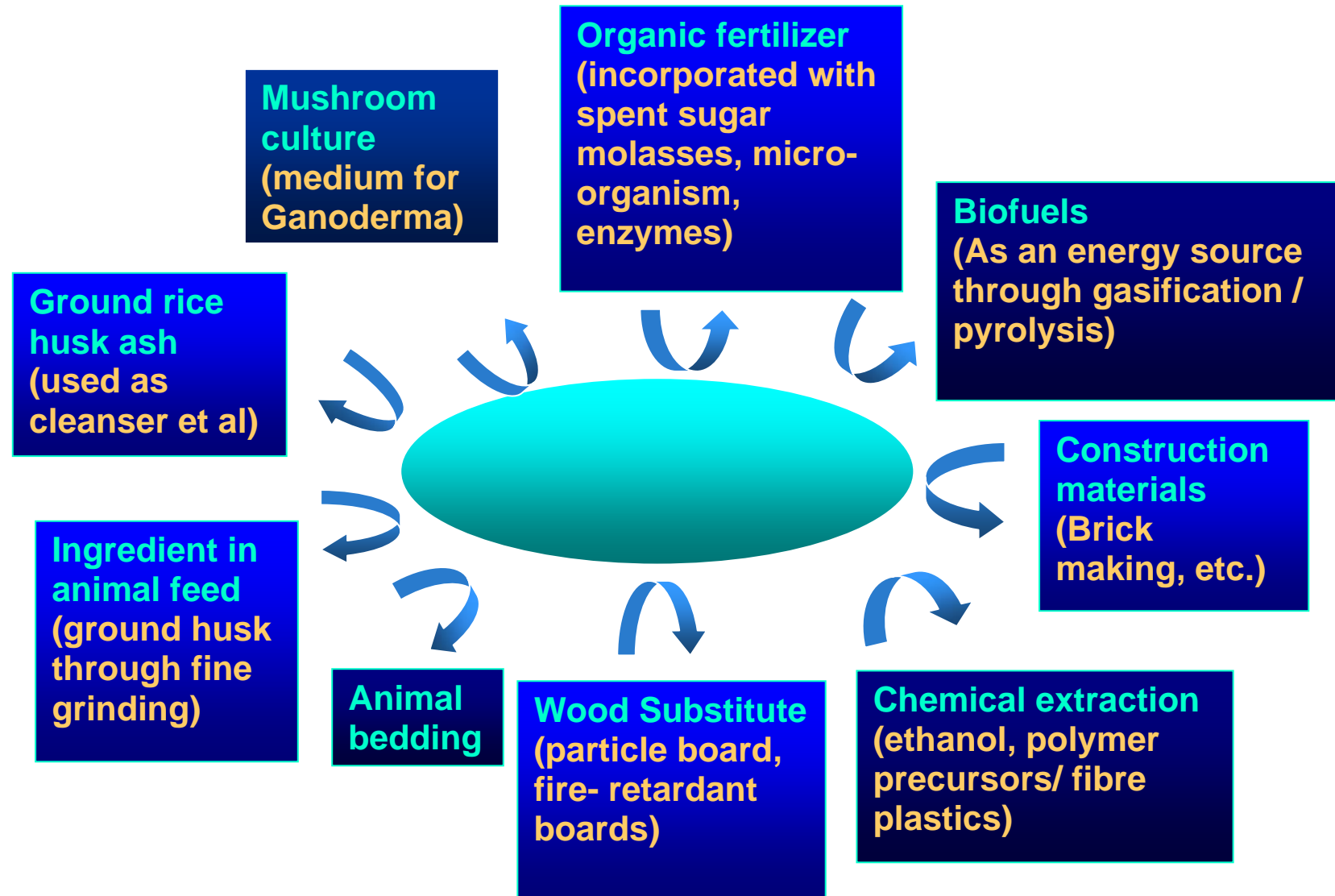


Figure 2: Alternative Uses for Rice Yield Components



Rice bran and rice bran oil

Rice bran is the most nutritious part of the rice grain and provides a good natural source of vitamin B. In Thailand, approximately 40% of the rice bran is extracted for cooking oil. The remaining 60% is utilized in animal feed production.

In the past, storage of rice bran has presented a problem due to the presence of a powerful lipase enzyme but in the past 20 years new rice bran stabilization methods based on dry heat extrusion / inactivation or proteolysis have been developed. These have allowed more efficient extractions of the economically important fractions present in the rice bran with varying functionalities. Products include natural emulsifiers, vitamin/mineral concentrates; rice bran fibre, and dough conditioners.

The dough conditioner, which contains protein, lipids, and pentosans from rice bran, is designed to improve machinability, leavening, and retard staling in breads and cakes. It is also used in cookies, pies, and tortillas. The emulsifier, which can be labelled 'rice extract,' already has applications in crackers, baked goods, and salad dressings, and is currently being evaluated in several extruded snack food items.

Rice bran oil is a popular cooking oil in Japan, noted for its nutritional value and delicate flavour. The demand for rice oil in Japan exceeds the country's production capacity, which has been estimated at about 100,000 metric tons annually. Crude rice bran oil contains 90% to 96% saponifiable lipids and 4.2% unsaponifiable lipids, including those components noted for the reduction of LDLs. (see below for extended discussion). Fatty acid composition is given below: -

- Palmitic 16:0 - 4.0%
- Stearic 18:0 - 2.0%
- Oleic 18:1 - 45.0%
- Linoleic 18:2 - 34.0%
- Linolenic 18:3 - 1.5%

Oryzanol (part of the unsaponifiable fraction), which seems to have the greatest effect on lowering serum cholesterol, is highest in crude rice bran oil. Alkaline refining and bleaching lower the level of oryzanol, so minimal refining results in the highest nutritional value.

Broken rice and rice flour

Approximately 70% of the broken rice produced in Thailand is used as feed ingredients or made into instant noodles and snacks. In the milling process of a highly efficient milling machine, 26% of the yield will be broken rice, with the remaining 39% whole head rice, 11% bran, and 24% husks.

Figure 3: Constituents of Rice Bran Oil

Major constituent	Content	Compounds/ components
Saturated fats	Major, 20%	Palmitic and stearic acids
Monounsaturated	Major, 45%	
Polyunsaturated fats	Major, 35%	Oleic acid, linoleic acid and linolenic acid 2-acetyl-1-pyrroline
Hydroxylated triterpene alcohol ferulates	Minor	(24S)-cycloart-25-ene-3 beta,24-diol-3 beta-trans-ferulate (24R)-cycloart-25-ene-3 beta,24-diol-3 beta-trans-ferulate Cycloart-23Z-ene-3 beta,25-diol-3 beta-trans-ferulate Cycloartenol trans-ferulate 24-methylenecycloartanol trans-ferulate
Tocotrienols	Micro	Alpha-, beta-, gamma-, and delta- tocotrienols, desmethyl tocotrienol [3, 4-dihydro-2-methyl-2-(4,8,12-trimethyltrideca-3'(E),7'(E), 11'-trienyl)-2H-1-benzopyran-6-ol] and didesmethyl tocotrienol [3, 4-dihydro-2-(4,8,12-trimethyltrideca-3'(E),7'(E), 11'-trienyl)-2H-1-benzopyran-6-ol]
Gamma-oryzanol	Micro	Ferulic acid esters of triterpene alcohols such as cycloartenol (CA) (106 mg%) and 24-methylene cycloartanol (494 mg%),
Total tocopherols	Micro 81.3 mg%	Alpha-, beta-, gamma-, and delta-tocopherols
Squalene.	Micro	
Phytosterols		β-Sitosterol, Campesterol, Stigmasterol Brassicasterol

Rice flour

Rice flour, made from 30% of the broken rice produced in Thailand, is used to produce rice pasta, chips, and other snacks, as well as cereals. It can also be a substitute for wheat flour products. The advantages of rice flour are: -

- Hypoallergenicity - based both on the consumer's low sensitivity to rice protein, and its processing method, which does not require the use of sulphur dioxide, a necessary process agent in the corn wet-milling industry.
- Rice flour can easily be certified as organic and natural, and is favoured by the health food industry.
- Micro and macro structures of the kernel make component separation and further processing simpler, thus eliminating the need for chemical processes.

Rice starches have also been a popular ingredient in fat-reduced products, partially due to the above characteristics, but also due to the physical characteristics of rice starch. Rice starch granules are very small relative to other starches. The granules are polygonal in shape and are about 2 - 8 microns in diameter. In comparison, corn averages about 15 microns, tapioca about 20 microns, and potato ranges from 15 to 100 microns.

When used in an ungelatinized form, these naturally small particles can produce a smooth texture. Rice starch gels tend to be smooth, creamy and spreadable, with a clean flavor.

The potential exists for a wide variety of rice derivatives based on the variety of grain, which influences amylose:amylopectin ratios, granulation, and type of milling. Starches or, more readily, flours could be prepared from parboiled or "instantized" rice. These processes influence the rate of granule swelling as well as resistance to shear.

Remy Industries, a Belgian company, produces about 70% of the world's rice starch supply. Their business in Europe has grown largely from the use of rice products developed for the pharmaceutical industry. Much of their business is based on a waxy rice starch which is 99+% amylopectin, and a starch with an 80:20 amylopectin: amylose ratio. Modified waxy rice starches have additional acid and shear stability.

The use of rice starches has grown primarily in response to health foods, the hypoallergenic sector, and the organic sector. The oral rehydration products industry - products that prevent dehydration caused by dysentery, plague and cholera - is another fast-growth area for rice-based ingredients.

Rice flour can be used to produce gluten-free rice bread for gluten-sensitive individuals, but hydroxypropyl methylcellulose is required for proper leavening. These breads tend to stale very rapidly, limiting their distribution. Rice flours, syrups, and starches can be used to provide a number of gluten-free baked products. This is a very small industry, but very necessary for individuals with coeliac disease.

Rice syrups

Rice syrups, syrup solids and maltodextrins are also available, but differ according to source and the method of processing. Specific amylases are used to generate maltodextrins and syrups that have functionality that allows substitution for corn-based products.

Rice syrups contain proteins as well as residual fat and, unlike corn syrup, are sulphite-free.

Since rice products cost roughly three times those made from corn, these syrups and maltodextrins cannot compete economically, but they do fill specific nutritional and functional needs. Lightly filtered rice syrups offset the beany note in soy milks more effectively than corn syrup. Brown syrups are strongly favoured in granola products, and also have a much higher acceptability in the key health and nutraceutical markets.

Overall, however the rice ingredient industry has been inhibited by the importance of rice as a world food staple, which has kept its economic value high. The growth of the health food industry and growing consumer interest in nutrition has generated a largely custom industry, which has resulted in a diverse range of ingredient possibilities. The food product developer benefits from the range of selections, but needs to remain aware of the chemical/functional differences between the many ingredients available.

Straw

Rice straw has various uses in Thailand. Approximately 10% of the straw is utilized as a medium to grow mushrooms, 50% are used for animal feeds, 30% are used in paper making, and the rest is burnt in other food production process.

Rice used in beverage making

A wide range of alcoholic beverages is made from rice (i.e. broken rice). Some of examples include sake or sake, traditionally called rice wine, and beer. In Thailand 'lao-khao' and 'Sato' are widely produced at village level, with the latter recently gaining popularity and appearing in supermarkets under many brand names. This sector presents particular opportunities to create new formulations of drinks that with suitable marketing could create beverages similar to those that have been developed with rum and vodka, targeting young adults.

Healthcare for the healthy (treating the healthy)

Ageing populations in many countries around the world present many opportunities for products for both the sick, and for those who want to take proactive measures to maintain wellness. The role of nutritional supplements in the prevention and management of age-related diseases / disorders has led to a lucrative global market. This new emphasis on prevention opens up many opportunities in the alternative care area, especially with regard to dietary supplements and nutraceuticals. The US market for nutrition products is well over \$60 billion annually - one-third of this being accounted for by the sale of supplements. The combination of supplement and functional food sales accounts for two-thirds of this market.

It is significant that more and more global pharmaceutical companies (“Big Pharma”) are looking at this sector as a revenue booster in face of competition from generic manufacturers and smaller pipelines for new conventional drugs. Moreover, with the reputation, status, and resources of the pharmaceutical and biotechnology industries addressing the prevention needs of an ageing population, it is clear that the market for nutritional products could grow and at accelerated rate for the next ten to twenty years. The reported effects on major age-related diseases / disorders, (e.g., rheumatoid arthritis, Type II diabetes, cardiovascular disease, cancer etc.), of various rice-based products presents a major opportunity for the rice-associated industries. Diseases that are particularly prevalent in Asia e.g. coronary heart disease, hepatic and nasopharyngeal cancers, and diabetes should be of particular interest.

Rice bran oil / oryzanol and coronary heart disease,

Rice bran contains high levels of the antioxidants known as tocopherols and tocotrienols, (vitamin E components) and oryzanol (complex compounds that can act as an antioxidant, improving solubility in cell membranes and potentially lowering cholesterol by competitive inhibition of absorption and synthesis).

In vitro assays showed oryzanol components reduced oxidation of cholesterol significantly more than the vitamin E components, indicating a possible application for these compounds in fighting heart disease **(25)**.

Rice bran oil / oryzanol and osteoporosis

Similar test have been carried out to test the effectiveness of oryzanols against osteoporosis, and positive effects have been noted when rice bran oil is part of the diet in rat model systems. Interestingly, no activity was noted when pure compounds were fed to the rats. This suggests that either the oryzanol as it occurs naturally in rice bran oil is more biologically active than crystalline oryzanol, or that some other component of the rice bran oil is influencing bone density positively **(25)**.

Ferulic acid

Ferulic acid (FA) is present in significant levels in rice bran oil. Its chemical structure strongly resembles that of curcumin, the substance responsible for the yellow color of the spice turmeric.

Ferulic acid has antioxidant properties that make it an important anti-ageing supplement, and they also contribute to FA's other potential uses. These include applications in diabetes, cardiovascular disease, cancer, neuro-protection, bone degeneration, menopause, and immune system disorders (26).

Squalene

Squalene is being investigated as an adjunctive therapy in some cancers. In animal models, it has proved effective in inhibiting lung tumors. It has also demonstrated chemopreventive effects against colon cancer in animal models. Supplementation of squalene in mice has produced enhanced immune function and, in other animal studies, it has reduced cholesterol levels, prompting one researcher to suggest that it might be used to potentiate cholesterol-lowering drugs.

A mouse study showed squalene to confer radioprotection against lethal whole-body radiation (27).

Inositol

Inositol is necessary for the formation of lecithin and functions closely with a B complex vitamin, choline. Since it is not essential in the human diet, it cannot be considered a vitamin. Inositol is a fundamental ingredient of cell membranes and is necessary for proper function of nerves, brain, and muscles in the body. Inositol works in conjunction with folacin, Vitamins B-6 and B-12, choline, betaine, and methionine to prevent the accumulation of fats in the liver. It exists as the fibre component phytic acid, which has been investigated for its anti-cancer properties.

Inositol is primarily used in the treatment of liver problems, depression, panic disorder, and diabetes. It also aids in the breakdown of fats, helps in the reduction of blood cholesterol, and helps to prevent thinning hair. A diet low in inositol may result in deficiency symptoms that culminate in high blood cholesterol, constipation, eczema, and hair loss. Neurotransmitters such as serotonin in the brain depend on inositol to function properly. Low levels of this nutrient may result in depression and some research has shown that increased levels of inositol appear to be a promising treatment for depression (28).

Phytosterols

In addition to the effects of the rice bran components noted above, phytosterols have been observed to have the following effects in experimental systems:

- Reducing total cholesterol
- Inhibiting the synthesis of LDL-C
- Reducing BPH (benign prostatic hyperplasia)

- Providing anti-inflammatory effect
- Inhibiting the growth of breast cancer cells
- Inhibiting colon cancer cells
- Helping in cancer prevention
- Improving the immune system (29).

Oligosaccharides

Non-digestible oligosaccharides have been claimed to benefit the colon by selectively stimulating the growth of bifidobacteria and by decreasing the toxicity of the colon contents. Oligosaccharides are fermented and consumed by the beneficial intestinal bacteria, bifidobacteria, in the colon.

Red yeast rice

Red yeast rice is rice that has been fermented by the red yeast, *Monascus purpureus*. The Chinese has used it for many centuries as a food preservative, food colourant (it is responsible for the red color of Peking duck), spice, and as an ingredient in rice wine. Red yeast rice continues to be a dietary staple in China, Japan, and Asian communities in the United States, with an estimated average consumption of 14 to 55 grams of red yeast rice per day per person.

Red yeast rice also has been used in China for over 1,000 years for medicinal purposes. Red yeast rice was described in an ancient Chinese list of drugs as useful for improving blood circulation and for alleviating indigestion and diarrhea.

Recently, red yeast rice has been developed by Chinese and American scientists as a product to lower blood lipids, including cholesterol and triglycerides.

There are three major preparations of red yeast rice; Zhitai, Cholestin or Hypocol, and Xuezhikang. Zhitai is produced by the fermentation of a mixture of different strains of *Monascus purpureus* on whole grain rice. Zhitai contains mainly rice and yeast, but is mostly rice by weight.

Cholestin or HypoCol is produced by the fermentation of selected strains of *Monascus purpureus*, using a proprietary process that produces a certain concentration of monacolin K (monacolin K is lovastatin, which is believed to be the major cholesterol-lowering ingredient).

Xuezhikang is produced by mixing the rice and red yeast with alcohol and then processing it to remove most of the rice gluten. Xuezhikang contains 40% more cholesterol-lowering ingredients than Cholestin or Hypocol.

In the United States, red yeast rice is available as a food supplement called Cholestin™ (Pharmanex, Inc.). In Singapore, red yeast rice is available as Hypocol™ (NatureWise™, Wearnes Biotech & Medicals (1998) PTE LTD). Cholestin™ in the United States and HypoCol™ in Singapore contain similar ingredients.

In China, Xuezhikang is available under the same name (Beijing WBL Peking University Biotech., Ltd.) (30).

A note of caution

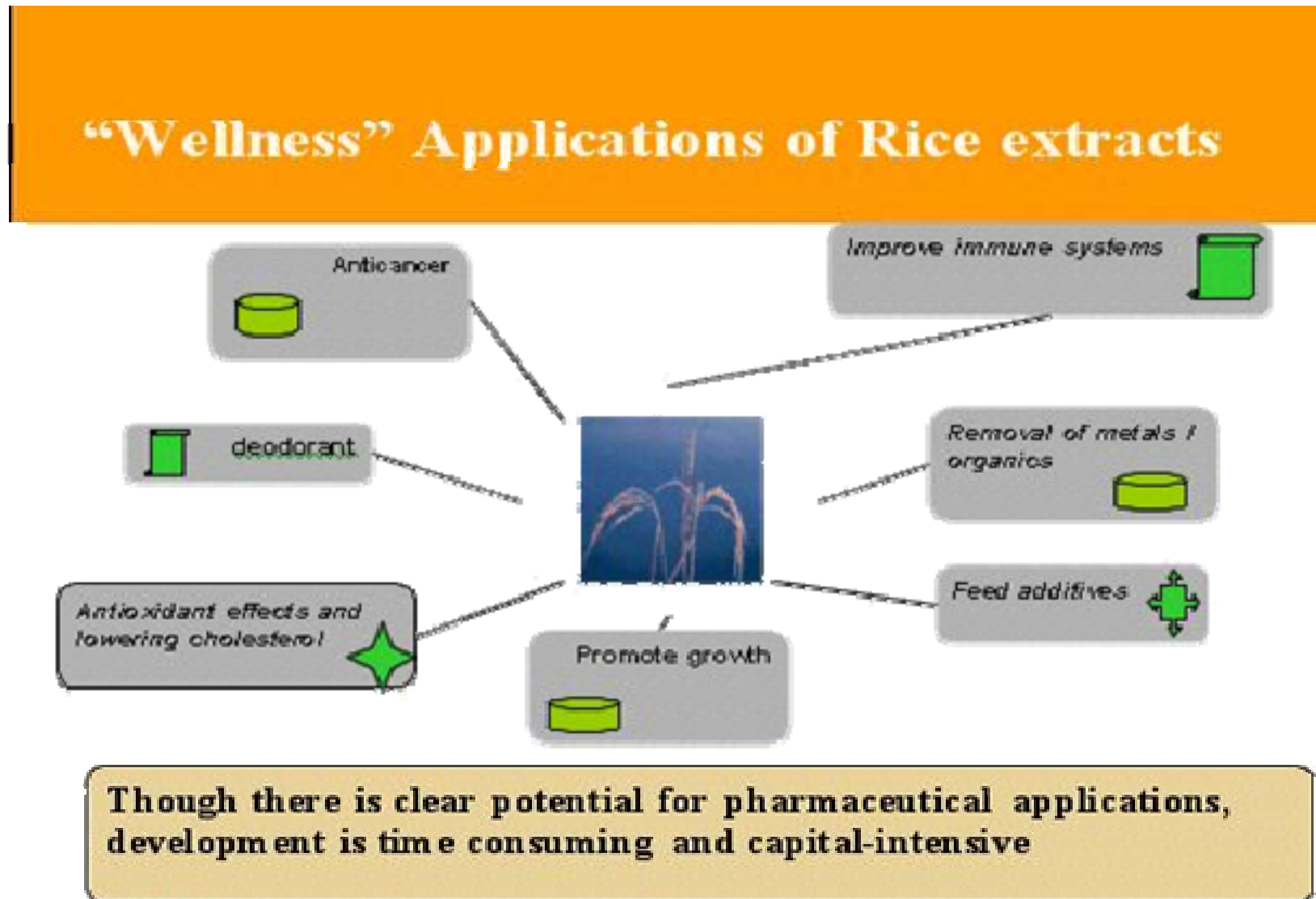
While there is a plethora of reports of the effectiveness of various rice extracts and purified phytochemicals against an equally wide range of indications, there has been relatively little validation of these effects through either preclinical or clinical trials. Most studies have failed to go beyond mouse models or in vitro testing and few primate tests have been conducted.

There is probably little likelihood of Big Pharma e.g. GSK, Novartis, investing in such trials because it will be impossible to file patents on the compounds. However, the development of a process to more effectively extract or enhance activity of some these supplements may in many cases offer significant potential for an attractive economic return.

Bearing the above in mind, serious scrutiny of the data reporting beneficial effects of these supplements is always warranted.

-

Figure 4: "Wellness" Application of Rice Extracts



Cosmetics and Cosmeceuticals

Rice cosmetics

Cosmetic are defined as substances “intended to be rubbed, poured, sprinkled or sprayed on, introduced into, or otherwise applied to the human body . . . for cleansing, beautifying, promoting attractiveness, or altering the appearance”. Companies around the world are creating novel formulations that use one or more ingredients from rice.

One such example is Fresh, a US-based cosmetics company. Its products include rice dry oil, rice body cream, rice shampoo, rice face wash, rice shower scrub, rice foot cream, rice foot soak, and even a rice footcare file. Rice bran oil, rice bran protein, starch, sake, enzymes extracted from rice fermentations, and crushed rice are all used, in combination with a wide array of other ingredients such as arnica, ginseng, and passion flower extracts, Chinese root extracts including *dong-quai*, *fo-ti*, ginger, extracts of white lily, camellia and honeysuckle (31).

Cosmeceuticals

Demand for cosmeceuticals—cosmetic products intended to have therapeutic effects on the body— are projected to increase by 11% per year to \$7 billion in 2008. Skin care products will account for over 60% of the total cosmeceutical market. Over half of these skincare cosmeceuticals consist of those with anti-ageing benefits. The demand for anti-ageing products is growing at over twice the rate of other skincare cosmeceuticals. The value of chemicals used in these products is expected to advance at a slightly faster pace, increasing 11.3% per year to \$965 million in 2008. Demand for cosmeceutical chemicals will continue to outpace products as producers invest more heavily into researching more effective, value-added ingredients for their product formulations.

Care must be taken in the marketing of cosmeceuticals. Many companies are under the misconception that cosmeceuticals are analogous to dietary supplements, and thus may use the same range of claims about therapeutic impacts. This, however, is mostly not the case. The cosmeceutical category is not recognized by FDA and therefore exists in a regulatory “limbo” between cosmetics and drugs. While the presence of dietary supplements has indirectly impacted the range of claims permitted for cosmeceuticals, there are important limitations that must be observed. Further, as cosmeceutical products are developed, it is critical to keep safety claims and substantiation issues in mind.

Examples of currently marketed cosmeceuticals include skin lotions with botanicals added to counter the effects of ageing, and creams containing antioxidants to fight environmental damage (32).

In addition to the food supplements noted in a previous section other ingredients from rice in cosmeceuticals include: -

Kojic acid

Kojic acid is a by-product in the fermentation process of malting rice for use in the manufacturing of sake, the Japanese rice wine. There is convincing research, both in vitro and in vivo, showing kojic acid to be effective in inhibiting melanin production. Glycolic or

kojic acid, or glycolic acid with hydroquinone, are both highly effective in reducing the pigment in melasma patients. Kojic acid is an extremely unstable ingredient in cosmetic formulations, however. It turns brown and loses its efficacy very quickly upon exposure to air or sunlight. Many cosmetic companies use kojic dipalmitate as an alternative because it is far more stable in formulation. However, there is no research showing kojic dipalmitate to be as effective as kojic acid, although it is a good antioxidant (33).

Hydrolyzed rice bran protein, soybean protein, oxido reductases

Hydrolyzed rice bran protein has been incorporated into a mixture with soybean protein, Oxido reductase as a new skin treatment that reduces dark circles and puffiness around the eyes. It is also claimed to improve microcirculation, strengthen native collagen and elastin matrix, and reduce the presence of free radicals to delay the visible signs of premature ageing.

This complex was created for facial care products, especially anti-ageing eye care creams and gels. It is principally aimed at mature skin that is already showing visible signs of ageing (34).

Rice peptides

Rice peptides are said to protect the skin from the collagen-degrading effects of collagenase. This activity can help delay early skin ageing characterized by wrinkle formation, reduced elasticity, skin dryness and age spots. Rice Peptides are an ideal component for anti-ageing products and well suited for sun and environmental stress protection formulations (35).

Innovation in Marketing

All of the above innovations, especially those in the wellness category, will require imaginative marketing initiatives and major investment. Innovative ideas will be required to ensure market entry and growth.

At the commodity and food product level there is also a need for more effective marketing to expand Thailand's Jasmine rice market share. A national brand that complements the "Kitchen of the World" initiative may be warranted. Such campaigns however, are costly to create and most maintain.

It may be possible to identify prominent spokespersons in target markets e.g. prominent chefs, e.g., Charlie Trotter (a major supporter of organic production) in the US or Jamie Oliver, Delia Smith in UK.

Ongoing Research Projects for Innovative Products from Rice in Thailand

Prepared by Prof. Onanong Naivikul

1. Production and market study for export potential of some selected rice products

This research aims to build a database of information on rice production, processing, and markets as well information on customer requirements and behaviour towards rice and rice products. Data will be used in order to aid in future new product development. Data were collected from related government agencies and the private sector. Market and consumer surveys were conducted within Thailand and in the target countries. Rice grain, rice noodle and rice snack products were targeted. Focus groups were used to investigate eating habits and buying behaviour. Customer studies were also conducted to identify sensory factors that influence buying decisions by Thais. This data will be used to identify profiles of products suitable for the future new rice product development.

2. Effect of coating substance on quality of frozen cooked brown rice

Eight formulas were developed to coat three varieties of rice before being frozen. The results showed that only two formulas were suitable to coat three cooked brown rice varieties (Niaw San-pah-tawng, Khao Dawk Mali 105 and Khao Tah Haeng 17), after cooking and freezing (-30 °C), then thawing for 3-5 freeze-thaw cycles, while the non-coating cooked brown rice could be accepted only within 1-3 freeze-thaw cycles. The chemical, physical and physio-chemical characteristics of each rice varieties were shown to relate to the quality of frozen cooked brown rice. The amylose content, the hardness (using Texture analyzer) and the retrogradation (using DSC) of each freeze-thaw cycles for each rice varieties were determined.

3. Process design of ready-to-eat glutinous rice with fried chicken or fried pork

Three varieties of glutinous rice (Niaw San-pah-tawng, RD 10 and RD 6) were used to study optimal process design for ready to eat glutinous rice. The objectives were to select optimum process, study shelf life, safety for consumer and design container for the marketing. The results showed that when cooking aged glutinous rice one must add more water and increase time for cooking compared to freshly harvested glutinous rice. Cooking by steam method caused the glutinous to be more yellow and have a stronger texture than when boiled. The chicken and pork were fried to 70% and 100% respectively. Optimum condition of retort for fried chicken and pork were found. The container of the ready to eat glutinous rice and fried pork was designed for convenience and attractive packaging.

4. Frozen flavor cooked rice products

Chai Nat 1 and Pathum Thani 1 were found to be suitable for fried rice but RD 6 was rejected due to the stickiness of the cooked rice. The normal freezer, contact plate freezer and cryogenic freezer using liquid nitrogen as batch system were compared for the two acceptable rice varieties for the production of flavored cooked rice product. The results showed that the suitable processes were the contact plate freezer and the cryogenic freezer. The product was then packed in the suitable packaging.

5. Effects of processing on changes in quality of rice and rice products

This project is aimed to analyse the basic characteristics of rice varieties products for develop quality rice noodle in retort pouch process and freezing process. The results of the effects of thermal processing using retort pouches on the properties of thin-stripe rice noodles showed that the conditions of heating profiles with F_0 of 0.13 to 11.85 min resulted in decreasing degree of polymerization (DPn) of rice noodles from 4 to 48% and changes in texture and color. The decrease in DPn values depended on rice varieties, heating profiles, and the interaction between rice varieties and thermal processing profiles.

Four rice varieties namely RD 6 (waxy rice with amylose content of 5.64%), Khao Dowk Mali 105 (low amylose content of 17.64%), RD 7 (medium amylose content of 27.60%) and Leuang 11 (high amylose content of 34.23%) were used for freezing process. The result showed that the optimum ratio of flour to water for noodle production was 40:60. Flour suspension at this ratio gave an appropriate viscosity as well as uniform thickness of rice sheet. In addition, Leuang 11 was found to be the best of four varieties in making rice stick noodles. Sen-Jun noodles from Leuang 11 had a tough and good flexible texture. The optimum freezing condition for cooked rice stick noodles was decreased temperature from 10 to -30°C within 20 minutes, decreased to -40°C within 10 minutes and decreased to -50 °C within 10 minutes. Then held at this temperature until sample temperature reached -30 °C. The optimum thawing condition was placing the frozen noodles at room temperature (25 °C) for 15 minutes and then heated with microwave oven at 100% level for 30 seconds. Noodles thawed by this condition had texture that was not significant difference as compared to the noodles before freezing.

6. Ready-to-eat rice noodles in retort pouch

This research was conducted to produce the ready-to-eat rice noodle products in retort pouch by using 2 types of noodles: Sen-Lek and Sen-Mee. The effects of various factors on noodle qualities such as types of noodle, pre-adjustment of noodle (moisture content and acidity), and heat treatment condition (time and temperature) were investigated. Development of the ready-to-eat seasoning mixes, in the forms of sauces and soups in retort pouch (Pad-Thai sauces, Tom Yum soup, Rad-Na thick soup, and Pad Se-iew) consumed with processed rice noodles showed that the panelists accepted the finished products.

7. Dehydrated fermented rice noodle (Kanomjeen)

Kanomjeen is the Thai traditional rice noodle which has short shelf life of 1-2 days at room temperature. It can be made of white rice or brown rice and has two types, fermented and unfermented. Dehydrated Kanomjeen noodle were designed to prolong the shelf life of at least 2 years for export. This innovative rice noodle provides convenience for cooking, assures safety and delicious food for consumption. The process of making dehydrated Kanomjeen noodle was patented in 2001. Dried natural sauces powder to be eaten with Kanomjeen noodle such as, Namya, Namprik and others were also developed and packed in sachet. The packaging of block and straight noodle were designed and developed. Pouch for dried Kanomjeen and dried power sauce sachet was also designed and developed. The preparation of Kanomjeen noodle is to put in boiling water for 8-10 minutes. The Namya sauce powder is dissolved in boiling water for 1 minute and spread on the top of rehydrated Kanomjeen noodle.

8. Effects of extrusion process on changes in quality of rice products

In product development, rice snack product from extrusion process was investigated by studying physicochemical properties of rice from various varieties with different amylose contents. The ground rice from intermediate amylose content of rice (Suphan Buri 60 and Chai Nat 1) gave the extrudate with better qualities in term of both physicochemical and sensory properties.

9. Development of snacks from rice mixed with fruit using extrusion process

Development of snack from a mixture of rice flour and processed banana was performed using an extrusion process. Two types of processed banana (banana chip with butter flavor, dried banana) were used and separately studied. These two snack products are crispy and brown containing banana and caramel flavor. The consumer test using a central test location showed the acceptance of snack made from rice and butter flavored banana chip and snack made from rice and dried banana were 92.8% and 91.1% respectively. Shelf life of both snacks were at least 3 months at room temperature (30°C).

10. Improved nutritional quality of Thai desserts using brown rice

Development of Thai dessert products by using brown rice (Khao Dawk Mali 105) was conducted, to improve the nutritional quality and value added of the products. The optimum ingredients in each formulae, their chemical composition and dietary fiber contents were investigated. Results showed that 30 –100% of brown rice and their flours could be replaced on the total weight to milled flour in the products, and the chemical composition of 10 products showed the energy content was ranging from 8.0 to 534.7 Kcal, while the quantity of protein, fat, carbohydrate and dietary fiber were ranging between 0.1 - 22.1, 1 - 34.7, 6.6 - 70.8, and 0.02 – 3.9 gram/100gram, respectively.

11. Utilization of low quality rice in fermented soy sauce industry

The selection of fungi and rice varieties for Japanese soy sauce production were investigated. Three varieties of rice which were Leuang 11, Jasmine and glutinous rice were compared in order to replace wheat and to reduce the color intensity of the soy sauce production in pilot scale. Koji preparation was done by mixing whole soybean or defatted soybean with wheat and the tested rice varieties. The result indicated that enzyme activity, color intensity and protein content decreased with the increasing of Leuang 11 rice amount which was replaced wheat.

12. Development of protein concentrates production process and improvement of its quality for use in beverage products

Process for production of rice bran protein concentrate powder (RBPCP) was developed. The optimum process conditions for modifying functional properties of RBPCP by using bromelain. The application of RBPCP as a clouding agent in processed orange juice was performed. The results showed that orange juice added with the RBPCP showed the clouding stability as high as those added with the 3 commercial clouding agent after stored at 5 °C for 3 days.

13. Alcoholic and non alcoholic beverage from rice

The malting of 16 varieties of rice were studied. The result showed that the steeping water temperature at 30°C was better than 20°C in term of water absorption of rice grain. In germination process, the rice variety RD 6 showed high germination power at 88 % and also high diastatic power. Malted rice from RD 6 was used to experiment for production of malted rice wine. The green malt was subjected to three conditions of kilning and rice wine was made from the dry malt received. Also the search for the addition of yeast extract and enzyme to improve the quality of beer from rice adjunct was carried on. The data showed that the broken rice could be incorporate up to 40 % broken rice and 60 % malted barley with the addition of enzyme and yeast extract. The finished beer has compatible quality as the beer brewing from 100 % malt. In order to be successfully in making the rice wine, the preparation of pure inoculum was studied. The red rice (ang-kok) with the growth of *Monascus purpureus* was prepared and added to rice to develop more color and health

benefit. The finished red wine were almost the same alcohol level and independent on the amount of red rice koji. However, the red pigment was increased as the amount of red koji increase.

14. Rice quality improvement for added value in nutrition

This project is aimed to determine the composition and quality of some Thai rice varieties. Develop the method to control the concentration of growth hormone to increase the nutrition quality values of some rice varieties. The study on effects of plant growth regulating chemical (PGRC) on carbohydrate metabolism, protein and mineral content in developing rice endosperm of rice varieties was carried out. The result showed that high content of protein was found in Nam Sa-gui 19, Khao Pahk Maw 148, Muey Nawng 50 M, Niaw San-Pah-tawng and Hahng Yi 70 rice varieties whereas Pan Kao Prakuat, Suphan Buri 2, Khao Khlong Laung, Phitsanulok 60-1, KD 1 and Lee Sao rice varieties gave high value of Ca content.

15. Development of color resistant material from rice flour for resist dyeing process

This research is the study of the possibility of using Thai rice flour in producing resisting agent for resist dyeing. The normally resisting agents are bee wax and paraffin, commonly known as “Batik”. In this research, studying of Batik supplier and consumer had been taken in order to collect costing, production process and marketing data. The research experiments were divided into two major parts. The development of Thai rice flour resist paste recipe and the development of resisting techniques. The paste can be trailed and stick on the cloth well.

16. The development of technology transfer pattern of value added rice products

This project is aimed to research about how to apply technology of value added rice products to expected group.

Rice research and development should be a multidisciplinary effort involving researchers, farmer, producers and consumers through the knowledge of science and technology. Rice scientists should focus on rice variety, post-harvest, storage, quality, processing, and utilization for staple food and especially for industrial uses as food and non-food products.

The active areas of rice research in the future should include breeding strategies used to satisfy grower, processor and consumers demands for certain quality features. The germinated brown rice (GBR) as a healthy food is still need basic research to support it used for staple foods as well as food ingredients and industrial raw materials for processed rice products. The new technology used for processing rice as milling, parboiled, drying, canning or retort pouch process, freezing, etc. are needed to develop. More research should be done to develop rice flour as composite flour to make bakery products such as breads, cookies, cakes, pastries as well as other kind of steamed and fried products. The utilization of chemical compositions of rice such as starch, protein, and fat as functional food ingredients for various rice products as well as non-food ingredients for cosmetics, pharmacy, etc. could increase more value-added to rice. The development of modification methods for rice starch to provide nutritional benefits and various functional properties as food ingredients for colloidal stabilizers, fat replacers, etc.

Potential Partner Companies

Rice Starch

Remy Industries

www.remy-industries.be/tiense/remycorporate.nsf/languages?openform

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Industry Demand

Whereas companies are ready to discuss their interest in specific product areas, they are reluctant to quantify the demand as this information is proprietary and would only be disclosed under the terms of a Non-Disclosure Agreement with NIA. Similarly, they would also require a Non Disclosure Agreement prior to discussing their demand forecasts for their processes and products. There are also other confounding factors, such as pricing, which influences the potential volume that a company may wish to purchase.

Nevertheless, it is expected that the greatest demand by volume would be in the less sophisticated applications e.g. rice husk ash production. This technology has considerable potential for the millers for a new add-on industry with a multiple product profile. Similarly, the demand for rice bran oil and starch will likely to be high as they can be incorporated in many different processes and products. These applications will likely expand along with the rapid development of the cosmeceutical sector. Increased demand for anti-oxidants is also forecast with the development of this sector. Finally, demand for other phytochemicals is set to increase, but will be a longer term prospect since commercialization will be contingent upon further validation of clinical effects.

Manufacturers in Thailand

1. Production of Jasmine rice 105 to commercialize project
 - Rattana Rice Co. Ltd
 - Farmer group at Prankratai, Kampanget Province

โครงการการผลิตข้าวหอมมะลิ 105 ครบวงจรสู่เชิงพาณิชย์
ผู้เข้าร่วมโครงการ : บริษัท โรงสีรัตนไรซ์ จำกัด
เครือข่ายเกษตรกรผู้ปลูกข้าว อ.พรานกระต่าย จ.กำแพงเพชร

2. Frozen rice product
 - President Rice Co. Ltd. (Mama)
 - Bangkok Industrial Gas Co Ltd

โครงการผลิตภัณฑ์ข้าวแช่เยือกแข็ง
ผู้เข้าร่วมโครงการ : บริษัท เพรสซิเด็นท์ ไรซ์ จำกัด (มาม่า)
บริษัท บางกอก อินดัสเทรียล แก๊ส จำกัด

3. GABA-Rice Project
 - Richie Confectionary Company Limited
 - Universal Rice Co. Ltd.
 - Pathum Rice Mill and Granary Pcl.
 - Chia Meng Co.,Ltd.
 - President Rice Co. Ltd. (Mama)

โครงการผลิตภัณฑ์เพื่อสุขภาพ GABA rice
ผู้เข้าร่วมโครงการ : บริษัท ริชชี แอนด์ คอนเฟกชันนารี จำกัด
บริษัท ยูนิเวอร์แซล ไรซ์ จำกัด
บริษัท ปทุมไรซ์มิล แอนด์ แคนารี จำกัด
บริษัท เจียแม็ง จำกัด
บริษัท เพรสซิเด็นท์ ไรซ์ จำกัด (มาม่า)

4. Baby Powder from Rice Starch
 - Erawan Pharmaceutical Research and Laboratory Co. Ltd.
 - International Laboratories Co. Ltd
 - Lion Thailand Co. Ltd.

โครงการแปงฝุ่นจากแป้งข้าวเจ้า
ผู้เข้าร่วมโครงการ : บริษัท เอรಾವัน ฟามาซูติคอล รีเซิร์ช แอนด์ ลาบอราตอรี จำกัด
บริษัท ILC
บริษัท ไลออน (ประเทศไทย) จำกัด

5. Nutrient – Enriched Rice from Herbs

- Bangkok Rice Co. Ltd.

ผู้เข้าร่วมโครงการ : บริษัท บางกอกตลาดข้าวไทย จำกัด

6. Oryzanol from Thai Rice

- President Grain Product Co. Ltd.

โครงการผลิตสาร Oryzanol จากข้าวไทย

ผู้เข้าร่วมโครงการ : บริษัท เพรสซิเด็นท์แกรนรี่ โพรดัคส์ จำกัด

7. Body Lotion from Rice Germ

- Angle Rice Co. Ltd

โครงการครีมบำรุงผิวจากน้ำมันจมูกข้าว

ผู้เข้าร่วมโครงการ : หจก.แองเจิลไรซ์

8. Production of Silica from Rice Husk

- Pathum Rice Mill and Granary Pcl.
- Chia Meng Co.,Ltd.

โครงการการผลิตซิลิกาจากเถ้าแกลบ

ผู้เข้าร่วมโครงการ : บริษัท ปทุมไรซ์มิล แอนด์ แคนารี จำกัด

บริษัท เจียเม้ง จำกัด

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Appendix I: Workshop Presentation by Dr Andrew D Powell, Asia BioBusiness Pte Ltd

Appendix II: Workshop Presentation by Prof Paul S Teng, Nanyang Technological University, Singapore

Appendix III: Asia BioBusiness Pte Ltd Company Profile