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Series on the Safety of Novel Foods and Feeds, No. 10

CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF RICE (Oryza sativa): KEY FOOD AND FEED NUTRIENTS AND ANTI-NUTRIENTS

English - Or. English

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OECD Environment, Health and Safety Publications

Series on the Safety of Novel Foods and Feeds

No. 10

Consensus Document on Compositional Considerations for New Varieties of Rice (*Oryza sativa*): Key Food and Feed Nutrients and Anti-nutrients

Environment Directorate

Organisation for Economic Co-operation and Development

Paris 2004

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or contact:

OECD Environment Directorate,
Environment, Health and Safety Division

2 rue André-Pascal
75775 Paris Cedex 16
France

Fax: (33) 01 45 24 16 75

E-mail: ehscont@oecd.org

FOREWORD

The OECD's Task Force for the Safety of Novel Foods and Feeds decided at its first session, in 1999, to focus its work on the development of science-based ***consensus documents,*** which are mutually acceptable among member countries. These consensus documents contain information for use during the regulatory assessment of a particular food/feed product. In the area of food and feed safety, consensus documents are being published on the nutrients, anti-nutrients or toxicants, information of its use as a food/feed and other relevant information.

This consensus document addresses compositional considerations for new varieties of rice by identifying the key food and feed nutrients and anti-nutrients. A general description of these components is provided. As well, there is background material on the production, processing and uses of rice and considerations to be taken when assessing new rice varieties.

Japan served as the lead country in the preparation of this document.

The Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology has recommended that this document be made available to the public. It is published on the authority of the Secretary-General of the OECD.

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PREAMBLE

Food and feed products of modern biotechnology are being commercialised and marketed in OECD member countries. The need has been identified for detailed technical work aimed at establishing appropriate approaches to the safety assessment of these products.

At a Workshop held in Aussois, France (OECD 1997), it was recognised that a consistent approach to the establishment of substantial equivalence might be improved through consensus on the appropriate components (*e.g*., key nutrients, key toxicants and anti-nutritional compounds) on a crop-by-crop basis, which should be considered in the comparison. It is recognised that the components may differ from crop to crop. The Task Force therefore decided to develop consensus documents on compositional data. These data are used to identify similarities and differences following a comparative approach as part of a food and feed safety assessment. They should be useful to the development of guidelines, both national and international and to encourage information sharing among OECD member countries.

These documents are a compilation of current information that is important in food and feed safety assessment. They provide a technical tool for regulatory officials as a general guide and reference source, and also for industry and other interested parties and will complement those of the Working Group on Harmonisation of Regulatory Oversight in Biotechnology. They are mutually acceptable to, but not legally binding on, member countries. They are not intended to be a comprehensive description of all issues considered to be necessary for a safety assessment, but a base set for an individual product that supports the comparative approach. In assessing an individual product, additional components may be required depending on the specific case in question.

In order to ensure that scientific and technical developments are taken into account, member countries have agreed that these consensus documents will be reviewed periodically and updated as necessary. Users of these documents are invited to provide the OECD with new scientific and technical information, and to make proposals for additional areas to be considered.

THE ROLE OF A COMPARATIVE APPROACH AS PART OF A SAFETY ASSESSMENT

In 1990, a joint consultation of the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) established that the comparison of a final product with one having an acceptable standard of safety provides an important element of safety assessment (WHO, 1991).

In 1993 the Organisation for Economic Co-operation and Development (OECD) further elaborated this concept and advocated the approach to safety assessment based on substantial equivalence as being the most practical approach to addressing the safety of foods and food components derived through modern biotechnology (as well as other methods of modifying a host genome including tissue culture methods and chemical or radiation induced mutation). In 2000 the Task Force concluded in its report to the G8 that the concept of substantial equivalence will need to be kept under review. (OECD, 2000)

The Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology in 2000 concluded that the safety assessment of genetically modified foods requires an integrated and stepwise, case-by-case approach, which can be aided by a structured series of questions. A comparative approach focusing on the determination of similarities and differences between the genetically modified food and its conventional counterpart aids in the identification of potential safety and nutritional issues and is considered the most appropriate strategy for the safety and nutritional assessment of genetically modified foods. The concept of substantial equivalence was developed as a practical approach to the safety assessment of genetically modified foods. It should be seen as a key step in the safety assessment process although it is not a safety assessment in itself; it does not characterise hazard, rather it is used to structure the safety assessment of a genetically modified food relative to a conventional counterpart. The Consultation concluded that the application of the concept of substantial equivalence contributes to a robust safety assessment framework.

A previous Joint FAO/WHO Expert Consultation on Biotechnology and Food Safety (1996) elaborated on compositional comparison as an important element in the determination of substantial equivalence. A comparison of critical components can be carried out at the level of the food source (*i.e.*, species) or the specific food product. Critical components are determined by identifying key nutrients, key toxicants and anti-nutrients for the food source in question. The comparison of critical components should be between the modified variety and non-modified comparators with an appropriate history of safe use. The data for the non-modified comparator can be the natural ranges published in the literature for commercial varieties or those measured levels in parental or other edible varieties of the species (FAO, 1996). The comparator used to detect unintended effects for all critical components should ideally be the near isogenic parental line grown under identical conditions. While the comparative approach is useful as part of the safety assessment of foods derived from plants developed using recombinant DNA technology, the approach could, in general, be applied to foods derived from new plant varieties that have been bred by other techniques.

SECTION I BACKGROUND

A. Production of Rice

Rice is cultivated in more than 100 countries around the world and is a staple food for about a half of the world's population. The world-wide production area for rice is 150 million hectares (ha), and the annual production of rice (paddy rice) is about 590 million tonnes (FAO, 2004a). Asia is the main producer of rice with 92% of the world total production. The country with the highest production is China, with 186 million tonnes or 31% of the total production. India is the second with 131 million tonnes or 22%. India has the largest production area with about 43 million hectares (Table 1). Yield (tonnes/hectare) has rapidly increased since the second half of the 1960s as the semi-short (short-stem) and high-yield varieties became widespread. Rice is mostly consumed in each producing country. The trade amount of rice is approximately 25 million tonnes (Table 2), which is less than 5% of the world production.

Table 1: Word Rice Production (average production per year: 1999-2002)

Rank	Country	Production Area (1,000 ha)	Yield (tonne/ha)	Production (1,000 tonne)
1	China	29,815	6.25	186,519
2	India	42,724	3.06	130,606
3	Indonesia	11,724	4.37	51,207
4	Bangladesh	10,809	3.37	36,658
5	Viet Nam	7,572	4.29	32,489
6	Thailand	9,928	2.59	25,670
7	Myanmar	6,228	3.42	21,312
8	Philippines	4,037	3.12	12,600
9	Japan	1,738	6.58	11,441
10	Brazil	3,446	3.16	10,871
11	USA	1,323	7.06	9,334
12	Republic of Korea	1,069	6.61	7,065
	World	151,385	3.94	596,989

Source: FAO, 2004a

Note: The yield and production values were expressed as paddy rice. The countries are listed in order of production quantity.

Table 2: World Rice Exports

In thousand tonnes

Country / Year	1999	2000	2001	2002
Argentina	659	467	366	231
Australia	669	622	615	331
China	2,819	3,071	2,011	2,068
Egypt	307	393	656	464
India	1,895	1,533	2,194	5,053
Italy	667	666	563	593
Myanmar	54	251	939	730
Pakistan	1,791	2,016	2,424	1,684
Thailand	6,839	6,141	7,685	7,338
USA	2,668	2,736	2,622	3,267
Uruguay	699	741	811	652
Viet Nam	4,508	3,477	3,721	3,241
World	25,250	23,560	26,827	27,372

Source: FAO, 2004b
Note: Rice export quantities are calculated on the basis of the following multiplication factors: paddy rice, 0.65; husked rice, 1.00; milled/husked rice, 1.00; milled paddy rice, 1.00; and broken rice, 1.00.

Most of the rice varieties grown in the world belong to the species *Oryza sativa* which has its origin in Asia. Another species grown in western Africa, *Oryza glaberrima*, is considered to have been domesticated in the Niger River delta. Varieties of the species *Oryza glaberrima* are cultivated in limited regions and detailed production data are scarcely available. For these reasons, this document deals only with *Oryza sativa* that occupies the great majority of the production and consumption in the world.

Rice is consumed in the world, mostly in Asia, as shown in Table 3 (FAO, 2001). Rice accounts for over 20 percent of global caloric intake (FAO, 2001).

Table 3: Production and Consumption of Milled Rice [a]

Region	Production (1000 tonne)	Consumption (kg/caput/year)
Asia	363,255	83.8
North and Central America	8,061	11.2
South America	13,225	29.6
Africa	11,070	19.1
Europe	2,109	4.4
Oceania	1,187	15.8
World	398,907	56.5

Source: FAO, 2001
[a] milled rice equivalent

B. Terminology

In this document, a number of technical and scientific terms that are specific to the rice industry are used. In order to facilitate common understanding of this document, these rice-specific terms and their definitions are listed in Table 4.

Table 4: Definition in This Document

Term	Definition in this document	Synonyms
Paddy rice	Rice grain after threshing and winnowing and retains its hull	rice grain, rough rice
Hull	Outermost layer of paddy rice	husk, shell, chaff
Hulling[a)]	Removal of the hull from paddy rice (note: sometimes referred to the removal of both hulls and bran)	dehulling, husking, dehusking, shelling
Parboiled rice	Hulled or milled rice processed from paddy or hulled rice which has been soaked in water and subjected to a heat treatment so that the starch is fully gelatinized, followed by a drying process	
Bran	Germ and several histologically identifiable soft layers (pericarp, seedcoat, nucellus, and aleurone layer)	
Germ	The part consisting of scutellum, plumule, radicle, and epiblast	embryo
Endosperm	Starchy tissue covered by the aleurone layer; divided into two regions, the subaleurone layer and the central core region containing mainly starch	
Glutinous rice	Rice of which amylose content is less than 5%	waxy rice
Brown rice	Paddy rice from which the hull only has been removed; the process of hulling and handling may result in some loss of bran	caryopsis, cargo rice, hulled rice, husked rice, dehusked rice
Milling	Removal of all or most of the bran to produce the milled rice that is white	scouring, whitening
Milled rice	Rice grain with removed germ and outer layer such as pericarp , seed coat and a part of aleulone layer by milling	
Polishing	Abrasive removal of traces of bran on the surface of milled rice to give a smoother finish	
Polished rice	Rice grain with removed outer layer by polishing	
Polishings	The by-product from polishing rice, consisting of the inner bran layers of the kernel with part of the germ and a small portion of the starchy interior	
Head rice	Milled whole rice kernels, exclusive of broken rice that is smaller than 3/4 of the grain length of the whole rice	head yield
Broken rice	Milled broken rice grains, subdivided into second heads (1/2 - 3/4), screenings (1/4 - 1/2), and brewer's rice (< 1/4) by the grain length, compared with that of the whole rice	

C. Cooking of Rice

Rice is eaten as brown rice or milled rice after being cooked in the grain form (for the processing of rice into brown or polished rice, see the following paragraph.). There are many recipes for cooked rice in which rice is boiled, steamed, boiled into porridge, or mixed with other grain flours. Boiled or steamed rice can be further baked or fried.

D. Processing of Rice

Paddy rice is processed as shown in Figure 1. Parboiled rice is obtained by boiling paddy rice as it is. Brown rice is produced by hulling, namely removing the hulls, from paddy rice. Milled rice is derived from brown rice by milling to remove all or most of the bran which primarily consists of seed coat, aleurone layer, and germ. Germ seed is separated through bolting of the by-products of milling. Milled rice is processed by polishing to remove residual bran on the surface to give a smoother finish; and may further be polished to obtain the inner part of rice grain containing less protein for further processing. Most of the rice used for food is polished rice. Rice flour, which is partly used for rice wine (*SAKE*) fermentation, is a pulverized product of the outer part or the whole part of milled rice. Rice bran oil is made from rice bran, which is used as cooking oil. Defatted bran (cake of rice bran) can be further utilized for feed and fertilizer.

Only a relatively small amount of rice is consumed as prepared rice products worldwide. However, prepared rice products are widely found and consumed in Asia as rice noodle, rice cake, rice cracker, rice sweets, and alcoholic beverages. For example, rice noodles are found in different shapes, flat or tubular, thick or thin, and given local names in Asian countries including China and Thailand. Rice sweets and cakes are also common in Asia. As for alcoholic beverages, there are rice wines and distilled rice wines in Japan, Korea and China. Those products that are undesirable for human consumption such as poor grade paddy rice, broken rice, hulls, bran, rice flour, and hulls/polishings of parboiled rice are used in animal feed.

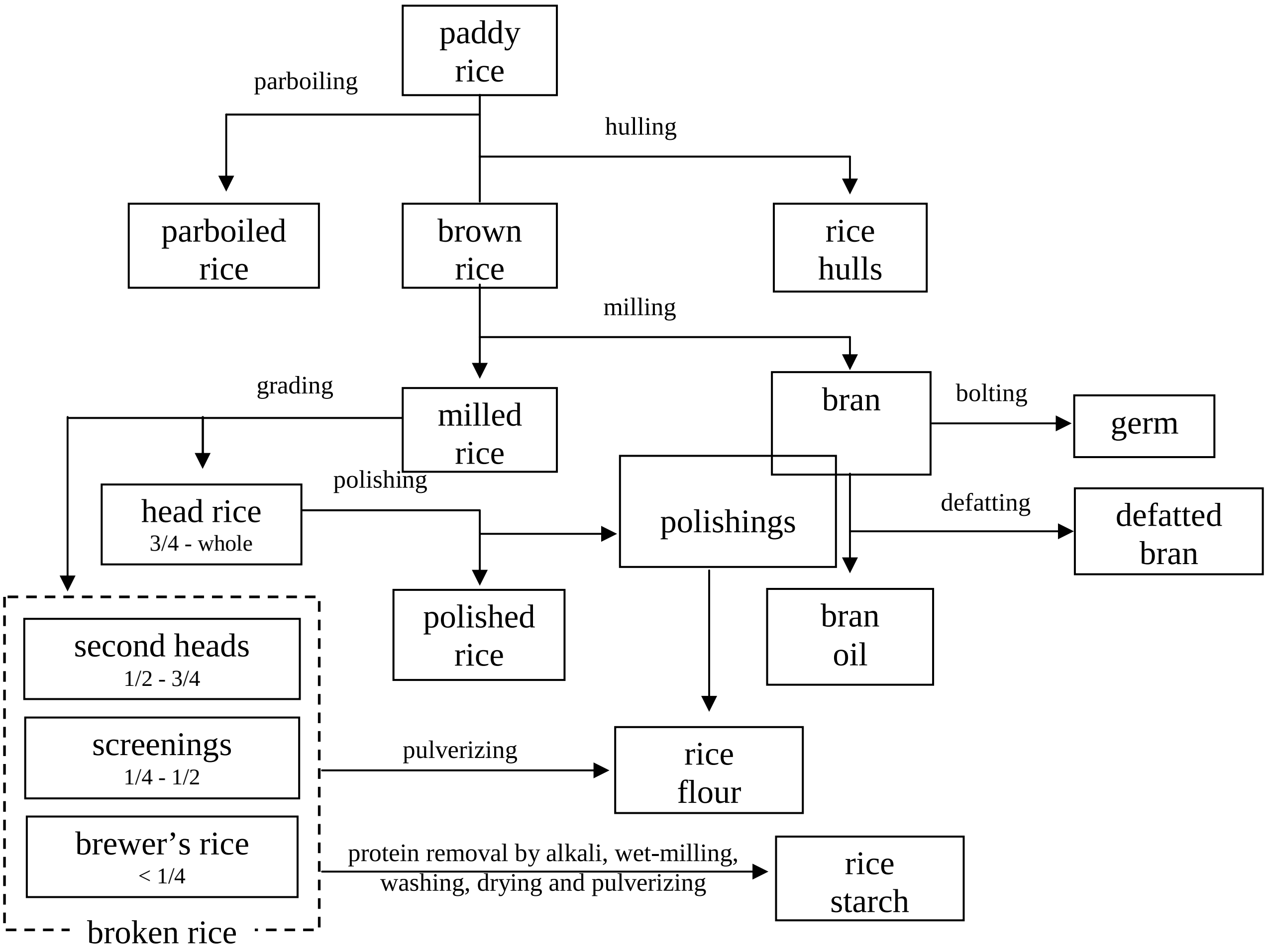

Figure 1 Rice Processing and the Resulting Products

E. Appropriate Comparators for Testing New Varieties

This document suggests parameters that rice developers should measure. Measurement data from the new variety should ideally be compared to those obtained from the near isogenic non-modified line grown under identical conditions. A developer can also compare values obtained from new varieties with the literature values of conventional counterparts presented in this document. Critical components include key nutrients and key toxicants for the food source in question. Key nutrients are those components in a particular product, which may have a substantial impact in the overall diet. These may be major constituents (carbohydrates, proteins, and lipids) or minor ones (minerals and vitamins). Key toxicants are those toxicologically significant compounds known to be inherently present in the species, that is, compounds whose toxic potency and level may impact on human and animal health. Similarly, the levels of known anti-nutrients and allergens should be considered.

F. Traditional Characteristics Screened by Rice Developers

Phenotype characteristics provide important information related to the suitability of new varieties for commercial distribution. Selecting new varieties is based on data from parental lines. Plant breeders developing new varieties of rice evaluate many parameters at different stages in the developmental process. In the early stages of growth, breeders evaluate stand count and seedling vigour. As plants mature, insect-resistance and resistance to disease such as blast disease are evaluated. At near maturity or maturity, heading, maturation, lodging, shedding, and pre-matured germination are evaluated. The matured plant is measured for plant height, ear height, number of ears, and yield. The harvested grain is measured for yield, moisture, test weight, shape, size, visual quality, component's contents, milling quality, and palatability.

SECTION II NUTRIENTS IN RICE

Paddy rice can be separated into hull and brown rice by hulling. Brown rice can further be separated by milling and polishing into polished rice and another fraction that consists of bran and polishings. The composition of each fraction of rice ranges widely as shown in Table 5.

Table 5: Rice Fractions by Hulling, Milling and Polishing

Fraction	Ratio (on a weight basis)
Hull	16 - 28 (average 20) % of paddy rice
Brown rice	72 - 84 (average 80) % of paddy rice
Polished rice	90 % of brown rice
Bran + Polishings	10 % of brown rice

Source: Juliano & Bechtel, 1985

A. Key Nutrients in Grain

Key nutrients in rice products for food use are listed in Table 6.

1) Carbohydrates

Most of the available carbohydrates such as starch are found in the endosperm of rice grain. Milled rice mainly consists of starch with a few other carbohydrates including free sugars and non-starch polysaccharides. The hull is comprised of a small amount of starch and mostly non-starch polysaccharides such as cellulose and hemicellulose. The bran and germ are comprised mainly of non-starch polysaccharides such as cellulose and hemicellulose and partly of free sugars as well as a small amount of starch.

Table 6: Proximate Content (% of dry matter) of Rice Products Used as Food[a].

Nutrient	Paddy	Brown	Milled	Bran	Germ	Polishings
Protein (N x 5.95)	5.8-7.7	7.1-8.3	6.3-7.1	11.3-14.9	14.1-20.6	11.2-12.4
Crude Fat	1.5-2.3	1.6-2.8	0.3-0.5	15.0-19.7	16.6-20.5	10.1-12.4
Crude Ash	2.9-5.2	1.0-1.5	0.3-0.8	6.6-9.9	4.8-8.7	5.2-7.3
Carbohydrates						
Available Carbohydrates	63.6-73.2	72.9-75.9	76.7-78.4	34.1-52.3	34.2-41.4	51.1-55.0
Starch	53.4	66.4	77.6	13.8	2.1	41.5-47.6
Free Sugars	0.5-1.2	0.7-1.3	0.22-0.45	5.5-6.9	8.0-12.0	…
Neutral Detergent Fibre	16.4	3.9	0.7-2.3	23.7-28.6	13.1	…
Crude Fibre	7.2-10.4	0.6-1.0	0.2-0.5	7.0-11.4	2.4-3.5	2.3-3.2
Cellulose	…	…		5.9-9.0	2.7	…
Hemicelluloses	…	…	0.1	9.5-16.9	9.7	…
Pentosans	3.7-5.3	1.2-2.1	0.5-1.4	7.0;8.3	4.9;6.4	3.6-4.7
Lignin	3.4	…	0.1	2.8-3.9	0.7-4.0	2.8
Energy (kJ/g)	15.8	15.2-16.1	14.6-15.6	16.7-19.9		17.9

Source: Juliano & Bechtel, 1985; Nyman *et al.* 1984; Dikeman *et al.*, 1981; Kennedy *et al.*, 1974; Houston, 1972.
[a] Sample contains 14% of moisture.
The figures and ranges in the table represent available analytical data.

(i) Starch

Starch, the principal component of rice, consists of amylose and amylopectin. Starch in non-glutinous rice is composed of 15 - 30% amylose and 70 - 85% amylopectin. Starch in glutinous rice contains less than 5% of amylose and consists mostly of amylopectin (Juliano & Villareal, 1993).

Amylose content in rice grown in Asia ranges widely from 0 to 32% (Nakagahra *et al.*, 1986).

Recently in Japan, a low-amylose variety of rice was developed, whose amylose content in starch is between those of non-glutinous rice and glutinous rice (Okuno *et al.*, 1983). Many types of rice exist across the range from non-glutinous to glutinous varieties.

(ii) Dietary fibre

Although dietary fibre is an important nutrient, it is low in cooked rice such as cooked polished rice and polished rice porridge. It is lost by milling and polishing as can be seen in Table 7.

Table 7: Dietary Fibre (weight %) in Rice Products

Product		Total Dietary Fibre	Soluble Fibre	Insoluble Fibre
Brown rice	(15.5)[a]	3.0	0.7	2.3
Milled rice with the germ	(15.5)[a]	1.3	0.3	1.0
Milled rice	(15.5)[a]	0.5	Trace	0.5
Cooked milled rice	(60.0)[a]	0.3	0.0	0.3
Milled rice porridge	(83.0)[a]	0.1	0.0	0.1

Source: Resources Council, Science and Technology Agency, Japan, 2000
[a] water content of the product
The figures in the table represent available analytical data.

2) Protein

Total protein content in rice is calculated by multiplying total nitrogen content by the rice-specific Kjeldahl conversion factor of 5.95, which is based on the nitrogen content of glutelin, the major protein in rice. The protein content in brown rice based on the analysis of about 8000 samples ranged from 5 to 17% (on a dry matter basis) (Juliano, 1968). The protein content of rice fluctuates according to the variety grown and can also be affected by growing conditions such as early or late maturing, soil fertility and water stress. Rice proteins are classified by their solubility in albumin (soluble in pure water), globulin (soluble in salt-water), prolamin (soluble in alcohol), and glutelin (soluble in aqueous alkaline solution) (Hoseney, 1986). The proportion of each protein type compared with the total protein is shown in Table 8. Albumin and globulin have a balanced composition of amino acids. They are found mostly in the outer layer of brown rice, and less in the inner layer of milled rice. Prolamin and glutelin are considered to be the storage proteins of rice, and exist in the outer layer and the inside of milled rice. Thus, the protein composition of bran and germ differs greatly from that of milled rice.

Table 8: Typical Proportions of Osborne Protein Fractions in Total Rice Protein

Protein Fraction	% of Total Protein
Albumin	2 – 5
Globulin	2 – 10
Prolamin	1 – 5
Glutelin	75 – 90

Source: Simmonds, 1978
Proteins were fractionated by the method of Osborne. (Hoseney, 1986)
The ranges in the table represent available analytical data.

(i) Amino acid composition

Protein content and amino acid composition varies in different fractions of rice kernel (Table 9). The key protein in rice is glutelin (oryzenin), and the most limiting amino acid is lysine. However, compared to other cereal grains, rice has nutritionally a more complete balance of amino acids. To evaluate the nutritional value of each protein, amino acid score is calculated as follows: 100 x (mg of essential amino acid in the protein) / (mg of the essential amino acid in the reference protein ideal for human) (FAO/WHO, 1973; WHO, 1985). Rice (amino acid score of 61) has more balanced amino acid composition than those of other major cereals such as wheat (medium flour: amino acid score of 39) and corn (corn grits: amino acid score of 31) due to its higher contents of lysine and sulphur-containing amino acids.

Table 9: Mean Amino Acid Composition (% protein) of Rice Products Used as Food.

Amino Acid	Paddy	Brown	Milled	Bran	Germ	Polishings
Alanine	4.6-6.7	5.8	5.6-5.8	6.2-6.7	6.6-7.2	6.2;6.3
Arginine	4.2-10.0	8.5-10.5	8.6-8.7	8.2-8.7	9.7-10.4	8.5;8.6
Aspartic	7.2-11.0	9.0;9.5	9.1-9.6	9.5-10.5	9.1-10.6	9.2;10.2
Cysteine	1.2-3.0	2.2-2.4	1.8-2.6	2.4-2.7	2.6-2.8	2.6;2.7
Glutamic	15.4-20.5	16.9;17.6	18.3-18.5	13.9-14.3	15.1-17.3	15.3;16.8
Glycine	4.1-5.7	4.7;4.8	4.5-4.8	5.5-5.9	6.0-6.6	5.3;5.4
Histidine	1.6-2.9	2.4;2.6	2.3-2.7	2.8-3.5	3.4-3.8	2.7;2.8
Isoleucine	3.2-5.0	3.6-4.6	3.7-4.8	2.8-4.3	3.2-3.8	2.8;4.0
Leucine	7.2-9.2	8.3-8.9	8.4-8.6	7.2-8.0	6.9-7.0	6.9;8.0
Lysine	3.4-4.9	3.9;4.3	3.4-4.2	5.0-5.7	6.2-7.4	4.4;4.9
Methionine	1.6-3.6	2.3;2.5	2.3-3.0	1.8-2.4	1.4-1.9	2.3;2.9
Phenylalanine	3.3-6.1	5.0;5.3	5.3-5.5	4.7-5.0	4.0-4.5	4.4;4.8
Proline	3.9-6.3	4.8;5.1	4.6-5.1	4.4-5.8	4.3-5.0	4.0;5.4
Serine	4.2-6.0	4.8-5.8	5.3-5.9	4.9-5.7	4.8-5.4	4.7;5.6
Threonine	3.2-4.7	3.9-4.0	3.7-3.9	4.0-4.4	4.2-4.5	3.7;4.2
Tryptophan	1.3-2.1	1.3-1.5	1.3-1.8	0.6;1.3	1.0-1.4	1.3
Tyrosine	4.0-5.7	3.8-4.6	4.4-5.5	3.3-3.6	3.3-3.7	3.6;4.1
Valine	4.8-7.4	5.0-6.6	4.9-6.8	5.1-6.3	5.1-6.3	4.6;5.9
Ammonia	1.4-6.8	2.8;6.8	3.0-7.0	1.8-7.2	1.8-9.7	2.1;6.2
alb/glo/pro/glu ratio[a]		6:10:3:81	5:9:3:83	37:36:5:22	24:14:8:54	30:14:5:51

Source: Juliano & Bechtel, 1985; Kennedy & Schelstraete, 1974; Houston *et al*., 1969.
[a] alb/glo/pro/glu, Albumin/Globulin/Prolamin/Glutelin.
The figures and ranges in the table represent available analytical data.

3) Lipids

Rice lipid is contained mainly in the germ, aleurone layer and sub-aleurone layer. Within a cell, lipids exist in the form of a lipid globule with a diameter of 0.7-3 µm, which is called a spherosome. Some exist as starch-lipid complexes.

Most of the rice lipids are neutral. They are triglycerides in which glycerol is esterified with three fatty acids, primarily oleic, linoleic, and palmitic. Besides triglycerides, free fatty acids, sterol, and diglycerides are also found in rice. Rice also contains lipid-conjugates like acylsterolglycoside and sterolglycoside, glycolipids, such as cerebroside, and phospholipids, such as phosphatidylcholine and phosphatidylethanolamine (Table 10).

Table 10: Mean Composition of Lipids in Hull, Brown Rice and its Fractions[a]

Property	Free lipids[b]						Complexed lipids in non-glutinous starch	
	Hull	Brown	Milled	Bran	Germ	Polish-ings	Brown	Milled
Lipid Content (wt %)	0.4	2.7	0.8	18.3	30.2	10.8	0.6	0.5
Fatty Acid Composition[c] (wt % of total)								
Palmitic (16:0)	18	23	33	23	24	23	46	45
Oleic (18:1)	42	35	21	37	36	35	12	11
Linoleic (18:2)	29	38	40	36	37	38	38	40
Others[d]	12	4	6	4	3	4	4	4
Neutral lipids[c] (% of total lipids)	64	86	82	89	91	87	28	26
Triglycerides	…	71	58	76	79	72	4	2
Free Fatty Acids	…	7	15	4	4	5	20	21
Glycolipids (% of total lipids)	25	5	8	4	2	5	19	16
Phospholipids (% of total lipids)	11	9	10	7	7	8	53	58
Phosphatidylcholine	…	4	9	3	3	3	4	4
Phosphatidylethanolamine	…	4	4	3	3	3	5	5
Lysophosphatidylcholine	…	<1	2	<1	<1	<1	21	23
Lysophosphatidylethanolamine	…	…	1	…	…	<1	22	25

Source: Juliano & Bechtel, 1985
[a] Based on 6% bran germ, 4% polishings, and 90% milled rice from brown rice.
[b] Free lipids stand for the lipids which are not involved in starch-lipid complexes.
[c] Mean of two non-glutinous and one glutinous rices for free lipids; mean of the two non-glutinous rices only for complexed lipids in non-glutinous starch (Choudhury & Juliano, 1980b); and values of IR42 only for the hull (Choudhury & Juliano, 1980a).
[d] Trace to 3% myristic acid; 2 - 4% stearic acid; and 1 - 2% linolenic acid
The figures and ranges in the table represent available analytical data.

Lipids in a starch-lipid complex are not extracted by such organic solvent as ether, but by water-saturated butanol and others. The percentage of these lipids contained in non-glutinous brown rice is 0.5-0.7% and approximately 0.2% in glutinous brown rice. The major components are phospholipids followed by neutral lipids and glycolipids. Among fatty acids, palmitic and linoleic acids make up a large proportion, and oleic acid makes up a lesser amount (Choudhury & Juliano, 1980a; Choudhury & Juliano, 1980b).

Fatty acid composition is dependent on the growing season and the ecogeographical varieties. Cultivated rice is classified into four varieties: Indian, Chinese, Japanese and Javanese. The amount of palmitic acid found in this order: Indian > Chinese > Japanese > Javanese (Taira *et al.*, 1988). In terms of the fatty acid content, there is a strong negative correlation between oleic acid and linoleic acid both of which are the key fatty acids of rice. In early crops, in which the ripening temperature is high, oleic acid content is high, while in late crops, linoleic acid content is high.

4) Minerals

Mineral content is greatly influenced by cultivation conditions including fertilization, and soil conditions. Among the inorganic elements contained in rice, silicon is dominant in paddy rice. In brown and milled rice, phosphorus is principal but comparable amounts of potassium, magnesium and silicon are also found (Table 11).

Table 11: Range of Mean Content of Elements in Paddy Rice and Milling Fractions

Element	Paddy	Brown	Milled	Hull	Bran	Germ	Polishings
Macroelements (mg/g dry matter)							
Calcium	0.1 - 0.9	0.1 - 0.6	0.1 - 0.3	0.7 -1.5	0.4 -1.4	0.2 -1.2	0.6 - 0.8
Magnesium	0.7 - 1.7	0.2 - 1.7	0.2 - 0.6	0.4	5.8 - 15.1	5 - 15	7 - 8
Phosphorus	2.0 - 4.5	2.0 - 5.0	0.9 - 1.7	0.4 - 0.8	13 - 29	11 - 24	12 - 26
Phytin Phosphorus	2.1 - 2.4	1.5 - 3.1	0.4 - 0.8	0	11 - 26	8 - 19	14 - 20
Potassium	1.7- 4.3	0.7 - 3.2	0.8 - 1.5	1.7 – 8.7	12 - 23	13 - 17	8; 13
Silicon	12.6	0.7 - 1.6	0.1 - 0.5	74 - 110	3 - 6	0.5 - 1.1	1.3; 1.9
Sulfur	0.5 - 0.7	0.3 - 2.2	0.9	0.5	2.0	…	1.9
Microelements (µg/g dry matter)							
Copper	2 - 13	1 - 7	2 - 3	35 - 45	11 - 40	11 - 40	6 - 30
Iron	16 - 70	2 - 60	2 - 33	45 - 110	100 - 500	70 - 210	50 - 180
Manganese	20 - 110	2 - 42	7 - 20	116 - 337	110 - 270	106 - 140	…
Sodium	62 - 940	20 - 400	6 - 100	78 - 960	83 - 390	162 - 740	trace - 160
Zinc	2.0 - 36	7 - 33	7 - 27	11 - 47	50 - 300	66 - 300	20; 70

Source: Juliano & Bechtel, 1985; Dikeman *et al.* 1981; Kennedy & Schelstraete, 1975.
The figures and ranges in the table represent available analytical data.

Minerals are unevenly distributed in a brown rice grain. By milling stepwise from outer layer of a brown rice with an abrasive rice mill, mineral contents in each layer fraction can be measured. Mineral contents in a brown rice grain tend to decrease toward the endosperm. Endosperm contains much less minerals than germ and the outer bran layer fractions (Table 12).

Table 12: Distribution of Minerals[a] in Brown Rice Grain

Fractions	Phosphorus	Potassium	Magnesium	Calcium	Manganese	Iron	Silica
Bran layer fractions							
100 - 98.5 [b]	100	100	100	100	100	100	100
98.5 - 97.0 [b]	109	108	111	98	90	100	66
97.0 - 95.5 [b]	117	108	112	90	81	79	49
95.5 - 94.0 [b]	108	95	100	76	58	76	34
94.0 - 92.5 [b]	100	81	83	61	40	54	24
92.5 - 91.0 [b]	82	61	65	41	29	46	17
91.0 - 88.0 [b]	42	39	40	35	18	29	13
88.0 - 85.0 [b]	20	19	19	23	11	23	10
85.0 - 82.0 [b]	12	10	10	14	7	16	--
Endosperm							
82.0 - 0 [b]	2.2	1.9	0.8	6.6	2.9	2.0	0.6
Germ	100	102	67	78	91	56	41

Source: Kubo, 1960; Ohtsubo & Ishitani, 1995.
[a] Mineral contents for each layer fractions and products are expressed in weight ratio in comparison with those of the most exterior layer of the seed coat as 100.
[b] Each value shows the weight ratio (%) of the milled rice to the whole grain, and each layer fraction was collected between two weight ratios indicated.
The figures in the table represent available analytical data.

5) Vitamins

Rice contains water-soluble vitamins including thiamine (B_1), riboflavin (B_2), pyridoxine (B_6), nicotinic acid, inositol and cyanocobalamin (B_{12}), and alpha-tocopherol (E). It does not contain significant amount of hydrophobic vitamins A and D. Vitamins mainly exist in the endosperm and bran layer, thus milled rice contains less vitamins compared with brown rice (Table 13).

Table 13: Vitamin Content (µg/g dry matter) in Paddy Rice and Milling Fractions

Vitamin	Paddy	Brown	Milled	Hull	Bran	Germ	Polishings
Retinol (A)	0 - 0.08	0 - 0.11	0 - trace	0	0 - 3.6	0 - 1.0	0 – 0.9
Thiamine (B_1)	2.6 - 3.3	2.9 - 6.1	0.2 - 1.1	0.9 - 2.1	12 - 24	17 – 59	3 - 19
Riboflavin (B_2)	0.6 - 1.1	0.4-1.4	0.2-0.6	0.5-0.7	1.8-4.3	1.7-4.3	1.7-2.4
Niacin (nicotinic acid)	29 - 56	35-53	13-24	16-42	267-499	28-83	224-389
Pyridoxine (B_6)	4 - 7	5-9	0.4-1.2	…	9-28	13-15	9-27
Pantothenic acid	7 - 12	9-15	3-7	…	20-61	11-28	26-56
Biotin	0.04 - 0.08	0.04 - 0.10	0.01 - 0.06	…	0.2 - 0.5	0.3 - 0.5	0.1 – 0.6
Inositol, total	800	1000	90 - 110	…	4000; 8000	3200; 5500	3700; 3900
Choline, total	760 - 980	950	390 - 880	…	920 - 1460	1700; 2600	860 - 1250
p-Aminobenzoic acid	0.3	0.3	0.12 - 0.14	…	0.65	0.9	0.6
Folic Acid	0.2 - 0.4	0.1 - 0.5	0.03 - 0.04	…	0.4 - 1.4	0.8 - 4.1	0.9 – 0.8
Cyanocobalamin (B_{12})	0 - 0.003	0 - 0.004	0 - 0.0014	…	0 - 0.004	0 - 0.01	0 - 0.003
alpha-Tocopherol (E)	9 - 20	9 – 25	trace - 3	…	26 - 130	76	54 - 86

Source: Juliano & Bechtel, 1985; Kennedy *et al.*, 1975
The figures and ranges in the table represent available analytical data.

B. Key Nutrients in Animal Feeds

The whole rice plant is sometimes used for animal feed. Table 14 provides proximate and major mineral content of the whole rice plant at different growth stages. Nutritional composition of whole rice plant is dependent on its growth stage. Starch content increases as rice kernel ripens. However, the nutritional value may decrease, as the rice kernel that is rich in nutrients could be lost if the harvest is delayed until its mature stage. Therefore, rice is generally harvested at its yellow ripe stage. Crude protein content of whole rice plant at that stage is low (about 7%). The mineral content of rice plant is high; however, the contents of calcium and phosphorus are low as is the case with rice straw, because the silica content is more than the half of the mineral content.

As most of the valuable nutrients are transferred from the leaves and stems and are stored in the ripening seeds, the straw which consists of the mature stems and leaves contains relatively little protein, starch and fat. Rice straw is low in calcium, phosphorus and most vitamins, but high in manganese. The high content of fibre, lignin and silica are responsible for the low digestibility. By adding 1-3 % ammonia on a dry matter basis, its crude protein content is increased by 2 to 3 times. The dry matter digestibility and preservability are also improved.

Table 15 provides the range of nutrient content of the major rice feed ingredients. Proximate and major minerals are provided for rough (paddy) and broken rice, hulls, bran, polishings, straw and ammoniated straw. Animal nutritionists prefer that fibre be measured as neutral detergent fibre (NDF) and acid detergent fibre (ADF). Both of these measures are used to calculate feed energy values. Crude fibre values are included because of existing data bases, but are not encouraged as a comparative method for feed. Only the major minerals are important since the mineral content of plants is highly influenced by the level of minerals in the soil, and animal diets are fortified with the important minerals. Amino acid composition is provided for rough and broken rice, and bran. The amino acids included are those that are essential to be added to the diet and those that can contribute to the conversion to essential amino acids. Fatty acids levels are provided in Table 10, but only linoleic acid is important in animal nutrition.

Table 14: Proximate and Major Mineral Content (% of dry matter) of Whole Rice Plant.

ripening stage		Protein	NDF	ADF	NFE	Ash	Calcium	Phosphorus
Whole rice plant	Early bloom	6.5 - 8.8	60.0 - 60.1	37.0 - 40.4	40.1 - 43.2	14.7 - 14.9	0.12	0.16
	Milk stage	5.6 - 8.5	52.5	33.1	45.6 - 49.9	12.0 - 13.6		
	Dough stage	5.3 - 9.6	49.3	29.9 - 31.6	49.7 - 61.4	9.7 - 15.6		
	Yellow ripe	4.9 - 7.2	43.4 - 56.8	26.1 - 35.0	50.9	12.6 - 12.9		
	Mature	4.0 - 7.6	38.9 - 48.3	22.9 - 33.7	52.9 - 60.6	9.1 - 15.5	0.17 - 0.19	0.40 - 0.67

Source: National Agricultural Research Organization, 2001; Enishi *et al.*, 1995; Enishi & Shijimaya, 1998; Horiguchi *et al.*, 1992; Itoh *et al*., 1975; Nakui *et al*., 1988; Quinitio, *et al*., 1990; Rahal *et al*., 1997; Taji *et al*., 1991; Taji & Quinitio, 1992
NDF, Neutral Detergent Fibre; ADF, Acid Detergent Fibre; NFE, Nitrogen Free Extract
The figures and ranges in the table represent available analytical data.

Table 15: Proximate, Major Mineral and Amino Acid Content (% of dry matter) of Rice Products Used as Feed.

Nutrient	Paddy[a]	Broken[b]	Hull[c]	Bran[d]	Polishings[e]	Straw[f]	Ammonia[f] Treated Straw
Dry Matter	81 - 90	87.0 - 89.0	87.0 - 92.5	89 - 94	90	90.9	
Protein (N x 6.25)[g]	7.5 - 9.7	6.7 - 9.8	2.1 - 4.3	10.6 - 16.9	11.2 - 13.4	1.2 - 7.5	8.2 - 16.0
Crude Fat	1.5 - 2.3	0.5 - 1.9	0.30 - 0.93	5.1 - 19.7	10.1 - 13.9	0.8 - 2.1	
Neutral detergent Fibre	3.9	13.7 - 16.0		26.1 - 33.0		67.9 - 78.6	60.3 - 63.9
Acid Detergent Fibre		3.5		13.1 - 15.4		38.3 - 56.7	41.7 - 46.8
Crude Fibre	7.2 - 20.2	0.6	30.0-53.4	7.0 - 18.9	2.3 - 3.6	33.5 - 68.9	
Ash	2.9 - 6.5	5.0	13.2-24.4	8.8 - 28.8	5.2 - 8..3	12.2 - 21.4	14.2 - 14.8
Carbohydrates	63.6 - 84.4		22.4-35.3	90	51.1 - 55.0	39.1 - 47.3	
Starch	53.4		1.5		41.5 - 47.6		
Calcium	0.01 - 0.11	0.09 - 0.19	0.04-0.21	0.08 - 1.4	.05	0.30 - 0.71	
Phosphorus	0.22 - 0.32	0.03 - 0.04	.07-.08	1.3 - 2.9	1.48	0.06 - 0.16	
Arginine	0.50 - 0.64	0.56 - 0.83		0.72 - 1.59			
Glycine	0.27 - 0.37	0.38 - 0.56		0.63 - 0.81			
Histidine	0.15 - 0.25	0.18 - 0.29		0.23 - 0.47			
Isoleucine	0.25 - 0.34	0.34 - 0.41		0.40 - 0.66			
Leucine	0.51 - 0.63	0.65 - 0.76		0.70 - 1.17			
Lysine	0.25 - 0.30	0.30 - 0.36		0.49 - 0.91			
Methionine	0.10 - 0.20	0.21 - 0.36		0.23 - 0.43			
Cystine	0.10 - 0.17	0.11 - 0.24		0.10 - 0.33			
Phenylalanine	0.32 - 0.38	0.43 - 0.54		0.44 - 0.76			
Threonine	0.25 - 0.30	0.27 - 0.40		0.41 - 0.64			
Tryptophan	0.10 - 0.12	0.11		0.10 - 0.19			
Tyrosine	0.10 - 0.60	0.29 - 0.70		0.32 - 0.48			
Valine	0.36 - 0.50	0.46 - 0.85		0.64 - 1.14			

[a] AgrEvo, 1999; Farrell & Hutton, 1990; Ffoulkes, 1998; FAO, 2003; Herd, 2003; Juliano & Bechtel, 1985; Miller *et al.*, 1991; NGFA, 2003; NRC, 1982.
[b] Farrell & Hutton, 1990; NGFA, 2003; NRC, 1982; NRC, 1994, NRC, 1998.
[c] AgrEvo, 1999; Farrell & Hutton, 1990; Ffoulkes, 1998; FAO, 2003; Herd, 2003; Juliano & Bechtel, 1985; Miller *et al.*, 1991; NGFA, 2003
[d] AgrEvo, 1999; Farrell & Hutton, 1990; Ffoulkes, 1998; FAO, 2003; Herd, 2003; Juliano & Bechtel, 1985; Miller *et al.*, 1991; NGFA, 2003; NRC, 1982; NRC, 1994, NRC, 1998; NRC, 2000, NRC, 2001.
[e] Miller *et al.*, 1991; NRC, 1994, NRC, 1998.
[f] Drake *et al.*, 2002: Fadel & MacKill, 2002; FAO, 2003; Ffoulkes, 1998; Wanapat *et al.*, 1996; Nour 2003.
[g] Animal scientists commonly use a conversion factor of N x 6.25 for crude protein (AOAC, 2002).
The figures and ranges in the table represent available analytical data.

SECTION III ANTI-NUTRIENTS IN RICE

A. Phytin

Phytin is an organic phosphorous compound contained primarily in the bran layer, and it exists as a mixture of calcium - magnesium salts of phytic acid. Free phytic acid (myo-inositol 1,2,3,4,5,6-hexakis dihydrogen phosphate) chelates nutritional metal ions such as calcium and iron ions, which reduces the absorbability of these ions into the body (Thompson & Weber, 1981).

It has recently been reported that phytic acid reduced platelet aggregation and had an inhibitory effect against blood clot formation which may cause thrombosis and atherosclerosis (Vucenik *et al.*, 1999). Phytic acid is considered to be an anti-carcinogen influencing signal transduction pathways, cell cycle regulatory genes, differentiation genes or suppressor genes (Shamsuddin, 1999).

B. Allergens

While rice is not considered to be a common cause of food allergic reactions, allergic reactions have been documented, and certain proteins in rice have been identified as rice allergens. The first reported allergens in rice were 14-16kDa proteins which were detected using sera from patients allergic to rice (Matsuda *et al.*, 1991). A 16 kDA protein was later recognized as a major rice allergen. This protein has significant amino acid homology to barley trypsin inhibitor and wheat alpha amylase inhibitor (Izumi *et al.*, 1992). Subsequently, rice seed proteins with molecular masses of 26, 33, and 56 kDA have been recognized as being allergenic. The 33 kDA protein has been recently characterized and identified as the enzyme glyoxalase I (Usui *et al.*, 2001).

There have been several attempts to produce hypoallergenic rice. Rice products of reduced allergenicity have been developed by specifically hydrolyzing or reducing allergenic proteins using protease, alkali, and ultra-high pressure treatment (Yamazaki & Sasagawa, 1997). Some rice products of reduced allergenicity were proven to be effective for individuals hypersensitive to rice and with atopic dermatitis (Watanabe *et al.*, 1990). Furthermore, transgenic rice lines with reduced expression levels of the 14-16 kDa allergens are under development.

C. Trypsin Inhibitor

A trypsin inhibitor has been isolated from rice bran and characterized (Tashiro and Maki, 1979). These investigators reported a specific activity of 0.0227 units per mg protein in defatted rice bran. There seems to be no standard way of reporting the quantity of the inhibitor, and it does appear to be heat labile. AgrEvo (1999) detected no trypsin inhibitor in the grain or polished rice, but did detect it in the bran.

D. Oryzacystatin

Oryzacystatin has been isolated from rice bran (Abe *et al.,* 1987) and is considered a cysteinyl proteinase inhibitor (cystatin). It is inactivated by heat above 120°C (Juliano, 1993).

E. Alpha-amylase Subtilisin Inhibitor

The amino acid sequence of the bifunctional α-amylase subtilisin inhibitor from rice has been published by Ohtsubo & Richardson (1992). Bifunctional inhibitors have been proposed to be associated with defence of the seed against insect pests and pathogenic microorganisms (Ryan, 1990).

F. Lectins

Lectins are carbohydrate-binding proteins which agglutinate cells and precipitate glycoconjugates or polysaccharides (Goldstein *et al.*, 1980). The toxicity of lectins is due to their ability to bind to specific carbohydrate receptor sites on the intestinal mucosal cells and interference with the absorption of nutrients across the intestinal wall (Liener, 1986). Rice bran lectin, haemagglutinin, has been found to be associated with agglutination of human A, B and O group receptors with specific binding to 2-acetamido-2-deoxy-D-glucose (Poola, 1989). Rice bran lectin is heat labile at temperatures above 80°C (Ory *et al.*, 1981; Poola, 1989). Mannnose-binding rice lectin is distributed in all parts of the rice plant, and it has a potential ability to agglutinate bacterial cells of *Xanthomonas campestris* pv. *oryzae*, the pathogen causing bacterial leaf blight in rice, and also spores and protoplasts of *Magnaporthe grisea*, the rice blast fungus (Hirano *et al.*, 2000).

SECTION IV FOOD USE

Brown, milled, and polished rice are the major rice products consumed by humans in the form of grain after being cooked. Rice is also consumed as food ingredients which are part of food products. For example, rice flour is used in cereals, baby food, and snacks. The primary nutrients provided by rice are carbohydrates and proteins. Rice bran also provides some vitamins, fat, and fibre. Rice oil extracted from bran is valued as a high-quality cooking oil.

Although relatively little rice is consumed as prepared products, a variety of such products is available in the market, in particular in Asia. Examples of prepared rice products include: parboiled rice, rice bread, rice noodle, mixed crop flour, ready-to-eat cooked rice, cooked rice for medical use, infant formulae, rice products specifically designed for aged people, rice bran, rice bran oil, rice germ, rice pudding, rice sweets and crackers, rice paper, swollen rice, sticky rice cake, fermented soybean paste (made from rice *koji*), rice vinegar and rice wine. Table 16 shows suggested nutritional and compositional parameters to be analysed in rice matrices for food use.

Table 16: Suggested Nutritional and Compositional Parameters to be Analysed in Rice Matrices for Food Use

Parameter	Bran oil	Rice flour	Paddy rice
Proximate Analysis[a]		X	X
Minerals			X
Vitamins			X
Amino Acids		X	X
Fatty Acids	X	X	X
Phytic Phosphorus			X
Amylose Content		X	X

[a] Proximate includes protein, fat, total dietary fibre, ash and carbohydrates.

SECTION V FEED USE

A. Identification of Key Rice Products Consumed by Animals

Animals are fed paddy rice and its by-products such as rice straw, rice hull, and rice bran. Whole rice plants can be fed as whole crop silage.

1) Paddy rice

The use of paddy rice and brown rice is limited as animal feeds because of the cost. Paddy rice is mostly consumed by humans, and fed to animals only when the quality is poor or off-grade. Because of the hull, paddy rice is higher in crude fibre content and lower in calorific content than brown rice.

Paddy rice can replace other grains in animal feeding. For dairy and beef cattle diets, paddy rice can replace maize at the maximum rates of 40% (hereafter, in weight percent figures) and 65%, respectively (JSFA, 1979a, 1979b). For poultry and swine, paddy rice can replace maize up to 60 - 65 % (JSFA, 1979a). As rice endosperm is hard and enclosed in hard rice hull, paddy rice should be ground for efficient feed use.

Brown rice is an excellent animal feed, but is usually too expensive. For swine and poultry feeds, brown rice can replace maize at a rate of 40% (JSFA, 1970). Brown rice should be ground before used as animal feed except in the case of poultry. It is also an excellent poultry feed because of its high energy and low fibre content. As paddy rice is lacking in carotene, the colour of egg yolks will become paler as rice content of poultry feed increases (JSFA, 1970). Broken rice is commonly used particularly in pet foods in the U.S. It is valued for its lack of significant allergens.

Rice provides a number of other by-products that are valuable feed stuffs through harvest and processing: rice straw, rice hull, and rice bran.

2) Rice Straw

As rice straw is high in fibre, it can be fed to ruminants as roughage. In the tropical zone of monsoon Asia, rice straw is used as roughage especially in the dry season.

Ruminants cannot subsist only on rice straw because of the low protein content (Table 15). Thus, an adequate protein balance should be achieved by supplementing the straw.

Rice straw can only partly replace forage because of the low protein content and low digestibility. The straw contains oxalates that chelate calcium and decrease its absorption. Rice is coated with prickly hairs to which cattle need some time to adapt. Rice straw containing less than 50% acid detergent fibre

(ADF) could be good forage. Rice straw treated with ammonia or urea improves crude protein content, digestibility and preservability (Itoh *et al.*, 1975: Rahal *et al.*, 1997).

3) Hull

The hull is not a very good feed, as it is very low in protein and high in fibre. The sharp edges of the hull that may irritate the digestive tract of cattle should be broken by sufficiently grinding the hull. Digestibility can be improved by specific processes which remove silica. Monocalcium phosphate is added to the hull, and the mixture is ammoniated under heat and pressure to make an acceptable sheep feed. The hull is commonly used as a carrier for mineral and animal drug premixes.

4) Bran

Rice bran is a good source of protein, thiamine (vitamin B_1) and niacin. The quality of feed is dependent on the amount of the hull content. Fresh bran is fairly palatable. However, it often turns rancid during storage unless treated with heat, because of the high oil content and the release of enzymes during processing. Heating and drying at milling can improve the storage life (Morimoto *et al.*, 1985).

Rice bran is a good feed for dairy cows unless the bran amount exceeds 20% of the concentrate mixture. In Japan, rice bran has been used as one of the most important feed ingredients for *WAGYU* (Japanese Black). Rice bran can be blended up to 20% of swine feed. When too much rice bran is fed to juvenile pigs, it may lead to serious scouring. Due to the fatty acid composition in bran, swine and dairy cattle fed with bran in excess may lead to both body fat and butter fat to an undesirable soft nature (Morimoto *et al.*, 1985).

Rice bran can replace wheat bran or wheat middlings in poultry feed. The bran contains a high amount of phytate (3 - 5 %) which reduces the availability of minerals, and particularly phosphorus (NRC, 1998). Compared with rice bran, defatted rice bran has a long storage life and a high content in crude protein, crude fibre and ash.

Rice polishings also find their way into animal diets. Rice polishings easily become rancid during storage as in the case of the bran. Therefore, the polishings, an excellent source of thiamine and niacin, should be fed as fresh as possible. The polishings can be used as a part of the concentrate mixture for dairy and beef cattle, and are good feed for swine.

Rice screenings, a mixture of small and broken rice seeds, can be used for feed. However, the nutrient content of screenings is highly variable.

5) Whole Rice Plant

Whole rice plants can be fed to dairy and beef cattle as whole crop silage. Its nutritional value is almost equivalent to that of barley whole crop silages (Horiguchi *et al.*, 1992). Rice whole crop silage is low in crude protein and calcium, which should be supplemented (Table 14). Rice whole crop silage is palatable for cows (Goto *et al.*, 1991), and dry matter intake by dairy cows ranges 6.3 - 9.5 kg per day (Ishida *et al.*, 2000). There is only limited compositional information on the whole rice plant.

B. Identification of Key Products and Suggested Analysis for New Varieties

In addition to proximate analysis, calcium, and phosphorus need to be analyzed in the forage which is fed to ruminants. Moreover, when using rice grain and its by-products as feed for swine or poultry, amino acids and phytic acid (as phytic phosphorus) should also be analyzed. The suggested nutritional and compositional parameters to be analysed in rice matrices for animal feed use are shown in Table 17.

Table 17: Suggested Nutritional and Compositional Parameters to be Analysed in Rice Matrices for Feed.

Parameter	Paddy Rice/Bran	Straw	Whole Plant
Proximate Analysis[1]	**X**	**X**	**X**
Amino Acids	**X**		
Calcium	**X**	**X**	**X**
Phosphorus	**X**	**X**	**X**
Phytic Phosphorus	**X**		

[1]NDF (neutral detergent fibre) and ADF (acid detergent fibre) should be substituted for crude fibre.

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