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Proximal composition and categorization by the amylose content of rice (*Oryza sativa* L.) varieties

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ABSTRACT

In spite of its great importance, rice (*Oryza sativa* L.) is classified on the base of its industrial and commercial parameters, and not on its nutritional value. Based on this fact, the goals of this research were to evaluate the proximal composition of 23 varieties of polished rice retrieved from experimental crops ('Vivero italiano1', 'F2000Mejorado', 'PN00A007', 'Vivero italiano', 'Vivero italiano2', 'PN00A017B', 'F2000', 'PN99A003', 'PN01A013', and 'PN00A014') and commercial ('Fedearroz 50', 'Z-15', 'FONAIAP-1', 'D-Sativa', and 'Cimarrón') grown by the Instituto Nacional de Investigaciones Agrícolas, and from the Republic of China ('Tianjin', 'Local índico', 'Japanese NE', 'Waxy vítreos', 'Japanese X' and 'Japanese'), as well as from the Venezuelan local market ('A1' and 'A2'). The varieties and cultivars were characterized in its proximal composition by official methods, and apparent amylose content was determined by a colorimetric method. Results pointed out highly significant differences among the varieties ($p<0.05$) in parameters, such as contents of ash, fat, and protein. Rice lines cultivated in Venezuela displayed higher protein content as compared to Asian varieties. Nevertheless, the experimental lines cultivated in the country showed higher crude fat and ash contents than the Venezuelan (commercial) and Asian lines. Rice varieties also were categorized as a function of their amylose contents, observing, that one of the Asian varieties ('Japanese X') was waxy type; the other Asiatic ('Japanese') had a very low amylose content (5-10%), and the other varieties varied from low to high amylose content (>10-25%).

Key words: *Oryza sativa* L, polished rice, commercial varieties, proximal composition, amylose, grain quality.

Composición proximal y categorización de variedades de arroz (*Oryza sativa* L.) por su contenido de amilosa

RESUMEN

A pesar de su gran importancia, el arroz (*Oryza sativa* L.) se clasifica con base en sus parámetros industriales y comerciales y no por su valor nutricional. Basado en estos postulados, los objetivos de esta investigación fueron evaluar la composición proximal de 23 variedades de arroz pulido obtenidas de cosechas experimentales ('Vivero italiano1', 'F2000Mejorado', 'PN00A007', 'Vivero italiano', 'Vivero italiano2', 'PN00A017B', 'F2000', 'PN99A003', 'PN01A013' y 'PN00A014') y comerciales ('Fedearroz 50', 'Z-15', 'FONAIAP-1', 'D-Sativa' y 'Cimarrón') del Instituto Nacional de Investigaciones Agrícolas y de la República de China ('Tianjin', 'Local índico', 'Japonesa NE', 'Waxy vítreos', 'Japonesa X' y 'Japonesa'), así como marcas comerciales del mercado local venezolano ('A1' y 'A2'). Las variedades y cultivares fueron caracterizadas en su composición proximal y el contenido de amilosa aparente fue determinado por método

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colorimétrico. Los resultados señalaron diferencias significativas entre las variedades ($p<0,05$), en cuanto a los contenidos de ceniza, grasa y proteína. Las líneas de arroces cultivados en Venezuela presentaron mayor contenido de proteína, en comparación con las variedades asiáticas. Sin embargo, en cuanto al contenido de grasa cruda y ceniza, las líneas experimentales cultivadas en el país mostraron mayor contenido de estas variables que las asiáticas y las líneas comerciales venezolanas. Las variedades de arroz fueron categorizadas en función de su contenido de amilosa, observándose que una de las variedades asiáticas ('Japonesa X') es del tipo ceroso; la otra variedad asiática ('Japonesa') mostró un valor muy bajo en amilosa (5-10%) y las líneas remanentes variaron de bajo a alto contenido de amilosa (>10-25%).

Palabras clave: *Oryza sativa* L, arroz pulido, variedades comerciales, composición proximal, amilosa, calidad del grano.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereals in human nutrition, consumed by 2/3 of the global population (Kennedy and Burlingame, 2003; OECD, 2004). Due to its daily consumption it supply 21, 14, and 2% of the global energy, protein, and fat, respectively (FAO, 1999; Juliano, 1993; FAO, 2001). Rice crop represents one of the most important food source within the agricultural sector of Venezuela, not only by its adaptability to the soil quality, climatic conditions, and economic magnitude, but due to of the preference as staple food.

In spite of its great importance, this cereal is classified on the base of its industrial and commercial parameters, and not on its nutritional value, which is the most important parameter to compose a balanced diet (Storck *et al.*, 2005). Moreover, the chemical and nutritional quality of rice grain varies considerably and this may be attributed to genetic factors, environmental influences, and fertilizer treatments, degree of milling and storage conditions (Juliano, 1993).

Coffman and Juliano (1987), Juliano and Villareal (1993), and Eggum *et al.* (1993) have pointed out that components such as protein, available starch, and dietary fiber can also be present in variable amounts in different rice cultivars. Indeed, 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 (OECD, 2004). Protein content of rice is important from a nutritional point of view, but in contrast it may perhaps be a quality parameter; at that point, it is well known that the protein content of rice grain is an indicator of taste of cooked rice in the countries who eat rice as staple (Kim *et al.*, 2006). For example, 'Japanese' consider rice with low protein content and low amylose:amylopectin ratio to have desirable taste and textural attributes (Champagne *et al.*, 1996).

Recent data for protein contents ranged from 5.8–7.7% for milled rice (Juliano, 1993; Singh *et al.*, 1998, Zhou *et al.*, 2002; Champagne *et al.*, 2004). In contrast, Zhang *et al.* (2007) have reported a range of 9.97 to 16.19% of protein content of 689 brown (unpolished) rice varieties from China and other countries.

There are thousands of different rice varieties; some have been in the diet for centuries, while others are new hybrids promoted for qualities such as high yield and drought and disease resistance (Kennedy and Burlingame, 2003). All of them have to be characterized nutritionally and functionally. Even though a number of different rice markets are using many varieties with differences in its functional properties, at the world level, only a small amount of the milled rice (5%) is used to make ingredients for processed foods and as feed, such as cooked rice, rice cakes, rice noodles (Yeh, 2004). Both the protein and the amylose content are important factors in determining the nutrient quality of rice (Zhang *et al.*, 2007). Each variety differs in the amount of nutritional constituents and, more importantly, the type of starch composition (amylose and amylopectin contents). The nature of the starch composition affects texture and retrogradation properties of the rice. Usually, rice with more amylopectin is softer, sticker, holds moisture better and is more resistant to retrogradation. The amylopectin/amylose ratio does not explain all textural issues related to rice, but is a very important factor. Juliano and Villareal (1993) have reported that the starch in non-glutinous rice is composed of 15-30% amylose and 70-85% amylopectin and in glutinous rice contains less than 5% of amylose. The amylose content in rice grown in Asia ranges widely from 0 to 32% (Nakagahara *et al.*, 1986). Indica type long grain rice has 22% amylose and 78% of amylopectin, Japonica medium grain rice has 18% amylose and 82% of amylopectin (Okuno *et al.*, 1983). 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. Many types of rice exist across the range from non-glutinous to glutinous varieties (Okuno *et al.*, 1983).

To produce different categories of rice products (e.g. cooked rice, rice cakes, rice noodles, etc.) the processors are using rice cultivars, mainly based upon their amylose contents (Yeh, 2004). However, it remains unclear, why some specific rice products are made with some particular rice cultivars superior to other varieties with similar amylose content (Lai *et al.*, 2000). Moreover, even with the achievement of sufficient yield of high yielding varieties, new varieties must be frequently searched, in order to broad its potential use in food industry and encourage its production. Rice millers prefer varieties with high milling and head rice out-turn, whereas consumers consider quality (Merca and Juliano, 1981). Then, these new varieties or lines have to be also characterized in their nutritional composition and functional properties.

Based on these considerations, the goals of this research were to verify variations in proximal composition and amylose content of some Venezuelan rice varieties and to compare them with those of some experimental varieties from Italy grown in Venezuela and some grown in China, and to evaluate their nutritional contribution. The purpose is to categorize them, according to some nutritional parameters and amylose content, into groups in order to recommend them as nutritional components to diets and ingredients in products development.

MATERIALS AND METHODS

Five commercial varieties of polished rice grown in Portuguesa state, Venezuela, were chosen in function of their yields and accessibility. They are identified as follow: 'Fedearroz 50', 'Z-15', 'FONAIAP-1', 'D-Sativa', and 'Cimarrón'. Three varieties ('Cimarrón', 'Zeta 15', and 'FONAIAP-1') were supplied by the Asociación de Productores Rurales del estado Portuguesa (ASOPORTUGUESA. Portuguesa, Venezuela) and the rest were supplied by Cargill C.A. Two polished commercial brands were randomly chosen from a local market. Ten polished lines were 'Vivero italiano1', 'F2000Mejorado', 'PN00A007', 'Vivero italiano', 'Vivero italiano2', 'PN00A017B', 'F2000', 'PN99A003', 'PN01A013' and 'PN00A014' and donated by the Instituto Nacional de Investigaciones Agrícolas (INIA).

Six polished varieties obtained from a local market at Nanjing, Jiangsu Province, Republic of China and from Venezuelan local Chinese market (Chacaíto, Caracas) were also evaluated. The code of these five were 'Tianjin', 'Local índico', 'Japanese NE', 'Waxy vitreous', 'Japanese X', and 'Japanese'.

Proximal composition of polished rice varieties

The rice varieties were analyzed in their proximal composition by using the AACC (2003) methods, as follows: Moisture content was determined using the gravimetric method. Crude protein content was calculated by converting the nitrogen content (N x 5.95, which is based on the nitrogen content of glutelin, the major protein in rice) determined by the micro-Kjeldahl method. Ash content was determined following the procedure of dry-ashing in a furnace oven at 550°C for 5 h. Crude fat was estimated using Soxhlet apparatus.

Amylose content

Amylose content was analyzed using the protocol of Mc Grance *et al.* (1998) and total carbohydrates were calculated by difference.

Statistical analysis

Data collected for the three replicates of three batches were subjected to analysis of variance (ANOVA one-way). Where significant differences were present, treatments were compared using Duncan multiple range test to detect which treatment (s) was (were) statistically different (s) at the same significance level (STSC, 1987).

RESULTS AND DISCUSION

Tables 1 and 2 summarize the proximal composition of the rice varieties from the commercial crops grown at Portuguesa state, Venezuela, the two obtained from the shelf of the grocery store, and the experimental lines. As it can be seen, the moisture contents of these samples range from 9.99 ('Z-15') to 12.99% ('Vivero italiano2'). These results are in agreement with the Venezuelan standard of 13% of moisture content (COVENIN, 1990), and with the established goal necessary to reach a stable shelf life (less than 14.0%; Juliano and Villareal 1993). They can be therefore considered a safe dry products with prolonged shelf life (Halverston and Zeleny 1971).

In relation to the Asian lines (Table 3), it is observed that despite these varieties had the same postharvest treatment, as the other varieties, the moisture contents were slightly higher than those established by the Venezuelan normative, ranging from 13.01 to 13.57%. Beside affecting taste, the moisture content is a quality factor for preservation, convenience in packaging, transport or shipping, and it also constitutes an identity standard (Bradley, 2003). Champagne *et al.* (1996) had pointed out that lower moisture contents in US rice, as compared to 'Japanese' rice, is also expected to contribute to a lower taste score.

The protein contents of the varieties studied, varied from 7.13 ('Japanese X') to 10.68% ('PN99A003'). The highest contents were found in 'PN99A003', followed by 'PN00A017B' and 'Vivero italiano 2' with 10.67 and 10.63%, respectively. These results agreed with those reported for Venezuelan rice by the Food Composition

Table 1. Varietal differences of the proximal composition and amylose contents of Venezuelan commercial polished rice

Varieties	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Total Carbohydrate (%)	Amylose (%)
'Fedearroz 50'	10.76c[1]	9.47ba	0.14c	0.34b	79.29b	13.53d
'Z-15'	9.99c	8.99c	0.45b	0.33b	80.24a	20.67a
'FONAIAP-1'	10.94c	8.46c	0.25d	0.45a	79.90b	13.46d
'D-Sativa'	11.19bc	8.39c	0.42b	0.30b	79.70b	17.09b
'Cimarrón'	11.24b	8.38c	0.20d	0.41a	79.77b	17.73b
'A1'	12.68c	9.07b	0.53a	0.39s	77.33c	13.89d
'A2'	11.43bc	9.93c	0.38c	0.30b	77.96c	16.53c
Mean	11.18±0.81	8.96±0.60	0.34±0.14	0.37±0.05	79.17±0.62	16.12±2.08
CV	0.07	0.07	0.41	0.14	0.01	0.13

[1]Values in a column followed by the same letter are not statically different at a significant level of 5%.

Table 2. Varietal differences of proximal composition and amylose contents of polished rice from Venezuelan experimental crop

Varieties	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Total Carbohydrate (%)	Amylose (%)
'Vivero italiano1'	11.29a[1]	9.96b	1.54-a	1.35-a	75.86ab	18.46a
'F2000Mejorado'	12.18b	9.23b	0.97b	0.50-d	72.12cb	13.57c
'PN00A007'	12.41a	10.31a	0.72c	0.67dc	76.16c	12.45c
'Vivero italiano'	11.74a	9.46b	0.52d	0.51d	77.77b	19.20a
'Vivero italiano2'	12.99a	10.63a	1.46a	0.80c	74.12c	12.50c
'PN00A017B'	12.17a	10.67a	0.98b	1.37a	74.81c	12.52c
'F2000'	11.44a	10.34a	1.09ae	0.59d	76.54b	16.15b
PN99A003	12.34a	10.68a	1.38a	0.85b	74.75c	19.90a
'PN01A013'	12.11a	7.81e	0.98b	0.76c	78.34ba	15.23b
'PN00A014'	11.76a	9.66b	0.29e	0.54d	77.75b	17.19a
Mean	12.10±0.46	9.88±0.89	1.03±0.35	0.76±0.32	76.32±1.27	15.72±2.90
CV	0.04	0.09	0.34	0.42	0.02	0.18

[1]Values in a column followed by the same letter are not statically different at a significant level of 5%.

Table of FAO (2001) and the Instituto Venezolano de Nutrición (INN, 1999). On the basis of nutritional value all varieties contained sufficient protein, which were above of the standard value of 7% (Shih, 2004). The protein content of the polished rice grain is relatively low compared with other cereals (Ashida *et al*., 2006). These differences are due to the removal of the aleurone layer and embryo tissue (high in proteins) during the polishing process (Champagne *et al.*, 2004). Recent data for protein content ranged from 5.8 to 7.7% for polished rice (Juliano, 1993; Singh *et al.*, 1998, Zhou *et al.*, 2002; Champagne *et al.*, 2004). In contrast, Zhang *et al.* (2007) have reported a range of 9.97 to 16,19% of protein contents of 689 brown (unpolished) rice varieties from China and other countries. Then, the typical protein content of the polished rice is inconsistent with the finding of the present study, because the protein contents in all of the varieties of polished rice here studied varied from 8.10 to 9.88%.

The lipid content of milled rice has been reported ranging from 0.2 to 2.0%, depending on the variety and growing conditions (Zhuo *et al.*, 2002). In this study the crude fat variation ranged from 0.14 ('Fedearroz 50') to 1.54% ('Vivero italiano1'). The mean of the commercial samples (Table 1) was 0.34% with a SD of 0.14, ranging from 0.13 to 0.52%. The lowest contents were found in 'Fedearroz 50' (0.14%) and the highest in 'A1' followed by 'Z-15' and 'D-Sativa' with 0.53, 0.45, and 0.42%, respectively.

Table 2 shows that the experimental varieties had the highest crude fat content as compared with the commercial lines, ranging from 0.29 to 1.54%. The lowest contents were found in 'PN00A014' (0.29%) and the highest in 'Vivero italiano1' followed by 'Vivero italiano2', 'PN99A003', and 'F2000' with 1.54, 1.46, 1.38, and 1.09%, respectively. Table 3 shows the crude fat content of the Chinese lines, which varied from 0.26 to 0.69%. As an observation, fatty acid

Table 3. Varietal differences at the proximal composition and amylose contents of Venezuelan imported polished rice

Varieties	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Total Carbohydrate (%)	Amylose (%)
'Tianjin'	13.08a[1]	7.99b	0.69a	0.37b	77.87b	16.13a
'Local índico'	13.37a	8.87a	0.52c	0.34b	76.90b	15.38a
'Japanese NE'	13.33a	7.54b	0.52c	0.33b	78.28a	15.38a
'Waxy vitreous'	13.57a	7.97ab	0.52c	0.18c	77.76b	13.80d
'Japanese X'	13.01a	8.72a	0.26d	0.17c	77.84b	3.76d
'Japanese'	13.24a	7.13b	0.33b	0.48a	78.82a	9.05c
Mean	13.30±0.19	8.10±0.67	0.47±0.16	0.37±0.11	77.91±0.71	12.62±5.22
CV	0.01	0.08	0.34	0.30	0.01	0.41

[1]Values in a column followed by the same letter are not statically different at a significant level of 5%.

composition is dependent on the growing season and the eco-geographical varieties. In early crops, in which the ripening temperature is high, oleic acid content is high, while in late crops, linoleic acid content is high (OECD, 2004). It could be of interesting to analyze the fatty acid profile of these varieties.

The total carbohydrates of the Venezuelan commercial lines and the brand from the market varied from 77.33 to 80.24% (Table 1), while the Italian lines from 74.12 to 78.34% (Table 2), and the Asian lines from 76.90 to 78.82%. Starch is the principal component in this fraction of the polished rice. The nature of the starch affects texture and retrogradation properties of the rice (Juliano and Villareal, 1993; Nakagahara *et al.*, 1986; Okuno *et al.*, 1983).

The amylose content of the Venezuelan commercial lines and the brand from the market ranged from 13.46 to 20.67% (Table 1), while that of the Italian lines varied from 12.45 to 19.90% (Table 2), and the Asian varieties from 3.76 to 16.13% (Table 3). The brown rice lines evaluated by Zhang *et al.* (2007) varied from 12.07 to 28.88% on its amylose content. The groups formed by analysis of the amylose from different lines samples (Table 4) varied from waxy to high amylose, but without a marked tendency as a function of its origin. The majority of them were classified as having low and medium amylose contents.

Table 4. Groups of the different varieties of rice in function of their amylose contents.

Amylose content (%)	Varieties	Groups
0-5	'Japanese X'	Waxy
> 5 -10	'Japanese'	Very low amylose
>10-14	'A1', 'Fedearroz 50', 'FONAIAP-1', 'Waxy vitreous', 'F2000Mejorado', 'PN00A007', 'PN00A017B'	Low amylose
> 14-18	'A2', 'D-Sativa', 'Cimarrón', 'Tianjin', 'Local índico', 'Japanese NE', 'F2000', 'PN01A013'	Medium amylose
> 18-25	'Z-15', 'Vivero italiano1', 'Vivero italiano', 'PN99A003', 'PN00A014'	High amylose

CONCLUSION

Results pointed out highly significant differences among the varieties in variables, such as content of ash, crude fat, and amylose contents, and crude protein content. The rice lines also were categorized as a function of their amylose contents, observing, that one Asian line was type waxy ('Japanese X') and the remnant lines varied from excessively low to high amylose. Further studies are needed to clarify the relationship between the previous factors and grain ripening and consequently the quality characters.

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