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Characterization of yellow rice and development of instant flours by hydrothermal process

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SUMMARY: Commercial brown and yellow milled rice submitted to inappropriate storage conditions were characterized and utilized to develop instant flours that were used in the preparation of atoles. The grains were classified as long-thin; the average size was 2.13 x 6.79 mm. The milling yields obtained in laboratory with paddy rice were 70% brown rice and 60% milled rice. Brown rice and yellow milled rice had similar amylose contents, 22.5 and 25.6% respectively. Gel consistency was soft with low gelatinization temperature (63-68°C) for both samples. Field fungi, such as *Helminthosporium* oryzae, and storage fungi, such as *Aspergillus* spp, were present in paddy, yellow milled and commercial rice. The fungus *Helminthosporium* oryzae, *Aspergillus* spp, and *Penicillum* spp were not present in instant flours. Instant flours were prepared by soaking the grain in water, and then steaming, drying and milling it. The highest values for water absorption index were obtained from yellow milled instant rice flour. The color of yellow milled instant rice flour varied from white ("L") to pale yellow (lesser values of "b"). The lower viscosity of the instant flours indicates the breakdown of polymers and reveals that unintact starch granules were not present in instant flours. Protein and ash contents of brown and milled rice were unaffected by hydrothermal process, and the lipid content showed only little changes. Sensory analyses carried out on the atoles prepared with instant flours considered them acceptable, specially for products made from milled yellow rice.

RESUMEN: Caracterización de arroz manchado y elaboración de harinas instantáneas por proceso hidrotérmico. Se caracterizaron arroz integral y pulido manchados por condiciones ambientales y/o inadecuadas de almacenamiento. Estos materiales fueron utilizados como materia prima para la elaboración de harinas instantáneas, que se utilizaron en la preparación de atoles. Los granos fueron clasificados como largos-delgados, con un tamaño promedio de 2.13 x 6.79 mm. Los rendimientos obtenidos en la molienda experimental a partir de arroz palay fueron de 70% en el descascarado y 60.33% en el pulido total. Arroz integral y arroz pulido manchados presentaron contenidos similares de amilosa, con valores de 22.5 y 25.6 respectivamente. La consistencia de gel fue blanda o baja, con una temperatura baja de gelatinización (63-68°C) para ambas muestras. En arroz palay, integral y pulido manchados se registraron la presencia de hongos de campo como *Helminthosporium oryzae* y hongos de almacén como *Aspergillus* spp. En harinas instantáneas no se registró la presencia de estos hongos. Las harinas instantáneas fueron preparadas por maceración del grano en agua a temperatura ambiente, tratamiento con vapor en autoclave, secado y molienda. Las harinas instantáneas obtenidas de arroz pulido manchado presentaron los más altos valores de índice de absorción de agua y presentaron un color blanco amarillento pálido y con un color más blanco en relación a las harinas instantáneas de arroz integral manchado, debido a la remoción del pericarpio. Los bajos valores de viscosidad en harinas instantáneas indicaron una hidrólisis completa de los gránulos de almidón. El proceso hidrotérmico evaluado no afectó los contenidos de proteína y cenizas, afectando ligeramente el contenido de lípidos. La evaluación sensorial de los atoles preparados con harinas instantáneas fueron considerados aceptables con mejores valores de aceptación para los atoles de arroz pulido manchado.

INTRODUCTION

Yellow rice are fermented grains resulted from a combination of microbiological and chemical activities triggered by over-exposure of harvested, unthereshed paddy rice in the field to extremely wet environmental conditions that result in overheating of the grain before it is dried. The percentage of yellow grain can be as high as 50%. This affects quality (1). Some of the factors contributing to the high percentage of broken grains are a rapid drying at higher temperature and fluctuating weather condition specially in the humid tropics, which lead to the development of numerous fissures, ultimately resulting in a number of full cracks (1). Yellowing of rice is a common post-harvest problem in some

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regions in the humid tropics of the southern Mexico, causing financial losses due to down-grading or rejection. In 1993, 28% of the harvested rice was broken grain and 21% was yellow rice (2). The yellow rice is not of good commercial quality since Mexican consumers prefer milled white rice. This problem cause the storage of large volumes, occupying the storage bins with low priced. Yellow rice is commonly used in the animal feed or brewing industries. In Mexico, a very popular beverage named atole, is frequently prepared from rice flour (3). Manufacturing processes for precooked cereal have been reported using doubledrum atmospheric dryer; however, the rheological properties of the slurry are difficult to control, and they affect the drying operation to a much higher degree than any other factor involved (4). The basic principle to obtain instant flour is soaking the grain in water, and then steaming, drying and milling it. Instant flour can be produced with a wide assortment of functional properties as water absorption capacity, water solubility capacity and viscosity properties in aqueous medium, depending on the inherent properties of the varieties and types used, pretreatment of the grain or flour before use (5). Hydrothermal process is a significant source of modified rice flours, which offers potential for instant drinks, baby foods, formulated foods and new and traditional baked products (6). The objective of this research was to characterize brown and yellow milled rice and elaborate instant flours by hydrothermal process.

MATERIAL AND METHODS

Rice samples. Paddy and yellow milled rice from humid zones (Campeche State, Spring-Summer 1989), were used in this study. Sinaloa A-80, Campeche and a mixture of commercial varieties were used as control.

Grain classification. Yellow milled rice was classified for grain size, shape and milling quality following the method of Adair et al (7). The grains were classified as long-thin with an average size of 2.13 mm x 6.79 mm. The protein, ash and lipid contents were 7.9, 1.2 and 2.3% for brown rice and 7.7, 6.0, and 7.0% for milled rice, respectively. These values are within the range reported by Juliano and Bechtel (8) to paddy rice and its milling fractions. Yellow milled rice grain was classified as long grain (81.45%), medium grain (6.9%), short grain (11.3%), seeds (0.25%), and dust (0. 1%). The yield of milled long grain can be considered satisfactory. However the yellowish color of some grains would be a factor for rejection in bins or rice industries. This type of coloration is considered as damage rice.

Mycological analysis. The analysis were performed as described y Phillips et al (9). Rice samples were surface sterilized in sodium hypochlorite followed by rinsing in sterile distilled water and dried. The following media were used: potato dextrose agar (PDA), yeast extract agar (YXT) and MY40 (10). Chloramphenicol was added to PD and YXT to inhibit the growth of bacteria and rose bengal to restrict the growth of *Mucorales*.

TABLE 1
Cooking quality of rice

Rice samples	Amylose content (%)	Gel consistency mm		Grade	Gelatinization temperature °C
Yellow milled	22.2	soft	79	7	63-68 low
Brown	22.2	soft	102	7	63-68 low
Sinaloa A-80[a]	22.2	Medium	64	5	69-73 Intermediate
Campeche[a]	25.6	Medium	50	7	63-68 low

means, n=3
[a] controls

TABLE 2
Percentage of rice grains infected with fungi

Rice samples	Percentage of grains infected with individual fungi		
	Aspergillus ssp	*Helminthosporium oryzae*	*Penicillum* spp
Paddy	5	4	-
Brown	6	7	-
Yellow milled	3	9	-
Instant flours	-	-	-

Means, n=20

TABLE 3
Water Absorption Index (WAI) Water Solubility Index (WSI) and color of rice samples

Rice sample	WSI (g/g of dry sample)	WAI (% of dry sample)	Color L	a	b
Brown rice	3.02c	2.81f	78.90e	0.67e	12.93e
Yellow milled	3.00c	2.76f	86.80a	0.40f	11.90g
Instant flours					
Brown rice (1min)*	8.06ab	4.44c	71.90f	1.43c	16.57b
Brown rice (5 min)	8.85a	4.00d	71.17f	1.47b	16.57b
Brown rice (15 min)*	9.19a	3.64e	78.37e	2.17a	17.60a
Yellow milled rice (1min)	8.64a	4.55c	81.70c	0.30g	14.26d
Yellow milled rice (5 min)	7.26b	6.47a	84.90b	1.03d	15.40c
Yellow milled rice (15 min)	8.17ab	5.02b	79.17d	0.40f	12.30f

N=3
Values with the same letter are not significantly different within each column at $P<0.05$. *Processing time in autoclave

Plates were incubated at room temperature (28-32°C) for 5-7 days. The mold growth in the rice was observed using a hand lens (x 10) and a high-power microscope (x 400).

Cooking and processing quality. Gelatinization temperature (GT) was determined with the method of Little et al (11). Six grains of milled rice were incubated in KOH at room temperature for 23 h and the degree of spreading measured using a seven-point scale as follows: 1,grain not affected; 2, grain swollen; 3, grain swollen, collar incomplete and narrow; 4, grain swollen, collar complete and wide: 5, grain split or segmented, collar complete and wide; 6, grain dispersed, merging with collar; and 7, grain completely dispersed and intermingled. Alkali spreading values correspond to GT as follows; 1-2, high (74.5-80°C); 3, high-intermediate; 4-5, intermediate (70-74°C);and 6-7, low (<70°C).

Amylose content was determined following the iodine colorimetric method of Juliano et al (12). Milled rice flour was dispersed in NaOH overnight at room temperature followed by iodine colorimetry.

Gel consistency was determined as described by Perez et al (13). Milled rice flour was wetted with ethanol containing bromthymol blue in culture tubes in KOH, using a vortex mixer. The tubes were covered with glass marbles and placed for 8 min in a boiling water bath. The tubes were removed for 5 min, mixed again and cooled in an ice-water bath for 20 min. The cooled tubes were laid horizontally over ruled graph paper and the gel length was measured after 1 h. The gel consistency values were classified as soft (61-100 mm) (41-60 mm), or hard (26-40 mm).

FIGURE 1

Preparation of instant flours by hydrothermal process

Brown or Yellow Milled Rice

⇓

Soaking

(Water, room temperature)

⇓

Thermal Procedure

(Autoclave 118°C, 1.94 Kg/cm^2, 1, 5 and 15 minutes)

⇓

Drying

(Oven, forced air 50°C)

⇓

Milling

(Hammer mill)

⇓

Instant Rice Flours

Water uptake. Two Kg of each sample (brown and yellow milled rice) were placed into a plastic vessel with 12 L of water at room temperature and it was determined moisture content of the samples each five minutes, according to the AACC method No. 44-18, (14).

Hydrothermal process. Instant flours were obtained according to the process developed by Martinez and El Dahs (5) and showed in Figure 1. The samples were lifted manually in baskets into an autoclave and steamed at 118°C, 1.94 Kg/cm^2, during 1,5 and 15 minutes. After steaming the gelatinizes grains contains around 30% moisture content were oven dried with forced air at 50°C. After rice was gelatinized and air-dried, it was milled using a hammer mill.

Preparation of atoles (instant rice flour drink). Instant rice flour (30 g of each sample) was mixed with 500 ml distilled water, 25 ml milk, 0.2 g cinnamon powder and 25 g of sugar. The mixture was heated during 3 min. and placed into seven thermal cups to be judged by the sensorial panel.

Chemical analysis. Moisture oontent, protein (N x 5.95), and ash were determined by AACC methods (13); lipids content was determined using the method of Bligh and Dyer (15).

Physical analysis. Flour color were measured with a Hunter Lab Color Difference Meter (Hunter Association, Inc, Fairfax, VA) equipped with a signal processor (Model D25-2) and an optical sensor (Model D25) (16). Water absorption (WAI) and water solubility indexes (WSI) of the flour were determined following the method of Anderson et al (17). Paste viscosity characteristics were measured with the Viscoamilograph according with the AACC method (14).

Sensory analysis. The products were evaluated by a trained seven-member panel with seven fittings for each sample. The products evaluated were prepared under six treatments consisting of two factors (brown and milled rice), and three times of hydrothermal treatment (1,5, and 15 minutes). Acceptability, texture, color, consistency, and aroma-flavor were the attributes evaluated in atoles.

Statistical analyses. Analysis of the treatments analysis was carried out using a random design with a factorial arrangement 3 x 2, and the Duncan's test. The attributes evaluated by the panel was subjective and for that reason a comparative (hedonic) scale was used with a modification in the interval scale according to the Larmond method (18), as well as a Duncan's test.

RESULTS AND DISCUSSION

Milling quality. The milling potential of the paddy rice largely determines the performance of a rice mill in tenms of milled rice recovery and quality. Milling yields is one of the most

FIGURE 2

Water uptake of rice

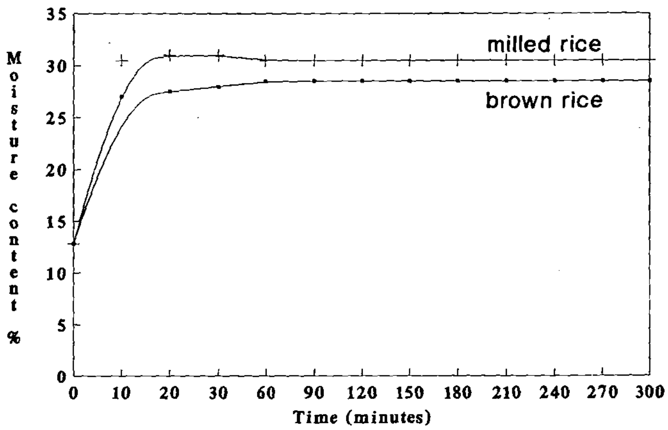
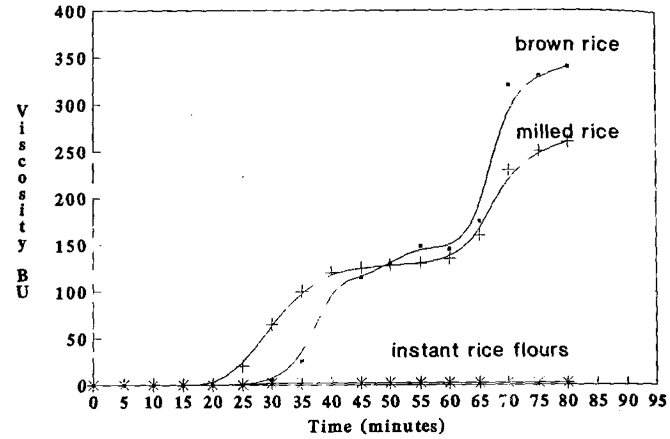


FIGURE 3

Viscosity of rice



important criteria of rice quality. The milling yields obtained in laboratory from paddy rice were 70% for brown rice and 60.33% for milled rice, considering seeds and empty grain that remained together with hulls in the step of milling, these yields are not acceptable since they were lower than 68%, that recommended by official standards (2).

Cooking quality. The cooking quality values of rice are shown in Table 1. The cooking quality of rice is determined by the uses and costumes of the consumers, its physicochemical properties, and the industrial uses for which it is destined. Amylose content is considered the single most important characteristic for predicting rice cooking and processing behavior (19). Brown and yellow milled rice showed similar amylose contents, and, those contents are within the value range established for the controls Sinaloa A-80 and Campeche varieties with 22.2 and 25.6% respectively. Amylose is a component of starch granule and it is an important factor in rice cooking quality related to cohesively, texture and appearance. Gel consistency values for both samples brown and yellow milled rice) showed a soft consistency with higher values to brown rice than for the control. These results were similar to those reported by Perez et al (20) for four varieties of long grain, non waxy milled rice. During the gelatinization temperature test, the rice grain starts to absorb water and swells. The value obtained was 7, similar to Campeche variety with grains completely disintegrated in white solution. The gelatinization temperatures of brown and yellow milled rice were low (63-68°C). This means that those samples are cooked in a short time with small quantities of water. Similar values were reported by Biliaderis et al (21).

Molds. In Table 2 are shown the percentages of rice grains infected with fungi. Numerous microbes cause deterioration of grain, provided suitable conditions for their grown. Perhaps the most common of these are various fungi. These are often classified as field fungi and storage fungi. The principal economic damage caused by fungi is discoloration of grains. Field fungi such as *Helminthosporium oryzae*, and storage fungi such as *Aspergillus* spp were present in paddy, milled yellow and commercial rice. These fungi are the causal agents of the disease «brown spot» (22). Field fungi are usually pathogenic organism that cause plant diseases. Recently harvested rice can contain numerous spores of species from this group, but in storage these tend to die out over time (22). Phillips et al (9) reported that fungi isolated from yellow milled grains were similar to those found in normal white grains. The fungus *Helminthosporium oryzae, Aspergillus* spp, and *Penicillum* spp were not present in instant flours (Table 2). It is well known that fungi are capable of causing discoloration of rice (23) but it is often difficult to associate a specific discoloration with its causal agent (24). Fungal spores are present in all harvested grain, and there is no method known for removing or excluding them. These spores. germinate and grow only in warm, moist environments (22).

Water uptake. The water uptake for both grains brown and yellow milled rice was done by soaking they in water at room temperature until they reached the equilibrium moisture content of approximately 30% (Figure 2). The rice grains initially absorbed water rapidly up to 27% and 30.5% in ten minutes, an the water uptake stabilized at 28.5 and 30.5% respectively after 60 minutes. When the grain is soaked at temperatures of 60°C or less, the equilibrium moisture content under these conditions does not exceed 30% (25). For hydration from 13 to 30% moisture, the increase in grain volume is about 30% for brown rice (26). Brown and yellow milled rice showed similar behavior during water uptake, however, yellow milled rice showed higher water uptake than brown rice. Bhattacharya et al (26) reported similar findings and cited that bran layer presented in brown rice act as a barrier to hydration.

Characteristics of instant flours. Water absorption index depends on the availability of hydrophilic groups that bind water molecules. WAI and WSI were lower for raw rice flours and maximum for instant flours (Table 3). The instant flours showed no significant differences in WSI except for instant flour elaborated with 5 minutes of thermal treatment. The WSI values were increased as the processing time was increased. The highest values for WAI were obtained with flours from yellow milled rice. Increases in water solubility and reductions in water absorption suggest a progressive degradation of starches. Water suspension of rice meals from instant flours showed good dispersion with a minimum tendency to form aglomerates, indicating that high quantities of molecules were soluble, originated for a high degree of starch gelatinization during the hydrothermal process.

Further evidence of the breakdown of carbohydrates is presented in Figure 3. The viscosity of brown and yellow milled rice showed typical viscosity curve of raw rice. Viscosity yield began at 55 and 60°C; and peak viscosity was reached at 85°C and 90°C and setback was 260 and 340 Brabender Units for yellow milled and brown rice respectively. These values are characteristics of rice with soft gel consistency and intermediate gelatinization temperature (27). Similar findings were reported by Pérez and Juliano (28) and Merca and Juliano (29). The lower viscosity of the instant flours indicates the breakdown of polymers and reveals that undamaged starch granules were not present in the instant flours. The swelling of the starchy endosperm during gelatization completely heals the preexisting defects. As a result, breakage is not just reduced but virtually eliminated.

Brown and yellow milled rice were characterized by a white color deepening to pale yellow (lesser values of »b») with better values of »L» for yellow milled rice due to bran removal (Table 3). After the hydrothermal process white («L») color values were decreased significantly and yellow («b») color values increased significantly (P>0.05). The processing conditions during hydrothermal process determine the intensity of the color. Mild conditions of soaking and yield a light color, whereas severe conditions lead to deeper discoloration. Rice was slightly discolored by the hydrothemal process, a light yellow or amber. These color changes can be resulted from heat treatment, chemical changes, the pigments of the outer layers and microbiological activities.

Proximate composition of rice flours. Rice provided 20% of the per capita energy and 13% of the protein for human consumption worldwide (30). Management and cultural practices have a major influence on the protein content of rice grain (31). Protein and ash contents of brown or milled rice were unaffected by hydrothermal process and the lipid content showed only little changes (Table 4). The protein content of brown rice was higher than yellow milled rice. Brown rice has a higher nutrient content, based on its higher protein content, higher lysine content of protein, and higher vitamin and mineral content, than milled rice (32). These values for brown rice are within the range reported for 17,587 cultivars in the world collection at the International Rice Research Institute (IRRI) ranged from 4.3 to 18.2% with a mean of 9.5 % (33). The lipid content of yellow milled rice was lesser than brown rice, similar trends were obtained by Taira and Hiraiwa (34) with ranges from 2.3 to 2.9 and from 0.6 to 1.2 for brown and milled rice respectively. Changes in the composition of lipids can be due to degree of milling. Sondi et al (35) showed that the oil content of parboiled brown rice remains virtually unchanged at various degrees of milling irrespective of the conditions of soaking and steaming.

TABLE 4
Proximate composition of instant flours from brown and yellow milled rice prepared by hydrothermal process

Rice samples	Protein (%)	Ash (%)	Lipids (%)
Yellow milled rice	7.7b	0.61b	0.67c
Brown rice	79a	1.21a	2.3a
Instant flours			
Brown rice (1min)*	79a	1.23a	2.2b
Brown rice (5 min)*	79a	1.22a	2.3a
Brown rice (15min)*	7.9a	1.23a	2.3a
Yellow milled rice (1min)*	7.7b	0.60b	0.65c
Yellow milled rice (5 min)*	7.7b	0.62b	0.66C
Yellow milled rice (15 min)*	7.7b	0.67c	0.65c

At 14% moisture content, n =3.
Values with the same letter are not significantly different within each column at P < 0.05
*Processing time in autoclave

TABLE 5
Sensory evaluation acceptability scores for atoles from instant rice flours

Atoles	General appearance	Texture	Color	Consistency	Aroma -Flavor
Brown rice (1min)*	0.2884b	0.3312bc	0.2341b	0.1810b	0.0569b
Brown rice (5 min)*	0.2788b	0.3163bc	0.2090b	0.2373b	0.1282b
Brown rice (15min)*	0.3063b	0.2820c	0.1651b	0.1924b	0.1463b
Yellow milled rice (1min)*	0.7304a	0.5994a	0.4733a	0.5059a	0.5561a
Yellow milled rice (5 min)*	0.7482a	0.6031a	0.4784a	0.4620a	0.4353a
Yellow milled rice (15 min)*	0.6514a	0.5106ab	0.5043a	0.3484ab	0.5198a

Values with the same letter are not significantly different within each column at P < 0.05
*Processing time in autoclave

Sensory analysis. The descriptive sensory analysis used in this study provides a basis for determining the sensory characteristics affecting the acceptability and processing variables. Specific ingredient or process variables could be related to specific changes in the sensory characteristics of a product. The results of the descriptive sensory analysis of six samples of atoles prepared with instant flours processed under different conditions are reported in Table 5. The variable type of rice did have a significant effect on the acceptability scores. Atoles prepared with instant flours brown and yellow milled rice showed good acceptation with better acceptation for atoles from yellow milled rice. The instant flours were easily reconstitued with milk, with a minimum lump. The atoles prepared from milled rice with 5 minutes of processing had a better apperance, and color than, the other samples. The consistency and aroma-flavor of atoles from yellow milled rice processed during 1 minute were judged better and did not differ significantly from the other samples of yellow milled rice. Color is also an important quality characteristic of instan flours and food products. Statistical analysis of the sensory data indicated that the higher color values were obtained with atoles from yellow milled rice compared to atoles from brown rice. These results showed that hydrothermal process is an excellent mean of salvaging any rough rice that has been damaged by drying, weathering, or wetting. Also harvesting paddy rice at an optimum time, so important for milling raw is not important if it is desired for cooking.

CONCLUSIONS

The milling, cooking and processing quality of yellow milled rice was considered acceptable for preparation of instant flour to be used in atole elaboration. The hydrothermal process was effective in eliminate *Helminthosporium oryzae, Aspergillus* spp. and *Penicillum* spp initially present in paddy, yellow milled and comercial rice. The process evaluated unaffected the protein showed good characteristics of IAA, degree of gelatinization and color. The atoles from instant flours were judged acceptable by the panel members, with better acceptation for atoles from milled rice. The good characteristics of atoles from brown or yellow milled rice suggest that instant flours offers potential for instant drinks and its products not suffer from the presence of fermented grains.

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