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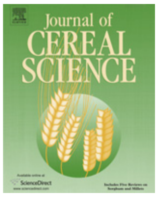

Rice-based pasta: A comparison between conventional pasta-making and extrusion-cooking

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ABSTRACT

Good quality gluten-free products continue to be in demand among the celiac community and the production of pasta from non-conventional raw materials is a major technological challenge. In this work, the effects of two different pasta-making processes (conventional and extrusion-cooking) were investigated on parboiled brown and milled rice flours. The two processes differentiated for extrusion temperature (conventional extrusion: 50 °C, max; extrusion-cooking: 115 °C), whereas the drying diagram was the same. Starch modifications induced by each pasta-making process were analyzed by using a Micro-ViscoAmylo-graph (MVAG), Differential Scanning Calorimetry (DSC), and X-ray Diffraction. The cooking quality was evaluated by weight increase, solid loss into the cooking water, and texture analysis. Pasta obtained from milled rice using the extrusion-cooking process was characterized by the best cooking behavior. In this sample, starch presented the highest peak and final viscosities, the highest gelatinization temperature and lower enthalpy value, and the lowest crystallinity. The cooking quality of pasta obtained from brown rice appeared less affected by the processing conditions. Therefore, the nature and intensity of starch modifications can be modulated by the processing conditions and might explain the different cooking behaviour of rice pasta.

1. Introduction

The replacement of gluten in cereal-based products presents a major technological challenge (Arendt et al., 2002). Two main approaches can be taken (Pagani, 1986). One is based on appropriate ingredients/additives suitable to produce a cohesive structure that can overcome the absence of gluten. In this regard, several additives/ingredients, including modified starches, gums, emulsifiers, proteins, and enzymes were used (Chillo et al., 2007; Lai, 2001; Yalcin and Basman, 2008; Sozer, 2009). Moreover, significant attention has been directed also towards the starch source, including rice, maize, sorghum, pseudocereals, and legume flours (Beta and Corke, 2001; Chillo et al., 2008; Mestres et al., 1988; Wang et al., 1999). A second approach focuses on the role of adequate processing conditions in order to promote new and efficacious starch organization able to substitute for the gluten network in the final product (Mestres et al., 1993; Resmini and Pagani, 1983). This procedure could be considered as a technological optimization of the ancient and still used processes for making Oriental-style rice noodles. In this case, the application of repeated heating and cooling treatments induces starch gelatinization and retrogradation phenomena, creating a starch network capable of standing up to cooking stresses (Pagani, 1986). The control of the extent of these phenomena is difficult and tricky to account for the use of pregelatinized non-gluten flours (Pagani, 1986). Moreover, starch noodles are frequently characterized by extreme springiness and hardness (Hormodok and Noomhorm, 2007).

Parboiling is a hydrothermal treatment wherein the main steps consist of soaking, steaming, and drying. During this process on paddy rice, kernels change their physicochemical, nutritional, and sensory properties: starch gelatinizes, part of the vitamins and minerals migrate towards the endosperm, and a lipid–amylose complex is formed, restricting starch swelling and amylose leaching during cooking (Bhattacharya, 2004). The modifications of starch organization are responsible for reducing stickiness and increasing hardness.

Abbreviations: BRF, Parboiled brown rice flour; BRP_A, Brown rice pasta obtained by conventional extrusion process; BRP_B, Brown rice pasta obtained by extrusion-cooking process; ΔH_{TS}, Gelatinization enthalpy expressed on total starch content; DSC, Differential Scanning Calorimetry; MRF, Parboiled milled rice flour; MRP_A, Milled rice pasta obtained by conventional extrusion; MRP_B, Milled rice pasta obtained by extrusion-cooking process; MVAG, Micro-ViscoAmylo-graph; TP, Temperature profile; Tc, Gelatinization conclusion temperature; To, Gelatinization onset temperature; Tp, Gelatinization peak temperature.

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The present study had two main goals. Firstly, the effect of processing parameters on starch granule organization was investigated by using various and complementary approaches. In this regard, rice parboiling was considered as a pre-processing suitable by itself to induce new macromolecular structure. The structure created is able to assure good cooking behavior in pasta products. The effects associated with the extrusion at different temperature were also examined. At the same time, the research investigated the role played by macromolecules other than starch, naturally present in rice, on the structural changes promoted by processing. For these purposes, starting from the same commercial paddy rice, two kinds of flour (brown and milled) were used for pasta production.

2. Experimental

2.1. Rice flours

Rice flours from brown and milled parboiled rice (Thai cultivar of commercial origin; amylose content 25%) were used in this study. Brown and milled rice flours were produced from the same batch of parboiled paddy rice, according to the conditions summarized by Bond (2004). The production of brown rice involved the removal of the husk from the dried kernels, by using a rubber-roll husker. Milled rice (or white rice) was produced with a further polishing step, by using a series of whiteners (REMO, Vertijet; Marco Technology Corporation, Miami, FL, USA). Both brown and milled rice kernels were then ground in order to produce flour with less than 250 μm particle size.

2.2. Rice pasta samples

Macaroni-shaped pasta was produced in the pilot-plant (50 kg/h) of DiSTAM, University of Milan. Flours from parboiled rice (brown or milled) and water were blended in order to produce a mixture with a final water content of 40%. After mixing (12–15 min), two different extrusion processes were applied. Conventional extrusion was carried out in a continuous press for semolina pasta production (Braibanti, Milano, Italy). A jacket with cold water kept dough temperature at about 50–55 °C at an extrusion pressure of 10–11 MPa.

A patented process (Grugni et al., 2009) was used to produce pasta by an extrusion-cooking process. The mixture was heat-treated for 2 min in a Progel® extruder (single screw; Braibanti, Milano, Italy) fed with steam at 115 °C. The heat-treated dough was extruded into small pellets (cylinder shape; 3 mm diameter), and then formed in a *macaroni* shape in the continuous extruder described for the conventional process. The four pasta samples were dried in an experimental drying cell (Braibanti, Milano, Italy) using a low-temperature drying cycle (50 °C for 14 h). All samples were stored at room temperature until analyzed.

2.3. Chemical analyses

The moisture and ash contents of the rice flours were determined according to official standard methods AACC 44-15A (2000) and AACC 08-12 (2001). Estimation of protein was done using an automated LECO Nitrogen Analyser (LECO FD-428, LECO Corporation, St Joseph, MI, USA), according to the AOAC Method 993.13 (1995). A value 5.95 was used as the conversion factor. Fat content was determined before (AACC 30-25; 2001) and after (AACC 30-10; 2001) acid hydrolysis. The soluble and insoluble fibre contents were determined by the enzymatic method of Prosky et al. (1988). All these determinations were made at least in duplicate. Total starch and damaged starch were determined enzymatically using the "Total Starch Assay Kit" (AACC 76-13, 2001) and the "Starch Damage Assay Kit" (AACC 76-31, 2001), respectively (Megazyme International Ireland Ltd., Bray Business Park, Bray, Co. Wicklow, Ireland). The results of these evaluations are the average of a minimum of four replicates.

2.4. Thermal properties

The thermal properties of rice flours and dried rice pasta samples were determined using a Perkin Elmer Differential Scanning Calorimeter (DSC-7/DX; Perkin Elmer, Cambridge, United Kingdom). A stainless steel pan was used for analysis. The equipment was calibrated using Indium. Distilled water was added to make a 1:3 (w/w) sample:water ratio. The pans were hermetically sealed and allowed to equilibrate 24 h at room temperature. Samples were heated from 25 to 180 °C at a rate of 10 °C/min. An empty steel pan was used as reference. The onset temperature (To,° C), peak temperature (Tp,°C), conclusion temperature (Tc,°C), and gelatinization enthalpy (ΔH, J/g) were determined using the software provided with the equipment. Gelatinization enthalpy expressed on total starch content (ΔH_{TS}, J/g) was also calculated. All measurements were replicated at least twice.

2.5. Pasting properties

The pasting profiles of flour and pasta samples were carried out in duplicate according to Mariotti et al. (2005), by using a Micro-Visco-Amylo-Graph (MVAG) (Brabender OHG, Duisburg, Germany). An aliquot of 15 g of the sample was dispersed in 100 mL of distilled water, scaling both flour and water weight on a 14% flour moisture basis. The pasting properties were evaluated under constant conditions (speed: 250 rpm; sensitivity: 300 cm gf) by using the following time–temperature profile: heating from 50 °C up to 95 °C; holding at 95 °C for 30 min; cooling from 95 °C to 50 °C; holding at 50 °C for 30 min, and cooling from 50 °C to 30 °C. The heating and cooling phases were carried out with a temperature gradient of 3 °C/min. The parameters of pasting properties were determined using the software provided with the instrument (Viscograph version 2.3.7).

2.6. Wide angle X-ray powder diffraction

Wide angle X-ray diffraction measurements of flour and pasta samples (0.1 g) were made with a Rigaku Powder Diffractometer equipment (Rigaku Co., Tokyo, Japan). The operational settings for the diffractometer were 40 mA and 40 kV. CuKα1 radiation ($\lambda = 1.54$ Å) was selected using a quartz monochromator. For this instrument, the diffractometer had a 0.5° divergence slit, a 0.33 mm receiving slit and a 0.5° scattering slit. The samples were scanned in the range 3–35° 2θ at a rate of 1° 2θ per second. Data were smoothed using Jade 6.5 software and were normalized to equal total scattering in 3–35° 2θ range.

2.7. Cooking quality

Cooking loss was evaluated by determining the amount of solids lost into cooking water (AACC 16–50, 2000). An aliquot of pasta sample was cooked in boiling natural spring water for cooking time (pasta:water ratio = 1:10) with no salt added. The optimum cooking time of rice pasta was evaluated as the time required for disappearance of the dry central core when gently squeezed between two glass plates (D'Egidio et al., 1990).

After cooking, the level of water was brought to the initial volume. Dry matter was determined on 25 ml of cooking water, dried to constant weight at 105 °C. The residue was weighed and

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Table 1
Chemical characterization of rice flours.

	Total starch	Protein	Crude fat		Ash	Fibre	
			Free	Total		Soluble	Insoluble
BRF	78.5 ± 0.8	6.8 ± 0.1	3.7 ± 0.1	3.8 ± 0.01	1.8 ± 0.03	1.0 ± 0.1	5.2 ± 0.5
MRF	83.5 ± 0.3	6.2 ± 0.2	1.2 ± 0.04	1.2 ± 0.04	0.9 ± 0.02	0.5 ± 0.05	1.8 ± 0.2

Data expressed as % dry basis.
BRF = parboiled brown rice flour; MRF = parboiled milled rice flour.

reported as percentage of the starting material. Results are expressed as grams of matter loss/100 g pasta d.b. Pasta weight increase due to cooking was evaluated by weighing pasta before and after cooking. The results were expressed as the ratio percentage between the weight increase and the weight of uncooked pasta.

2.8. *Textural characteristics*

Textural characteristics of cooked pasta were determined by using a Texture Analyzer TA.HD-plus (Stable Micro System Ltd., Godalming, United Kingdom), calibrated for a load cell of 250 kN. The analysis was repeated at least five times and for each replicate, 6 pieces of pasta were cooked at the optimal cooking time and analyzed using a Kramer cell (test speed of 0.67 mm/s). Firmness (expressed as the maximum strength necessary to pack the sample), shear force (expressed as the force necessary so that blades pass through the sample), and springiness (expressed as the area under the part of the curve related to compression-shear-extrusion) were calculated using Texture Exponent TEE32 software (v. 3.0.4.0).

2.9. *Statistical analysis*

The data was subjected to analysis of variance (ANOVA) to determine if there were statistically significant ($P < 0.05$) differences among the samples.

3. Results and discussion

3.1. *Rice flour composition*

Rice flour composition was reported in Table 1. In agreement with the literature (Champagne et al., 2004), the milling process induced a relevant increase in starch content and, at the same time, a pronounced decrease in protein, lipid, ash, and fibre, that are concentrated in the germ and bran layers. In fact, milled flour presented only 1/3 of fat and fibre amounts, compared to brown flour, whereas the ash reduction was about 50%.

3.2. *Cooking quality*

The cooking parameters of pasta samples were affected not only by the raw material but also by the extrusion temperature (Table 2). Milled rice pasta produced by using the extrusion-cooking process exhibited higher water absorption and lower cooking loss, compared to the pasta sample extruded using a conventional process. Mestres et al. (1993) also reported that corn pasta obtained by using a double-steaming process exhibited better cooking quality characteristics than pasta made through a mono-steaming process. Furthermore, milled pasta from extrusion-cooking exhibited higher firmness, shear force and springiness. The cooking behavior of milled rice pasta suggests that extrusion at high temperature created a new macromolecular structure that was more hydrophilic, and therefore, more suited to absorb a higher amount of water (75.9%). At the same time, the conditions applied during extrusion-cooking created a more continuous and less soluble structure, accounting for the low cooking loss (4.2%) and for improved texture of the cooked product (Table 2). In gluten-free pasta, solid loss during cooking is mostly due to solubilization of loosely bound gelatinized starch from the surface of the product. This phenomenon mainly depends on the degree of starch gelatinization and the strength of the retrograded starch network surrounding the gelatinized starch (Resmini and Pagani, 1983).

Regarding the conventional extrusion process, even using preheated flour, the temperature reached during the extrusion seems to be related to the formation of a less hydrophilic and more discontinuous structure among starch macromolecules. This accounts for a product characterized by lower values for firmness (525.5 N), shear force (304.8 N) and springiness (3131.3 N mm), that are more similar to those of a cooked semolina pasta (firmness: 488 N; shear force: 293 N; data not published).

The increase in cooking loss observed in pasta from brown rice was likely due to its higher fibre content, responsible for a weakening of the starch network. At the same time, the inclusion of fibre in the starch matrix partially reduced the extreme firmness and springiness found in pasta from milled rice flour (Table 2). The extrusion conditions also influenced the cooking quality of brown rice pasta. In particular, the positive effect of extrusion-cooking using brown flour was evident, even if the differences between conventional extrusion and extrusion-cooking were less marked than those with milled rice pasta (Table 2). The highest extrusion

Table 2
Rice pasta cooking quality.

	Water absorption (%)	Solid loss (%db)	Texture properties		
			Firmness (N)	Shear force (N)	Springiness (N mm)
MRP_A	61.8a	15.9d	525.5b	304.8b	3131.3b
MRP_B	75.9c	4.2a	1529.2d	752.5c	7062.0d
BRP_A	68.9bc	11.5c	367.5a	205.6a	2408.3a
BRP_B	62.4ab	10.0b	796.2c	381.0b	4482.7c

Means followed by different letters in a column are significantly different at $p < 0.05$.
MRP_A = milled rice pasta obtained by conventional extrusion; MRP_B = milled rice pasta obtained by extrusion-cooking process; BRP_A = brown rice pasta obtained by conventional extrusion; BRP_B = brown rice pasta obtained by extrusion-cooking process.

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temperature reduced the cooking loss (from 11.5% to 10%) and increased the cooked product firmness (from 2408.3 N to 4482.7 N). This behavior could be related to the formation of a polysaccharide network involving starch and non-starch polysaccharide molecules. According to Gualberto et al. (1997), the high physical stress during the extrusion-cooking reduces the amount of insoluble fibre. Therefore, the formation of a higher amount of soluble fibre after the extrusion-cooking could enable a strengthening of pasta structure, as supported by Tudorica et al. (2002) in durum wheat pasta.

3.3. Starch susceptibility to α-amylase

The damaged starch ~~assay~~ values ~~on an enzymatic test~~ quantify the amount of starch granules that are physically damaged during the milling process and therefore maybe hydrolyzed quickly by α-amylase. The damaged starch content in rice flour and pasta samples is provided in Table 3. Parboiled rice flours presented a damaged starch content equal to 8% d.b., approximately double to that of untreated rice flour (3.3–3.6% on total starch content; data not shown). The increase in α-amylase susceptibility in parboiled rice flour is surely due to the steaming step of the parboiling process.

The enzymatic susceptibility increased after the pasta-making process (Table 3). The damaged starch content was dependent on both the raw material and the technological process. In particular, the percentage of starch susceptible to α-amylase action in milled rice pasta was higher after the extrusion process compared to the conventional one, as a result of a different structure induced by temperature. In the extrusion-cooked product, the high temperature used with the process seems to promote a starch network more available to α-amylase hydrolysis.

The higher amount of fibre in brown rice pasta could be responsible for the reduction in starch accessibility observed in the sample pasta after α-amylase action (Table 3). A likely reason for this could be the formation of a protective coat around starch granules, thus delaying the starch enzymatic hydrolysis (Tudorica et al., 2002). Moreover, the damaged starch in brown rice pasta samples did not differ as a function of the process. As hypothesized before, the fibre amount in these pasta samples could interfere with starch during the pasta-making process, reducing the effect of the extrusion temperature on starch structure formation.

3.4. Pasting properties

Pasting properties of the flours and pasta are reported in Table 3. No significant differences were observed in the pasting behaviour of brown and milled rice flours. This suggests that rice parboiling before milling into flour resulted in relevant starch gelatinization. The flour treatment minimized the differences in pasting properties that are otherwise evident in untreated brown and milled rice flours. Brown and milled flours were obtained from the same paddy rice. Therefore, the differences in pasting profile of pasta samples can be related solely to starch changes during the pasta-making process and on protein, starch, and non-starch polysaccharide interactions ensuing from the processing.

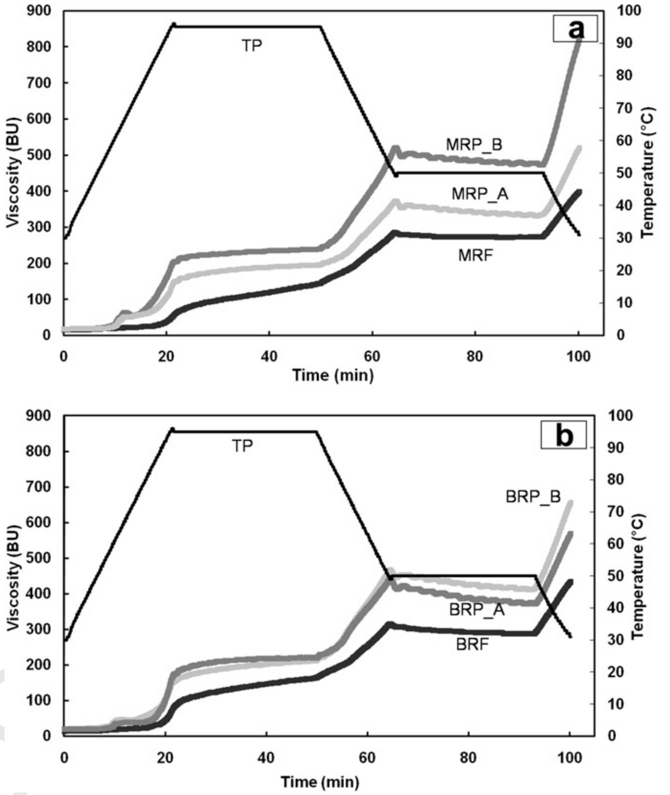

Fig. 1. Pasting profile of milled (a) and brown (b) rice flours and pasta samples. MRF = parboiled milled rice flour; MRP_A = milled rice pasta obtained by conventional extrusion; MRP_B = milled rice pasta obtained by extrusion-cooking process; BRF = parboiled brown rice flour; BRP_A = brown rice pasta obtained by conventional extrusion; BRP_B = brown rice pasta obtained by extrusion-cooking process; TP = Temperature profile.

Pasta samples presented a lower pasting temperature and higher peak and final viscosities compared to those of the respective rice flours (Table 3). Vansteelandt and Delcour (1998) reported similar observations for pasta obtained from semolina. Pasta samples also exhibited a small plateau prior to the onset of pasting viscosity (Fig. 1). This plateau was more evident in milled rice pasta made by extrusion-cooking than in pasta obtained by using the conventional process or in brown rice pasta, suggesting that both the nature of the raw materials and the pasta-making process affect starch structure and, consequently, pasting properties.

Table 3
Damaged Starch and pasting properties of rice flours and rice pasta samples.

	Damaged starch (% d.b.)	Pasting temperature (°C)	Viscosity at 95 °C (BU)	Max viscosity during heating (BU)	Final viscosity (BU)	Setback (BU)
MRF	7.7b	75.5b	63.5a	146.7a	378.0a	231.0a
MRP_A	10.8d	61.9a	129.5b	195.0b	521.5b	326.0b
MRP_B	12.5e	59.1a	187.0c	239.0c	825.0d	583.0d
BRF	6.6a	76.9b	52.0a	136.8a	357.7a	219.8a
BRP_A	9.1c	60.8a	135.0b	221.5c	558.5bc	336.5b
BRP_B	9.0c	58.9a	128.5b	212.9bc	657.5c	444.5c

Means followed by different letters in a column are significantly different at $p < 0.05$.
MRF = parboiled milled rice flour; MRP_A = milled rice pasta obtained by conventional extrusion; MRP_B = milled rice pasta obtained by extrusion-cooking process; BRF = parboiled brown rice flour; BRP_A = brown rice pasta obtained by conventional extrusion; BRP_B = brown rice pasta obtained by extrusion-cooking process.

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The differences in pasting properties were more apparent in milled rice pasta. Pasta made using the extrusion-cooking process exhibited a higher viscosity at 95 °C (187 BU), as well as after the heating step (239 BU), and at the end of the test (825 BU) compared to those of pasta made by conventional extrusion (129.5 BU, 195 BU, and 521.5 BU, respectively) (Table 3). The lower peak viscosity of pasta made by using the conventional process suggests that the starch was characterized by a lower water-holding capacity and granule swollen ability.

3.5. Thermal properties

Thermal properties of rice flours and pasta are presented in Table 4. Both brown and milled rice flours did not exhibit the typical peak associated with starch gelatinization, because starch gelatinization occurred during parboiling. These samples showed two broad peaks; a first one in the 47–71 °C interval, likely related to recrystallized amylopectin, and a second one from about 80 °C to 125 °C, likely related to the amylose–lipid complex (Lamberts et al., 2009). However, the two broad peaks suggest that in the pasta sample, starch granules with a different crystalline organization were present, accounting for the differences in melting temperatures.

Milled rice pasta made using the conventional process exhibited a peak in the 55–72 °C interval, with an enthalpy value of 6.1 J/g starch. The milled rice pasta made using the extrusion-cooking process exhibited a small peak (from 75 °C to 83 °C) with an enthalpy value of only 1.1 J/g starch. After extrusion-cooking, starch presented a high melting temperature, in comparison with pasta after conventional extrusion. In sample MRP_B, starch started to melt 20 °C after the sample obtained by the conventional process. Moreover, the melting phenomenon finished 10 °C later. The data obtained by DSC suggested that sample MRP_B requires high temperature values for melting (from 75.2 °C to 83.6 °C), resulting in a product that is more stable during heating. This feature can likely explain pasta behavior during cooking: the strong network in pasta obtained by extrusion-cooking accounted for the low cooking loss value (Table 2). Moreover, compared to pasta extruded in a conventional continuous press, sample MRP_B required less energy for melting (Table 4), suggesting that the crystalline order in this product was ~~higher~~ than that of sample MRP_A and thus further highlighting differences in the starch network established.

The thermal properties of brown rice pasta were markedly different not only from those of brown rice flour, but also from those of milled rice pasta. In particular, brown rice pasta exhibited temperature profiles similar to those of brown rice flour, regardless of the process (Table 4). However, the enthalpy values for pasta were significantly higher than that observed for the flour, and pasta made by using the extrusion-cooking process exhibited a higher enthalpy value than pasta made by using the conventional process. Both milled and brown rice pasta samples exhibited small peaks at a temperature higher than 100 °C. However, pasta made by using the conventional process exhibited a distinct peak, while the pasta made by using the extrusion process appeared to have a multi-endothermal peak (data not shown). Lamberts et al. (2009) reported that two different amylose–lipid complexes can be formed depending on the crystallization temperature; complex I with a melting temperature below 100 °C and complex II with melting temperature above 100 °C. The presence of a multiple endothermal peak between 90 and 120 °C indicates a rearrangement of both amylose–lipid complex and starch chains during extrusion processing, that in turn resulted in the formation of crystallites of different stability.

Table 4
Thermal properties of rice flours and pasta samples.

	To (°C)	Tp (°C)	Tc (°C)	ΔH_{TS} (J/g)
MRF	47.8a	56.0a	65.7a	4.3bc
MRP_A	55.4b	63.9c	72.5b	6.1c
MRP_B	75.2c	78.8d	83.6c	1.1a
BRF	47.0a	59.5ab	71.5b	3.9b
BRP_A	46.4a	62.0bc	72.6b	11.4d
BRP_B	46.2a	59.7ab	79.4c	14.4e

Means followed by different letters in a column are significantly different at $p < 0.05$.
To = gelatinization onset temperature; Tp = gelatinization peak temperature; Tc = gelatinization conclusion temperature; ΔH_{TS} = gelatinization enthalpy expressed on total starch content; MRF = parboiled milled rice flour; MRP_A = milled rice pasta obtained by conventional extrusion; MRP_B = milled rice pasta obtained by extrusion-cooking process; BRF = parboiled brown rice flour; BRP_A = brown rice pasta obtained by conventional extrusion; BRP_B = brown rice pasta obtained by extrusion-cooking process.

3.6. Crystalline order

The X-ray diffractograms of rice flours and pasta samples are shown in Fig. 2. All the samples showed a typical A-type diffraction pattern with peaks at about 15° and 23°, and doublets at 17° and 18° 2θ.

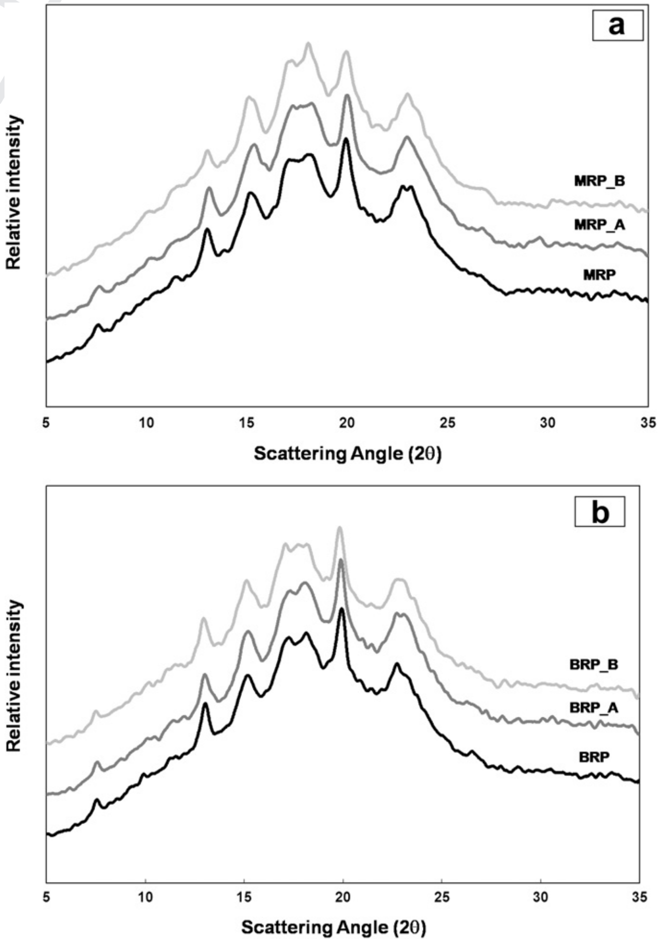

Fig. 2. X-ray diffractograms of milled (a) and brown (b) rice pasta. MRF = parboiled milled rice flour; MRP_A = milled rice pasta obtained by conventional extrusion; MRP_B = milled rice pasta obtained by extrusion-cooking process; BRF = parboiled brown rice flour; BRP_A = brown rice pasta obtained by conventional extrusion; BRP_B = brown rice pasta obtained by extrusion-cooking process.

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Milled pasta from the conventional extrusion showed a crystalline pattern similar to those observed in parboiled milled rice flour (Fig. 2a). Peaks were observed at 7°, 13° and 20° 2θ, representative of single helical amylose–lipd complexes, both in the treated rice flour and pasta from conventional extrusion. The presence of a 2θ peak at 13° also suggests gelatinization or loss of crystallinity of starch (Kadan and Pepperman, 2002). Compared to pasta from extrusion-cooking, in the sample from conventional extrusion, peaks at 13 and 20° 2θ appeared narrower, suggesting that in this sample the ~~double~~ helices were organized in a more packed structure. The result supported what DSC analysis suggested: the more packed structure required higher energy to melt the ~~double~~ helices (Table 4). On the contrary, the extrusion-cooking was responsible for the formation of a starch structure very different compared to those of flour. In particular, the intensity of peaks at 7°, 13° and 20° decreased in extrusion-cooked pasta suggesting a decrease in crystalline packing due to the extrusion temperature.

In contrast, the X-ray diffractograms of brown rice pasta samples showed that the crystalline pattern was unchanged after the pasta-making process. Thus, in this case, the process used to make pasta did not affect the crystalline order (Fig. 2b). In fact, the peaks detected in both pasta samples are characterized by the same scattering angle and the same intensity as that observed in the corresponding flour.

4. Conclusions

Since starch is the major component of the rice kernel, the change of its physicochemical properties during pasta-making processes will dominate the properties of rice pasta. Despite the dramatic changes induced by the parboiling process, new and different (according to the extrusion conditions) starch molecule rearrangements were observed in the dried pasta. Pasting and thermal properties, and crystalline order suggest a different organization of starch granules in milled rice pasta, accounting for the different cooking quality. In particular, conventional extrusion seems to induce the perfection of the small crystalline regions resulting in a low water absorption. On the contrary, the extrusion-cooking process caused strong interactions of amylopectin and/or amylose. Consequently, the product had a low cooking loss but a high firmness.

Further studies are underway to optimize both the pasta-making process and formulation in order to reduce the hardness of the cooked product, while keeping as low as possible the cooking loss. Also, regarding brown rice pasta, the role of fibre and of its interactions with starch seems to warrant investigation, also in view of the ever increasing popularity of high-fibre pasta and of the associated technological problems.

Uncited references

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