LWT - Food Science and Technology 54 (2013) 229–235

Contents lists available at SciVerse ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Cooking behavior of rice pasta: Effect of thermal treatments and extrusion conditions

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ARTICLE INFO

Article history:
Received 16 November 2011
Received in revised form
3 July 2012
Accepted 5 May 2013

Keywords:
Rice
Pre-gelatinization
Parboiling
Gluten-free pasta
Cooking quality

ABSTRACT

The effects of pre-gelatinization, mild and severe parboiling processes on paddy rice and the utilization of the corresponding flours (PGF, MPF, and SPF) for gluten-free (GF) pasta-making were investigated. Flour from native rice (NF) was considered as a control. Two pasta-making processes (extrusion-cooking and conventional extrusion) were carried out and seven GF pasta samples, with different thermal treatments without the addition of additives, were obtained. The thermal treatments affected the physical properties and the susceptibility to α-amylase hydrolysis of rice flours to different extents. The loss of starch granule integrity during the pre-gelatinization process promoted high viscosity at 30 °C and dramatically increased the mass of absorbed water, the amount of soluble components leached out from the granules and the fraction of starch quickly hydrolyzed by α-amylase. Compared to pre-gelatinization, both parboiling processes induced lower pasting viscosity at any temperature, enzymatic susceptibility, and hydration. The magnitude of these changes significantly increased with the severity of the parboiling treatment. The lowest value for cooking loss was detected for samples prepared by 100% SPF (extrusion-cooking) or by mixture of SPF and PGF (50:50) (conventional extrusion). Nevertheless, the extrusion-cooking process promoted an extremely firm texture of cooked pasta when applied to parboiled flours.

1. Introduction

Rice flour is widely used as a raw material to prepare gluten-free (GF) products for its bland taste, white color, high digestibility, and hypoallergenic properties (Rosell & Marco, 2008). However, in spite of its advantages, rice is low in protein and has relatively poor technological properties for interacting and developing a cohesive network.

Up to now, GF pasta made from rice flour has usually been prepared in one of two ways (Pagani, 1986). In the first approach, native rice flour is treated with steam and extruded at high temperatures (more than 100 °C) for promoting starch gelatinization directly inside the extruder-cooker. The second approach focuses on the use of pre-gelatinized flours, in which starch is already mostly gelatinized; the pre-treated flour can be formed into pasta by the continuous extrusion press commonly used in durum wheat semolina pasta-making. In this regard, annealing and heat-moisture treatments have been proposed for rice flour and/or cereal starch to induce new physiochemical properties. Because it is easy to use, pre-gelatinized flour is the most commonly used in industrial GF pasta production. Even if the effects of pre-gelatinization on starch from different sources (cassava, corn, rice, etc.) have been extensively investigated (Anastasiades, Thanou, Loulis, Stapatoris & Karapantsios, 2002; Lai, 2001; Lai & Cheng, 2004; Nakorn, Tongdang & Sirivongpaisal, 2009; Perez-Sira & González-Parada, 1997; Vallous, Gavrielidou, Karapantsios & Kostoglou, 2002), there is not much information about the relationship between the induced starch properties and rheological properties of pre-gelatinized flour or its suitability for pasta-making or its cooking behavior.

Recently, the use of flour from parboiled rice as a raw material for pasta products was proposed (Grugni, Mazzini, Viazzo&Viazzo, 2009), by obtaining GF pasta with a good cooking behavior (Marti, Seetharaman & Pagani, 2010) due to the particular starch arrangements in the product (Marti, Pagani & Seetharaman, 2011).

Abbreviations: BD, breakdown; BU, Brabender units; FV, final viscosity; GF, gluten-free; IV, initial viscosity; MPF, mild parboiled rice flour; NF, native rice flour; PaMPF_A, pasta from mild parboiled rice flour (extrusion-cooking); PaMPF_B, pasta from mild parboiled rice flour (conventional extrusion); PaNF_A, pasta from native rice flour (extrusion-cooking); PaPGF_B, pasta from pregelatinized rice flour (conventional extrusion); PaSPF_A, pasta from severe parboiled rice flour (extrusion-cooking); PaSPF_B, pasta from severe parboiled rice flour (conventional extrusion); PaSPF + PGF_B, pasta from severe parboiled and pregelatinized rice flour (50:50) (conventional extrusion); PGF, pregelatinized rice flour; PT, pasting temperature; PV, peak viscosity; SB, setback; SP, swelling power; SPF, severe parboiled rice flour; WAI, water absorption index; WSI, water solubility index.

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http://dx.doi.org/10.1016/j.lwt.2013.05.008

The first objective of this study was to investigate the effects of three heating processes (pre-gelatinization and two parboiling processes differing in their steeping temperature) on rice flour properties, with particular attention to starch properties; the latter were evaluated by enzymatic and rheological approaches. Then, the relationship between starch properties and cooking behavior of the pasta samples was studied. The experimental products were prepared according to the two technologies currently used in the GF field, avoiding the addition of any additives (modified starches, gums, emulsifiers, etc.) to determine if physical treatments of raw rice materials can induce effective macromolecular organization, thus assuring the formation of a cohesive and regular starchy network.

2. Experimental

2.1. Rice flours and pasta production

Four types of rice flours were produced with different thermal treatments (Fig. 1). Starting from Indica type cultivar of commercial origin, a native flour (NF; total starch: 84 g/100 g db, AACC 76-13; amylose: 25 g/100 g db, UNI, 1991; Standard UNI-ISO 6647; protein: 6.8 g/100 g db, AOAC, 1999; Method *n*. 920.87; ash: 0.66 g/100 g db, AACC 08-12) was produced by directly grinding the milled (or white) rice (particle size <500 μm). The pre-gelatinized flour (PGF) was obtained by treating with steam the milled rice kernels ($3.5*10^5$ Pa, 115 °C, 45 min; cooling: 40 °C). The same paddy rice was also subjected to two parboiling treatments, namely "mild" (steeping: 60 °C; steaming: $1.1*10^5$ Pa, 100 °C; drying: 50 °C, 5 h) and "severe" (steeping: 70 °C; steaming: $1.1*10^5$ Pa, 100 °C; drying: 50 °C, 5 h) parboiling. Both parboiled rice types were milled and then ground (particle size <500 μm) for obtaining mild (MPF) and severe (SPF) parboiled rice flour. The moisture content (AACC, 44-01, 2001) of rice flours was 13.4, 10.3, 12.3, and 12.4 g/100 g for NF, PGF, MPF, and SPF, respectively. Pasta from NF was prepared by using the extrusion-cooking process (Process A), as shown in Fig 2a.

Rice flour (NF) and water at 60 °C were blended in order to produce a mixture with a final moisture of 40 g/100 g inside a premixer. The mixture was heated by steam at $2.5*10^5$ Pa (120 °C) for 10 min in a Progel extruder (500 kg/h; 25 rpm; single-screw type, Braibanti, Milano, Italy). After that, the pre-treated dough was subjected to a first extrusion at 120 °C (extrusion-cooking) and formed into pellets (small cylinders of 2–3 mm diameter). After this first extrusion step, the pellets were transferred into a lab-scale extruder for semolina pasta (20 kg/h; MAC 30, Italpast, Parma, Italy), for the second extrusion step at 50 °C. Samples were formed into macaroni shape (7 mm external diameter) and dried in an experimental drying cell using a low-temperature drying cycle (50 °C max; 14 h).

Pasta from PGF was prepared using the conventional extrusion process for semolina (Process B; Fig. 2b). PGF and water (40 g/100 g dough moisture) mixture were formed into pasta in the lab scale extruder used for Process A, keeping the extrusion temperature at 50 °C. Pasta drying was carried out in the same manner for Process A. Only the presence of partially disorganized starch, such as in MPF and SPF, guarantees the formation of pasta by using both Process A and B.

Another sample was prepared by adding the PGF to the SPF at a level of 50% and the mixture was extruded by using Process B.

To summarize, starting from the same commercial rice type, seven pasta samples (all of the same shape) were prepared and stored at room temperature until analyzed.

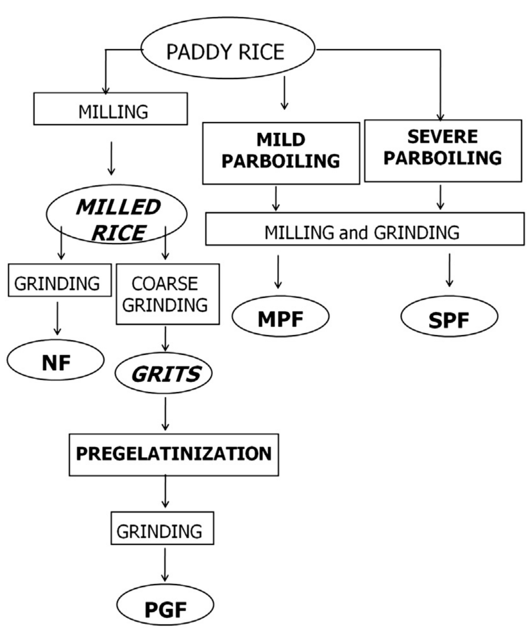

Fig. 1. Milling and heat-treatments on rice to obtain flours for pasta-making.

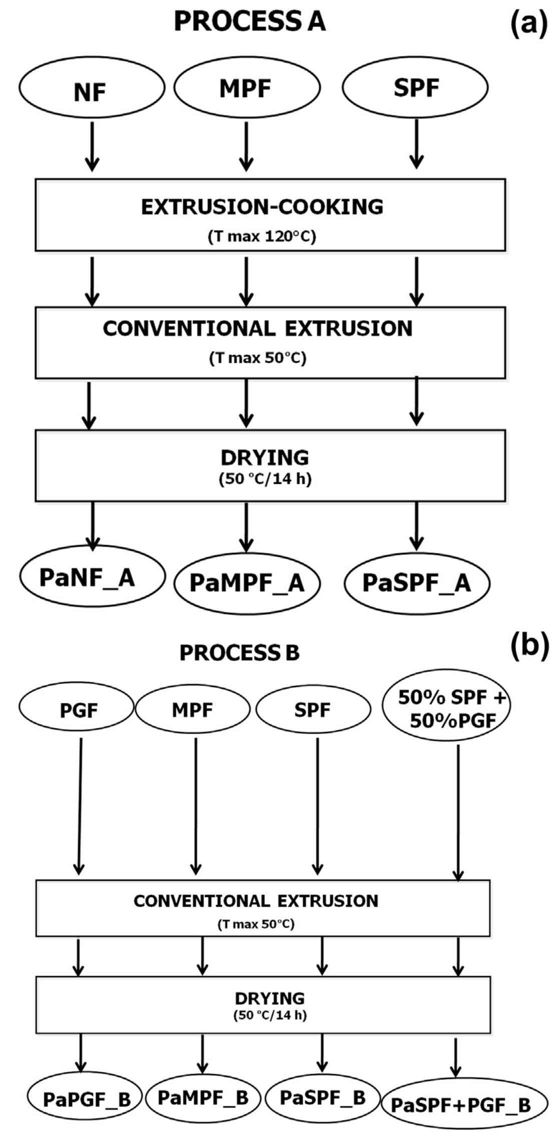

Fig. 2. Processing conditions for experimental rice pasta-making: (a) extrusion-cooking; (b) conventional extrusion.