Isolation and characterization of starch from industrial fresh pasta by-product and its potential use in sugar-snap cookie making

Soumaya Zouari Ellouzi · Dorra Driss · Sameh Maktouf ·
Mohamed Neifar · Ameni Kobbi · Hounaida Kamoun ·
Semia Ellouze Chaabouni · Raoudha Ellouze Ghorbel

Revised: 1 September 2014 / Accepted: 15 September 2014 / Published online: 6 December 2014

© Association of Food Scientists & Technologists (India) 2014

Abstract In this paper, starch was extracted from fresh pasta by-product (*PS*) and its chemical composition and physical and microscopic characteristics were determined. Commercial wheat starch (*CS*) was used as reference. In general, purity was similar between starches studied. However, others compounds such as protein, lipid and ash were significantly different. *PS* starch granules had large lenticular-shape (25–33 μm) and small spherical-shape (5–8 μm). The pH and color of *PS* starch were similar to those reported for *CS* starch. On the other hand, *PS* had higher water absorption capacity, viscosity and cooking stability than *CS*. The gelatinization temperature of *PS* was similar to that of *CS* (60 and 61 °C). At high temperature (90 °C) both starches had similar rheological behavior. The results achieved suggest that *PS* starch has potential for application in food systems requiring high processing temperatures such the manufacture of sugar snap cookie. The effects of *PS* starch addition on the dough making stage and the final cookie quality were analyzed.

Improvements in dough cohesiveness (24 %) and springiness (10 %) were significant relative to those of *CS* dough. Texture profile analysis confirmed the rheological changes.

Keywords Fresh pasta by-product · Starch · Structural properties · Rheological behavior · Cookie making

Introduction

The pasta-making process consists of few steps starting from mixing and kneading of semolina and water to supply the mechanical energy necessary to form viscoelastic dough. The latter is then formed into the desired shape with either an extrusion or a lamination step. The product, characterized by its own shape, may then be stabilized with a pasteurization treatment and sold as “Fresh Pasta” or it can be dried to obtain “Pasta” (Carini et al. 2009). In Tunisia, the durum wheat pasta processing industry annually generates a huge amount of a fresh pasta by-product (approximately 1,000 t) which is an important starch source (Ellouze-Ghorbel et al. 2010).

Starch is the main storage carbohydrate of plants. It is deposited as insoluble, semi-crystalline granules in storage tissues (grains, tubers, roots) and it also occurs to a lesser extent in most vegetative tissues of plants (Lindeboom et al. 2004; Copeland et al. 2009). It is a major determinant of wheat yield; it accounts for 65–75 % of wheat grain weight and can exceed 80 % of endosperm weight (Labuschagne et al. 2009). Starch is made up of two polymers of D-glucose: amylose and amylopectin (Lindeboom et al. 2004) which their proportional variations and their size distribution could affect its functional properties (Dengate 1984) and therefore the starch marketing (Swinkels 1985). Starch varies greatly in form and functionality between and within botanical species, and even from the same plant cultivar grown under different conditions. This

Dorra Driss and Sameh Maktouf have equally participated to this work.

S. Z. Ellouzi (✉) · D. Driss · S. Maktouf · A. Kobbi ·

S. E. Chaabouni · R. E. Ghorbel

Unité d’Enzymes et Bioconversion, Ecole Nationale d’Ingénieurs de
Sfax, Route de Soukra, 3038 Sfax, Tunisia
e-mail: soumayazouari@gmail.com

M. Neifar

Laboratoire des Microorganismes et Biomolécules Actives, Faculté
des Sciences de Tunis, Campus Universitaire, 2092El-ManarII,
Tunis, Tunisia

S. E. Chaabouni · R. E. Ghorbel

Unité de service commun bioréacteur couplé à un ultrafiltre, Ecole
Nationale d’Ingénieurs de Sfax, Route de Soukra 3038, Sfax, Tunisia

A. Kobbi · H. Kamoun

Industrie de fabrication des pâtes alimentaires et du couscous CDS,
Zone Industrielle, Zone Poudrière 1, Sfax, Tunisia

variability provides starches of diverse properties, but it can also cause problems in processing due to inconsistency of raw materials (Copeland et al. 2009).

Starch is present as a macro-constituent in many foods and its properties and interactions with other constituents, particularly water and lipids, are of interest to the food industry (Perry et al. 2007). Approximately, 60 million tones of starch are extracted annually worldwide from various cereal, tuber and root crops, of which roughly 40 % in pharmaceutical and non-edible purposes, such as fertilizers, paper, textiles, bioplastics and 60 % is used in food (e.g. bakery products, sauces, confectionery, sugar syrups, fat replacers) (Burrell 2003). Thus, starch has been used as an ingredient and provides texture of several foods as thickener, adhesive, gelling agent, emulsion and foam stabilizer and water retention agents (Friedman 1995). Moreover, starch properties might give useful information related to the quality of wheat products such as cookies (Ozturk et al. 2008).

Cookies are baked products which generally contain three major ingredients, i.e. flour, sugar and fat, and have low final water contents (Chevallier et al. 2000). More in particular, sugar-snap cookies typically contain 47.5–54 % flour, 33.3–42 % sugar and 9.4–18 % fat (Wade 1988). The role of starch, gluten, lipids and water-soluble has been often examined in cookie making by the fractionation/ reconstitution technique and interchange studies (Fustier et al. 2008). Cookies baked from the blends of such flour fractions may match closely the spread of those made with the native flour. Previous reconstitution studies, conducted on gluten, crude starch and water-soluble fractions isolated from various flour streams with markedly different biochemical composition revealed that the biscuits exhibited acceptable dimensional characteristics and surface appearance compared with their native flour counterparts, in a semi-sweet biscuit recipe with a flour: sugar: fat: water ratio of 100:30:8:36 on 14 % flour basis (Fustier et al. 2007). However, little attention has been paid to the role of gluten, water soluble and starch fractions and, more specifically, on the effect of their constituents on dough rheology and biscuit quality (Fustier et al. 2008).

Since in literature, there are not reports describing the use of pasta by-products, as a non-conventional starch source, the aim of the present work is to extract and characterize fresh pasta by-product starch, as an alternative for application in sugar snap cookie making.

Materials and methods

Materials

The fresh pasta by-product [moisture content: 26.11 %, protein content ($N \times 5.7$): 15.54 % on dry basis (db), starch content: 78.49 % (db), ash content: 1.14 % and lipid content:

0.51 %] was kindly supplied by a Tunisian pasta industry (DIARI-SPIGA, Sfax, Tunisia). It was preserved in hermetic bags at -20°C for 10 days, at most, prior to the extraction of starch. The commercial wheat starch (CS) was from Tate & Lyle (Aalst, Belgium) and the commercial gluten (CG) was a gift from Roquette Company (Keokuk, IL). Margarine, sugar and sodium bicarbonate were purchased from a local market. All the chemicals and reagents used in this work were food grade or reagent grade.

Starch extraction

Starch was extracted from the fresh pasta by-product by hand washing method according to the method of Ellouze-Ghorbel et al. (2010) with a minor modification. This method consisted in keeping the gluten in the paste residue and having the starch pulled by the water run-off. The starch was kept in decantation, then, centrifuged at $4,000 \times g$ for 10 min. The wet starch was allowed to dry at 40°C for 24–48 h. The dry starch was then transferred to a mortar and crushed with a pestle (Kaldy et al. 1993). The resulting powder was sieved to pass through a $100\text{ }\mu\text{m}$ screen and stored in vacuo at 4°C .

Chemical composition

Total nitrogen, total lipid, moisture and ash contents of starch samples were analyzed according to AACC standard methods 46–30, 30–10, 44–19 and 08–01, respectively (AACC 2000). Total protein was calculated using a multiple number of $N \times 5.7$. The starch content was evaluated by an enzymatic colorimetric method (Khabou et al. 1996). Damaged starch was analyzed iodometrically by a Chopin RFT (Seedburo Equipment Co., Chicago, IL) with the original calibration curve provided by Chopin Co. according to AACC standard method 76–31 (AACC 1992). Finally, reducing sugar was evaluated using the method of Miller (1959).

pH determination

A starch–water dispersion at 1 % (w/v) at room temperature was prepared, pH was determined using a Metrohm 827 potentiometer (Pérez-Pacheco et al. 2014).

Color measurement

The surface color of starch samples (PS and CS) was determined by using a chroma meter Minolta CR-300 (Minolta Chroma Meter, Osaka, Japan). Three color values (L^* , a^* and b^*) were measured. The L^* value indicates the lightness, 0–100 representing dark to light. The a^* value gives the degree of the red–green color, with a higher positive a^* value indicating more redness. The b^* value indicates the degree of the yellow–blue color, with a higher positive b^* value indicating

more yellowness. The instrument was standardized against a white tile before use.

Scanning electron microscopy (SEM)

Electron micrographs of the starch granules were acquired with a Philips XL30 scanning electron microscope (Philips, Leimeil-Brevannes, France). Starch samples were stuck on a specimen holder using a silver plate, and then coated with gold by Ion Sputter (Bio-Rad SC-500, Hercules, CA). The specimens obtained were imaged under an accelerating voltage of 20 kV.

X-ray diffraction (XRD) measurements

X-ray diffraction studies of the starch samples were performed using X-ray diffraction (XRD) theta–theta diffractometer (Bruker axs D8, Germany). The XRD experiments were carried out in symmetrical reflection mode with $\text{CuK}\alpha$ radiation ($1.54\text{\AA}$) using Göbel Mirror bent gradient multilayer optics. The scattered intensities were measured with a scintillation counter. The angular range was from 5 to 60° , in steps of 0.05° , and the measuring time was 10 s/step. The instrumental broadening was estimated as 0.03° , from a reflection of silicon. The crystalline component was determined from the diffraction pattern by subtracting the amorphous component (Krogars et al. 2003).

Functional properties

Water absorption capacity (WAC) and Oil absorption capacity (OAC) were measured using the method of Beuchat (1977) and Abdul-Hamdi and Luan (2000) respectively. They were expressed as gram of water or oil retained by one gram of the sample on a dry basis.

Rheological properties of starch

Mixing and baking behaviors of both starches dough (PS and CS) were studied using a Mixolab (Chopin Technologies, Villeneuve la Garenne, France) with the standard “Chopin+” protocol, which allows mixing the dough under controlled temperature and also a temperature sweep until 90°C followed by a cooling step. It measures in real time the torque (expressed in Nm) produced by passage of the dough between the kneading arms, thus allowing the study of the physico-chemical behavior of the constituted dough (Rosell et al. 2007; Wang et al. 2010). For the assays, 90 g of starch were placed into the Mixolab bowl and mixed. After tempering the solid, the water required for optimum consistency was added. The hydration of two samples was fixed at 65 %. The settings used in the test were initial equilibrium at 30°C for 8 min heating to 90°C for 15 min (at a rate of $4^\circ\text{C}/\text{min}$), holding at

90°C for 7 min cooling to 50°C over 5 min (at a rate of $4^\circ\text{C}/\text{min}$) and holding at 50°C for 5 min. The mixing speed was kept constant at 80 rpm. The process was repeated three times for each starch sample.

Parameters that were obtained from the recorded curve were the maximum point of the first mixing stage (C1) which is proportional to water absorption (%) or the percentage of water required for the dough to produce a torque of 1.1 ± 0.07 Nm; dough development time (min:s) or the time to reach the maximum torque at 30°C ; stability (min:s) or the elapsed time at which the torque produced is kept at 1.1 Nm; the minimum torque (C2) shows the protein behavior when the dough is heated to a high temperature. Peak viscosity of peak torque (C3), cooking stability or the torque at the end of the holding period at 90°C (C4) and starch retrogradation or the torque at the end of the test (C5) measured the starch behavior of dough during heating, holding and cooling, respectively. In addition, the angles between ascending and descending curves were calculated to determine α and β , which can measure the speed of the weakening of the protein network due to the effects of heat and starching speed, respectively (Bonet et al. 2006). Besides these parameters, mechanical weakening, thermal weakening and setback were also calculated. Mechanical weakening is the torque difference between the maximum torque at 30°C and the torque at the end of the holding time at 30°C . Thermal weakening is the difference between the torque at the end of the holding time at 30°C and the minimum torque. Setback is recorded as the difference between C5 and C4 (Rosell et al. 2007). However some of parameters were analyzed: C1, C3, C4, C5, C3-C4, C5-C6, dough development time and stability.

Application of starch in cookie making

Preparation of starch-gluten blends

Starch-Gluten (PS-Gluten or CS-Gluten) blends were prepared by dry mixing of starch and gluten in ratio of 88:12 % according to the natural ratio in the flour (Chen et al. 2010) based on dry weight of starch and gluten. However, cookie's texture was unacceptable texture which is a very important element for the initial acceptability of baked goods by consumers. Therefore, only Starch-Gluten blends prepared in ratios 92:8 % and 90:10 % were selected (Pareyt et al. 2008).

Cookie making

The cookie dough formulations were prepared according to the method of Pareyt et al. (2008). 90 g of margarine and 144 g of sugar were creamed for 3 min with scraping down every minute. Deionised water (24 g) was then added, and mixing was carried out for 2 min with intermediate scraping. At the end, the cream was scraped down. G-S blends (200 g) and

sodium bicarbonate (4 g) were added, followed by mixing for 2 min, with scraping down every 30 s. A kitchen mixer (Moulinex, Supermix 150, France) was used. Dough pieces were slightly flattened with the palm of the hand and sheeted with a National Mfg. sheeter (gap width 0.6 cm). Cookie dough was cut with a circular cookie cutter (inside diameter 35 mm) and dough pieces were immediately baked for 15 min at 160 °C in an electrically heated rotary oven (National Mfg.) on a stamped steel baking tray with baking paper. At least 3 pans of 4 cookies were baked per test and these were all used for further quality assessment. Baked cookies were removed from the oven and their diameter was measured (AACC 1983) after cooling for 30 min.

Instrumental texture determination

Dough hardness, cohesiveness, springiness and adhesiveness were determined with the texture analyzer (texture analyzer: Lloyd Instruments, Leicester, England) using the texture profile analyse (TPA). Eight dough pieces (25 mm in diameter, 20 mm in height) of cookie dough were compressed twice to 50 % of their original height at a constant crosshead speed of 50 mm/min with a cylindrical probe (9.5 mm in diameter).

Cookie texture was measured using the three point bending test in which two beams at a known distance support the product. A third beam is brought down through the product at a point equidistant from both support beams. Downward movement of the top beam, being a metal blade (70 mm wide and 3 mm thick), is continued until the product breaks (snaps) (Gaines et al. 1992). The Texture Analyzer, with the 5 kg load cell, was used in the measure force in compression mode. The base gap of the two support beams was adjusted to 61.6 mm. Each cookie was centered on the base and the travel distance of the blade was 30 mm. Pre-test, test and post test speeds were respectively 2.5, 2.0 and 10.0 mm/s. The peak force, an index of cookie break strength, was then measured. Texture experiments were replicated on at least 8 cookies.

The texture analyses were interfaced with a computer, which controlled the instruments and analyzed the data using the software supplied by Texture Technologies Corp. (Scarsdale, NY).

Color observation of cookies

The surface color of cookies was determined by using Hunter Lab system with a colorimeter (Minolta Chroma Meter CR-300, Osaka, Japan).

Statistical analyses

Data are the means of at least triplicate determinations and they are expressed as means $\pm$ SD, with the exception of color parameters which are determined singly. Statistical analyses were performed using student's test with $P<0.05$ as the minimal level of significance.

The means for dough texture and cookie characteristics were statistically analyzed by SPSS software (version 17.0; SPSS Inc., Chicago, IL, USA) using Duncan test performed after analysis of variance (ANOVA).

Results and discussion

Chemical composition

Table 1 showed the chemical composition (average values) of pasta by-product starch and commercial starch. *PS* showed a similar crude starch content (95.05 ± 2.17) with *CS* (91.26 ± 3.45). These values demonstrated that the purity of extracted starch was similar to the commercial one, indicating that *PS* could be considered as a novel non-conventional source of high purity starch. Furthermore, protein content was higher for *PS* than for *CS* (1.88 ± 0.19 and 1.61 ± 0.06 %, respectively). There is evidence that starch-wheat protein interactions in dough and starch play an active role in determining dough rheological characteristics (Van Der Borgh et al. 2005). A significant difference ($P<0.05$) was observed between *PS* and *CS* ash contents (1.15 ± 0.02 versus 1.43 ± 0.01 per 100 g of dry weight, respectively). It has been suggested that mineral matter influence a number of starch characteristics such as paste viscosity (Moorthy 2001). *PS* was richer in lipid content than *CS* (1.79 ± 0.11 , 1.15 ± 0.09 , respectively). Lipids may be reduced stickiness of starchy

Table 1 Chemical composition of starch samples (*PS* and *CS*)

Starch	Yield starch	Chemical composition						
		Moisture(%)	Starch(%d.b)	Protein (%d.b)	Ash (%d.b)	Lipid (%d.b)	Reducing sugar (%d.b)	Damaged starch (UCD)
<i>PS</i>	71	12.31 ± 0.98	95.05 ± 2.17	1.88 ± 0.19	1.15 ± 0.02	1.79 ± 0.11	0.86 ± 0.03	21 ± 2.58
<i>CS</i>	na	13.60 ± 0.14	91.26 ± 3.45	1.61 ± 0.06	1.43 ± 0.01	1.15 ± 0.09	0.42 ± 0.08	11.9 ± 1.24

Data are means $\pm$ standard error

n.a. not available

Table 2 Physicochemical characteristics and functional properties of starch samples (*PS* and *CS*)

Starch	pH	Color			Functional properties (g/g)	
		L*	a*	b*	WAC	OAC
<i>PS</i>	7.05±0.07	91.58	−0.77	2.47	0.679±0.037	1.06±0.02
<i>CS</i>	6.98±0.03	90.57	−0.71	2.46	0.467±0.021	1.10±0.08

Data are means±standard error

foods, improved freeze-thaw stability, to retard staling in biscuits and as dough conditioners (Copeland et al. 2009). Also, lipids can play an important role on dough development as they can interact with the protein and starch matrix (Fustier et al. 2008). The moisture content of the starches under study was <14 %, which is acceptable (Wolfgang et al. 1999), because commercially up to 20 % of moisture is allowed in starch as raw material (Pérez-Pacheco et al. 2014). The chemical compositions of *PS* and *CS* were in agreement with those of Copeland et al. (2009) who reported that dry starch usually contained approximately 90 % starch, up to 10 % moisture and varying amounts of protein, lipid and minerals. Results also showed that damaged starch content of *PS* was twice than *CS* (21±2.58, 11.9±1.24 UCD, respectively). The level of damaged starch depends on the severity of grinding and hardness of the wheat (Van Der Borght et al. 2005). The reducing sugar content decreased from 0.86±0.03 % for *PS* to 0.42±0.08 % for *CS*. There is evidence that reducing sugar affect cooked products color (Gazmuri and Bouchon 2009).

Physicochemical characteristics

Table 2 shows the physicochemical characteristics of *PS* and *CS*. From these results both starches presented neutral pH values of 7.05 and 6.98, respectively. pH favors the degree of ionization in the amylose and amylopectin chains (Pérez-Pacheco et al. 2014). The degree of ionization affects

hydration behavior in starches by facilitating the interaction between water molecules and amylose and amylopectin chains (Jimenez-Hernández et al. 2011). The by-product starch yield, based on dry weight, was 71 % dry weight. This value was in agreement with Van Der Borght et al. (2005) who proved that starch yield was an average of 69–79 %.

Color measurement

The color parameters, L*, a* and b* of *PS* were similar to those of *CS* (Table 2) which illustrated that ingredients of pasta were removed with water during starch extraction, resulting in bright starch (L* =91.58) like the commercial one (L*=90.57). Wang et al. (2000) have shown L* values higher than 90 for the starches tested in their study, and pointed out that starch with this value have a satisfactory lightness degree. Parameter a* was low with negative values in both starches (−0.77 and −0.71 for *PS* and *CS* respectively), and showed a light green chrome. The parameter b*, found positive for the two starches (2.47 and 2.46), is an index of light yellow chrome.

Scanning electron microscopy (SEM)

SEM of *PS* and *CS* granules are shown in Fig. 1. Distinct bimodal size distributions were observed for both starch samples: there is one population of large lenticular-shape granules ranging in size from about 25 to 33 µm known as A-granules, and another population of small spherical granules ranging from approximately 5 to 8 µm, which are referred to as B-granules. This diversity in granule size and morphology gives rise to diverse functional properties that result in many end-uses for these starches. These results were in agreement with those reported by Shinde et al. (2003); Sandhu et al. (2003). This diversity in granule size and morphology gives rise to

Fig. 1 Scanning electron microscopy of *PS* (I) and *CS* (II) (Scale bar=20 µm)

Fig. 2 X-ray diffraction patterns of *PS* and *CS*

diverse functional properties (Copeland et al. 2009) that result in many end-uses for these starches.

X-ray diffraction (XRD)

X-ray diffraction measurements were carried out to investigate the crystallinity of both extracted and commercial starches, and the results were presented in Fig. 2. For both starches (*PS* and *CS*), X-ray diffractograms exhibited an A-type diffraction pattern, typical of cereal starches (Shujun et al. 2005; Zhou et al. 2010). As it can be seen, *PS* and *CS* powders give two similar patterns with strong diffraction peaks (2θ) at approximate 15° and 23° 2θ , and an unresolved doublet appears at 17° and 18° (Fig. 2). This similarity between both starch samples suggests that the crystallinity of *PS* was not affected during pasta-making process.

Functional properties (WAC and OAC)

It proves to be interesting to determine the functional properties of starch in order to incorporate it in cookie formulation. The most important properties are water absorption capacity (WAC) and oil absorption capacity (OAC).

Table 2 showed the results of functional properties of *PS* and those of *CS*. The OAC of both starches were similar. However, *PS* had higher WAC than *CS* (0.679 ± 0.037 and 0.467 ± 0.021 g/g, respectively). The difference in water absorption capacity could be explained by the high content of damaged starch for *PS* than *CS*, because it was proved that WAC was very well correlated with the damaged starch content (Berton et al. 2002). In fact, Bushuk (1966) showed that the hydrophilic constituents like damaged starch have WAC of 2 to 4.3 g/g and Van Der Borgh et al. (2005) suggested that damaged starch could absorb water three times more than native starch and can, therefore, interfere with gluten protein agglomeration. These values were in agreement with those of Larsen (1964) and Rasper and De Man (1980) who reported that wheat granular starch could absorb between 0.39 and 0.87 g/g.

Rheological measurements

In order to understand the individual behavior of wheat starch dough during mixing and baking, a preliminary explanation of the dough changes associated with those processes is included (Table 3). The torque C1 was higher for *PS* than for *CS* (1.05 and 0.59 Nm respectively), so the extracted starch can absorb

Table 3 Mixolab characteristics of starch samples

Parameters ^a	C1 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	C3-C4	C5-C4	Time C1 (min:s)	Stability (min:s)	Gelatinization temperature (°C)
<i>PS</i>	1.05	0.44	0.07	3.88	0.37	3.81	00:30	00:24	59
<i>CS</i>	0.59	0.12	0.02	3.85	0.1	3.83	00:30	00:27	60

^a C1 : maximum point of the first mixing stage

C3: Peak viscosity of peak torque

C4: Cooking stability

C5: starch retrogradation

C3-C4: stability at high temperature

C5-C4: Setback

Table 4 Dough pieces and cookie parameters. Data are means±standard error

Blends		Dough				Cookie				
		Hardness (N)	Cohesiveness	Springiness (mm)	Adhesiveness (N)	L*	a*	b*	Diameter (mm)	Break strength (N)
S-Gluten	92:8 %	2.98±0.12	0.51±0.02	11.05±0.14	1.24±0.22	60.04	−1.36	16.61	57.3±0.51	18.49±0.93
	90:10 %	2.87±0.12	0.52±0.03	11.15±0.13	1.49±0.03	57.16	−0.81	15.18	55±0.68	15.91±0.71
CS-Gluten	92:8 %	3.52±0.21	0.41±0.06	10.50±0.03	1.81±0.11	70.30	−1.57	15.13	54.3±0.57	24.09±0.74
	90:10 %	4.04±0.15	0.44±0.06	10.40±0.28	1.87±0.21	65.76	−1.07	16.49	52.3±0.78	18.19±0.42

water more than the commercial one. This result was in agreement with the WAC represented in Table 1. No pronounced significant difference ($P<0.05$) in stability (min:s) at low temperature (30 °C) was observed between *PS* and *CS* (00:24 and 00:27 min:s respectively). At high temperature, *PS* and *CS* showed different behavior. The peak viscosity (C3) of *PS* was three times higher than that of *CS* (0.44 and 0.12 Nm respectively). During heat treatment, starch granules were gelatinized, losing their crystallinity and structural organization (Copeland et al. 2009). In this stage, starch granules absorb the water available in the medium and they swell. Amylose chains leach out into the aqueous intergranular phase promoting the increase in the viscosity and thus the increase in the torque. That enhancement continued until the mechanical shear stress and the temperature constraint led to the granule physical breakdown, which was associated with a reduction in viscosity (Rosell et al. 2007). Starches under study had a similar gelatinization temperature (60 and 61 °C for *PS* and *CS*, respectively). This result was in agreement with the research of Copeland et al. (2009) who said that the gelatinization temperature of most starches is between 60 and 80 °C. The difference (C3–C4) was higher for *PS* than *CS*. Therefore the stability at 90 °C was less important for *PS* than *CS*. This result can be explained to a great extent to differences in the starch composition (Jobling 2004) (Table 1) e.g. damaged starch what reduce the starch stability at high temperature. As the starch paste cools no significant difference ($P<0.05$) between the rheological behavior of *PS* and *CS* was shown.

Starch retrogradation (C5) was 3.88 and 3.85 Nm for *PS* and *CS*, respectively and the setback (C5–C4) was 3.81 and 3.83 for *PS* and *CS*, respectively. On cooling, starch molecules first form a gel and then retrograde gradually into semi-crystalline aggregates that differ in form from the native granules (Copeland et al. 2009).

Application of starch in cookie making

Dough properties

The textural properties of sugar-snap cookie dough made from blends of *PS*-Gluten and *CS*-Gluten were compared. TPA texture properties of dough samples are shown in Table 4. *PS*-Gluten dough had lower hardness and adhesiveness and higher springiness and cohesiveness than those of *CS*-Gluten dough. This difference can be related to the interactions between starch and other components present in the blends (Manley 2000). Fustier et al. (2007) explained the hardness reduction by a good interaction between water and other ingredients. The high level of hydrophilic compounds (damaged starch) in *PS* could contribute to the rheological characteristics of dough by inhibiting the development of gluten and therefore decreased significantly the hardness (Fustier et al. 2008). The adhesiveness reduction remains a significant property for the industrialist because a high adhesiveness can cause interruption of the production and contamination of materials (Rudolph and Tscheuner 1979).

Fig. 3 Front view photos of cookies baked with blends of starch and gluten: 1, (92%*PS*: 8%Gluten); 2, (90%*PS*: 10%Gluten); 3, (92%*CS*: 8%Gluten); 4, (90%*CS*: 10%Gluten)

Cookie properties

The color of sugar-snap cookie is one of the most significant quality factors for its acceptance (Gazmuri and Bouchon 2009). Table 4 and Fig. 3 showed a significant difference between color parameters of cookies from *PS* and those from *CS* with L^* (lightness) values fewer than 70. In fact, cookies from *PS* had the lowest L^* values, therefore, they were darker than cookies from *CS*. The color of cookies could be due to the non-enzymatic browning during cooking which is a result of reaction between reducing sugars and amino acids at high temperature (Gazmuri and Bouchon 2009). The difference between cookie lightness could be attributed to starch and gluten properties and the interaction between them (Manohar and Rao 1997). From the above, *PS* had the highest content of reducing sugar which contributes to the Maillard reactions. Indeed, the high degree of the Maillard reactions usually reflects the presence of higher amounts of free amino acids and carbonyl groups from reducing sugars (Feather 1994). Therefore, cookies from *PS* were darker than those from *CS*. It was observed that the color parameters of *PS* were similar with *CS*, as previously described in paragraph 3.7.2. Therefore, the difference between cookies' color couldn't be probably attributed to the starch color.

Cookie diameter increased during baking (Table 4). It decreased with increasing gluten levels for *PS* and *CS*. This result was in agreement with Pareyt et al. (2008). However, cookies from *PS* had a greater diameter than those from *CS*. This result can be explained by the highest level of damaged starch and Mixolab parameter, C3 of *PS*. These parameters give correlation with cookie diameter and C3 seems to be enough to predict the cookie quality (Ozturk et al. 2008). In addition, the development of the gluten network, the properties of the raw materials, the manufacturing process (Manley 2000) and the thermomechanical properties at high temperature of starch (Fustier et al. 2008) could explain the difference between cookies from *PS* and *CS*.

Moreover, a significant difference ($P < 0.05$) in break strength was observed between cookies. This difference can be reported to the damaged starch, the starch interactions with protein, fat, water and sugar and the gluten incorporation rate (Pareyt et al. 2008). *PS*: Gluten blends with gluten incorporation rates of 8 and 10 % gave cookies with break strengths 18.48 and 15.19 N respectively. These results are in line with those reported by Pareyt et al. (2008) who used commercial starch and gluten.

Conclusion

Since there is a paucity of studies describing extraction of starch from industrial fresh pasta by-product, the present study

aimed to valorize and to characterize the resultant starch. Interestingly, the obtained results showed that *PS* had similar starch content, structure and retrogradation to *CS* and higher water absorption capacity than *CS*. In addition, rheological characterization showed that there was no significant difference between the stability at low temperature of both starches. However, at high temperature, *PS* had the highest stability. In the other hand, significant improvements of cookie characteristics were noticed. Diameter and color parameters supported by texture analysis clearly proved that superior quality of cookie could be prepared by substitution of the commercial starch by our newly isolated starch from fresh pasta by-product. Further works are required to study the functional and rheological properties of *PS* to more diversify its applications.

Acknowledgments We are grateful to Dr. Abdesslem Affes, chairman and managing director of the company "Couscousserie Du Sud" (CDS Sfax, Tunisia), for the facilities provided for sample preparation and rheological measurements. We extend our thanks to Mr. Hamadi Attia, for textural measurements. This work was supported financially by the "Ministère de l'Enseignement Supérieur, de la Recherche Scientifique et de la Technologie-Tunisia" through a grant to "Unité Enzyme et Bioconversion—ENIS".

References

- AACC (1983) Approved Methods of the American Association of Cereal Chemists. AACC-methods 10-50D, 44-19, 54-40A, 56-10, 76-31, eighth edn. American Association of Cereal Chemists Inc, St. Paul
- AACC (1992) Approved Methods of the American Association of Cereal Chemists. 9th ed. Method 76-31, approved September 1992, reviewed October 1994. The American Association of Cereal Chemists, St. Paul
- AACC (2000) Approved Methods of the American Association of Cereal Chemists, 10th Ed., Methods 46-30, 30-10, 44-19, 08-01, 54-30. The American Association of Cereal Chemists, St. Paul
- Abdul-Hamdi A, Luan YS (2000) Functional properties of dietary fiber prepared from defatted rice bran. Food Chem 68:15-19
- Berton B, Scher J, Villieras F, Hardy J (2002) Measurement of hydration capacity of wheat flour: influence of composition and physical characteristics. Powder Technol 128:326-331
- Beuchat LR (1977) Functional and electrophoretic characteristics of succinylated peanut flour protein. J Agric Food Chem 25:258-261
- Bonet A, Blaszcak W, Rosell CM (2006) Formation of homopolymers and heteropolymers between wheat flour and several protein sources by transglutaminase-catalyzed cross-linking. Cereal Chem 83:655-662
- Burrell MM (2003) Starch: the need for improved quality and quantity—an overview. J Exp Bot 54:451-456
- Bushuk W (1966) Distribution of water in dough and bread. Baker's Dig 40:38-40
- Carini E, Vittadini E, Curti E, Antoniazzi F (2009) Effects of different shaping modes on physico-chemical properties and water status of fresh pasta. J Food Eng 93:400-406
- Chen JS, Deng ZY, Wu P, Tian JC, Xie QG (2010) Effect of gluten on pasting properties of wheat starch. Agric Sci China 9:1836-1844
- Chevallier S, Colonna P, Buleon A, Della Valle G (2000) Physicochemical behaviors of sugars, lipids, and gluten in short dough and biscuit. J Agric Food Chem 48:1322-1326

- Copeland L, Blazek J, Salman H, Tang MC (2009) Form and functionality of starch. *Food Hydrocoll* 23:1527–1534
- Dengate HN (1984) Swelling, pasting, and gelling of wheat starch. In: Pomeranz Y (ed) *Advances in cereal science and technology*. American Association of Cereal Chemists, USA, pp 49–82
- Ellouze-Ghorbel R, Zouari ES, Neifar M, Zalila K, Blibech M, Kamoun H, Ellouze CS (2010) Gluten extracted from fresh pasta by-product: physicochemical properties and potential use in bread making. *J Texture Stud* 41:245–261
- Feather MS (1994) The mechanism of non enzymatic browning reactions occurring during cookie and cracker making. In: Faridi H (ed) *The science of cookie and cracker production*. Chapman & Hall, New York, pp 434–453
- Friedman RB (1995) Interactions of starches in foods. In: Gaonkar AG (ed) *Ingredient interactions: effects on food quality*. M Dekker, New York
- Fustier P, Castaigne F, Turgeon SL, Biliaderis CG (2007) Semi-sweet biscuit making potential of soft wheat flour patent, middle-cut and clear mill streams made with native and reconstituted flour. *J Cereal Sci* 46:119–131
- Fustier P, Castaigne F, Turgeon SL, Biliaderis CG (2008) Flour constituent interactions and their influence on dough rheology and quality of semi-sweet biscuits: a mixture design approach with reconstituted blends of gluten, water-solubles and starch fractions. *J Cereal Sci* 48:144–158
- Gaines CS, Kassuba A, Finney PL (1992) Instrumental measurement of cookie hardness. 1. Assessment of methods. *Cereal Chem* 69:115–119
- Gazmuri AM, Bouchon P (2009) Analysis of wheat gluten and starch matrices during deep-fat frying. *Food Chem* 115:999–1005
- Jimenez-Hernández J, Meneses-Esparza F, Rosendo-Escobar J, Vivar-Vera MA, Bello-Pérez LA, García-Suárez FJ (2011) Extraction and characterization of starch from *Enterolobium cyclocarpum* seeds. *CyTA-J Food* 9:89–95
- Jobling S (2004) Improving starch for food and industrial applications. *Curr Opin Plant Biol* 7:210–218
- Kaldy MS, Kereliuk GR, Kozub GC (1993) Influence of gluten components and flour lipids on soft white wheat quality. *Cereal Chem* 70:77–80
- Khabou W, Trigui A, Ghorbel R, Bejar S (1996) L'amidon dans les rameaux d'olivier (*Olea europaea*) Cv. "Chemlali de sfax" Etude comparative de deux méthodes d'hydrolyse. *Olivea* 61:57–61
- Krogars K, Heinamaki J, Karjalainen M, Rantanen J, Luukkonen P, Yliruusi J (2003) Development and characterization of aqueous amylose-rich maize starch dispersion for film formation. *Eur J Pharm Biopharm* 56:215–221
- Labuschagne MT, Elago O, Koen E (2009) The influence of the temperature extremes on some quality and starch characteristics in bread, biscuit and durum wheat. *J Cereal Sci* 49:184–189
- Larsen RA (1964) Hydration as factor in bread quality. *Cereal Chem* 41:181–187
- Lindeboom N, Chang PR, Tyler RT (2004) Analytical, biochemical and physicochemical aspects of starch granule size, with emphasis on small granule starches: a review. *Starch-Starke* 56:89–99
- Manley D (2000) *Technologie of biscuits, crackers and cookies*. Woodhead Publ. Ltd, Cambridge, p 528
- Manohar RS, Rao PH (1997) Effect of sugars on the rheological characteristics of biscuit dough and quality of biscuits. *J Sci Food Agric* 75:383–390
- Miller GL (1959) Use of dinitrosalicylic acid reagent for the determination of reducing sugars. *Anal Chem* 31:426–428
- Moorthy S (2001) Tuber crop starches, Tech Bulletin No. 18. CTCRI, Trivandrum
- Ozturk S, Kahraman K, Tiftik B, Koksel H (2008) Predicting the cookie quality of flours by using Mixolab. *Eur Food Res Technol* 227:1549–1554
- Pareyt B, Wilderjans E, Goesaert H, Brijs K, Delcour JA (2008) The role of gluten in a sugar-snap cookie system: A model approach based on gluten-starch blends. *Cereal Sci* 48:863–869
- Pérez-Pacheco E, Moo-Huchin VM, Estarda-Leon RJ, Ortiz-Fernandez A, May-Hernandez LH, Rios-Soberanis CR, Betancur-Ancona D (2014) Isolation and characterization of starch obtained from *Brosimum alicastrum* Swaets Seeds. *Carbohydr Polym* 101:920–927
- Perry GH, Dominy NJ, Claw KG, Lee AS, Fiegler H, Redon R et al (2007) Diet and evolution of human amylase gene copy number variation. *Nat Genet* 39:1256–1260
- Rasper VF, De Man JM (1980) Measurement of hydration capacity of wheat flour/starch mixtures. *Cereal Chem* 57:27–31
- Rosell CM, Collar C, Haros M (2007) Assessment of hydrocolloid effects on the thermo-mechanical properties of wheat using the Mixolab. *Food Hydrocoll* 21:452–462
- Rudolph H, Tscheuner HD (1979) Adhesiveness in wheat dough. *Backer and Konditor* 27:229
- Sandhu KS, Singh N, Kaur M (2003) Characteristics of the different corns types and their grain fractions: physicochemical, thermal, morphological, and rheological properties of starches. *J Food Eng* 64:199–127
- Shinde SV, Nelson JE, Huber KC (2003) Soft wheat starch pasting behavior in relation to A- and B-type granule content and composition. *Cereal Chem* 80:91–98
- Shujun W, Jinglin Y, Wenyuan G (2005) Use of X-ray diffractometry (XRD) for identification of *Fritillaria* according to geographical origin. *Am J Biochem Biotechnol* 1:207–211
- Swinkels JJM (1985) Composition and properties of commercial native starches. *Starch-Starke* 37:1–5
- Van Der Borgh A, Goesaert H, Veraverbeke WS, Delcour JA (2005) Fractionation of wheat and wheat flour into starch and gluten: overview of the main processes and the factors involved. *J Cereal Sci* 41:221–237
- Wade P (1988) *Biscuits, cookies and crackers: the principles of the craft*, vol 1. Elsevier Applied Science, London
- Wang FC, Chung DS, Seib PA, Kim YS (2000) Optimum steeping process for wet milling of sorghum. *Cereal Chem* 77:478–483
- Wang F, Wan J, Huang W, Tilley M (2010) Effect of transglutaminase on the rheological and mixolab thermomechanical characteristics of oat dough. *Food Chem* 121:934–939
- Wolfgang B, Detmold W, Hans-Peter G (1999) Potato starch technology. *Starch-Starke* 51:235–242
- Zhou X, Blaik BK, Wang R, Lim ST (2010) Retrogradation of waxy and normal corn starch gels by temperature cycling. *J Cereal Sci* 51:57–65