Received: 10 August 2021 | Revised: 13 September 2021 | Accepted: 10 October 2021

DOI: 10.1002/cche.10490

NOTE

Molecular features and cooking behavior of pasta from pulses

Andrea Bresciani | **Stefania Iametti** | **Davide Emide** | **Alessandra Marti** | **Alberto Barbiroli**

Department of Food, Environmental and Nutritional Sciences (DeFENS), Università degli Studi di Milano, Milan, Italy

Correspondence
Alessandra Marti, Department of Food, Environmental and Nutritional Sciences (DeFENS), Università degli Studi di Milano, via G. Celoria 2, 20133 Milan, Italy.
Email: alessandra.marti@unimi.it

Abstract

Background and objectives: Pulse pasta is one of the latest responses of the food industry to meet the consumers request for healthy and sustainable foods. Among pulses, red lentils and chickpeas are the preferred raw materials for making 100% pulse pasta. This study aimed at addressing starch and protein features in commercial pulse pasta to provide an insight on how their molecular organization may affect cooking behavior.

Findings: Differences in starch pasting profile and in protein overall organization were found among commercial pasta samples. Considering the same pulse, the best performing pasta showed a protein network characterized by a more compact structure. Regardless of the producer, lentils gave pasta with the best cooking behavior (low cooking loss and high firmness).

Conclusions: Cooking quality of pulse pasta depends on both the type of pulse (chickpeas or red lentils) and pasta-making process.

Significance and novelty: This study lays some molecular groundwork as for elucidating the role of individual pulses and of the pasta-making process in determining the quality of pulse pasta.

KEYWORDS

chickpea, legumes, pasta, protein aggregation, red lentil

1 | INTRODUCTION

The production of 100% pulse pasta represents the most recent innovation in the pasta industry in response to the consumer request for healthy and sustainable food products (Lascialfari et al., 2019; Tucci et al., 2021). Pasta from 100% lentils, beans, green peas, and chickpeas is currently available on the market; and differences in nutritional traits and cooking behavior have been reported for a few commercial products (Turco et al., 2019). Such differences are related to differences in raw materials and in processing conditions, as both are known to drive the molecular rearrangements affecting the quality of pasta from both wheat (Bock et al., 2015; Bonomi et al., 2012) and gluten-free cereals (Barbiroli et al., 2013; Marti et al., 2010). However, no information is available on the relation between starch and protein features and cooking behavior in pulse pasta. In this

study, commercial pasta from 100% chickpea and 100% red lentil flours (each from two different brands) was characterized from several standpoints to address the nature and role of starch and protein features that may impact on cooking behavior.

2 | MATERIALS AND METHODS

2.1 | Pasta samples

Pasta produced by two companies (brand A and brand B) was considered. For each brand, two production batches of pasta from 100% chickpeas and 100% red lentils were analyzed. Chemical composition as reported in the label is shown in Table S1. Pasta samples were used *as such* for assessing cooking quality. For furosine, starch, and protein analysis, pasta samples were ground to <250 μm using a laboratory mill (IKA Universalmühle M20; IKA Laborteknic), with a water-cooling system to avoid overheating. Furosine was determined according to Resmini et al. (1990).

2.2 | Cooking behavior

Pasta cooking quality (i.e., water absorption, cooking loss, and firmness) was assessed at the optimum cooking time (7 min) and upon overcooking (9 min), as reported by Bresciani et al. (2021).

2.3 | Pasting properties

Pasting properties were evaluated by using a Micro Visco-Amylo-Graph (Brabender GmbH), using a heat/cooling rate of 1.5°C/min (Bresciani et al., 2021).

2.4 | Protein features

The nature of protein aggregates was assessed by the differential solubility approach followed by SDS-PAGE (Barbiroli et al., 2013; Bonomi et al., 2012) with modifications. In particular, ground pasta (0.15 g) was extracted in 5 ml of saline buffer (50 mM phosphate buffer, 0.1 M NaCl, and pH 7), and the concentration of urea—when present—was kept at 4 M instead of 8 M. Readily accessible and total thiols were assessed by adapting the original protocol (Bonomi et al., 2012), by using 0.05 g sample in 6 ml buffer and 4 M urea.

2.5 | Statistical analysis

Three independent trials were carried out on each sample for water absorption, cooking loss, and texture analysis. Furosine, pasting properties, protein aggregation state, and accessibility of protein thiols were measured in triplicate. All results represent the average of the data from two sample batches. Statgraphics Plus 5.1 (StatPoint Inc) was used for data analysis.

TABLE 1 Cooking behavior of chickpea and red lentil pasta from different brands

		Chickpea pasta		Red lentil pasta	
		Sample A	**Sample B**	**Sample A**	**Sample B**
Heat damage, uncooked pasta	Furosine (mg/100 g)	96***	926	91***	699
Cooking quality at 7 min	Water absorption (g/100 g)	109	113	104	107
	Cooking loss (g/100 $g_{d.m.}$)	11.4***	8.0	8.1***	7.5
	Firmness (*N*)	282***	411	398*	437
Cooking quality at 9 min	Water absorption (g/100 g)	113*	119	123	124
	Cooking loss (g/100 $g_{d.m.}$)	13.1***	8.9	9.1**	8.0
	Firmness (*N*)	270***	407	369**	439

Note: Asterisks indicate significant differences (*t* test; *$p < .05$; **$p < .01$; ***$p < .001$). Separate *t* test was carried out for chickpea and red lentil pasta.

Abbreviation: d.m., dry matter.

3 | RESULTS AND DISCUSSION

Data will be discussed focusing on the comparison between pasta samples prepared by two companies (A and B), rather than on the comparison between pasta samples made from different pulses (chickpeas or red lentils). Regardless of the producer, differences between pasta prepared from different raw materials (chickpeas and red lentils) are expected, due to differences in the protein nature, abundance, and organization and in starch structure between the two types of pulses (Boye et al., 2010; Keskin et al., 2021; Wani et al., 2016). On the other hand, for the same pulse, differences between brands A and B might be accounted by pasta-making process since their chemical composition—as reported on the label—was similar (Table S1).

Regardless of the type of pulse, sample A showed a higher cooking loss and lower firmness than sample B, either at optimal cooking time or upon overcooking (Table 1). Brand-related differences in cooking behavior were greater in chickpea pasta than in red lentil pasta. The heat damage parameters in Table 1 indicate that pasta from brand B was likely produced using a different heat treatment than A, regardless of the pulse used as the ingredient. Furosine (ε-N-furoylmethyl-l-lysine) is the most widely used molecular marker of Maillard reaction in pasta (Resmini & Pellegrino, 1994). In wholegrain pasta, furosine levels higher than 300 mg/100 g protein are indicative of a mild heat damage and medium temperature drying cycle (Marti et al., 2017).

When comparing chickpea pasta, pasta A exhibited a significant lower maximum viscosity ($p < .01$) and setback ($p < .001$) values, indicating lower swelling capacity and retrogradation tendency, respectively (Figure 1, upper panel). No significant differences in starch swelling were measured in red lentil pasta (Figure 1, lower panel). On the contrary, sample A exhibited a slight (but significant) higher retrogradation tendency than B, contrarily to what found for chickpea pasta. Data suggested that the pasta-making process adopted by the two brands might differently impact the starch properties of chickpeas and red lentils. Differences in starch organization in the different pulses might account for the obtained results.

Differential solubility is a way of discriminating among the different intermolecular bonds in protein aggregates, by quantifying protein soluble in saline buffer (ionic interactions), in high urea (hydrophobic interactions), and in urea/dithiothreitol (disulfide bonds). No major differences between samples belonging to the same pulse type and no qualitative difference among protein solubilized in different conditions was evident from SDS-PAGE (Figure S1). However, the solubility data suggested some difference in the nature of the polymeric network of various

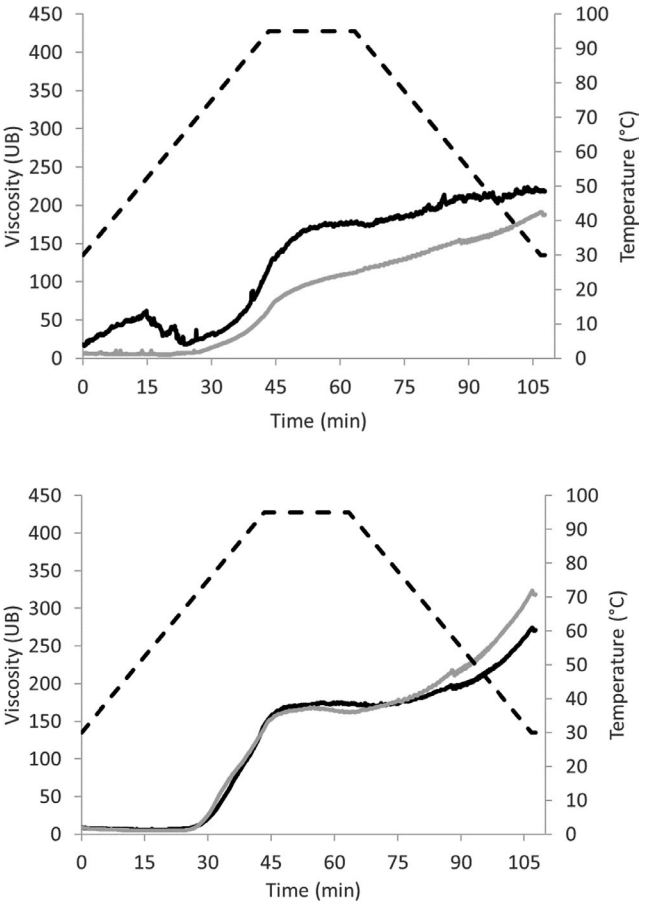

FIGURE 1 Pasting properties of chickpea (upper panel) and red lentil (lower panel) pasta from brands A (gray solid line) and B (black solid line). One representative curve for each sample was reported. Black dotted line: temperature profile

pasta samples. As for the pasta from different pulses, the data shown in Table 2 indicated that more proteins are soluble in chickpea pasta than in red lentil pasta, suggesting that the pasta processes had a different impact on proteins from individual pulses.

By comparing the solubility figures in Table 2, it is evident that about 50%–60% of the total solubilized proteins were bound by ionic interactions in chickpea pasta, with respect to about 40% in red lentil pasta, suggesting a lower overall level of denaturation/aggregation in chickpea pasta. As for red lentils, pasta A was the only sample in which protein solubility did not increase further when a disulfide reductant was added to the urea/buffered saline extractant, suggesting that low heat treatment (see Table 1) may impair or prevent the formation of red lentil protein aggregates stabilized by covalent disulfide bonds. On the contrary, in pasta B, we observed an increase in the amount of proteins solubilized by buffered saline in the presence of urea and of a disulfide reductant, suggesting that the treatment used for the production of pasta promotes the formation

TABLE 2 Differential solubility of chickpea and red lentil pasta protein from different brands

		Chickpea pasta		Red lentil pasta	
		Sample A	**Sample B**	**Sample A**	**Sample B**
Protein solubility (mg protein/g pasta)	Buffered saline	160^{a}	221^{b}	112^{A}	117^{A}
	Buffered saline + 4 M urea	271^{c}	305^{cd}	291^{D}	231^{B}
	Buffered saline + 4 M urea + 10 mM DTT	322^{d}	375^{e}	300^{D}	270^{C}
Accessibility of cysteine thiols (μmol SH/g pasta)	Buffered saline	1.54^{b}	0.49^{a}	1.17^{C}	0.26^{A}
	Buffered saline + 4 M urea	2.04^{c}	1.37^{b}	1.50^{D}	0.86^{B}

Note: Samples with the same superscript letter are not significantly different (Tukey's honestly significant difference test, $p < .05$). Separate one-way analysis of variance (ANOVA) was carried out for chickpea (lowercase letters) and red lentil (uppercase letters) pasta. Abbreviation: DTT, dithiothreitol.

of protein aggregates stabilized by covalent disulfide bonds. As for the chickpea pasta, the solubility data suggested a different protein polymerization between samples A and B. However, the effect of thermal treatments on the interprotein interactions is much less evident in chickpea pasta.

Regardless of the type of pulse, high-temperature-treated pasta B had a lower content of readily accessible thiol residues, and thiol accessibility in pasta B was markedly increased upon addition of urea. Thus, thiol residues in pasta B are somehow hidden within protein aggregates stabilized by hydrophobic interactions, similar to what is observed for high-temperature dried semolina pasta (Bock et al., 2015; Bonomi et al., 2012) or in pasta nonpulse from gluten-free materials (Barbiroli et al., 2013; Marengo et al., 2015).

All the pasta samples exhibited a good cooking quality (Table 1), as indicated by the following observations: (1) cooking losses were similar—or even lower—than those reported for commercial pasta from either pulses (Turco et al., 2019) as well as from gluten-free cereals/pseudocereals (Morreale et al., 2019); (2) instrumental firmness was similar to semolina pasta (data not shown); and (3) cooking loss and firmness did not dramatically change upon overcooking.

The stiffer protein network formed by some high-temperature treatment in the production of sample B resulted in a better cooking behavior than sample A, especially in the case of chickpea pasta. Differences among the samples cannot be accounted simply by their protein content, since it was similar (21%) in samples A and B (see Table S1). In semolina pasta, high-temperature drying promotes the formation of a continuous network that traps the swollen starch granules upon cooking, ensuring a firm texture and low leaching (De Noni & Pagani, 2010). Low-temperature drying leads to semolina pasta with high pasting viscosity (Bonomi et al., 2012; Marti et al., 2013), but an opposite trend was evident in chickpea pasta, whereas no difference was apparent for red lentil pasta, suggesting that factors other than drying temperature might intervene.

4 | CONCLUSIONS

SDS-PAGE profiling indicated that the same proteins were present in the samples from the same pulse in closely comparable amounts. However, it is possible that their structure in the starting materials was not similar, so that sensitivity to heat treatment or to shear forces in the pasta-making process was different. Of course, as commented above, also the process conditions used by each individual producer were different. In this frame, characterization of the pulse preparation used by individual producers and/or availability of samples taken at various processing steps would have provided valuable information on process-related changes, including those recently reported for starch in extrusion-cooked yellow lentil products (Bresciani et al., 2021).

ACKNOWLEDGMENTS

Authors would like to thank Prof. Francesco Bonomi for his constructive contribution to this report and Open Fields S.r.l. (Collecchio, Parma, Italy) for supporting the study.

ORCID

Alessandra Marti https://orcid.org/0000-0002-9483-7754

REFERENCES

Barbiroli, A., Bonomi, F., Casiraghi, M. C., Iametti, S., Pagani, M. A., & Marti, A. (2013). Process conditions affect starch structure and its interactions with proteins in rice pasta. *Carbohydrate Polymers*, *92*, 1865–1872. https://doi.org/10.1016/j.carbpol.2012.11.047

Bock, J. E., West, R., Iametti, S., Bonomi, F., Marengo, M., & Seetharaman, K. (2015). Gluten structural evolution during pasta processing of refined and whole wheat pasta from hard white winter wheat: The influence of mixing, drying, and cooking. *Cereal Chemistry*, *92*, 460–465. https://doi.org/10.1094/CCHEM-07-14-0152-R

Bonomi, F., D'Egidio, M. G., Iametti, S., Marengo, M., Marti, A., Pagani, M. A., & Ragg, E. M. (2012). Structure-quality

relationship in commercial pasta: A molecular glimpse. *Food Chemistry*, *135*, 348–355. https://doi.org/10.1016/j.foodchem.2012.05.026

Boye, J., Zare, F., & Pletch, A. (2010). Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International*, *43*, 414–431. https://doi.org/10.1016/j.foodres.2009.09.003

Bresciani, A., Giuberti, G., Cervini, M., & Marti, A. (2021). Pasta from yellow lentils: How process affects starch features and pasta quality. *Food Chemistry*, *364*, 130387. https://doi.org/10.1016/j.foodchem.2021.130387

De Noni, I., & Pagani, M. A. (2010). Cooking properties and heat damage of dried pasta as influenced by raw material characteristics and processing conditions. *Critical Reviews in Food Science and Nutrition*, *50*, 465–472. https://doi.org/10.1080/10408390802437154

Keskin, S. O., Ali, T. M., Ahmed, J., Shaikh, M., Siddiq, M., & Uebersax, M. A. (2021). Physico-chemical and functional properties of legume protein, starch, and dietary fiber—A review. *Legume Science*, e117. https://doi.org/10.1002/leg3.117

Lascialfari, M., Magrini, M. B., & Triboulet, P. (2019). The drivers of product innovations in pulse-based foods: Insights from case studies in France, Italy and USA. *Journal of Innovation Economics*, *1*, 111–143. https://doi.org/10.3917/jie.028.0111

Marengo, M., Bonomi, F., Marti, A., Pagani, M. A., Abd Elmoneim, O. E., & Iametti, S. (2015). Molecular features of fermented and sprouted sorghum flours relate to their suitability as components of enriched gluten-free pasta. *LWT - Food Science and Technology*, *63*, 511–518. https://doi.org/10.1016/j.lwt.2015.03.070

Marti, A., Cattaneo, S., Benedetti, S., Buratti, S., Abbasi Parizad, P., Masotti, F., Iametti, S., & Pagani, M. A. (2017). Characterization of whole grain pasta: Integrating physical, chemical, molecular, and instrumental sensory approaches. *Journal of Food Science*, *82*, 2583–2590. https://doi.org/10.1111/1750-3841.13938

Marti, A., Seetharaman, K., & Pagani, M. A. (2010). Rice-based pasta: A comparison between conventional pasta-making and extrusion-cooking. *Journal of Cereal Science*, *52*, 404–409. https://doi.org/10.1016/j.jcs.2010.07.002

Marti, A., Seetharaman, K., & Pagani, M. A. (2013). Rheological approaches suitable for investigating starch and protein properties related to cooking quality of durum wheat pasta. *Journal of Food Quality*, *36*, 133–138. https://doi.org/10.1111/jfq.12015

Morreale, F., Boukid, F., Carini, E., Federici, E., Vittadini, E., & Pellegrini, N. (2019). An overview of the Italian market for 2015: Cooking quality and nutritional value of gluten-free pasta. *International Journal of Food Science & Technology*, *54*, 780–786. https://doi.org/10.1111/ijfs.13995

Resmini, P., & Pellegrino, L. (1994). Occurrence of protein-bound lysylpirrolaldehyde in dried pasta. *Cereal Chemistry*, *71*, 254–262.

Resmini, P., Pellegrino, L., & Battelli, G. (1990). Accurate quantification of furosine in milk and dairy products by a direct HPLC method. *Italian Journal of Food Science*, *2*, 173–183.

Tucci, M., Martini, D., Del Bo, C., Marino, M., Battezzati, A., Bertoli, S., Porrini, M., & Riso, P. (2021). An Italian-Mediterranean dietary pattern developed based on the EAT-Lancet reference diet (EAT-IT): A nutritional evaluation. *Foods*, *10*, 558. https://doi.org/10.3390/foods10030558

Turco, I., Bacchetti, T., Morresi, C., Padalino, L., & Ferretti, G. (2019). Polyphenols and the glycaemic index of legume pasta. *Food and Function*, *10*, 5931–5938. https://doi.org/10.1039/C9FO00696F

Wani, I. A., Sogi, D. S., Hamdani, A. M., Gani, A., Bhat, N. A., & Shah, A. (2016). Isolation, composition, and physicochemical properties of starch from legumes: A review. *Starch-Stärke*, *68*, 834–845. https://doi.org/10.1002/star.201600007

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Bresciani, A., Iametti, S., Emide, D., Marti, A., & Barbiroli, A. (2021). Molecular features and cooking behavior of pasta from pulses. *Cereal Chemistry*, 00, 1–5. https://doi.org/10.1002/cche.10490