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Comparing the quality of two traditional fried street foods from the raw material to the end product: The Beninese cowpea-based *ata* and the Italian wheat-based *popizza*

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Abstract

Street food plays a recognized socioeconomic role, offering opportunities of employment particularly for women and providing cheap food to lower income people. West Africa is characterized by a great diversity of traditional foods, widely consumed but poorly investigated. *Ata* is a fried dough made of cowpea flour, very popular in Benin. In Southern Italy, *popizza* is prepared in a very similar way as *ata*, but using wheat flour. This work aimed at comparing the main physicochemical characteristics of *ata* and *popizza*, from the raw material to the end product. Cowpea flour showed significantly higher levels of proteins (23.25 vs. 13.48 g 100 g^{-1} on dry matter), total phenolic compounds (0.73 vs. 0.41 mg g^{-1} of ferulic acid d.m.), antioxidant activity (2.84 vs. 0.86 μmoL Trolox g^{-1} d.m.), as well as higher water absorption capacity (1.01 vs. 0.61 g water per gram flour) and particularly higher water solubility index (23.01 vs. 6.69 g 100 g^{-1}) than wheat flour. The two flours showed different pasting characteristics: starch swelling occurred at a lower temperature in cowpea than in wheat flour and produced a less viscous gel. Due to absence of gluten and limited viscosity of starchy fraction, *ata* was less porous and more springy than *popizza*. Moreover, *ata* showed higher oil uptake than *popizza* (22.2 vs. 14.1 g oil 100 g^{-1} product) and was also characterized by a browner surface than *popizza*. Knowledge about the quality features of these traditional foods and their raw material could enhance their marketing, with positive effects on local economy.

KEYWORDS

ata, cowpea flour, phenolic compounds, popizza, street food, traditional food, wheat flour

1 | INTRODUCTION

The preparation of street food plays a recognized socioeconomic role, offering opportunities of employment particularly for women and providing food at affordable cost to lower income people (Okojie & Isah, 2014). On the other hand, the way street foods are prepared arises several food safety issues. Among street foods, those prepared by frying and immediately consumed are the safest (Rane, 2011).

Cowpea (*Vigna unguiculata* L. Walp), also known as black-eyed pea, is the fifth most produced pulse in the world (Food and Agriculture Organization, 2017) and has the peculiar characteristic of growing in semiarid and dry environments. Owing to its drought tolerance, cowpea production is mainly concentrated in Africa (Gómez, 2003).

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West Africa, in particular, where cowpea is commonly and traditionally consumed, accounts for the majority of the world production (Food and Agriculture Organization, 2017). Characterized by a high content of proteins (Jayathilake et al., 2018), cowpea is the principal proteinaceous food for a nutritionally vulnerable population.

African food culture is characterized by several indigenous and traditional food products, widely consumed but poorly investigated (Madodé et al., 2011). In Benin, cowpea is the basic ingredient in the preparation of *abobo* (boiled cotyledons), *ata* (fried dumplings, also named *atta*), *magni-magni* (steam cooked paste), *adowè* (purée), and *ataclè* (very dry fritters; Dovlo, Williams, & Zoaka, 1976; Madodé et al., 2011). In particular, *ata* is a fried street food eaten at breakfast, lunch, or as a snack, popular also in Togo, Nigeria (where is named *akara*) and Ghana (where is named *koose*) (Madodé et al., 2011). *Ata* is traditionally made by steeping, wet dehulling, and then grinding cowpea beans. The resulting paste is then used to prepare a batter that can be variously seasoned prior to deep frying (Madodé et al., 2011). To skip the laborious and time-consuming traditional wet dehulling, the batter can be prepared more rapidly starting from dry-milled cowpea flour (Dovlo et al., 1976; Ihediohanma, Ofoedu, Ojimba, Okafor, & Adedokun, 2014; Kethireddipalli, Hung, McWatters, & Phillips, 2002). The nutritional composition of *ata* has already been investigated, showing high fat content but also a good protein content and an interesting presence of micronutrients such as calcium, iron, and zinc (Madodé et al., 2011). Cowpea processing into *ata* is traditionally made by women, and the income consequent to the sale of these fritters contributes to poverty reduction (Agazounon, Coulibaly, & Houndekon, 2004).

Very far from Benin, in the Apulia region of Southern Italy, a fried street food named *popizza* (plural *popizze*, also named *pettola*, pl. *pettole*) is traditionally prepared in a very similar way as *ata* (Trabace, 2015). *Popizza* is prepared from common wheat flour, instead of cowpea flour in the case of *ata*, and its artisanal production has become an unexpected source of income for Apulian jobless women, who prepare this dish at the corners of the streets close to historical sites. Such practice recalls the picture of *ata* production in Benin and also in West Africa. *Popizza* is much appreciated by locals, as well as by the increasing number of tourists visiting Apulia, being tasty and inexpensive. However, despite its popularity, *popizza* has never been studied, and there are no scientific data about its characteristics.

In this frame, the aim of this work was to define the main quality characteristics of these two poorly studied traditional street foods, *ata* and *popizza*, starting from the analysis of the flours used for their preparation.

2 | MATERIAL AND METHODS

2.1 | Raw material

Refined flour of cowpea (*Vigna unguiculata* L. Walp), produced in Benin by a local company (Produits Dajo, Abomey-Calavi, Benin), was kindly provided by Laboratory of Food Sciences of the University of Abomey-Calavi, Abomey-Calavi, Benin. Refined flour of common wheat (*Triticum aestivum* L.) "0" type (Selezione Casillo, Corato, Italy) was purchased in Italy at local retailers. The quality characteristics of 0 type flour are legally ruled (Italian Presidential Decree, 2001). Compressed baker's yeast (*Saccaromyces cerevisiae*, "Pinnacle" yeast, AB Mauri, Casteggio, Italy) and salt (Piazzolla Sali, Margherita di Savoia, Italy) were purchased at local Italian retailers.

2.2 | Preparation of *ata* and *popizza*

Ata and *popizza* fritters were prepared at the Food Science laboratories of the Department of Soil, Plant and Food Science of the University of Bari, Italy. Ingredients of *ata* were the following: 100 g of cowpea refined flour, 120 ml of tap water, 2.5 g of compressed baker's yeast, and 4 g of salt. Ingredients of *popizza* were the following: 100 g of wheat refined flour "0" type, 95 ml of tap water, 2.5 g of compressed baker's yeast, and 4 g of salt. The amount of water was adjusted so that a batter with similar consistency was obtained both for *ata* and *popizza*. *Ata* and *popizza* fritters were prepared according to the procedure mentioned on cowpea flour packaging. Flour and yeast were put in a bowl and water at room temperature was added little by little, while constantly mixing (manually, with a fork) for 5 min, in order to obtain a homogeneous mixture without lumps. Then, salt was added and the mixture was stirred for other 15 min. The dense batter thus obtained was left to rise in the bowl, covered by a clean cotton cloth, for 90 min at room temperature (approximately 25°C). After leavening, batter portions of uniform size (sphere, 4.0 ± 0.3-cm diameter) were taken with the help of two tablespoons and immersed in extra virgin olive oil, previously heated to 150°C, for deep frying (Zephir deep fryer, ZHC501, Westim S.p.A., Rome, Italy). *Ata* was fried for 6 min, whereas *popizza* for 10 min. The frying time was defined in preliminary trials to obtain perfect cooking at the center of the products, assessed by cutting and inspecting them. Samples were left to cool spontaneously at room temperature and immediately analyzed.

2.3 | Flour particle size distribution

The particle size distribution was analyzed by a LabSifter (KBF7SN, Buhler, Switzerland). Flours (100 g) were sifted for 5 min on sieves with opening of 425, 300, 212, 150, and 106 μm. The analysis was carried out in triplicate.

2.4 | Flour chemical composition

Protein (total nitrogen × 5.7), ash, and moisture contents were determined according to the Association of Official Analytical Chemists (AOAC) methods 979.09, 923.03, and 925.10, respectively (AOAC, 2006). Total dietary fiber was determined by the enzymatic-gravimetric procedure described in the AOAC method 991.43 (AOAC, 2006). Lipid content was determined by means of a Soxhlet apparatus using diethyl ether (Sigma Aldrich, Milan, Italy) as extracting solvent (AOAC, 2006). Total carbohydrate content was obtained by subtracting from 100 g of flour, on dry basis, its content of protein, lipid, ash, and dietary fiber. The fatty acid composition was determined by gas chromatographic analysis of fatty acid methyl esters according to AOCS method Ch 1–91 (AOCS, 1993), with the conditions previously described in Summo et al. (2019a). All determinations were performed in triplicate.

2.5 | Total phenolic compounds and antioxidant activity of flours

An aqueous-methanol extract (20/80 v/v) was prepared as follows: 1 g of flour was mixed with 10 ml of solvent in a centrifuge tube, stirred for 2 hr in the dark, and centrifuged at 12,000 × *g* for 3 min to recover the supernatant. The total phenolic compounds were then determined using the method of Pasqualone et al. (2015) and expressed in milligram per gram of ferulic acid on dry matter, with ferulic acid being one of the most represented phenolic compounds in both cowpea (Gutiérrez-Uribe, Romo-Lopez, & Serna-Saldívar, 2011) and wheat (Hernández, Afonso, Rodríguez, & Díaz, 2011). The antioxidant activity was evaluated by the 2,2-diphenyl-1-picrylhydrazyl radical scavenging capacity assay as reported in Pasqualone et al. (2015) and was expressed as μmol Trolox equivalent g^{-1} on dry matter. The determinations were performed in triplicate.

2.6 | Physicochemical properties of flours

Water absorption index (WAI), water solubility index (WSI), water absorption capacity (WAC), and bulk density of flours were determined according to the procedures reported by Du, Jiang, Yu, and Jane (2014). WAI (expressed in g swollen sediment g^{-1} flour) and WSI (expressed in g dissolved solids 100 g^{-1} flour) were assessed after heating a flour suspension in distilled water at 70°C, whereas WAC (expressed in g water g^{-1} flour) was assessed at room temperature. All determinations were performed in triplicate.

2.7 | Pasting characteristics of flours

Starch properties were determined using a Brabender micro-viscoamylograph (Brabender Instruments, Duisburg, Germany), suspending 15 g of flour (14.0% moisture basis) in 100 ml of distilled water. The instrument was programmed to continuously stir at 250 rpm while performing heating and cooling steps as follows: from 30°C up to 95°C at the rate of 1.5°C/min, keeping 95°C for 30 min, cooling down to 50°C at 1.5°C/min, and holding 50°C for 30 min. The viscosity values at the peak (peak viscosity), at the end of the holding period at 95°C (minimum viscosity), and at the end of cooling period (cooling maximum viscosity) were recorded. The differences between peak viscosity and minimum viscosity and between cooling maximum viscosity and minimum viscosity were evaluated as breakdown (BD) and setback, respectively. All determinations were performed in triplicate.

2.8 | Color of *ata* and *popizza* fritters

Instrumental determination of surface and inner color of *ata* and *popizza* fritters was carried out using the CM-600d colorimeter (Konica Minolta, Tokyo, Japan) supported by SpectraMagic NX software (Konica Minolta, Tokyo, Japan). Lightness (L^*), redness (a^*), and yellowness (b^*) were determined. All color determinations were replicated four times.

2.9 | Specific volume of *ata* and *popizza* fritters

Specific volume was determined by rapeseed displacement, as in AACC method 10-10 (AACC, 2000). The determination was performed in triplicate.

2.10 | Texture profile analysis of *ata* and *popizza* fritters

Texture profile analysis was carried out using the Z1.0 TN texture analyzer (Zwick Roell, Ulm, Germany) equipped with a 3.5-cm diameter cylindrical probe and a 50-N load cell. The samples were subjected to a two-compression cycle, with 5 s of break and 1 mm s^{-1} of speed, up to 40% of recorded deformation, with 10 replications.

2.11 | Image analysis of *ata* and *popizza* fritters

Ata and *popizza* fritters were cut in two halves, and the image of the inner was acquired by a Canon 600d DSLR camera (Canon, Tokyo, Japan), equipped with a Sigma 17–70 mm f/2.8 (Sigma Corporation, Kawasaki, Japan), saved in TIFF format with no compression, and processed by ImageJ software (National Institutes of Health, Bethesda, USA). Each image was converted into 8-bit grayscale, and a section of 25 × 25 mm was cropped from the center of the product, then it was filtered by thresholding function in order to obtain the best cell resolution. Image analysis was performed to detect the cells with an area >0.05 mm^2 and circularity in the range 0–1, where 1 is the value attributed to perfectly circular cells and 0 to thin thread-like cells. The total number of cells, mean area of all the observed cells, and cell density (number of cells/mm^2) have been measured according to Scheuer et al. (2014). Three replicated analyses were done.

2.12 | Oil uptake of *ata* and *popizza* fritters

Oil uptake was determined by Soxhlet extraction as in Shih and Daigle (1999). Diethyl ether (Sigma Aldrich, Milan, Italy) was used as extracting solvent. The extraction time accounted to 6 hr. Three replicated analyses were done.

2.13 | Statistical analysis

All the experimental data were subjected to one-way analysis of variance followed by the Tukey's honestly significant difference test. Significant differences were determined at $p < .05$ by the XLStat software (Addinsoft SARL, New York, NY, USA).

3 | RESULTS

3.1 | Nutritional composition, bioactive compounds, and physicochemical properties of flours

As for nutritional composition, the protein content of cowpea flour reached 23.25 g 100 g^{-1} d.m., almost doubling the protein content of wheat flour (Table 1). On the contrary, the carbohydrate content was much lower in cowpea than in wheat flour.

The lipid fraction, significantly more abundant in cowpea than in wheat flour, was mostly constituted by polyunsaturated fatty acids (PUFAs), whose sum was higher in wheat than in cowpea flour (Table 2). Linoleic acid was the most represented fatty acid, followed by the linolenic one. The sum of monounsaturated fatty acids, mainly constituted by oleic acid, was higher in wheat than in cowpea flour. In cowpea flour, the content of saturated fatty acids (SFAs) accounted for 40.96% of total fatty acids, approximately doubling the value found in wheat flour. Palmitic acid was the most important SFA of cowpea flour, followed by stearic acid.

No significant differences between flours were found in the content of total dietary fiber that was slightly higher than 3 g 100 g^{-1} d.m. in both the flours, whereas ash content was higher in cowpea than in wheat flour (Table 1).

Cowpea flour was characterized by significantly higher levels of total phenolic compounds (0.73 mg g^{-1} of ferulic acid d.m.) than wheat flour (0.41 mg g^{-1} of ferulic acid d.m.). Owing to its higher content of total phenolic compounds, cowpea flour showed higher in vitro antioxidant activity than wheat flour (2.84 vs. 0.86 μmoL Trolox g^{-1} d.m.).

Cowpea and wheat flour showed a similar particle size distribution, but wheat flour was slightly coarser, with significantly higher amounts of particles in the ranges 212–300 and 150–212 μm.

Significant differences between cowpea and wheat flours were observed in terms of physicochemical properties. Indeed, the BD, which indicates the mass per unit of occupied volume, was significantly higher in cowpea than in wheat flour. Cowpea flour showed higher WSI (23.01 g dissolved solids 100 g^{-1} flour) and lower WAI (2.96 g swollen sediment g^{-1} flour) than wheat flour (6.69 g dissolved solids 100 g^{-1} flour and 5.13 g swollen sediment g^{-1} flour, respectively). Moreover, cowpea flour showed higher WAC than wheat flour.

TABLE 1 Average nutritional composition, bioactive compounds, and physicochemical properties of cowpea and wheat flours used to prepare *ata* and *popizza* fritters

	Cowpea flour	Wheat flour
Proximate composition and bioactive compounds		
Lipids (g 100 g^{-1} d.m.)	1.95^a ± 0.19	1.17^b ± 0.05
Proteins (g 100 g^{-1} d.m.)	23.25^a ± 0.35	13.48^b ± 0.19
Carbohydrates (g 100 g^{-1} d.m.)	69.11^b ± 0.46	81.38^a ± 0.26
Ashes (g 100 g^{-1} d.m.)	2.55^a ± 0.09	0.62^b ± 0.02
Total dietary fiber (g 100 g^{-1} d.m.)	3.14^a ± 0.02	3.38^a ± 0.02
Total phenolic compounds (mg ferulic acid g^{-1} d.m.)	0.73^a ± 0.03	0.41^b ± 0.02
Antioxidant activity (μmoL Trolox g^{-1} d.m.)	2.84^a ± 0.05	0.86^b ± 0.12
Particle size distribution		
>425 μm (g 100 g^{-1})	0.3^a ± 0.1	0.5^a ± 0.2
300–425 μm (g 100 g^{-1})	1.9^b ± 0.1	2.7^a ± 0.5
212–300 μm (g 100 g^{-1})	7.9^b ± 1.7	13.8^a ± 1.3
150–212 μm (g 100 g^{-1})	44.5^a ± 4.2	57.5^a ± 9.1
106–150 μm (g 100 g^{-1})	28.2^a ± 1.2	12.5^b ± 2.1
<106 μm (g 100 g^{-1})	17.2^a ± 4.5	6.9^b ± 0.1
Physicochemical properties		
Bulk density (g ml^{-1})	0.91^a ± 0.00	0.84^b ± 0.01
Water absorption index (g swollen sediment g^{-1} flour)	2.96^b ± 0.01	5.13^a ± 0.02
Water solubility index (g dissolved solids 100 g^{-1} flour)	23.01^a ± 0.73	6.69^b ± 0.60
Water absorption capacity (g water g^{-1} flour)	1.01^a ± 0.00	0.61^b ± 0.00
Pasting characteristics		
Pasting temperature at peak (°C)	77^b ± 1	86^a ± 1
Peak viscosity (BU)	457^b ± 13	651^a ± 19
Minimum viscosity (BU)	215^b ± 11	354^a ± 8
Cooling maximum viscosity (BU)	613^b ± 9	1005^a ± 21
Breakdown (BU)	242^b ± 6	297^a ± 9
Setback (BU)	398^b ± 11	651^a ± 17

[a,b] Different superscript letters in the same row indicate significant differences at $p < .05$.
Abbreviation: BU, Brabender Units.

The pasting properties of aqueous suspensions of cowpea and wheat flour were different. Cowpea paste showed a lower peak viscosity than wheat paste. When the gel was held at 95°C for 30 min, cowpea paste showed also a lower value of minimum viscosity than wheat paste. During subsequent cooling, cowpea formed a less firm gel than wheat flour (613 vs. 1,005 BU).

TABLE 2 Fatty acid composition (mean and standard deviation, expressed as g 100 g^{-1}) and sum of saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids of cowpea and wheat flours used to prepare *ata* and *popizza* fritters

	Cowpea flour	Wheat flour
$C_{14:0}$	1.85[a] ± 0.14	0.84[b] ± 0.06
$C_{15:0}$	0.12[b] ± 0.01	0.15[a] ± 0.00
$C_{16:0}$	25.15[a] ± 0.15	18.90[b] ± 0.19
$C_{16:1}$	0.11[b] ± 0.05	0.27[a] ± 0.02
$C_{17:0}$	0.35[a] ± 0.00	0.12[b] ± 0.00
$C_{17:1}$	0.02[b] ± 0.01	0.09[a] ± 0.02
$C_{18:0}$	5.58[a] ± 0.02	1.26[b] ± 0.24
$C_{18:1}$	10.58[b] ± 0.61	16.07[a] ± 0.06
$C_{18:2}$	29.52[b] ± 0.49	57.31[a] ± 0.08
$C_{20:0}$	1.89[a] ± 0.06	0.45[b] ± 0.16
$C_{18:3}$	18.54[a] ± 0.41	3.85[b] ± 0.18
$C_{20:1}$	0.11 ± 0.00	n.d.
$C_{20:2}$	0.08[a] ± 0.02	0.07[a] ± 0.00
$C_{22:0}$	3.74[a] ± 0.11	0.25[b] ± 0.07
$C_{23:0}$	0.42[a] ± 0.14	0.20[a] ± 0.21
$C_{24:0}$	1.86[a] ± 0.04	0.17[b] ± 0.01
Σ_{SFA}	40.96[a]	22.34[b]
Σ_{MUFA}	10.85[b]	16.42[a]
Σ_{PUFA}	48.19[b]	61.23[a]

[a,b] Different superscript letters in the same row indicate significant differences at $p < .05$.

TABLE 3 *Surface* and inner color, crumb texture and structure, and oil uptake of *ata* and *popizza* fritters

	Ata	Popizza
Surface color		
*L**	36.36[b] ± 2.43	62.54[a] ± 5.43
*a**	19.20[a] ± 1.71	3.71[b] ± 1.13
*b**	23.48[b] ± 4.07	32.11[a] ± 1.93
Inner color		
*L**	69.52[a] ± 1.99	68.61[a] ± 3.11
*a**	2.27[a] ± 0.42	−0.26[b] ± 0.14
*b**	21.43[a] ± 1.08	17.25[b] ± 1.81
Crumb texture		
Springiness	0.84[a] ± 0.05	0.77[b] ± 0.05
Gumminess (N)	12.45[a] ± 2.92	9.83[a] ± 1.72
Chewiness (N)	10.45[a] ± 2.31	8.31[a] ± 2.47
Cohesiveness	0.50[a] ± 0.09	0.54[a] ± 0.10
Hardness (N)	22.63[a] ± 3.01	21.44[a] ± 4.00
Crumb structure		
Mean cell area (mm^2)	0.43[b] ± 0.09	1.47[a] ± 0.55
Cell density (no. cells/mm^2)	524[a] ± 139	73[b] ± 32
Number of cells	220[a] ± 23	96[b] ± 19
Specific volume (ml g^{-1})	3.73[b] ± 0.51	5.11[a] ± 0.19
Oil uptake (g oil 100 g^{-1} product)	22.2[a] ± 3.5	14.1[b] ± 0.5

*Note. L**, *a**, and *b** indicate lightness, redness, and yellowness, respectively.

[a,b] Different superscript letters in the same row indicate significant differences at $p < .05$.

3.2 | Physicochemical properties of fritters

3.2.1 | Surface and inner color

Table 3 reports the colorimetric indices of *ata* and *popizza*, determined on both crust and crumb. The external surface of the two fritters showed a considerably different color. *Ata* was characterized by an intensely brown external color, whereas *popizza* showed a light yellow surface. Therefore, redness (*a**) was higher in *ata*, whereas *popizza* had a significantly higher yellowness (*b**) and lightness (*L**).

The color of crumb was lighter than surface in both the fritters. Lightness of inner crumb did not show significant differences between *ata* and *popizza*, whereas both redness and yellowness were significantly higher in *ata* (2.27 and 21.43, respectively) than in *popizza* (−0.26 and 17.25, respectively), although the differences in these parameters were low compared with those found for the crust.

3.2.2 | Crumb structure and texture, oil uptake

Ata showed a more finely porous crumb structure than *popizza*, with a significantly higher number of cells (220 vs. 96 in *ata* and in *popizza*, respectively) (Table 3). The number of crumb cells identified is inversely related to cell area, therefore *ata* was characterized by a smaller cell area than *popizza*. Consequently, cell density, calculated as the number of observations divided by cell area, was also higher in *ata* than in *popizza*.

To better explain the results of image analysis, cell area was categorized in 12 classes. The relative frequency of each class is reported in Figure 1. In both fritters, the majority of cells were in the range 0.05–1 mm^2. The differences found considering separately the first three cell area classes (0.05–0.1, 0.1–0.2, and 0.2–1.0 mm^2) were not significant. However, by considering the sum of cells in the range 0.05–1 mm^2, *ata* was characterized by the highest presence of small cells (p = .003). On the other hand, a significantly higher number of large cells was found in *popizza* crumb. In this case, the range of cells area was between 1 and 30 mm^2, with significant differences found only for the ranges 1–2, 2–4, 4–6, 6–8, and 10–15 mm^2 (Figure 1).

Regarding texture, although not significantly, *ata* was harder, gummier, and chewier than *popizza*. Significant differences, however, were observed for springiness that was higher in *ata* than in *popizza* fritters. *Ata* showed a lower specific volume than *popizza*.

Regarding oil uptake (Table 3), *ata* was characterized by a markedly higher oil uptake than *popizza*.

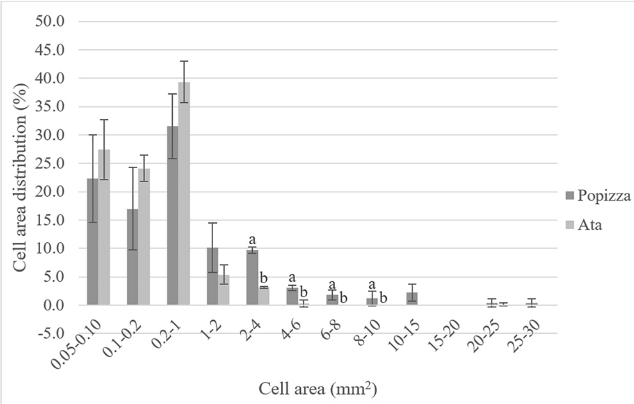

FIGURE 1 Cell area distribution of the inner surface of *popizza* and *ata* fritters. A total of 12 classes of cell areas were identified. Different letters indicate significant differences at $p < .05$

4 | DISCUSSION

4.1 | Nutritional composition, bioactive compounds, and physicochemical properties of flours

As for wheat flour (Table 1), protein and ash content met the requirements of current Italian rules for "type 0" category (Italian Presidential Decree, 2001). Lipid content and fatty acid composition (Table 2) agreed with previous works (Caponio, Summo, Pasqualone, Paradiso, & Gomes, 2009; Pasqualone, Paradiso, Summo, Caponio, & Gomes, 2014).

Cowpea was richer in proteins than wheat flour, which is particularly important in developing countries. Both protein and lipid contents of cowpea flour agreed with other studies (Antova, Stoilova, & Ivanova, 2014; Carvalho et al., 2012; Madodé et al., 2012). Also fiber content was within the range observed by other authors: Rivas-Vega et al. (2006) reported 2.6 g 100 g^{-1}, and Khalid, Elhardallou, and Elkhalifa (2012) ascertained a fiber content of 4.1 g 100 g^{-1}. The ash content, instead, was slightly lower than that reported in other studies (Antova et al., 2014; Ihediohanma et al., 2014; Kerr, Ward, McWatters, & Resurreccion, 2000).

The fatty acid composition of cowpea flour (Table 2) agreed with the findings of Antova et al. (2014). Overall, cowpea flour shows an unusual fatty acid composition if compared with other pulses, due to its high content of SFA and low content of monounsaturated fatty acid. The content of PUFAs, especially linolenic acid, that was more abundant than in other pulses such as chickpeas (Summo et al., 2019b), lentils, and peas (Caprioli et al., 2016) was particularly interesting. Linolenic acid is an n-3 essential fatty acid and, together with other PUFAs, is positively associated with favorable effects on human health, reducing the risk of cardiovascular diseases (Baum et al., 2012).

Cowpea flour contained also higher levels of phenolic compounds than wheat flour (Table 1). These molecules act as scavengers for free radicals, thus preventing the cells from oxidative stress (Zhang & Tsao, 2016). The content of total phenolic compounds of cowpea seeds was previously studied by other authors, that reported a range from 0.46 to 2.69 mg g^{-1} of gallic acid, depending on the variety (Adjei-Fremah, Jackai, & Worku, 2015). The phenolic compounds are mainly located in the seed coat, thus the production process of cowpea flour causes a loss in phenolics (Adebooye & Singh, 2007).

The physicochemical characteristics, which have a strong influence on food properties, showed significant differences between the two flour types. The cowpea flour showed higher BD than wheat flour, probably also due to the finer particle size compared with wheat flour. The values observed for cowpea flour were higher than those reported in previous studies for raw cowpea flours (Akubor, 2003; Appiah, Asibuo, & Kumah, 2011). Such difference could result from the treatments (soaking, dehulling, and drying) that underwent the bean for obtaining the flour or by differences in the milling process. BD influences both the textural properties of food and the packaging specifications of flour and is particularly significant in the preparation of weaning food formulations. During the cooking process of weaning foods, the gelatinization of starch produces a highly viscous matrix, which shows the best texture when it is appropriately thick and viscous in order to be easily eaten by an infant. Therefore, flours with low BD are easy digestible (Desikachar, 1980) and are suitable for the production of infant and weaning foods. However, high BD values are preferable for packing, storage, and transport because high amounts of flour occupy a limited volume.

WAI represents the weight of swollen starch after heat treatment of flour. It is related to the integrity of starch granules and to their gelation properties (Du et al., 2014). WSI, related to WAI, quantifies the amount of soluble solids remaining in the aqueous phase after flour heating. The values observed for both WAI and WSI indicate a higher presence of damaged starch—able to gelatinize easily absorbing high amounts of water and releasing amylose—in cowpea flour than in wheat flour.

WAC, determined at room temperature, directly reflects the ability of some macromolecules to bind water, such as polysaccharides and proteins (Du et al., 2014). Cowpea flour showed higher WAC than wheat flour, due to higher protein content and to the presence of damaged starch, the latter indicated by the observed values of WAI and WSI. The values of WAC observed in cowpea flour were lower than those reported in other studies (Appiah et al., 2011; Khalid & Elharadallou, 2013), probably due to differences in flour particle size, as observed by Kerr et al. (2000), indicating that cowpea milling is not perfectly standardized among different milling companies. WAC of wheat flour agreed with previous works (Kumar & Saini, 2016).

The two types of flour showed different pasting characteristics (Table 1). Starch swelling occurred at a lower temperature in cowpea than in wheat flour and produced a less viscous gel. With cooling, wheat flour showed a more marked setback, indicating a greater tendency to starch retrogradation, as observed in previous works (Mariotti, Zardi, Lucisano, & Pagani, 2005; Pasqualone et al., 2010). The results for cowpea flour were similar to those reported by other authors (Adebooye & Singh, 2008).

Proteins influence the pasting properties by reducing heat-induced swelling of starch (Dericke et al., 2005). Therefore, the lower peak viscosity of cowpea paste compared with wheat paste could be due to the higher protein content of cowpea flour. Another factor that concurred to lower the viscosity of cowpea paste was the higher presence of damaged starch than in wheat flour, as indicated by both WAI and WSI. Damaged starch, in fact, increases water absorbing capacity and sensibility to α-amylase and, consequently, decreases paste viscosity (Farrand, 1964). Moreover, the heat-induced cross-linking of gluten by disulfide bonds, occurring only in wheat flour, causes an increase of paste viscosity (Attenburrow, Barnes, Davies, & Ingman, 1990).

4.2 | Physicochemical properties of fritters

4.2.1 | Surface and inner color

The differences in color between *ata* and *popizza* could be explained by the highest content of damaged starch in cowpea flour, as indirectly indicated by WAI, WSI, and by viscosity measures. In fact, the combined presence of damaged starch and amylase determines an increase of reducing sugars in the food matrix that could enhance Maillard reaction with consequent browning, more marked in *ata* surface. The brown external color of *ata* has been reported also by Prinyawiwatkul, McWatters, Beuchat, and Phillips (1994), whereas a light-colored interior has been reported to be a quality feature, as the result of perfect removal of seed coats and "black eyes" of cowpea beans (Patterson, Phillips, McWatters, Hung, & Chinnan, 2004).

4.2.2 | Crumb structure and texture, oil uptake

The structural differences between the two fritters were related to the different chemical composition and pasting properties of flours. In particular, the lack of gluten in cowpea flour was the cause of the finer crumb structure of *ata* compared with *popizza* (Figure 2). Indeed, gluten confers to the dough its typical viscoelasticity and keeps the integrity of gas cells allowing their expansion during fermentation and baking, thus resulting in a spongy crumb (Masure, Wouters, Fierens, & Delcour, 2019). Moreover, gluten network hampers the moisture loss during frying, by holding the steam inside the product and creating large cells, that contributes to a considerably spongy texture. In *ata*, the gas could not be easily retained by the matrix, due to both the lack of a viscoelastic gluten network and the scarce ability of the starchy fraction of cowpea flour to produce a highly viscous paste. These two conditions together caused the reduced porosity observed in *ata*.

The different crumb structure of the two types of fritters impacted their texture (Table 3), with denser structure corresponding to harder consistency. Hallén, İbanoğlu, and Ainsworth (2004) reported that even a partial substitution of wheat flour by cowpea flour is responsible, in bread making, for a worsening of the dough characteristics due to the absence of gluten. The dough becomes sticky and less able to retain air, resulting in harder and more compact bread. The production of batter, instead, as in these fritters, which tolerates the absence of gluten better than a more consistent dough, smoothed the textural differences between *ata* and *popizza* explaining the lack of statistical significance for many of the parameters measured.

Regarding oil uptake, it is known that during frying water migrates from the center to the surface of food and then evaporates, leading to the formation of voids and capillary pathways that cause the adhesion of oil. After frying, the temperature decreases and the absorbed oil tends to migrate from the surface to the center of the product, due to a vacuum effect caused by steam condensation (Gamble & Rice, 1987). Oil absorption is related to pore radius, with smaller pores causing higher capillary pressure and then higher oil uptake (Moreira, Sun, & Chen, 1997). *Ata* fritters showed a more finely porous crumb structure than *popizza*, and this explains why *ata* absorbed more frying oil. Also gluten plays a role (Gazmuri & Bouchon, 2009), because after thermal denaturation, it contributes in creating a compact external layer, reducing the oil uptake of *popizza*. Together with the above

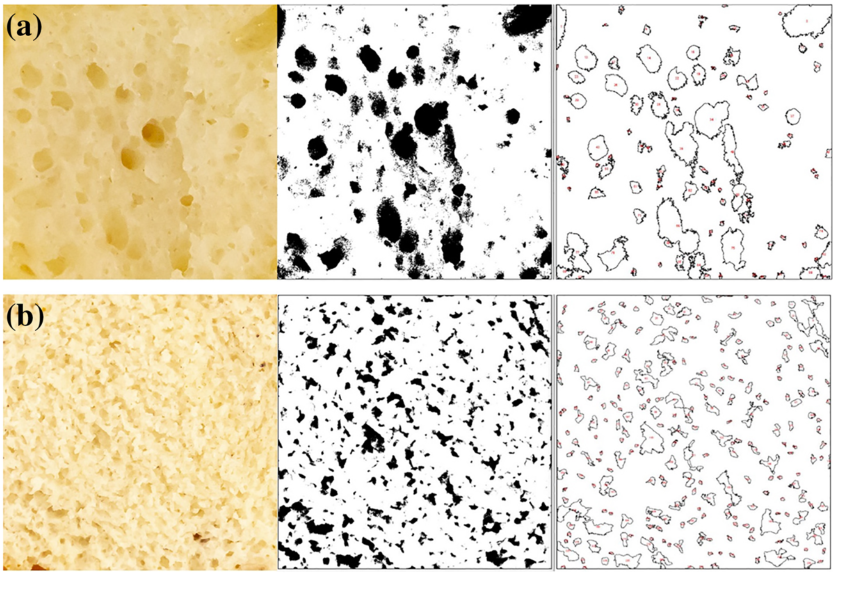

FIGURE 2 Inner surface of *popizza* (a) and *ata* (b) fritters. A section of 25 × 25 mm has been processed. Original tiff image (left); threshold image (center); outlined cells (right) [Colour figure can be viewed at wileyonlinelibrary.com]

reported less porous structure (Figure 2), the high oil uptake had a further detrimental effect on the specific volume of *ata*, which was significantly lower than in *popizza*.

5 | CONCLUSIONS

The evaluation of the physicochemical properties of *ata* and *popizza* and their raw flours showed that, despite *ata* fritters are gluten free, they showed good textural properties, not significantly different compared with those of the gluten-containing Italian *popizza.* Therefore, *ata* is a well-structured street food suitable for people with coeliac disease. However, the high oil content of these fritters, particularly that of *ata*, undermines a daily consumption.

Food, and in particular, the street food, can be a vehicle for sharing culture and traditions, which are strongly related to food. A strong linkage, in fact, exists between food, culture, and locality.

The obtained results could help establishing a quality record of these little studied minor productions. In particular, the findings could represent a first step towards a better knowledge of these products also outside their area of origin, as a vehicle of local culture and with potential further positive effects on local economy. To enhance the production of cowpea in a food sovereignty perspective could be the basis for achieving food security.

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CONFLICT OF INTERESTS

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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