Exploitation of lettuce waste flour to increase bread functionality: effect on physical, nutritional, sensory properties and on consumer response

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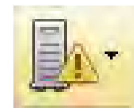

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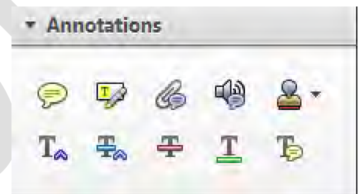

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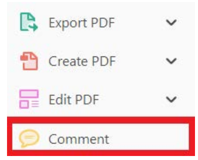

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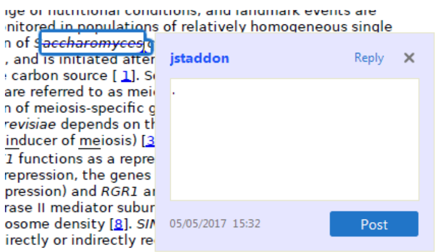

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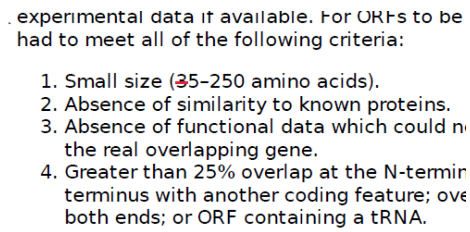

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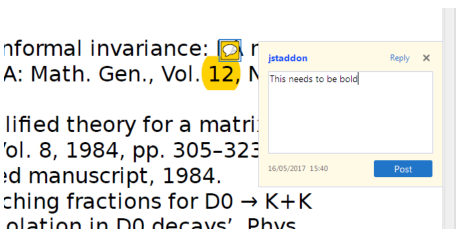

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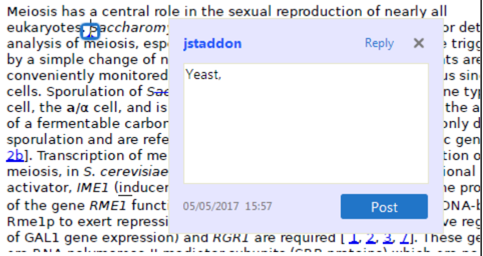

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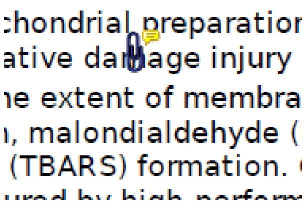

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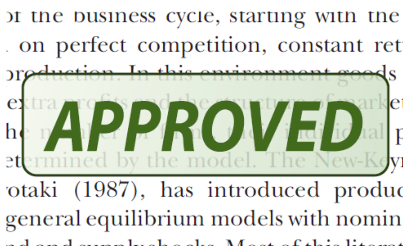

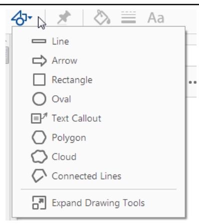

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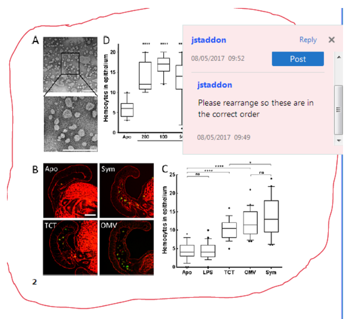

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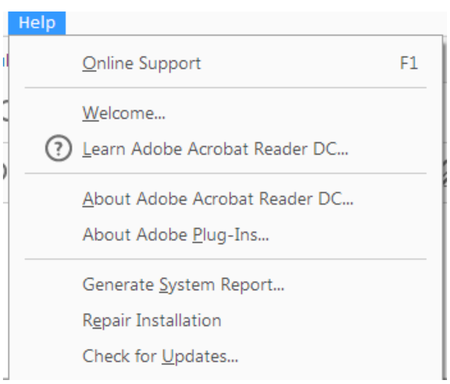

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Original article

Exploitation of lettuce waste flour to increase bread functionality: effect on physical, nutritional, sensory properties and on consumer response

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Summary Phenol and fibre-rich flour obtained by air-drying and grinding of lettuce waste was partially substituted (26, 53, 170 and 575 g kg^{-1}) with wheat flour to produce functional bread. The addition of flour progressively decreased dough leavening capacity while increased bread moisture and firmness. Lettuce waste flour significantly increased the polyphenolic content (up to 3.4 g GAE kg^{-1}) of bread samples and enhanced their antioxidant activity by 200%. Bread containing 170 and 575 g kg^{-1} of lettuce waste flour presented sensory properties and consumer acceptability comparable to those of commercial wholemeal bread with similar rye bran content. Bread containing at least 170 g kg^{-1} of lettuce waste flour could be associated to nutritional claims related to its enhanced fibre content (>30 g kg^{-1}). Data obtained by conjoint analysis demonstrate the possibility of increasing consumer preference for lettuce waste flour bread by proper nutritional (fibre content) and sustainability (lettuce waste valorisation) claims.

Keywords Acceptability, consumer response, functional bread, lettuce waste, sensory properties.

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Introduction

The market of functional foods has been constantly growing, following consumer awareness of their potential in maintaining a healthy state (Sikand *et al*., 2015; Gul *et al*., 2016). Being a staple food in several countries, bread is an optimal candidate for functionalisation (Akhtar *et al*., 2011). To this aim, wholemeal flour is traditionally used due to its content in antioxidants and fibres from bran and aleurone (Dewettinck *et al*., 2008; Dziki *et al*., 2014). This goal could be equally reached using flours from fruit and vegetables or from their wastes, which are often richer in nutritional compounds (Nilnakara *et al*., 2009; Mastromatteo *et al*., 2014). Functional bread has been produced using flours from tomato, cabbage and pineapple waste (Nilnakara *et al*., 2009; Nour *et al*., 2015; Wu & Shiau, 2015; Chareonthaikij *et al*., 2016).

Fresh-cut processing of lettuce heads generates huge amounts of waste, due to removal of external leaves and core. Waste amounts up to 40% of the initial lettuce weight, leading to high management costs (Plazzotta *et al*., 2017). This waste can be air-dried and ground to obtain flour with 3.05 mg GAE g^{-1} dw polyphenols, similar to that of cabbage and pumpkin functional flour (Que *et al*., 2008; Nilnakara *et al*., 2009), and fibre content (260 g kg^{-1}) comparable to that of rice and oat bran (USDA, 2016). Lettuce waste flour could thus represent a suitable ingredient for functional bread. However, its use is expected to strongly affect product processability as well as physical, sensory and nutritional properties.

Functional bread containing lettuce waste flour could represent a value-added food derived from a cheap and always available source, associated to an eco-friendly image appreciated by consumers (Simoes *et al*., 2015). Reversely, the presence of a waste derivative in bread could negatively affect consumers' reaction (Pickett-Baker & Ozaki, 2008; Simoes *et al*., 2015).

The aim of this study was to evaluate the potential of flour from *Iceberg* lettuce waste in functional bread production. Bread containing increasing amounts of lettuce waste flour were characterised for colour, moisture, phenol and fibre content, antioxidant activity, firmness, specific volume and sensory properties. Bread acceptability was evaluated and compared to that of commercial bread containing rye bran. Consumer response towards claims associable to bread containing lettuce waste flour was investigated by conjoint analysis.

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Materials and methods

Lettuce waste flour

Lettuce waste was prepared by removing external leaves and core from heads, simulating fresh-cut processing. One kg waste was then air-dried (15 h) in single layers (UM100; Memmert, Schwabach, Germany) at 70 ± 0.5 °C and a 55–65 ERH%, ground into flour (MC3001; Moulinex, Milan, Italy), sieved using a 125 μm sieve (Endecotts Ltd, London, UK) and stored at 20 °C in sealed aluminised aseptic bags until use (Plazzotta *et al.*, 2018). Flour presented a moisture amount of 42 ± 2 g kg^{-1}.

Bread

Bread was obtained substituting Manitoba type '0' wheat flour (Molino Spadoni, Coccolia, Italy; 141 g kg^{-1} moisture, 12 g kg^{-1} fat, 675 g kg^{-1} carbohydrates of which 15 g kg^{-1} sugars, 22 g kg^{-1} fibres and 135 g kg^{-1} proteins) with increasing amounts of lettuce waste flour (0, 10, 25, 70, 225 g kg^{-1} of dough, corresponding to a replacement of wheat flour of 2%, 4%, 12% and 40% w/w), while maintaining a constant ratio among the other ingredients (Table 1). Water (at 30 ± 0.5 °C), sugar and fresh yeast were premixed 3 min (KM285; Kenwood, Milan, Italy), added with flour and salt and mixed 15 min. Subsequently, dough portions (250 g) were manually rounded, leavened on a tray at 37 °C and 80 ERH% (ST500; Pol-Eko-Aparatura S.P.J., Wodzslaw, Poland) for 60 min, baked (170 °C, 20 min; 10GN1/1; Air-O-Steam Touchline, Electrolux, Porcia, Italy) and cooled at room temperature for 1 h (Mastromatteo *et al.*, 2012).

Commercial wholegrain bread samples (Gilli srl, Laives, Italy) containing 180 and 510 g kg^{-1} rye bran (fibre content of 55 and 93 g kg^{-1}, respectively, as declared on the product label) were also purchased on the local market.

Image acquisition

Images were acquired by a EOS-550D camera (Canon, Milan, Italy) placed 45 cm above a black cardboard base where samples were positioned and enlighten by 4 100 W-frosted photographic floodlights, in a position allowing minimum shadow and glare (Immagini & Computer, Bareggio, Italy).

Colour

A tristimulus Chromameter-2-Reflectance colorimeter (Minolta, Osaka, Japan) with a CR-300 measuring head, standardised against a white tile, was used and data were expressed in L*, a* and b* Hunter-scale parameters (Ortolan *et al.*, 2015). Samples were positioned on a white cardboard, and the colorimeter head was placed perpendicular to sample surface. At least five measures were taken on different points of bread dough samples and on the crust of bread ones. 5

Table 1 Formulation of dough samples containing increasing amounts of lettuce waste flour

Dough ingredient (g kg^{-1})					
Lettuce waste flour	Wheat flour	Water	Sugar	Salt	Yeast
0	561	404	9	13	13
10	551	404	9	13	13
25	536	404	9	13	13
70	491	404	9	13	13
225	336	404	9	13	13

Specific volume

Loaf-specific volume (cm^3 g^{-1}) was obtained by rapeseed displacement according to AOAC methods (AOAC, 2000).

Moisture

Moisture content was calculated according to AOAC methods (AOAC, 2000). Around 2 g of sample was dried in a vacuum oven (1.32 kPa) at 75 °C until constant weight (12 h).

Firmness

Firmness was measured by uniaxial compression test using an Instron 4301 (Instron LTD., High Wycombe, UK). Samples were tested by a 12.7-mm-diameter cylindrical probe (100 N compression head) at a 5-mm min^{-1} crosshead speed. Firmness was taken as the maximum force (N) for 5-mm sample penetration. Dough firmness was evaluated by penetrating the surface of the leavened dough. In the case of bread, six slices (20 mm thick) were cut from the central portion of each loaf. Firmness was evaluated by penetrating the crumb of each slice in five different points (Calligaris *et al.*, 2013).

Total dietary fibre

Total dietary fibre was determined according to AOAC methods (AOAC, 2000), using TDF-100A kit (Sigma-Aldrich, St. Louis, MO, USA). Results were expressed as g of fibres per kg of bread.

Polyphenolic extract

Extracts were prepared according to Llorach *et al.* (2004) with some modifications. Bread was extracted by reflux for 60 min in boiling water (dilution 0.2 g mL^{-1}). Extracts were then added in methanol (1 mL g^{-1} of bread) and centrifuged (9450 ***g***, 15 min, 20 °C; Mikro 20; Hettich Zentrifugen, Tuttlingen, Germany). The supernatant was used for polyphenols and antioxidant activity analyses.

Total polyphenols

The Folin-Ciocalteau reagent was used (Singleton & Rossi, 1985). The reaction mixture contained 100 μL polyphenolic extract, 500 μL Folin-Ciocalteau reagent, 4 mL water and 2 mL sodium carbonate-water solution (0.15 g mL^{-1}). After 2 h-reaction in the dark at ambient temperature, absorbance was read at 750 nm (UV-2501PC, UV-Vis spectrophotometer; Shimadzu Corporation, Kyoto, Japan). A calibration curve ($R^2 = 0.99$) was made with 0.1–1000 mg L^{-1} solutions of gallic acid. Results were expressed as mg of gallic acid equivalents (GAE) per kg of bread.

Antioxidant activity

A volume of 1.80 mL of 6.1×10^{-5} M DPPH· methanol solution was added with 150 μL polyphenolic extract. DPPH· bleaching was followed at 515 nm (UV-2501PC; Shimadzu Corporation) at 20 °C for 10 min and resulted proportional to extract concentration. Equation 1 was chosen to obtain the reaction rate of DPPH· bleaching, k (Manzocco *et al*., 1998):

$$\frac{1}{A^3} - \frac{1}{A_0^3} = 3kt, \quad (1)$$

where A_0 is initial optical density (OD) and A is optical density at increasing time, t. The chain-breaking activity was expressed as k (OD^{-3} min^{-1}) per sample mass.

Sensory attributes

A focus group of ten judges was used to identify sensory attributes of bread containing lettuce flour. Judges were not trained on sensory analysis of bread but were experts in the use of the selected sensory methods. White bread and bread containing 575 g kg^{-1} of lettuce flour were evaluated. The focus group decided, through consensus and independently on consumer response, which descriptors better discriminated the samples. Judges were then asked to evaluate the intensity of the selected descriptors in bread containing 0, 170 and 575 g kg^{-1} of lettuce waste flour. Descriptors of bread samples, identified with a three-digit random code, were evaluated on a 1- to 9-point hedonic scale, in which one corresponded to 'extremely low descriptor intensity', and 9 to 'extremely high descriptor intensity'. Three bread samples were evaluated in each session, and water was used to rinse mouth among samples (Manzocco & Lagazio, 2009).

Consumer acceptability

About eighty bread consumers (thirty-seven men and forty-three women, age 18–55) were recruited at the University of Udine, Italy. Samples, indicated by a three-digit random code, were served in odourless plastic dishes. Consumers were asked to taste samples and score their acceptability on a 1- to 9-hedonic scale anchored with 'highly nonacceptable' (score 1) and 'highly acceptable' (score 9; Peryam & Pilgrim, 1957). Four bread samples containing lettuce flour (170 and 575 g kg^{-1}) and rye bran (180 and 510 g kg^{-1}) were evaluated in each session. Water was used to rinse mouth among samples.

Consumer response

Conjoint analysis was used to evaluate consumer preference towards bread by decomposing total preference in partial preferences relevant to independent product attributes (De Pelsmaeker *et al*., 2017; Sillani *et al*., 2017). Five attributes of bread containing lettuce flour were selected as experimental variables and named 'lettuce flour', 'health', 'waste recovery', 'waste reduction' (discrete variables) and 'price' (linear variable). Different levels were associated to each experimental variable (Table 2). For discrete variables, two levels (claim presence or absence) were used. For price, three values were used. Experimental variables were combined according to an orthogonal experimental design, obtaining eleven product profiles, which represent information available to consumer on a possible bread label. A nonprobabilistic sample of 525 bread consumers, equally distributed among men and women (age 18–41), was recruited at the University of Udine, Italy. Consumers were asked to fill up a structured questionnaire, indicating, for each product profile, their preference on a 1–100 scale. No prior information was provided about origin and preparation of lettuce waste flour. In other words, the response of

Table 2 Experimental variables defining bread attributes and relevant levels used for conjoint analysis

Experimental variable	Levels
Lettuce flour	Absent; 'Containing lettuce flour'
Health	Absent; 'Rich in fibre'
Waste recovery	Absent; 'Produced recovering lettuce waste'
Waste reduction	Absent; 'Produced reducing food waste'
Price (€ kg^{-1})	3.00; 4.50; 6.00

consumers towards a bread label reporting different information was assessed. A total of 370 responses were valid and analysed.

Data analysis

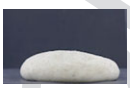
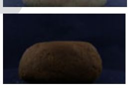
Determinations were expressed as the mean ± standard deviation of at least three measurements from three experiment replications. Statistical analysis was performed using R v.2.15.0 (The R foundation for Statistical Computing, Vienna, Austria). Bartlett's test was used to check the homogeneity of variance. One-way ANOVA was carried out, and Tukey's test was used as *post hoc* test to determine statistically significant differences among means ($P < 0.05$). For conjoint analysis, IBM SPSS Statistics 20 (Armonk, NY, USA) was used to calculate partial preference values, their relative importance and model goodness of fit (Pearson's R and Kendall's τ).

Results and discussion

Wheat flour in bread dough was substituted with increasing amounts of lettuce waste flour. Leavened dough was characterised for appearance, colour and firmness (Table 3). The addition of lettuce waste flour decreased luminosity (L*) and yellowness (b*), while increased red point (a*). This can be attributed to the brownish colour of air-dried lettuce flour. Air-drying has actually been reported to promote oxidation of the main phenolic compounds of *Iceberg* lettuce waste, including 3-O-caffeoylquinic acid, caffeoyltartaric acid, 4-O-caffeoylquinic acid, 5-O-caffeoylquinic acid, caffeic acid derivatives, isochlorogenic acid, chicoric acid, luteolin 7-O-glucuronide and quercetin 3-O-glucuronide (Plazzotta *et al*., 2018). Images show that lettuce flour hindered dough leavening, leading to progressively firmer and less aerated dough. Lettuce flour reduced gluten concentration in the dough, while increased the presence of water holding fibres. To this regard, Plazzotta *et al*. (2018) demonstrated that 1 g of lettuce flour can hold up to 9 g of water. Water would thus be less available for gluten-starch network formation, reducing dough elasticity, gas entrapment and leavening capacity. The addition of vegetable fibres was demonstrated to affect dough moisture distribution, altering rheological properties and leavening (Ameh *et al*., 2013; Chareonthaikij *et al*., 2016).

Increasing amounts of brownish lettuce flour resulted in brown bread samples (Table 4). The changes in luminosity and colorimetric parameters presented a discontinuity point in correspondence of 170 g kg^{-1} lettuce flour concentration. This is probably attributable to the counterbalancing colour effects of the increase in brownish flour and the inhibition of Maillard reaction by water holding fibres, which reduce dehydration rate and extent (Kent-Jones & Amos, 1967). As reported for other vegetable flours (Greene & Bovell-Benjamin, 2004; Marpalle *et al*., 2014), the water holding capacity of lettuce fibres was

Table 3 Appearance, hunter scale colour parameters (L*, a*, b*) and firmness of leavened dough containing increasing amounts of lettuce waste flour

Lettuce waste flour (g kg^{-1})	Appearance after leavening	Colour L*	Colour a*	Colour b*	Firmness (N)
0		81.8 ± 0.5^{a}	−0.1 ± 0.3^{a}	18.6 ± 0.9^{c}	0.110 ± 0.015^{b}
10		72.6 ± 1.0^{b}	2.4 ± 0.3^{b}	21.7 ± 0.9^{b}	0.139 ± 0.005^{b}
25		60.4 ± 0.7^{c}	7.5 ± 0.4^{c}	28.1 ± 1.6^{a}	0.217 ± 0.023^{b}
70		48.7 ± 0.6^{d}	10.2 ± 0.3^{d}	16.2 ± 0.5^{d}	0.139 ± 0.015^{b}
225		33.3 ± 1.1^{e}	11.0 ± 0.4^{e}	7.3 ± 2.0^{e}	1.803 ± 0.145^{a}

Mean values indicated by different superscript letters are statistically different ($P < 0.05$).

Table 4 Visual appearance, crust Hunter scale colour parameters (L*, a*, b*), crumb firmness, specific volume, humidity, total phenolic content (TPC), chain-breaking activity (CBA) and total dietary fibre (TDF) of bread samples containing increasing amount of lettuce waste flour

Lettuce waste flour (g kg^{-1})			Colour								
Dough	Bread	Image	L*	a*	b*	Firmness (N)	Specific volume (cm^3 g^{-1})	Moisture content (g kg^{-1})	TPC (mg GAE kg^{-1})	CBA (DO^{-3} min^{-1} kg^{-1})	TDF (g kg^{-1})
0	0		64.9 ± 2.0^{a}	7.5 ± 1.5^{c}	26.4 ± 0.8^{b}	0.573 ± 0.143^{d}	5.595 ± 0.683^{a}	431 ± 1^{c}	438.5 ± 8.3^{c}	3873.3 ± 505.6^{c}	13.2 ± 1.1^{e}
10	26		52.3 ± 1.1^{c}	11.4 ± 0.4^{a}	24.9 ± 0.9^{cd}	0.523 ± 0.033^{d}	3.580 ± 0.288^{b}	445 ± 1^{c}	585.6 ± 4.2^{c}	4486.7 ± 14.1^{bc}	16.2 ± 1.2^{d}
25	53		50.4 ± 3.3^{c}	12.0 ± 0.9^{a}	23.4 ± 1.8^{c}	0.849 ± 0.056^{c}	3.439 ± 0.259^{b}	462 ± 3^{b}	731.2 ± 2.1^{c}	4644.4 ± 937.5^{bc}	19.3 ± 1.1^{c}
70	170		59.1 ± 2.7^{b}	9.9 ± 0.7^{b}	29.3 ± 1.2^{a}	1.351 ± 0.214^{b}	1.625 ± 0.098^{c}	464 ± 2^{b}	1354.7 ± 6.2^{b}	5602.2 ± 288.8^{b}	31.1 ± 2.0^{b}
225	575		43.9 ± 0.6^{a}	10.9 ± 0.5^{ab}	9.4 ± 1.3^{d}	5.212 ± 0.174^{a}	0.886 ± 0.060^{d}	487 ± 8^{a}	3406.2 ± 78.9^{a}	$10\,290.0 \pm 621.6^{a}$	71.5 ± 2.2^{a}

Mean values indicated by different superscript letters are statistically different ($P < 0.05$).

reflected in progressively increasing bread loaf moisture (Table 4). This might pose stability issues for lettuce flour bread, due to its altered response to both microbial spoilage and staling (Rosell & Santos, 2010; Ameh *et al.*, 2013). Bread containing increasing amounts of lettuce flour resulted progressively firmer and with lower specific volume (Table 4), due to the water absorption capacity of lettuce fibres and reduced dough leavening (Table 3). The latter should not be regarded as a negative feature, as promoting stomach filling and sense of satiety (Greene & Bovell-Benjamin, 2004; Ameh *et al.*, 2013). The addition of lettuce flour, rich in antioxidant polyphenols (Plazzotta *et al.*, 2018), promoted the increase in bread phenolic content and antioxidant activity (Table 4). Phenolic compounds are mostly located in cereal cell wall, linked to hemicelluloses or other wall constituents, with the highest concentration in the aleurone grain layer. Subsequently, white bread is poor in these compounds. *Iceberg* lettuce flour could be exploited to increase its phenolic content, being rich in these compounds (Llorach *et al.*, 2004; Naczk & Shahidi, 2006). An increase in phenolic content and antioxidant activity of bakery products was also obtained by adding mango peel, dried tomato waste, broccoli, carrot and beetroot (Ajila *et al.*, 2007; Nour *et al.*, 2015; Ranawana *et al.*, 2016). By contrast, no change in total phenolic was detected when apple and lemon fibre was added to cookies (Bilgiçli *et al.*, 2007). Interactions between phenols and wheat proteins/polysaccharides as well as oxidation, isomerisation/epimerisation and degradation of bioactive compounds during dough preparation and baking may account for these contrasting results (Wang & Zhou, 2004). As a result, bread antioxidant properties would depend on phenols naturally occurring in wheat and lettuce flour as well as on thermally induced products and phenol complexes with proteins/polysaccharides (Rupasinghe *et al.*, 2008; Sivam *et al.*, 2010).

As reported for other baked goods containing vegetable derivatives (Bilgiçli *et al.*, 2007; Ajila *et al.*, 2008; Rupasinghe *et al.*, 2008), the addition of lettuce 6 flour also promoted the increase of bread fibre concentration (Table 4). Lettuce mainly contains insoluble dietary fibre, known for its beneficial health effects on intestinal regularity and weight control (Lattimer & Haub, 2010). The fibre content of bread with 170 and 7 575 g kg^{-1} lettuce flour could be associated to the nutritional claims ‘rich in fibre’ and ‘source of fibres’, respectively (Reg. CE. 1924/2006). As these high levels of fibres and polyphenols may significantly affect bread sensory attributes, these samples were submitted to sensory evaluation, using white bread as control (Mastromatteo *et al.*, 2012). Data reported in Table 5 show that lettuce flour decreased the perceived intensity of yeast odour and flavour while increased silage and herbaceous odour and flavour, dried fruit flavour,

Table 5 Sensory attributes scores of bread samples containing increasing amounts of lettuce waste flour

Lettuce waste flour (g kg^{-1})		Sensory attribute												
		Odour			Taste				Flavour				Texture	
Dough	Bread	Yeast	Silage	Herbaceous	Acid	Sweet	Salty	Sour	Yeast	Silage	Herbaceous	Dried fruit	Softness	Gumminess
0	0	6.6 ± 1.7^{a}	1.9 ± 1.9^{b}	1.2 ± 0.4^{b}	3.3 ± 1.9^{b}	3.4 ± 1.2^{a}	6.0 ± 1.6^{a}	1.0 ± 0.5^{b}	6.1 ± 1.5^{a}	1.5 ± 1.3^{b}	1.2 ± 0.4^{b}	1.1 ± 0.3^{b}	6.0 ± 1.9^{a}	2.0 ± 0.8^{b}
70	170	1.3 ± 0.5^{b}	5.7 ± 1.4^{a}	6.1 ± 1.4^{a}	3.7 ± 1.9^{ab}	4.0 ± 1.9^{a}	4.6 ± 1.3^{a}	3.1 ± 0.9^{ab}	1.4 ± 0.5^{b}	4.5 ± 1.4^{ab}	5.0 ± 1.3^{ab}	4.2 ± 1.1^{a}	5.2 ± 1.0^{a}	5.5 ± 1.8^{a}
225	575	1.8 ± 1.6^{b}	5.9 ± 1.6^{a}	6.1 ± 1.4^{a}	5.8 ± 1.7^{a}	4.3 ± 1.1^{a}	4.3 ± 1.2^{a}	5.2 ± 1.9^{a}	1.7 ± 0.8^{b}	5.6 ± 1.6^{a}	6.4 ± 1.4^{a}	5.3 ± 1.5^{a}	2.5 ± 1.2^{b}	5.4 ± 1.3^{a}

For each sensory attribute, mean values indicated by different superscript letters are statistically different ($P < 0.05$).
Sensory attributes were scored by a panel of ten judges.

acid and sour taste. In accordance with increasing bread firmness data (Table 4), lettuce flour promoted an increase in gumminess and a decrease in bread softness. Sensory attributes of bread containing lettuce flour are those typically associated to wholemeal bread (Greene & Bovell-Benjamin, 2004; Ameh *et al.*, 2013). Consumer acceptability of bread containing lettuce waste flour was thus compared to that of commercial rye bran bread (Table 6). To this aim, two commercial products were selected based on rye bran content (180 and 510 g kg^{-1}) comparable to that of lettuce waste flour in the selected samples (170 and 575 g kg^{-1}) as well as on similar colour ($P \geq 0.05$; Table 4). In particular, L*, a* and b* of bread containing 180 and 510 g kg^{-1} rye bran were 58.1 ± 0.2, 9.7 ± 1.2, 30.3 ± 0.2 and 41.9 ± 1.1, 11.9 ± 1.6, 10.4 ± 0.9, respectively.

Bread containing the highest level of rye bran (510 g kg^{-1}) or lettuce waste flour (575 g kg^{-1}) resulted less acceptable, probably due to the peculiar sensory attributes of fibre-rich bread (Table 6; Ameh *et al.*, 2013). Similar concentrations of rye bran or lettuce waste flour were associated to analogous acceptability scores, confirming lettuce flour bread to be just as acceptable as traditional wholemeal bread.

Despite consumer acceptability results, the reaction of consumers towards consumption of bread containing an ingredient deriving from waste could be a critical issue. Conjoint analysis was thus applied to assess

Table 6 Acceptability scores of bread samples containing increasing amounts of lettuce waste flour or rye bran

Sample	Acceptability
Bread with 180 g kg^{-1} rye bran	6.4 ± 0.7^{a}
Bread with 170 g kg^{-1} lettuce waste flour	6.6 ± 0.4^{a}
Bread with 510 g kg^{-1} rye bran	4.4 ± 0.9^{b}
Bread with 575 g kg^{-1} lettuce waste flour	4.4 ± 0.4^{b}

Mean values indicated by different superscript letters are statistically different ($P < 0.05$).
Bread acceptability was scored by eighty consumers.

Table 7 Partial preference coefficients and relative importance of different label information in defining consumer preference

Information	Partial preference coefficient	Relative importance
Price (€ kg^{-1}) 3.00	−16.057 ± 1.133	32.4 ± 1.1
4.50	−24.086 ± 1.700	
6.00	−32.114 ± 2.267	
Produced recovering lettuce waste	1.353 ± 0.469	20.9 ± 0.8
Rich in fibre	3.466 ± 0.333	17.2 ± 0.6
Produced reducing food waste	2.668 ± 0.344	15.7 ± 0.6
Containing lettuce flour	1.816 ± 0.328	13.9 ± 0.6

Partial preference was scored by 370 consumers.

consumers' response towards a bread label reporting different information relevant to the presence of lettuce waste flour in bread (Table 2). Beside price, claims associated with nutritional value ('containing lettuce flour'; 'rich in fibre') or sustainability issues ('produced recovering lettuce waste'; 'produced reducing food waste') were considered. The obtained model resulted significant with *P*-values of both Pearson's *R* and Kendall's $\tau < 0.0001$. Partial preference coefficients and relative importance of each label information in defining consumer preference are reported in Table 7.

As expected, the increase in price led to a decrease in consumer preference. Price affected consumer preference by more than 30%, resulting the most important variable among those considered. Partial preference coefficients related to the presence of nutritional claims ('rich in fibre'; 'containing lettuce flour') resulted positive, indicating these claims to increase consumer preference. This result is consistent with the increasing consumer awareness of the importance of a diet rich in plant foods containing fibre (Rooney *et al*., 2017). Sustainability claims ('produced recovering lettuce waste'; 'produced reducing food waste') also promoted a positive consumer reaction, probably due to increasing consumer concern about food sustainability (Grunert *et al*., 2014; Simoes *et al*., 2015). Noteworthily, the use of the word 'waste' was not associated with adverse consumer response. By contrast, the claim 'produced recovering lettuce waste' was the most important information after price in defining consumer preference. It can be inferred that waste-related claims could contribute in developing an eco-friendly image of bread containing lettuce waste flour and be strategically exploited to steer consumer preference towards more sustainable bread alternatives.

Conclusions

The use of flour obtained by air-drying of lettuce waste represents a promising strategy to improve bread functionality and sustainability. Such an approach could be easily extended to other vegetable wastes and to baked goods other than bread.

Although this valorisation strategy shows the potential for consumer acceptance, additional studies would be required to assess its feasibility. For instance, the effect of vegetable waste flour addition on bakery product shelf-life could be not negligible. Moreover, the success of this valorisation strategy will depend on the availability of vegetable waste flour with standardised composition and technological performance as well as safety and quality parameters suitable for food production. To this regard, the presence of contaminants deriving from both cultivation practices and process should be carefully assessed.

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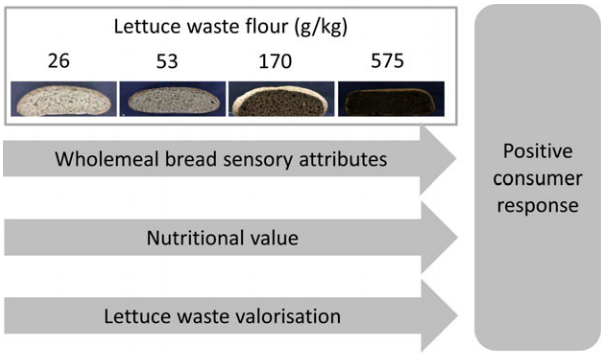

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