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Corresponding Author: Dr. Alessio Cimini, Ph.D

Corresponding Author's Institution: Tuscia University

First Author: Alessio Cimini, Ph.D

Order of Authors: Alessio Cimini, Ph.D; Diana De Santis, Prof.

Abstract: Fresh pasta is largely consumed in Italy and, given its widespread use worldwide, has been recently used as an important source of functional ingredients. The sensory and texture quality of novel functional foods is equally important as their health effects. In the case of β-glucan (i.e., a soluble dietary fibre strongly limiting blood cholesterol levels), its high concentration in food formulation exerts a negative effect on the sensory and texture quality of the final product. This paper focuses on the sensory evaluation of two nutraceutical low-cholesterol fresh pastas made with wheat semolina and pasteurised egg white and integrated with β-glucan enriched barley or oat flour to assure 3 g of β-glucan per serving (100 g).
The Principal Component Analysis applied to sensory data discriminated the samples according to three eigenvectors, linked to the attributes that best contribute to the characterisation of the samples, many of which seemed to be positively correlated to the consumer preference. Indeed, all β-glucan rich samples resulted higher in brownness, rougher appearance and less homogeneous (dotting), taste of cereals. This attribute give this special fresh pasta type an aspect of craftsmanship plus an enrichment of the aromatic bouquet, which positively affected the judgment.

Suggested Reviewers: Marika Lyly
VTT Biotechnology,
marika.lyly@vtt.fi
Expert in betaglucan preparation

Angel Angelov
Department of Biotechnology, University of Food Technologies, 26 Maritza Blvd, 4002 Plovdiv, Bulgaria
angelov@uft-bio.com
Author of many articles in probiotic food

Hely Tuorila
Professor (Sensory food science), Department of Food and Environmental Sciences, University of Helsinki
hely.tuorila@helsinki.fi
author of many paper in acceptance and consumer preference of food

Cover Letter

Manuscript title: **Sensory evaluation of functional β-glucan enriched fresh white egg pasta**

Corresponding author:
Alessio Cimini
Department for Innovation in the Biological, Agrofood and Forestry Systems,
University of Tuscia, Via S. C. de Lellis, 01100 Viterbo, Italy
Tel. n° +39-0761-357497;
Fax n° +39-0761-357498;
E-mail: a.cimini@unitus.it

This paper focuses on the sensory evaluation of two nutraceutical low-cholesterol fresh pastas made with wheat semolina and pasteurised egg white and integrated with β-glucan enriched barley or oat flour, appropriately designed to comply with the EU Regulation n. 1169/2011 and Nutritional Claims for dietary fibre foods (Official Journal of European Commission, 2006) to assure 3 g of β-glucan per serving (100 g).

I thank you, in advance, for the attention and the time spent considering this research paper.
I look forward to hearing from you very soon.

Sincerely yours,

Alessio Cimini

Highlights

- The sensory and texture quality of novel functional foods is equally important as their health effects.
- In the EU, the use of specific health claim is authorized for the only food products containing at least 1 g of β-glucan per serving.
- The viscosifying effect of β-glucan may be problematic towards the sensory quality of foods
- The attributes that contribute to the characterisation of the functional β-glucan enriched fresh white egg pasta samples, are positively correlated to the consumer preference.

Sensory evaluation of functional β-glucan enriched fresh white egg pasta.

Diana De Santis, Mauro Moresi, Alessio Cimini*

Department for Innovation in the Biological, Agrofood and Forestry Systems,
University of Tuscia
Via S. C. de Lellis
01100 Viterbo, Italy

Corresponding author:
Alessio Cimini (a.cimini@unitus.it)

Abstract

Fresh pasta is largely consumed in Italy and, given its widespread use worldwide, has been recently used as an important source of functional ingredients. The sensory and texture quality of novel functional foods is equally important as their health effects. In the case of β-glucan (i.e., a soluble dietary fibre strongly limiting blood cholesterol levels), its high concentration in food formulation exerts a negative effect on the sensory and texture quality of the final product.

This paper focuses on the sensory evaluation of two nutraceutical low-cholesterol fresh pastas made with wheat semolina and pasteurised egg white and integrated with β-glucan enriched barley or oat flour to assure 3 g of β-glucan per serving (100 g).

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Key words: β-glucan**;** fresh pasta; sensory evaluation; low-cholesterol; barley flour; oat flour; white egg.

1. Introduction

The market for functional and nutraceutical foods is growing (Daliri & Lee, 2015), thanks to the their potential health and nutritional benefits not only for disease prevention and health enhancement, but also for an increasing health promotion marketing strategies of the food industry, especially for consumers with a higher nutritional knowledge who pay particular attention to health-related claims and for elderly consumers with a health condition (Cavaliere, Ricci & Banterle, 2015). Indeed, this growing demand for functional foods has been fostered with a series of compounds and/or diets, the effectiveness of which was, in many cases, devoid of any scientific proof. This resulted in a misleading and deceptive conduct, false representations and unfair practices in the food industry.

Over the last decades, β–glucan has been one of the most studied compounds. Several clinical studies highlighted the positive effect of this soluble fibre not only on the blood cholesterol level (Braaten et al., 1994; Hsing-Hsien and Ming-Hoang, 2000; Bae, Kim, S. Lee & H.G. Lee, 2010; Drozdowski et al., 2010), but also on the postprandial blood glucose level and insulinemic response (Wood, Beer & Butler, 2000; Hooda, Matte, Vasanthan & Zijlstra, 2010). It was also reported a reduced risk for colon cancer (Malkki & Virtanen, 2001), an immune-stimulating activity against viral, bacterial, and fungal pathogens and a promoting one towards the growth of *Lactobacillus* and *Bifidobacterium* strains (Arora & Sharma, 2011).

The Food and Drug Administration (FDA, 1997; FDA, 2003) approved the use of healthy claims for food containing oat and barley β-glucan. In 2011, the EU Regulation n° 1169, dealing with food product labelling, confirmed the relationship between oat β-glucan intakes and lowering of low-density lipoprotein (LDL) cholesterol concentration in blood. In the EU, the use of specific health claim is authorized for the only food products containing at least 1 g of β-glucan per serving, and the positive effect can be achieved on condition that the total daily β–glucan intake is about 3 g. The indiscriminate addition of β-glucan to a certain amount of cereal-based food products to verify their potential nutritional benefits and healthy efficacy on ill patients or healthy consumers has shown improvements on the medical parameters but, in most cases, these products were not evaluated for their sensorial aspects. It is well known that the viscosifying effect of β-glucan may be problematic towards the sensory quality of foods, even if such an effect enhances the physiological effectiveness of β-glucan. The higher the concentration of water-soluble fibres the more unacceptable the food texture propriety becomes. Indeed, high β-glucan concentrations increase the viscosity of most beverages. In beer, its presence causes filtration problems (Cimini & Moresi, 2015), reduces the drinkability of a few beverages (Beristain et al., 2006) and gives rise to a typical slimy texture on solid foods, that may be unacceptable even at low concentrations (Staffolo, Bertola & Martina, 2004; Sanz, Salvador, Jimenez & Fiszman, 2008). In other cases, the use of β-glucan with lower molecular mass or at smaller concentrations may cause much more acceptable sensory characteristics at the expanse of a less physiological effect (Kwong, Wolever, Brummer & Tosh,, 2013; Anttila, Sontag-Strohm & Salovaara, 2004).

According to Marika (2006), well-designed consumer studies are needed to define the actual consumer acceptance of functional foods with a high β-glucan content to avoid disregarding that the novel food sensory and texture qualities are at least as important as the expected health effects (Brennan & Cleary, 2005). In particular, elderly people are generally unwilling to compromise between poor taste and health effects

(Tuorila & Cardello, 2002). In addition, food texture significantly affects its liking (Moskowitz & Krieger, 1995).

Today, the presence on the market of a wide selection of β-glucan-enriched products might positively ensure the regular uptake of the healthy amount of β-glucan, as well as their long-term acceptance.

Pasta is one of the most consumed foods in Italy with an average per-capita consumption of nearly 23.5 kg of pasta annually. In Tunisia, Venezuela, and Greece it is about 17, 12, and 11.1 kg yr^{-1}, respectively (Donley, 2018). Moreover, Italy is the world's largest pasta producer. Among this sector, fresh egg pasta is a product made exclusively of soft wheat flour and whole chicken (yolk and albumen) eggs with no less than two hundred grams per kg of flour.

This paper focuses on the sensory evaluation of a novel nutraceutical fresh pasta appropriately designed to comply with the EU Regulation n. 1169/2011 and Nutritional Claims for dietary fibre foods (Official Journal of European Commission, 2006). In particular, this novel fresh pasta was formulated to assure a total daily intake of about 3 g of β-glucan per serving (100 g) and thus to be labelled with the specific claims reserved for food products that contain at least 1 g of β-glucan, as also with "high-fibre" claim (>6 g dietary fibre per 100 g of food). Two β-glucan enriched barley and oat flours were used to formulate two fresh pastas using pasteurised egg whites to overcome the problem associated with the high cholesterol content in conventional fresh egg pasta.

A sensory test was primarily performed to compare the organoleptic properties of fresh egg and white-egg pastas as such or integrated with β-glucan enriched barley or oat flours. Then, the collected data were used to identify which sensory attributes given by the functional ingredients used here were to be regarded as defects or main contributors to the overall liking of novel fresh pasta products.

2. Materials and Methods

2.1. Raw materials

Four fresh pasta samples were produced using the following flours: i) soft wheat flour type 00 (Barilla, Parma, Italy), ii) durum wheat semolina flour (Garofalo, Naples, Italy), iii) 11% (w/w) β-glucan enriched barley flour (Agroalimentare Sud, Potenza, Italy), and iv) 22% (w/w) β-glucan enriched oatmeal (DSM Nutritional Products Ltd, Kaiseraugst, CH). Their basic composition is shown in the electronic supplement (Table S1). The egg products used were fresh whole eggs (Ovito, Gruppo Novelli srl, Spoleto, Italy) and pasteurised egg white liquids (Le Naturelle, Eurovo, Ravenna, Italy)**.**

2.2 Pasta preparation

Any flour type or egg product was weighed and mixed in a home pasta maker (Pastamatic 1000, SIMAC, Treviso, Italy) for 12-15 min. The resulting dough was finally hand-kneaded for 5 min and let resting for 15 min to develop its elastic structure. The fresh dough was then rolled with a manual roller machine to obtain a sheet with a thickness of 1.5±0.2 mm. Afterwards, a double cutter machine (Imperia 400, Imperia, Italy) was used to make a traditional type of pasta (i.e., tagliatelle) with a width and thickness of about 0.5 cm and 1.2 mm respectively. Prior to cooking, such strips were let rest for 1 h to prevent from sticking.

Table 1 shows the formulation used for all fresh pastas prepared here. In particular, the sample labelled STD was a reference standard fresh egg pasta made with whole eggs and wheat flour. The sample labelled ALB referred to a fresh pasta made with wheat flour and egg white (i.e., albumen). To improve its firmness (and raw protein content), it was enriched with durum wheat semolina. The samples labelled BFP or OFP referred to fresh egg white pasta enriched with high β-glucan barley or oat flour, respectively.

All samples were cooked in boiling water by adding 25 g of tagliatelle 12-cm long and 1.5±0.2 mm thick in 300 mL of bottled still mineral water (with a fixed residue of about 300 mg L^{-1}at 180 °C, as suggested by ISO (2016), that was integrated with 2.7 g of kitchen salt. During pasta cooking the water volume was kept almost constant by adding boiling water and covering the backer to minimize water evaporation. All pasta types were cooked for as long as the so-called optimal cooking time (ISO, 2016), recovered using a colander, and cooled by running tap water for 60 s. Excess water was then drained by shaking the colander for 10 s.

2.3 Raw and cooked pasta analyses

Moisture content of raw and cooked pasta was determined according to the AACC 44-40 method (AACC, 2000).

The optimal cooking time for each pasta type under study was determined using the AACC 66-50 method. A few short pasta strands were collected at different cooking times and immediately cut at right angles with a cutter to detect the presence of a central white portion. The time required for such a continuous white line to disappear represented the so-called optimum cooking time (ISO, 2016). Actually, when a broken white line was visible, the cooking process was regarded as completed, the resulting pasta being described as cooked “al dente” (i.e., tender, but still firm to the bite).

The amount of solids dispersed in the cooking water or *cooking loss* (CL) was determined as suggested by D’Egidio et al. (1990). The mass of the *pasta water* recovered from cooking was brought again to its initial value. A few aliquots (~10 g) were collected under constant mixing and dried to constant weight at 105 °C overnight. It was expressed as the ratio between the masses of residue and raw dried pasta used.

The tristimulus colour system CIE-Lab was used to record the colour of cooked pasta surface by using a portable colour-measuring instrument (mod. D25-PC2; Hunterlab, Restow,Virginia, USA) with a diffuse (0/45°) illuminating viewing geometry. After calibrating the instrument, it was possible to assess the three CIE-Lab coordinates, namely the lightness value (L^*) ranging from black (0) to white (100), its position (a^*) between red/magenta and green ($a^*>0$ indicates redness, $a^*<0$ indicates greenness), and its position (b^*) between yellow and blue ($b^*>0$ indicates yellowness, $b^*<0$ indicates blueness). Moreover, the true neutral gray is characterized by the values of $a^*=0$ and $b^*=0$.

Finally, the concentration of β-glucan in all flour types and raw and cooked pastas was determined according to the AACC Method 32-23.01.

2.4 Sensory analysis

2.4.1 Development of the lexicon

To develop the lexicon, ten expert sensory evaluators (4 males and 6 females, aged between 23 and 58 years), previously selected, trained and monitored according to ISO standards (ISO 8586-1.2012; ISO 8586-2, 2008), received all types of pasta as produced according to the experimental design. The generation of descriptors of the novel fresh pasta samples was performed in panel booths of a sensory evaluation laboratory that conformed with the international standards (ISO 8589, 1988). Before the test, two preliminary sessions were carried out to allow the assessors to become familiar with the products examined. The development of the lexicon was completed in three sessions, according to ISO 13299 (2010). At the beginning, the panellists evaluated the samples, presented in a monadic sequential order, to recognize individually the attributes that best described each sample. All the descriptors were collected into a list that was reduced by eliminating the inappropriate terms and by grouping synonymous and descriptors, which unequivocally referred to the same characteristics. The list was then reduced to 32 terms (Table 2). These were discussed with the evaluators to be sure to have shared the correct meaning of each descriptor by resorting, for some of them, to a standard reference anchored to a point of the scale of intensity. These standards were mainly natural products, while others were prepared as indicated in ISO 5496: 1992.

Finally, in two separate sessions, the evaluators assessed the fresh pasta samples using the 32 descriptors mentioned above, collected in a profile sheet, according to a linear intensity scale ranging from 0 to 9, where (0) was absence and (9) was high intensity.

The results were collected and calculated using the geometric mean (M), according to the UNI EN ISO11035 (1994):

$$M=\sqrt{I\,F} \quad (1)$$

where *F* is the ratio between the number of times a descriptor is mentioned and the maximum number of times this descriptor might be theoretically mentioned, and *I* the ratio between the current intensity of a descriptor assigned by the panel and the maximum intensity allowable for the same descriptor. Two odour (i.e., Hay, and Cooked semolina) and flavour (i.e., Hay, Cooked semolina) attributes of the 32 preliminary ones were excluded because they were not detected in all samples. Other nine odour (oat, hazelnut, bread crust, vegetal dried), taste (bitter, sour) and flavour (oat, hazelnut) descriptors were also discarded, their geometric mean being lower than 35, as shown in the electronic supplement (Table S2). Finally, the main descriptors were collected in a profile sheet used for sample tests. The definition of sensory attributes selected and standards used with the corresponding intensity values were defined in the electronic supplement (Table S3).

The samples prepared as described above were submitted to all assessors in a group session. Each assessor received 3 pieces 7-cm long and 1-cm wide of cooked pasta for each encoded sample, served on plastic disposable plates. The samples were coded with three-digit numbers and served to each assessor, in a random order, in sensory booths at room temperature (ISO 6658, 2005), in the sensory lab (ISO 8589,1988). The assessors were provided with mineral medium sparkly water to cleanse their palates between subsequent testing. All data were registered on a profile sheet.

2.4.2 Consumer test

The consumer test was carried out on pasta samples prepared in the same way used for the descriptive test. Each consumer received three strips of pasta for each type, served on plastic plates, coded with three-digit numbers, in random order. The tests were conducted in the sensory booths of the air-conditioned sensory laboratory. The pasta samples were evaluated for the acceptability of smell, external appearance, flavour and sensation in the mouth and overall acceptability. The affective test was conducted by 33 consumers, recruited from the students and staff of Department (DIBAF, Tuscia University), using a 9-point hedonic scale, (1=extremely dislike and 9= extremely like).

2.5 Statistical analysis

Each determination was conducted in triplicate, except for the descriptive sensory data (n=10) and hedonic test (n=33). Once all data had been collected, the ANOVA test was performed to discard the no-significant and redundant attributes. The Principal Component Analysis (PCA) was used to determine the most useful descriptors for sensory differentiation of the samples, and it was carried out on all the significant attributes of the matrix of the assessments of the sensory judges. To evaluate the contribution of each attribute to preference was calculated Pearson's correlation matrix to correlate the values of the sensory profile attributes, such as X variables, to the preferences evaluations, variable Y. The statistical analysis was carried out using a statistical analysis software (XLSTAT premium, Addinsoft, Paris).

3. Results and discussion

3.1 Pasta characterisation

Owing to the milling process, soft or durum wheat flour presented a non-detectable β-glucan concentration. Moreover, high β-glucan oat or barley flour exhibited a content in line with the product data sheet, this amounting to 22.0±0.3 or 11.1±0.5 g/100 g, respectively (Table S1).

Table 3 shows the β-glucan content in all the four pasta types examined here. The egg (STD) and egg white (ALB) pastas were practically free of such a fibre, while barley- (BFP) and oat- (OFP) rich pastas had a β-glucan content of 4.0±0.6 and 4.1±0.3 g/(100 g), respectively. Since the final concentration of β-glucan may vary with the pasta moisture content at the point of sale or at consumption stage, the β-glucan concentration in cooked pasta was also determined. It was found to be equal to 4.9±0.2 or 5.1±0.2 g/(100 g) for BFP or OFP types, respectively, probably due to the decrease in the starch fraction during the pasta cooking process (cooking loss).

The optimum cooking time (for the pasta types under study is shown in Table 3. The pasta STD exhibited the highest cooking time (7.17 min), probably because of the presence of whole eggs and its higher protein concentration. The cooking time of the other pasta samples ranged from 5 to 6 min owing to the presence of the only egg albumen.

Cooking loss (CL) represents the mass of organic matter lost into boiling water during pasta cooking. The smaller the cooking loss the greater the physical and sensory quality of cooked pasta become. According to Wu, Young, Warner & Bookwalter. (1987), CL should not exceed 10 g per 100 g of dry pasta. According to the Croatian Official Regulation (1991) cooking loss should not exceed 12 g/100 g. As shown in Table 3, all pasta samples examined here exhibited a higher cooking loss ranging from 12.1 to 14.1 g/100 g. Nevertheless, such cooking losses were in line with that founded in the case of noodles with different supplements (Sabo & Hardi, 2007).

Figure 1 shows the appearance of raw and cooked pasta samples. The CIE-Lab coordinates (L*, a*, b*) of the cooked pasta samples are reported in Table 3. Colour is an important quality parameter of fresh pasta. It results from the desirable yellow component and undesirable brown one. The ALB cooked samples exhibited the highest L* values (brightness). All β-glucan rich samples resulted higher in brownness, most likely for their higher ash and dietary fibre contents. Despite all samples were characterized by positive a* values (redness direction), the BFP and OFP samples displayed the highest values. The highest b* values (yellowness) were observed in ALB samples having used no fibre-rich flour and just egg white. Thanks to the use of whole eggs, the STD samples presented a high b* value (19±2), this being desirable for pasta colour scoring. ALB samples were bright yellow (higher b* values and lower a* ones). On the contrary, the use of β-glucan rich flours made the resulting pasta samples more brownish. In fact, brown colour (low L* value) tends to mask the yellow colour. Nevertheless, the use of egg albumen partly offset such an effect and the colour of such pastas were almost bright.

3.2 Sensory evaluation

The descriptive sensorial analysis, as resulting from the elaboration of the specific profile sheet mentioned above, allowed the selection of the descriptors best representing the peculiar features of the pasta samples studied.

From the ANOVA test shown in Table 4, the addition of barley or oat flour to wheat semolina appeared to be ineffective on the attributes related to the firmness (FIv), smell of wheat flour (WFs), the sweetness (SW) and salinity (SA) of the pasta (see Italic characters in Table 4). On the contrary, as shown by the bold characters in Table 4, the features more influenced by the addition of barley or oat flour to wheat semolina were the roughness (RGv) and colour (COv), the smell of chestnut (CHs) and cereals (CEs,) the aroma of toasted (ROf), bread crust (BCf), chestnut (CHf), the perception of fibre during chewing (FB) and aftertaste (AT).

3.3 Principal Component Analysis

Principal component analysis (PCA) was used to select the most significant sensory descriptors of the pasta samples under study.

The PCA analysis resulted in 12 eigenvectors PC_i, as shown in Fig. 2.

According to Kaiser's rule, only the first three principal components were characterised by an eigenvalue greater than 1 (Fig. 2), and were able to explain around 80 % of the overall variance.

As expected, the main discrimination among the four pasta samples assessed was linked to the addition of barley or oat flour, when compared to traditional pasta with egg or albumen. As shown Fig. 3, that plots the scores of the first two principal components PC_1 and PC_2, the first one explaining 59.3 % of the overall variance was able to discriminate the two groups of pasta samples, namely traditional and enriched with β-glucan enriched ones. As shown in Table S4 in the electronic supplement, PC_1 was positively influenced by all the descriptors related to cereals, (CEs, BCf, CHf), toasted (TOf) as well as to fibrousness (FB) and aftertaste (AT), by negatively affected by the olfactory and gustatory perception of egg and albumen (AL, EG, ALf, EGf). More details resulted from the second component (PC_2), explaining 14.5 % of the experimental variance. Although not completely, it led to the separation of the four types of pasta. Moreover, in some way, it promoted such separation thanks to the appearance attributes, such as colour (CO) and pitting (PI).

Although the groupings influenced by PC_1 were a priori predictable, the analysis was useful to highlight the main differences between the pastes enriched with barley or oat beta-glucans, as suggested by the second eigenvector PC_2. In particular, the addition of barley flour (BFP) increased the intensity of the flavour attributes, such as bread crust (BCf), toasted (TOf), cereals (CE), chestnuts (CH), and induced a greater perception of roughness (RG) and astringency (AS), this suggesting a greater aromatic complexity. The addition of oat flour (OFP), on the other hand, most influenced the appearance attributes, such as colour (CO), pitting (PI) and aftertaste (AT) of the pasta samples. Furthermore, the ANOVA analysis shown in Table 4 allowed both insignificant (i.e., FIv, WFs, SW, SA) and redundant (e.g., EGs, BCs, ALs, and CHs are closely related to EGf, BCf, ALf and CHf) attributes to be discarded.

3.4 Consumer preference

Table 5 shows the matrix of the correlation coefficients among the consumer preference and the attributes given by the judges to the pasta samples examined. By assuming an arbitrary threshold of 0.5 for each correlation coefficient, the attributes that mostly contribute to preference were related to smell (e.g., bread crust, BCs, and Cereal, CEs) and flavour (e.g., Roasted (ROf), Bread crust (BCf) and (CHf) chestnut flavour. This unexpected result suggested that our panellists appreciated the increase in the pasta aroma added by oat or barley flour.

Table S5 shows the mean scores of the preference, as evaluated by 33 consumers. Between the β-glucans enriched fresh pasta samples, OFP had the highest sensory score, followed by samples BFP for odour, external appearance, flavour and mouthfeel. Sample ALB obtained the lowest preference score. Indeed, such a sample had significantly lower values for all attributes than the control sample STD. In particular, the score for the external appearance was definitively low due to pale colour and firmness. The scores of the samples containing whole eggs were lower than that obtained for oat or barley flour enriched fresh pastas. Samples OFP and BFP exhibited high values for odour and flavour and mouthfeel.

Furthermore, from the correlation matrix (fig.4), it is possible to observe how the variables are related to each other, highlighting that the Cereal (CE) attribute appreciated by the judges in the samples is also strongly correlated to RGv, BCs, CHs, VDs and for the aroma to ROf, BCf, and CHf.

These data are confirmed by the clustered heat map, for which the preferred samples appear to be BFP and OFP. The samples obtained with oats flour seems to show a good correlation between preference and traits related to appearance (CO, PI), probably linked, by consumers, to the nutritional quality. The barley flour pasta, instead, the preference seems more tied to sensorial features as “cereal smell” (CEs), “bread crust smell” (BCs), and roughness (RG).

4. Conclusions

The fresh white egg pasta supplemented with β-glucan enriched barley or oat flour to assure 3 g of β-glucan per serving (100 g) was formulated using only liquid fresh pasteurised white eggs, nominally with an undetectable cholesterol content. The Principal Component Analysis (PCA) used as multivariate analytical statistical technique for the descriptive sensory test based on hedonic data showed a difference between the conventional and novel fresh pasta samples, and also allowed the identification of a number of characterising descriptors deriving from the functional ingredients added, that seem to be positively correlated with the overall consumer liking. Finally, the dark colour, rougher appearance and less homogeneous (dotting), hints and taste of cereals, as well as the presence of the fibres, give this special fresh pasta type an aspect of craftsmanship and healthiness plus an enrichment of the aromatic bouquet, which positively affected the judgment and seemed to increase the judgment of consumer friendliness.

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Declarations of interest

None

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Table 1
Formulation for the β-glucan enriched fresh egg pasta samples examined in this work: Fresh egg pasta (STD) and white egg ones, as such (ALB) or enriched with β-glucan barley (BFP) or oat (OFP) flour.

Sample Label	Composition
STD	Wheat flour type 00 (60±1 % w/w) and pasteurised whole egg liquid (40±1 % w/w)
ALB	Wheat flour type 00 (51±1 % w/w), durum wheat semolina (9±1 % w/w), and pasteurised egg white liquid (40±1 % w/w)
BFP	Wheat flour type 00 (24±1 % w/w); durum wheat semolina (7±1 % w/w), 11 % (w/w) β-glucan enriched barley flour (28±1% w/w), and pasteurised egg white liquid (41±1 % w/w).
OFP	Wheat flour type 00 (32±1% w/w), durum wheat semolina (9±1 % w/w), 22 % (w/w) β-glucan enriched oat flour (17±1 % w/w), and pasteurised egg white liquid (42±1 % w/w).

Table 2
Selected attributes (descriptors) for appearance, smell, and gustatory evaluation

External Appearance		Odour		Flavour and Mouthfeel	
Descriptor	**Code**	**Descriptor**	**Code**	**Descriptor**	**Code**
Colour	COv	Egg	EGs	Sweet	SW
Pitting	PIv	Chestnut	CHs	Astringent	AS
Rugosity	RGv	Albumen	ALs	Bitter	BI
		Oat	OAs	Salty	SA
		Hazelnut	HNs	Acidity	SO
		Hay	HAs	Roasted	ROf
		Cooked Semolina	CSs	Egg	EGf
		Bread Crust	BCs	Albumen	ALf
		Cardboard	CBs	Oat	OAf
		Vegetal dried	VDs	Hazelnut	HNf
		Wheat flour	WFs	Hay	HAf
		Cereals	CEs	Cooked semolina	CSf
		Hay	HAs	Fibre	FB
				Firmness	FI
				Bread Crust	BCf
				Aftertaste	AT

Table 3
Main characteristics of the fresh pasta samples studied (BG: β-glucan).

Pasta Label	Cooking Time	Cooking Loss	CIELAB Colour Scale Cooked Pasta			BG Raw pasta	BG Cooked Pasta
	[min]	**[g/100 g]**	**a***	**b***	**L***	**[g/100 g]**	**[g/100 g]**
STD	7.17 ±0.17	12.9±0.3	3.6±1.7	19.0±2.1	74±2	0±0	0±0
ALB	5.50±0.17	13.8±1.8	3.1±0.8	30.2±1.1	76±1	0±0	0±0
BFP	5.00 ±0.17	14.1±0.8	7.3±1.0	21.1±0.8	64±3	4.0±0.6	4.9±0.2
OFP	6.00±0.17	12.1±0.1	6.7±1.0	16.2±0.9	69±3	4.1±0.3	5.1±0.2

Table 4
Anova analysis: product effect for each descriptor

Descriptors	F	Pr > F
COv	37.489	< 0.0001
FIv	*1.151*	*0.347*
PI	7.596	0.001
RGv	9.747	0.000
EGs	47.911	**< 0.0001**
BCs	29.092	**< 0.0001**
ALs	14.899	**< 0.0001**
CHs	8.187	**0.000**
WFs	*0.383*	*0.766*
CEs	16.822	< 0.0001
SW	*1.166*	*0.341*
AS	5.587	0.004
SA	*1.729*	*0.185*
ROf	21.605	< 0.0001
EGf	32.770	< 0.0001
BCf	24.809	< 0.0001
ALf	13.343	< 0.0001
CHf	9.786	0.000
FB	32.666	< 0.0001
AT	9.125	0.000
PRE	5.759	0.004

Values displayed in bold characters correspond to descriptors that were removed

Table 5. Correlation matrix

Variables	**PRE**	COv	PIv	RGv	EGv	BCs	ALs	CHs	CEs	ROf	EGf	BCf	ALf	CHf	AS	FB	AT
PRE	**1**	0.384	0.558	0.596	-0.452	0.680	-0.522	0.772	0.767	0.776	-0.402	0.782	-0.601	0.809	0.374	0.833	0.782
COv	0.384	**1**	0.637	0.197	0.167	-0.126	-0.317	0.289	0.085	0.204	0.169	0.118	-0.324	0.235	0.079	0.378	0.499
PIv	0.558	0.637	**1**	0.434	-0.134	0.210	-0.370	0.475	0.422	0.436	-0.001	0.363	-0.479	0.492	0.335	0.532	0.594
RGv	0.596	0.197	0.434	**1**	-0.699	0.624	-0.333	0.633	0.741	0.752	-0.469	0.718	-0.384	0.777	0.438	0.773	0.617
EGv	-0.452	0.167	-0.134	-0.699	**1**	-0.672	0.182	-0.657	-0.760	-0.683	0.837	-0.632	0.224	-0.684	-0.393	-0.637	-0.383
BCs	0.680	-0.126	0.210	0.624	-0.672	**1**	-0.441	0.739	0.862	0.849	-0.560	0.898	-0.393	0.760	0.304	0.711	0.604
ALs	-0.522	-0.317	-0.370	-0.333	0.182	-0.441	**1**	-0.449	-0.421	-0.476	0.159	-0.536	0.747	-0.502	-0.065	-0.532	-0.474
CHs	**0.772**	0.289	0.475	0.633	-0.657	0.739	-0.449	**1**	0.828	0.805	-0.671	0.851	-0.489	0.880	0.350	0.870	0.690
CEs	**0.767**	0.085	0.422	0.741	-0.760	0.862	-0.421	0.828	**1**	0.878	-0.685	0.861	-0.521	0.869	0.370	0.817	0.691
ROf	**0.776**	0.204	0.436	0.752	-0.683	0.849	-0.476	0.805	0.878	**1**	-0.569	0.915	-0.527	0.847	0.353	0.817	0.755
EGf	-0.402	0.169	-0.001	-0.469	0.837	-0.560	0.159	-0.671	-0.685	-0.569	**1**	-0.545	0.303	-0.602	-0.299	-0.629	-0.341
BCf	**0.782**	0.118	0.363	0.718	-0.632	0.898	-0.536	0.851	0.861	0.915	-0.545	**1**	-0.503	0.856	0.329	0.812	0.744
ALf	-0.601	-0.324	-0.479	-0.384	0.224	-0.393	0.747	-0.489	-0.521	-0.527	0.303	-0.503	**1**	-0.592	-0.102	-0.609	-0.587
CHf	**0.809**	0.235	0.492	0.777	-0.684	0.760	-0.502	0.880	0.869	0.847	-0.602	0.856	-0.592	**1**	0.387	0.874	0.710
AS	0.374	0.079	0.335	0.438	-0.393	0.304	-0.065	0.350	0.370	0.353	-0.299	0.329	-0.102	0.387	**1**	0.524	0.225
FB	**0.833**	0.378	0.532	0.773	-0.637	0.711	-0.532	0.870	0.817	0.817	-0.629	0.812	-0.609	0.874	0.524	**1**	0.782
AT	**0.782**	0.499	0.594	0.617	-0.383	0.604	-0.474	0.690	0.691	0.755	-0.341	0.744	-0.587	0.710	0.225	0.782	**1**

FIGURES AND FIGURE HEADINGS

Figure 1
Pictures of raw and cooked pasta samples examined here.

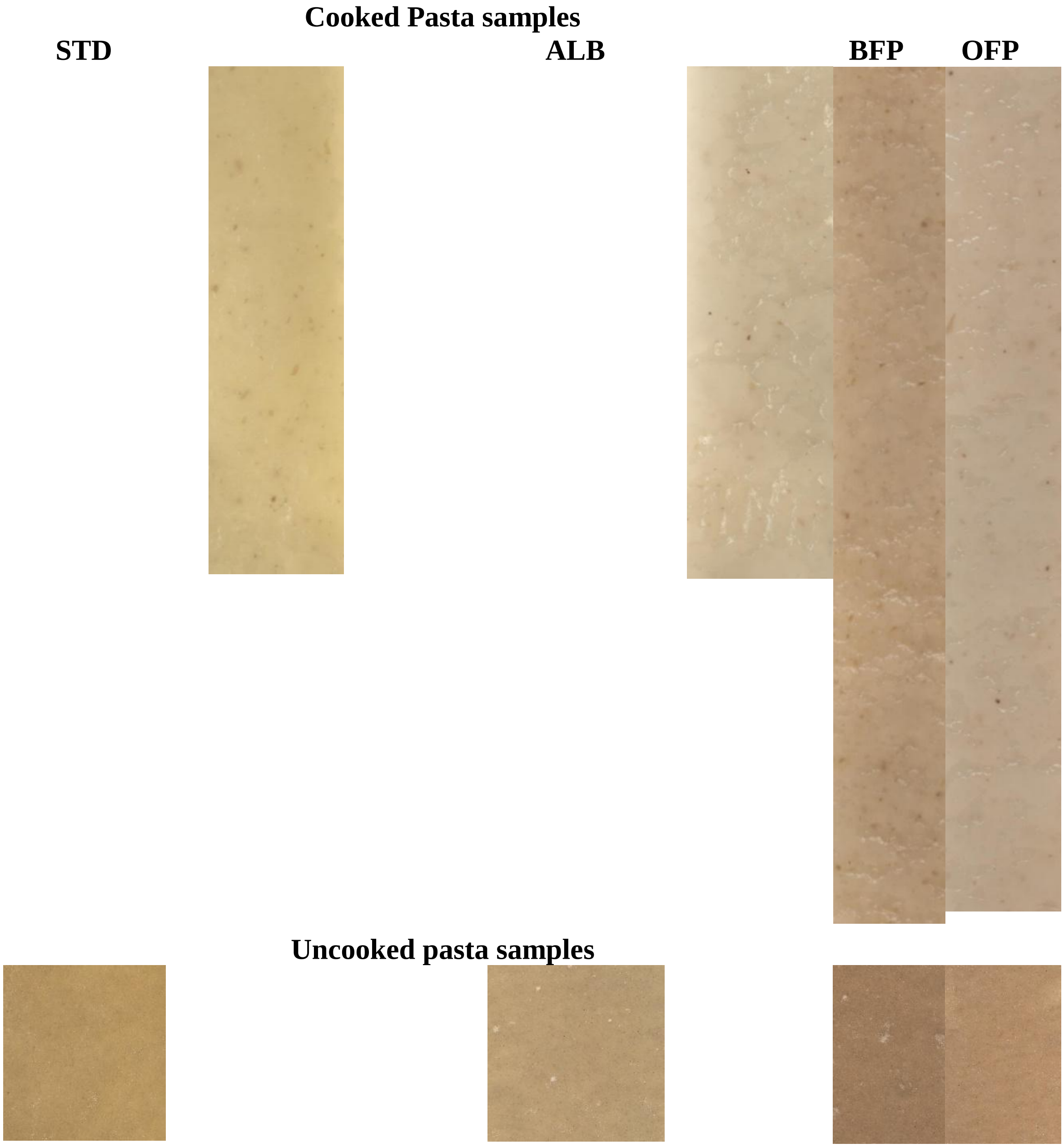


Figure 2
PCA: Eigenvalues and cumulative explained variance

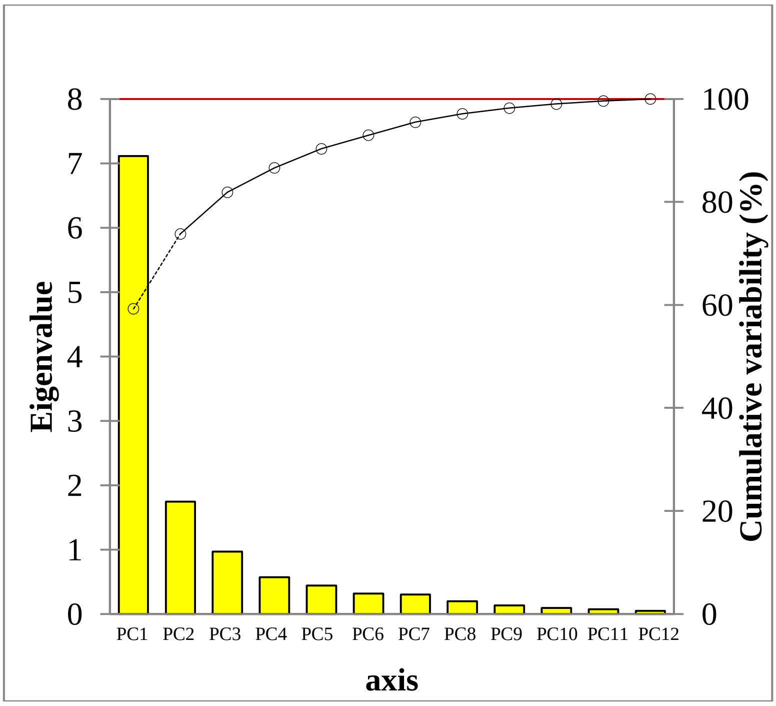


Figure 3. PCA bi-plot of sensory attributes of pasta PC1 and PC2 axes;

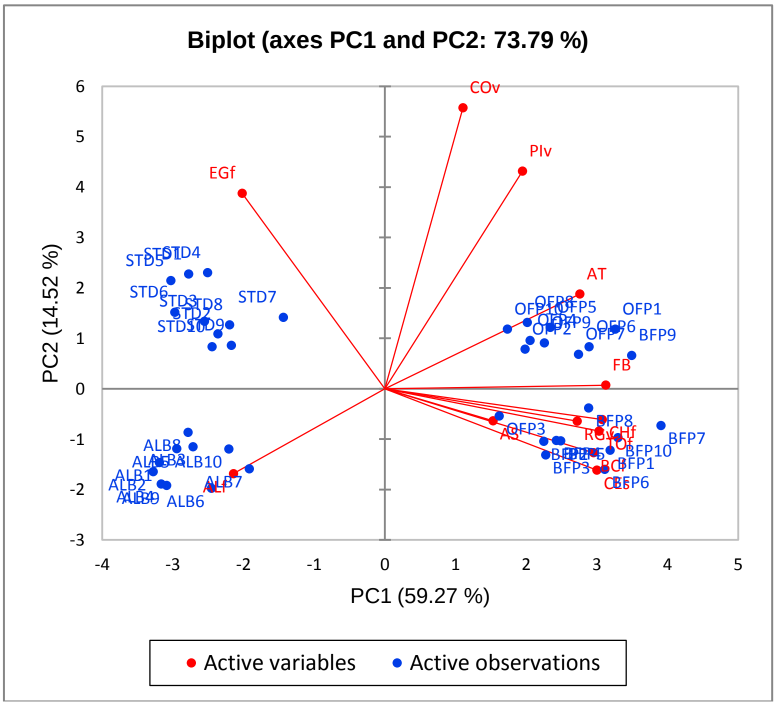
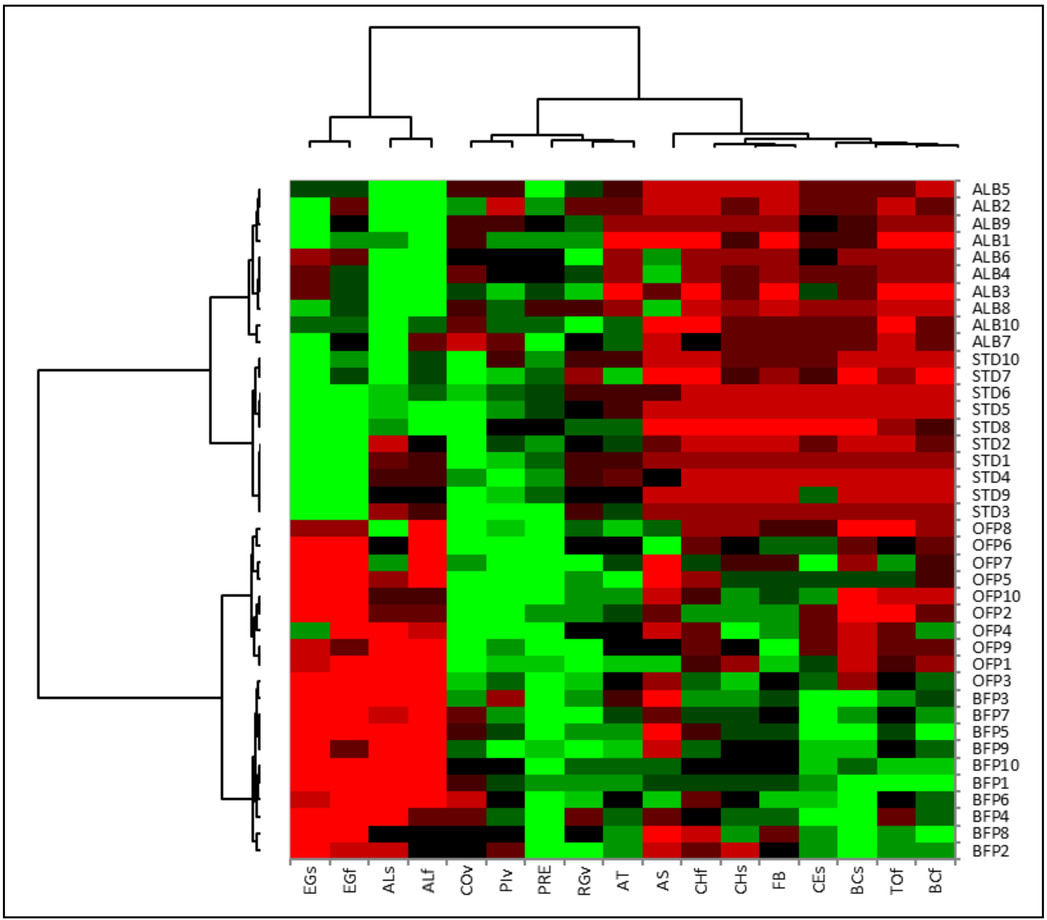


Figure 4 Clustered heat map of sensorial attributes in the pasta samples



Supplementary Material
Click here to download Supplementary Material: Sensory evaluation of novel fresh pastas 2020 - LWT SUP B.docx

*Conflict of Interest Form

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Declarations of interest

None