Received: 17 May 2021 | Revised: 17 November 2021 | Accepted: 12 December 2021

DOI: 10.1111/jfpp.16261

Journal of Food Processing and Preservation | Institute of Food Science + Technology ifst | WILEY

ORIGINAL ARTICLE

Quality parameters and technological properties of pasta enriched with a fish by-product: A healthy novel food

Andrea Ainsa | Sergio Roldan | Pedro L. Marquina | Pedro Roncalés | José Antonio Beltrán | Juan B. Calanche Morales

Instituto Agroalimentario de Aragón -IA2- Universidad de Zaragoza-CITA, Zaragoza, Spain

Correspondence
Juan B. Calanche Morales, Instituto Agroalimentario de Aragón -IA2- Universidad de Zaragoza-CITA, Miguel Servet, 177, 50013 Zaragoza, Spain.
Email: calanche@unizar.es

Abstract

The effect of incorporating a fish (*D. labrax*) by-product on pasta quality was evaluated to assess its technological viability in comparison with a common pasta. Two enriched pastas, both dried and fresh and including or not a natural antioxidant (*R. officinalis*) were analyzed and compared to traditional pasta (durum and spelt). Findings indicated that enriched pasta showed a decrease in their texture properties, except for adhesiveness which was higher compared to traditional pasta. The addition of fish caused slight changes in color. Regarding the technological quality, it was moderately affected by fish inclusion, presenting lower gains in weight respect to control pasta (>15% of difference). Therefore, enriched pasta appears to be a good alternative to offer food with an improved nutritional profile with a low impact on the quality of the product from a technological point of view since the introduction of fish does not extensively affect pasta quality.

Novelty impact statement

- The enrichment of pasta from fish by-product is a good alternative to improve its nutritional value.
- The cooking had a beneficial effect on the bioavailability of nutrients in enriched pasta with fish.
- Technological properties of enriched pasta with fish after cooking was similar to traditional pasta made with durum wheat.

1 | INTRODUCTION

Pasta is one of the most consumed foods in the world due to its versatility, easy preparation and storage conditions (Krishnan & Prabhasankar, 2012). The cooking properties of pasta are determined by different parameters such as optimal cooking time, weight gain and hydration, cooking loss and texture (Ficco et al., 2016). The quality behavior of pasta during cooking depends on its structure, defined as a compact matrix made up of swollen starch granules, trapped in a net of proteins. The optimal cooking time is the time required for the opaque central core of the pasta to disappear (Sui et al., 2006). Pasta prepared following an optimal cooking is characterized by a high firmness, low volume, absence of stickiness, and low cooking loss (D'Egidio et al., 1990).

The protein present in the wheat grain affects technological properties of pasta. In this sense, gluten proteins give firmness and elasticity to the mass. The formation of the continuous and stable protein network during the mixing and extrusion stages determines the texture of pasta, which can be measured by instrumental methods (Sissons, 2016). The most common instrumental method is TPA (Texture Profile Analysis) and has been used in multiple pasta studies (Ainsa et al., 2021a; El-Sohaimy et al., 2020; Odey & Lee, 2020; Olivera & Salvadori, 2009).

Furthermore, color is an important attribute of pasta which influences its acceptance by consumers, who generally prefer a bright yellow color related to the carotenoids present in the wheat grain. The loss of this typical color could be caused by lipoxygenase, which degrades carotenoids. Thus, the reduction of this enzyme during processing is of interest from a technological point of view (Sicignano et al., 2015). Color of pasta depends, too, on the mixture of different ingredients in its formulation, and so, it is common to find pasta with different colors.

A healthy diet prevents diseases (Babuskin et al., 2014). In this sense, marine food is an important resource to obtain healthy ingredients and bioactive compounds such as oils, proteins, peptides, and microalgae (Kadam & Prabhasankar, 2010). Besides this, the industrial processing of fishery products generates a large amount of underused by-products, which also require costly processes for their elimination (Yan & Chen, 2015). Fish concentrates are products derived from fish processing, which represent a cheap source of high-quality nutrients suitable for the human diet. Its incorporation into pasta could help to increase its content in essential amino acids and polyunsaturated Ω3 fatty acids, especially eicosapentaenoic acid -EPA- and docosahexaenoic acid-DHA (Oliveira et al., 2015). However, the incorporation of ingredients into pasta can modify its physicochemical properties and texture (Liu et al., 2016).

According to Mercier et al. (2016), three of the most important quality attributes are cooking, color, and mechanical properties. Therefore, the purpose of this study was to evaluate the effect of the addition of sea bass concentrate (*Dicentrarchus labrax*) on the physical and technological characteristics of pasta in order to see the feasibility of pasta quality for future industrial scaling.

2 | MATERIALS AND METHODS

2.1 | Fish concentrates preparation

Frozen fish cuts (by-product) from the processing of sea bass (*D. labrax*) in a local factory of Spain (Scanfisk®) were defrosted 24 hr before use. After that, they were dipped in an 8% saline solution and dried in a slow air velocity (60°C for 24 hr) oven and ground until finely uniform (Calanche et al., 2019). Two kinds of concentrates (with antioxidant and without antioxidant) were made because of the interest in antioxidant incorporation. The antioxidant used was natural rosemary extract powder (E-392) provided by Marbys® which acts as manufacturing aid in fish concentrate.

2.2 | Pasta preparation

Two pasta formulations were elaborated according to specifications of local company Innova Obrador® (Zaragoza, Spain). This company has two production lines: the first one dedicated to pasta from durum semolina addressed to all kinds of consumers, and a second line producing integral pasta using spelt semolina and bran addressed to specific food regimes or to consumers with a concern for a healthier diet. In this way, the first one was made with durum semolina (*Triticum durum*) and fish concentrate, called "Durum" while in the second one, identified as "Spelt," was chosen from spelt flour (*Triticum spelt*) and fish concentrates. The extrusion format used was *fusilli* of approximately 4 cm in length. Two preservation methods, dry (room temperature) and frozen fresh (−20°C) pasta and two treatments were proposed: without antioxidant and with antioxidant. In addition, two pasta without fish were elaborated as controls to evaluate the effect of fish addition. All pasta formulation and codes of experimental design are shown in Table 1.

2.3 | Optimal cooking time

The determination of the optimal cooking time was carried out by measuring the hardness of the cooked pasta using a texturometer (ANAME Instrumentation Scientific, mod. TA-XT2i) with a flat Warner-Bratzler probe. The procedures and conditions used in a previous study were repeated (Ainsa et al., 2021b). Dry pasta was measured in a cooking time interval of 180 to 360 s (except durum control pasta, that reached 520 s) and fresh pasta, varying from 30 to 180 s. The measurements for each cooking time were repeated 7 times.

As an alternative to the instrumental method, the optimal cooking time was determined following the AACC 66–50.01 method (AACC, 2000). During cooking, a certain number of *fusilli* (≈3–4) were extracted every 30 s. Once tempered, they were compressed using two transparent methacrylate plates. The time was estimated visually, when the white core of pasta completely disappeared.

2.4 | Texture Profile Analysis (TPA)

A texture profile analysis (TPA) of pasta was made using a texturometer (ANAME Scientific Instrumentation, mod. TA-XT2i) with a cylindrical flat aluminum probe and consisted in the application of two compression cycles with a decompression of 20 s, which allowed the determination of different texture properties: hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience. The pasta samples used were cooked prior to the optimal cooking time established. The conditions were the following: test speed: 2 mm/s; sample deformation: 75%; force threshold: 10 g. Seven measurements were made to each pasta.

2.5 | Pasta color

Color measurements were performed in cooked pasta using a colorimeter (Minolta. CM-2002. Japan). For the characterization, the CIEL* *a** *b** system was used which is represented by *L** (brightness), *a** (redness), and *b** (yelowness). For each sample, readings were taken six times. The color variation produced by fish was

TABLE 1 Formulations and experimental design of each pasta assayed

Formulation

Durum	%	Durum with antioxidant	%	Durum Control	%	Spelt	%	Spelt with antioxidant	%	Spelt Control	%
Durum wheat	64.5	Durum wheat	64.5	Durum wheat	75	Spelt wheat	55	Spelt wheat	55	Spelt wheat	75
Fish concentrate	10	Fish concentrate & antioxidant	10	—	—	Spelt bran	10	Spelt bran	10	—	—
Aromatic herbs and spices	0.5	Aromatic herbs and spices	0.5	—	—	Fish concentrate	10	Fish concentrate & antioxidant	10	—	—
Water	25	Water	25	Water	25	Water	25	Water	25	Water	25
				die							

Experimental design

Code	Type	Preservation	Treatment
Enriched pasta			
DD	Durum	Dry	Without antioxidant
DDA	Durum	Dry	With antioxidant
DF	Durum	Fresh	Without antioxidant
DFA	Durum	Fresh	With antioxidant
SD	Spelt	Dry	Without antioxidant
SDA	Spelt	Dry	With antioxidant
SF	Spelt	Fresh	Without antioxidant
SFA	Spelt	Fresh	With antioxidant
Control pasta			
DDC	Durum	Dry	—
DFC	Durum	Fresh	—
SDC	Spelt	Dry	—
SFC	Spelt	Fresh	—

TABLE 2 Optimal cooking times of each pasta according to both methods used

Pasta	OPTIMAL COOKING TIME (S) Warner-Bratzler (WB)	Visual (AACC 66–50.01)	Spearman correlation (ρ)
Durum Dry Control (DDC)	390	390	−0.686*
Durum Dry (DD)	300	300	−0.801*
Durum Dry Antioxidant (DDA)	300	300	−0.882*
Durum Fresh Control (DFC)	120	120	−0.884*
Durum Fresh (DF)	90	120	−0.901*
Durum Fresh Antioxidant (DFA)	90	120	−0.946*
Spelt Dry Control (SDC)	300	300	−0.722
Spelt Dry (SD)	270	270	−0.808*
Spelt Dry Antioxidant (SDA)	270	270	−0.808*
Spelt Fresh Control (SFC)	120	150	−0.739
Spelt Fresh (SF)	90	120	−0.965*
Spelt Fresh Antioxidant (SFA)	90	120	−0.983*

Note: No sé si incluir el valor de la fuerza de corte!!!
*Correlations with statistical significance.

calculated with the total color difference (ΔE) between control pasta and each enriched pasta, which is determined by the following equation:

$$\Delta E = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2}, \quad (1)$$

$\Delta L = L^*$ Fish pasta−L^* Standard pasta; $\Delta a = a$ Fish pasta−a^* Standard pasta and $\Delta b = b^*$ Fish pasta−b^* Standard pasta

2.6 | Technological parameters

2.6.1 | Weight gain and swelling index

The weight gain and hydration of pasta were determined with the following modifications: 3 g of pasta were cooked in 180 mL of distilled water for the time of estimated optimal cooking for each pasta, they were cooled in 100 mL of cold water; then pasta were dried and weighed on an analytical balance (Cleary & Brennan, 2006). The weight gain is determined by the following equation:

$$\text{WG}(\%) = \frac{\text{Weight of cooked pasta} - \text{Weight of pasta after drying}}{\text{Weight after pasta drying}}, \quad (2)$$

Then, cooked pasta was dehydrated in an oven at 105°C until reaching constant weight (24 hr). This index was calculated from the following formula:

$$\text{SI}(\text{g/g}) = \frac{\text{Weight of cooked pasta (g)}}{\text{Weight of dried pasta }(g)}, \quad (3)$$

2.6.2 | Cooking losses

A portion (3g) of each developed pasta were immersed in 180 mL of water and boiled during their optimal cooking times (AACC, 2000). The water resulting after heating was collected in crucibles and allowed to evaporate in a stove at 105°C until reaching a constant weight. The dry residue was weighed on an analytical balance and determined as a percentage of the total weight of pasta before cooking.

2.6.3 | Moisture

Moisture was evaluated by a gravimetric method. Samples were weighed in the analytical balance and dried in a stove at 105°C until reaching a constant weight. They were cooled to room temperature in a desiccator for 60 min and were weighed again.

$$\text{Moisture}(\%) = \frac{\text{raw pasta weight} - \text{dried pasta weight}}{\text{raw pasta weight}}, \quad (4)$$

2.7 | Statistical analysis

Results were statistically analyzed using the software XLSTAT (Version 16, Addinsof). Analysis of variance (ANOVA), test of multiple comparisons (Fisher -LSD-) with a 95% confidence interval, and in certain cases, Pearson's correlation coefficients were determined. Concerning TPA results, a Principal Component Analysis (PCA) was carried out with Varimax rotation that allowed to visualize the existing relationships among texture parameters and developed pasta, thus facilitating interpretation and obtaining a comprehensive overview of the study.

3 | RESULTS

3.1 | Optimal cooking time

Table 2 shows the optimal cooking time for each pasta, using the Warner-Bratzler cutting test (WB) and visual determination, which showed a positive Pearson correlation between them ($r^2 = 0.996$). The optimal cooking time for dry enriched durum pasta was 300 s while dry control durum needed 390 s. However, in the case of spelt pasta, their optimal cooking times were 270 s, unlike its analogue without fish which reached 300 s. For fresh pasta, the optimal cooking time was 90 s according to Warner-Bratzler and 120 s respect to visual test whereas for both control pasta was 120 s, while it was 150 s in visual test in control spelt.

3.2 | Texture profile analysis (TPA)

As can be seen in Table 3, enriched pasta presented a significantly lower hardness ($p < .05$) than control pasta. However, in fresh spelt pasta, there were no significant differences in hardness between control and pasta with fish.

The addition of fish caused an increase in adhesiveness in both types of pasta (durum and spelt). Enriched pasta was significantly less elastic ($p < .05$) than control pasta. The cohesiveness of enriched pasta was significantly lower than that of control pasta, with the only exception of durum dry enriched pasta which presented a very similar behaviour to its control. Similarly, all other parameters showed lower values in pasta with fish compared to pasta without fish.

An Analysis of Principal Components (PCA) was applied to the results obtained in Table 3 (Figure 1), which allowed to visualize the relationships among all the measured variables studied and types of pasta. In Figure 1a (dry pasta), components F1 and F2 accounted for 63.14% of the variability. The F1 component (47.1%) allowed to separate control from enriched pasta. Control pasta showed higher values than enriched pasta in most parameters, except for adhesiveness, which was higher for enriched pasta. All developed dry pasta had significant ($p < .001$) and high Pearson correlation coefficients between hardness and gumminess ($r^2 > 0.92$) as well as between cohesiveness and resilience ($r^2 > 0.85$). According to F2 component, durum pasta with fish had a higher adhesiveness than spelt pasta with fish. In addition, it could be seen that pasta without antioxidant were more adhesive than pasta with antioxidant.

With respect to fresh pasta, shown in Figure 1b, a 64.7% of the variability was explained. Control pasta were separated from pasta with fish in F1 (49.5%). Pasta without fish had higher values in all parameters except for adhesiveness which was higher for enriched pasta. Enriched fresh pasta showed significant ($p < .001$) and high Pearson correlation coefficients, too, between hardness and gumminess ($r^2 > 0.88$) but highlighted a relationship ($r^2 > -0.85$) between adhesiveness and gumminess. In F2 component, both kinds of enriched pasta (spelt and durum) were separated and a clear difference was appreciated when antioxidant was included in each one.

3.3 | Pasta color

The effect of fish in durum and spelt pasta was evaluated separately because formulations had different color as shown in Figure 2.

TABLE 3 Texture parameters at optimal cooking time for each type of pasta assayed

Code	Hardness (g)	Adhesiveness (g/s)	Springiness (%)	Cohesiveness	Gumminess	Chewiness	Resilience
Dryed pasta							
DDC	2530.12a	3.47b	0.71a	0.40c	1009.99a	715.43a	0.18b
DD	2264.00b	35.79a	0.47cd	0.44b	988.08a	470.32b	0.16c
DDA	1990.77c	32.95a	0.49c	0.41bc	813.36b	397.85b	0.15c
SDC	2140.90bc	6.73b	0.64b	0.50a	1084.34a	695.89a	0.20a
SD	1718.81d	28.41a	0.42d	0.36d	616.60c	260.14c	0.11d
SDA	1515.42d	13.52b	0.42d	0.33d	497.00c	211.23c	0.11d
Fresh pasta							
DFC	3024.45a	4.00d	0.75a	0.53b	1594.61a	1205.65a	0.25a
DF	2299.07b	103.49a	0.35b	0.45c	1019.27c	355.04c	0.14c
DFA	1710.78c	76.62b	0.35b	0.39d	673.75d	232.80d	0.11d
SFC	2346.19b	9.95d	0.70a	0.59a	1386.09b	974.51b	0.21b
SF	2167.78b	32.97c	0.36b	0.32e	697.11d	250.71cd	0.10d
SFA	2100.39bc	21.86cd	0.33b	0.31e	646.55d	217.78d	0.10d

Note: Lowercase letters show significant differences between types of pasta for dry and fresh pasta for each texture parameter.

Abbreviations: DD, Durum Dry; DDA, Durum Dry Antioxidant; DDC, Durum Dry Control; DF, Durum Fresh; DFA, Durum Fresh Antioxidant; DFC, Durum Fresh Control; SD, Spelt Dry; SDA, Spelt Dry Antioxidant; SDC, Spelt Dry Control; SF, Spelt Fresh; SFA, Spelt Fresh Antioxidant; SFC, Spelt Fresh Control.

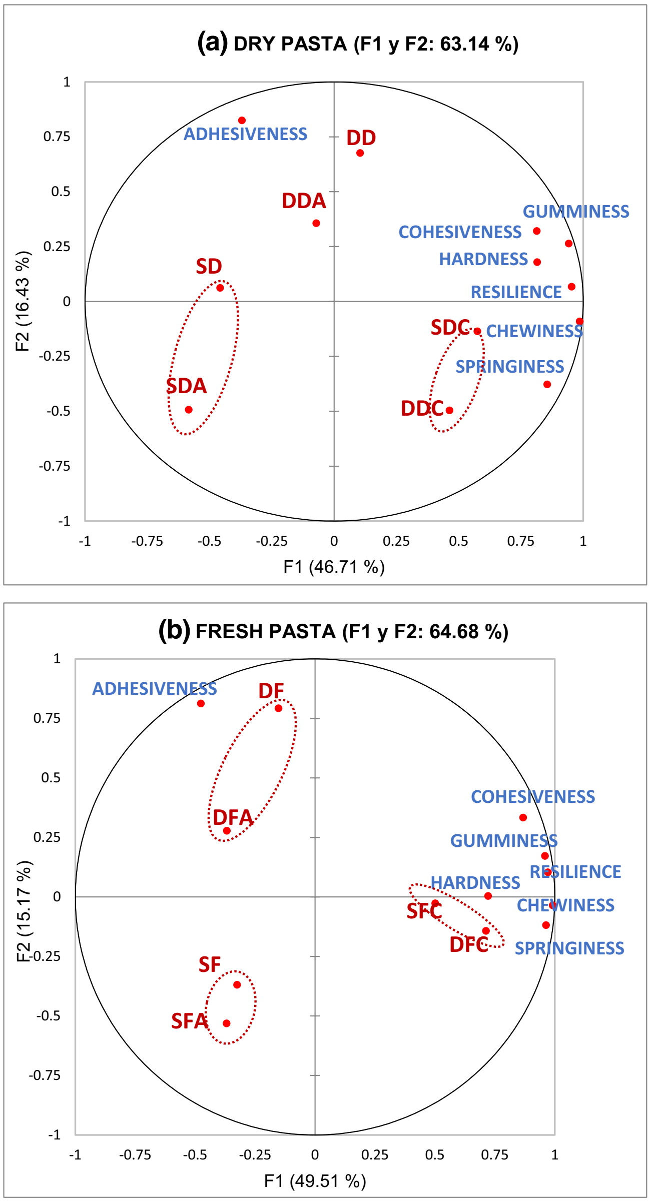

FIGURE 1 PCA of developed pasta for dry pasta (a) and fresh pasta (b). Abbreviations: DD: Durum Dry; DDA: Durum Dry Antioxidant; DDC: Durum Dry Control; DF: Durum Fresh; DFA: Durum Fresh Antioxidant; DFC: Durum Fresh Control; SD: Spelt Dry; SDA: Spelt Dry Antioxidant; SDC: Spelt Dry Control; SF: Spelt Fresh; SFA: Spelt Fresh Antioxidant; SFC: Spelt Fresh Control

As seen in Figure 2a, the luminosity (L^*) in durum pasta experienced a significant decrease ($p < .05$) in enriched pasta with respect to control pasta. On the other hand, the value of the red index (a^*) was significantly higher in enriched pasta than in control pasta. Furthermore, the yellow index (b^*) presented a significantly higher intensity in enriched pasta than in durum control pasta.

Regarding spelt pasta (Figure 2c), the luminosity (L^*) of enriched pasta was significantly lower than that of the control. Significant ($p < .05$) differences were also observed among pasta in which different storage methods had been applied. In addition, spelt pasta with fish had a higher a^* value than that without fish. Finally, the intensity of the yellow index (b^*) was moderate in all enriched pasta.

In order to assess globally the differences in the color of pasta related to the addition of fish, the total color difference (ΔE) was evaluated, as shown in Figure 2. Regarding durum pasta (Figure 2b), fresh enriched pasta showed a higher difference ($p < .05$) than dried pasta with fish. In addition, fresh pasta without antioxidant presented a greater color change than that with antioxidant. ΔE values were very similar for spelt formulations (Figure 2d), although in the case of dry pasta, there were significant differences ($p < .05$) between pasta with or without antioxidant. Apparently, the incorporation of antioxidant attenuated the color variation in wholemeal pasta with the lowest value of ΔE. Differences in color in spelt enriched pasta compared to control were lower than in the case of durum enriched and durum control pasta. This suggests that the incorporation of spelt flour and bran in spelt pasta gave it a darker color that might mask the color provided by fish.

3.4 | Technological parameters

Values of technological parameters are shown in Table 4. The addition of fish caused a significant decrease in weight gain. Control pasta presented weight gains greater than pasta with fish, with 167.1% for durum and 136.3% for spelt. Comparing pasta with fish, weigh gain was greater in dry durum than in spelt pasta, while durum was different from each other in fresh pasta, either with antioxidant or not. A very clear distinction in weight gain between fresh and dry pasta was evident, being higher in the latter.

Regarding the swelling index, a significant decrease was observed in durum enriched pasta with respect to durum control, while these differences were not significant when comparing spelt with fish to spelt control pasta.

In general, cooking losses were significantly higher in enriched pasta. In this regard, it was more accentuated in dry enriched durum pasta, whose loss exceeded 9% of its respective dry weight. This was in contrast to control formulations, which did not exceed 6%. When comparing enriched pasta, the increase was lower in spelt than in durum pasta. Cooking losses of spelt enriched pasta increased less than 1% in relation to spelt control.

Regarding moisture, it did not present significant differences in dry durum enriched pasta with respect to control durum; however, in dry spelt with antioxidant it was observed a significant decrease in comparison with fresh control spelt pasta. In contrast, the moisture of fresh enriched pasta was around 34%, resulting significantly higher than in fresh control, which presented values of approximately 31% for durum and 29% for spelt pasta.

4 | DISCUSSION

4.1 | Cooking times

Enriched pasta required lower cooking times than control pasta. This might be due to the modification of the physico-chemical characteristics due to the incorporation of fish (Ainsa et al., 2021a). Because of

Journal of Food Processing and Preservation

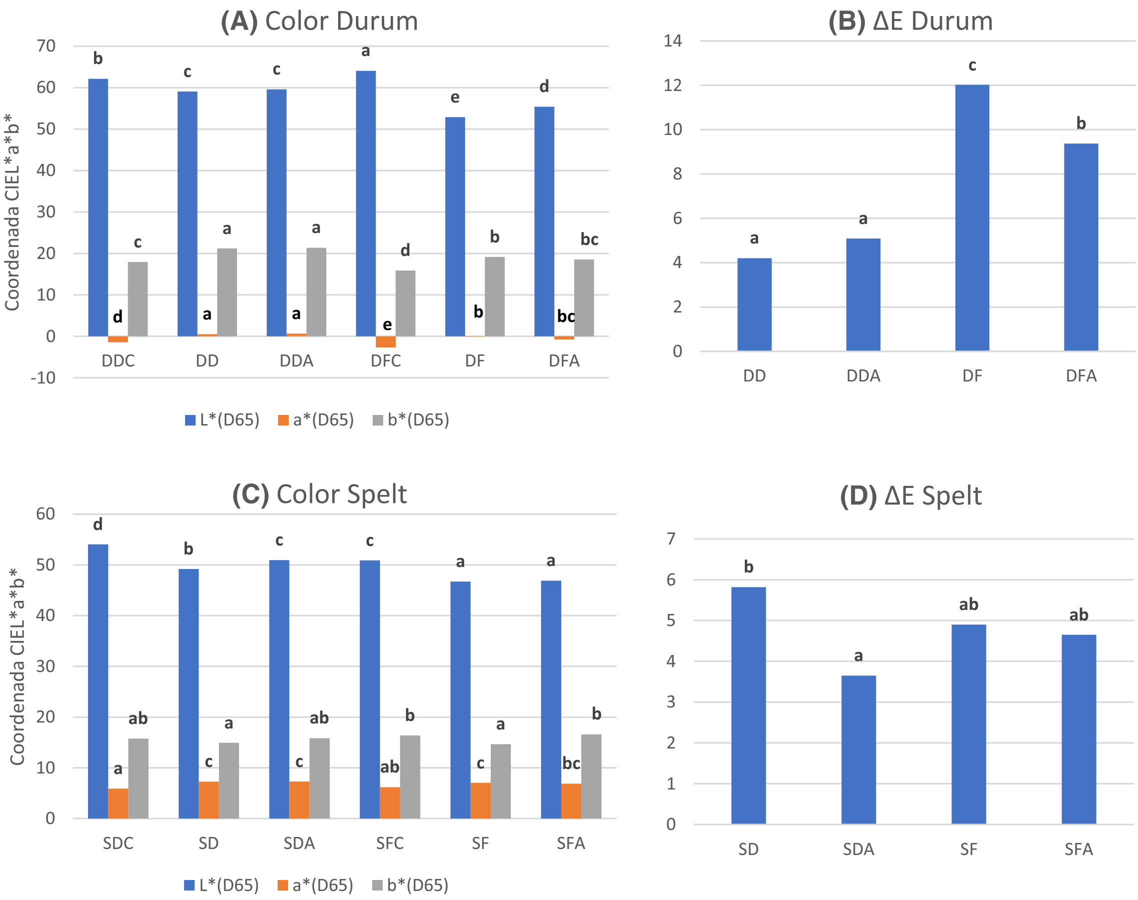

FIGURE 2 Color parameters in different types of pasta. Distinc letters indicate significant difference ($p < .05$) among the different parameters between treatments. (a) Color Durum; (b) Color Spelt. Abbreviations: DD, Durum Dry; DDA, Durum Dry Antioxidant; DDC, Durum Dry Control; DF, Durum Fresh; DFA, Durum Fresh Antioxidant; DFC, Durum Fresh Control; SD, Spelt Dry; SDA, Spelt Dry Antioxidant; SDC, Spelt Dry Control; SF, Spelt Fresh; SFA, Spelt Fresh Antioxidant; SFC, Spelt Fresh Control

the replacement of semolina by fish, the starch content decreases and, consequently, the amount of water required for its gelatinization, too. Furthermore, this substitution implies a decrease of the glutenin content and an increase in components of lower molecular weight, which require less time to hydrate during cooking (Vernaza et al., 2012).

4.2 | Texture profile (TPA)

The hardness of pasta depends chiefly on the integrity of the matrix formed by the gluten proteins during cooking (Larrosa et al., 2016), besides the effect of components such as starch, lipids, and other ingredients added which could promote a weakening in dough structure of pasta. (Ainsa et al., 2021a; Chang & Wu, 2008). This decrease in hardness is associated with the enfeebling condition of the three-dimensional structure as a consequence mainly of fish addition, as it provides lipids and myofibrillar proteins that interfere in the matrix formed by gluten and starch (Kowalczewski et al., 2019). This effect was appreciated during pasta making with the incorporation of an antioxidant (rosemary) which caused a decrease not only in hardness but also in other texture parameters, especially in enriched fresh durum pasta.

Other studies pointed out that pasta enrichment causes a weakening of its structure, which is accompanied by higher cooking losses. These losses are associated with the leaching of amylose from starch granules, which may be the cause of the appearance of unwanted textures (Islas-Rubio et al., 2014; Sissons et al., 2005). The mechanical properties depend on the quality and quantity of gluten proteins (glutenins and gliadins). Specifically, its springiness is determined by the ability of glutenin subunits to establish intermolecular hydrogen bonds (Atwell, 2016). Based on this, enriched pasta has a lower gluten content than control pasta by replacing wheat semolina by fish. Furthermore, the exploratory study with all attributes studied in this work had not been previously observed in any other previous study. In this case, it was carried out on both fresh and dry pasta, investigating the effect of drying.

4.3 | Color

A decrease in brightness due to the incorporation of fish has been found, too, in previous studies (Desai et al., 2018; Mercier et al., 2016). The yellow index (b^*) is of great interest since, in most cases, consumers show a preference for pasta with an intense yellow color (Pongpichaiudom & Songsermpong, 2018), so this change appears to be beneficial from a

TABLE 4 Values of technological properties for each pasta analyzed

	WG (%)	SI (g/g)	CL (%)	H (%)
DDC	167.06i	3.20f	4.46b	11.25a
DD	148.32hr	3.01e	9.38e	11.58ab
DDA	148.59hr	3.04ef	9.38e	10.70a
DFC	93.23e	2.92d	3.62a	31.22d
DF	49.90a	2.56b	5.33c	34.04e
DFA	58.89b	2.70c	5.46c	34.46e
SD	136.33g	2.91d	5.71cd	12.57b
SDC	123.31f	2.76cd	6.58d	10.91a
SDA	127.28f	2.78cd	5.47c	10.83a
SFC	72.72d	2.59b	3.67a	29.40c
SF	51.74a	2.44a	4.26b	34.20e
SFA	65.85c	2.44a	4.37b	32.01d

Note: Distinct letters indicate significant difference ($p < .05$) among different pasta for each technological property.

Abbreviations: CL, cooking losses; DD, Durum Dry; DDA, Durum Dry Antioxidant; DDC, Durum Dry Control; DF, Durum Fresh; DFA, Durum Fresh Antioxidant; DFC, Durum Fresh Control; H, humidity; SD, Spelt Dry; SDA, Spelt Dry Antioxidant; SDC, Spelt Dry Control; SF, Spelt Fresh; SFA, Spelt Fresh Antioxidant; SFC, Spelt Fresh Control; SI, swelling index; WG, weight gain.

technological point of view. The global color variation (ΔE) allowed to estimating changes in color among all analyzed pasta (control versus. enriched) concerning the addition of other ingredients in its manufacture. Although the highest value of ΔE was found in enriched durum fresh pasta, thus demonstrating its liability to color changes, values obtained in this experiment were in agreement with those of previous studies in enriched durum pasta with fish ($\Delta E = 3.79$ -Aínsa et al., 2021b & $\Delta E = 3.49–9.59$ -Desai et al.,2018), showing variations within the range 3–12 as can be seen in Figure 2. Furthermore, in the case of spelt pasta, the addition of antioxidant seemed to reduce the color variation.

The color of pasta without additives depends on the properties of the flour used such as carotenoids and protein composition (Ohm et al., 2008). The addition of rosemary as antioxidant protected all pastas against colour changes related to fish addition, in agreement with Mercier et al (2016) who indicated that the lower brightness with enrichment can be attributed to the dark colour of most enrichment ingredients, the no enzymatic browning of the reducing sugars in the enrichment ingredient.

In summary, considering both TPA and colour tests, our findings were in agreement with the results of previous research that indicated that the main differences detected between pasta enriched with seabass concentrates and the durum pasta were mainly due to colour and texture properties (Calanche et al., 2019).

4.4 | Technological properties

The ability of pasta to taking up water is determined both by its composition and processing conditions (Marti et al., 2011). In fact, fish proteins and lipids interact and compete with starch for water absorption during cooking, reducing starch hydration and gelling, which results in a lower weight gain of pasta. The incorporation of fish modifies the physico-chemical characteristics of pasta, inducing the formation of complexes between cereal starch and fish lipids, which can decrease the uptake of water, as well as starch gelatinization (Desai et al., 2018). Both types of cereal showed different values of weight gain as would be expected according to the difference between the type of cereal shown in a previous study (Frakolaki et al., 2018).

According to Smatanová and Lacko-Bartosová (2014), cooking loses of quality pasta should not exceed 8% of the dry weight, so the developed pasta with fish conformed to this specification. The increase of cooking losses is clearly related to the presence of fish, since this implies the incorporation of proteins of a different nature to that of gluten, mainly myofibrillar proteins (Desai et al., 2018). Enrichment with cereal fiber (spelt pasta) reduced cooking losses. This may reflect the dual effect that fibres exert on cooking losses (Mercier et al., 2016).

Regarding moisture, the content of dry enriched durum (≈11.5%) and enriched spelt pasta (≈11%) presented values below those marked by legal regulations (Real Decreto, 2181/1975), which sets maximum humidity limits of 12.5% for dry pasta. However, fresh enriched durum and spelt pasta had a moisture content slightly higher than this indicated by legislation (>32%) possibly due to rehydration of pasta after preparation.

5 | CONCLUSIONS

Enriched pasta by fish incorporation showed a lower cooking time. In the same way, texture profiles of enriched pasta were distinct to control for both cereals (durum and spelt) showing a significant decrease in all parameters except for adhesiveness. Regarding colour, pasta with fish was slightly darker, redder and more yellow than control pasta, although this effect was partly reduced by the presence of rosemary. The addition of antioxidant caused positive changes in terms of colour and weight gain, which were the most discriminating technological parameters. Finally, it is worth highlighting that enriched pasta appears to be a good alternative in order to offer food with an improved nutritional profile with a low impact on product quality.

ACKNOWLEDGMENTS

The authors thank the University of Zaragoza for financial support through the "Valle de la Muerte 2019" project.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Andrea Ainsa: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Visualization; Writing—original draft. **Sergio Roldón:** Data curation; Investigation; Methodology. **Pedro Marquina G.:** Data curation; Investigation; Visualization. **Pedro Roncales:** Formal analysis; Validation; Visualization; Writing—review

& editing. **José A. Beltrán:** Conceptualization; Formal analysis; Funding acquisition; Investigation; Project administration; Resources; Supervision; Visualization; Writing—review & editing. **Juan Benito Calanche Morales:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Software; Supervision; Validation; Visualization; Writing—review & editing.

ORCID

Andrea Ainsa https://orcid.org/0000-0001-6892-4160
Juan B. Calanche Morales https://orcid.org/0000-0001-9660-8579

REFERENCES

AACC (2000). *Approved methods of the American Association of Cereal Chemists*, 10th ed. AACC.

Ainsaa, A., Honrado, A., Marquina, P. L., Roncalés, P., Beltrán, J. A., & Calanche, J. B. (2021). Innovative development of pasta with the addition of fish by-products from two species. *Foods*, *10*(8), 1889. https://doi.org/10.3390/foods10081889

Ainsab, A., Marquina, P. L., Roncalés, P., Beltrán, J. A., & Calanche, J. B. (2021). Enriched fresh pasta with a sea bass by-product, a novel food: Fatty acid stability and sensory properties throughout shelf life. *Foods*, *10*(2), 255. https://doi.org/10.3390/foods10020255

Babuskin, S., Krishnan, K. R., Saravana, P. A., Sivarajan, M., & Sukumar, M. (2014). Functional foods enriched with marine microalga nannochloropsis oculata as a source of w-3 fatty acids. *Food Technol. Biotechnol*, *52*, 292–299.

Calanche, J., Beltrán, H., Marquina, P., Roncalés, P., & Beltrán, J. A. (2019). Eating fish in another way: Development of functional pasta with added concentrates of farmed sea bass (*Dicentrarchus labrax*). *Cereal Chemistry*, *96*(5), 856–865. https://doi.org/10.1002/cche.10186

Chang, H. C., & Wu, L.-C. (2008). Texture and quality properties of Chinese fresh egg noodles formulated with green seaweed (*Monostroma nitidum*) powder. *Journal of Food Science*, *73*(8), S398–S404. https://doi.org/10.1111/j.1750-3841.2008.00912.x

Cleary, L., & Brennan, C. (2006). The influence of a (1→3)(1→4)-β-d-glucan rich fraction from barley on the physico-chemical properties and in vitro reducing sugars release of durum wheat pasta. *International Journal of Food Science and Technology*, *41*(8), 910–918. https://doi.org/10.1111/j.1365-2621.2005.01141.x

D'Egidio, M. G., Mariani, B. M., Nardi, S., Novaro, P., & Cubadda, R. (1990). Chemical and technological variables and their relationships: A predictive equation for pasta cooking quality. *Cereal Chemistry*, *67*, 275–281.

Desai, A. S., Brennan, M. A., & Brennan, C. S. (2018). Influence of semolina replacement with salmon (*Oncorhynchus tschawytscha*) powder on the physicochemical attributes of fresh pasta. *International Journal of Food Science & Technology*, *54*(5), 1497–1505. https://doi.org/10.1111/ijfs.13842

El-Sohaimy, S. A., Brennan, M., Darwish, A. M. G., & Brennan, C. (2020). Physicochemical, texture and sensorial evaluation of pasta enriched with chickpea flour and protein isolate. *Annals of Agricultural Sciences*, *65*(1), 28–34. https://doi.org/10.1016/j.aoas.2020.05.005

Ficco, D. B. M., De Simone, V., De Leonardis, A. M., Giovanniello, V., Del Nobile, M. A., Padalino, L., Lecce, L., Borrelli, G. M., & De Vita, P. (2016). Use of purple durum wheat to produce naturally functional fresh and dry pasta. *Food Chemistry*, *205*, 187–195. https://doi.org/10.1016/j.foodchem.2016.03.014

Frakolaki, G., Giannou, V., Topakas, E., & Tzia, C. (2018). Chemical characterization and breadmaking potential of spelt versus wheat flour. *Journal of Cereal Science*, *79*, 50–56. https://doi.org/10.1016/j.jcs.2017.08.023

Islas-Rubio, A. R., Calderón de la Barca, A. M., Cabrera-Chávez, F., Cota-Gastélum, A. G., & Beta, T. (2014). Effect of semolina replacement with a raw: Popped amaranth flour blend on cooking quality and texture of pasta. *LWT - Food Science and Technology*, *57*(1), 217–222. https://doi.org/10.1016/j.lwt.2014.01.014

Kadam, S. U., & Prabhasankar, P. (2010). Marine foods as functional ingredients in bakery and pasta products. *Food Research International*, *43*(8), 1975–1980. https://doi.org/10.1016/j.foodres.2010.06.007

Kowalczewski, P. Ł., Pauter, P., Smarzyński, K., Różańska, M. B., Jeżowski, P., Dwiecki, K., & Mildner-Szkudlarz, S. (2019). Thermal processing of pasta enriched with black locust flowers affect quality, phenolics, and antioxidant activity. *Journal of Food Processing and Preservation*, *43*(10), e14106. https://doi.org/10.1111/jfpp.14106

Krishnan, M., & Prabhasankar, P. (2012). Health based pasta: Redefining the concept of the next generation convenience food. *Critical Reviews in Food Science and Nutrition*, *52*(1), 9–20. https://doi.org/10.1080/10408398.2010.486909

Larrosa, V., Lorenzo, G., Zaritzky, N., & Califano, A. (2016). Improvement of the texture and quality of cooked gluten-free pasta. *LWT*, *70*, 96–103. https://doi.org/10.1016/j.lwt.2016.02.039

Liu, T., Hamid, N., Kantono, K., Pereira, L., Farouk, M. M., & Knowles, S. O. (2016). Effects of meat addition on pasta structure, nutrition and in vitro digestibility. *Food Chemistry*, *213*, 108–114. https://doi.org/10.1016/j.foodchem.2016.06.058

Marti, A., Fongaro, L., Rossi, M., Lucisano, M., & Pagani, M. A. (2011). Quality characteristics of dried pasta enriched with buckwheat flour: Quality characteristics of dried pasta. *International Journal of Food Science & Technology*, *46*(11), 2393–2400. https://doi.org/10.1111/j.1365-2621.2011.02762.x

Mercier, S., Moresoli, C., Mondor, M., Villeneuve, S., & Marcos, B. (2016). A meta-analysis of enriched pasta: what are the effects of enrichment and process specifications on the quality attributes of pasta? *Comprehensive Reviews in Food Science and Food Safety*, *15*, 685–704. https://doi.org/10.1111/1541-4337.12207

Odey, G. N., & Lee, W. Y. (2020). Evaluation of the quality characteristics of flour and pasta from fermented cassava roots. *International Journal of Food Science & Technology*, *55*(2), 813–822. https://doi.org/10.1111/ijfs.14364

Ohm, J.-B., Ross, A. S., Peterson, C. J., & Ong, Y.-L. (2008). Relationships of high molecular weight glutenin subunit composition and molecular weight distribution of wheat flour protein with water absorption and color characteristics of noodle dough. *Cereal Chemistry Journal*, *85*(2), 123–131. https://doi.org/10.1094/CCHEM-85-2-0123

Oliveira, I. S. D., Lourenço, L. D. F. H., Sousa, C. L., Peixoto Joele, M. R. S., & Ribeiro, S. D. C. D. A. (2015). Composition of MSM from Brazilian catfish and technological properties of fish flour. *Food Control*, *50*, 38–44. https://doi.org/10.1016/j.foodcont.2014.08.018

Olivera, D. F., & Salvadori, V. O. (2009). Effect of freezing rate in textural and rheological characteristics of frozen cooked organic pasta. *Journal of Food Engineering*, *90*(2), 271–276. https://doi.org/10.1016/j.jfoodeng.2008.06.041

Pongpichaiudom, A., & Songsermpong, S. (2018). Evaluation of microstructure and quality characteristics of microwave-dried instant noodles enriched with chicken meat, egg yolk, and seaweed. *Journal of Food Measurement and Characterization*, *12*(1), 22–34. https://doi.org/10.1007/s11694-017-9613-3

Real Decreto (2181/1975). de 12 de septiembre, por el que se aprueba la Reglamentación Técnico-Sanitaria para la Elaboración, Circulación y Comercio de Pastas Alimenticias. Boletín Oficial del Estado No 220, de septiembre de 1975.

Sean, F., & Atwell, W. A. (2016). *Wheat flour* (2nd ed.). Woodhead Publishing and AACC International Press, Elsevier. https://doi.org/10.1016/C2015-0-06189-5

Sicignano, A., Di Monaco, R., Masi, P., & Cavella, S. (2015). From raw material to dish: Pasta quality step by step: Pasta from raw material to dish. *Journal of the Science of Food and Agriculture*, *95*(13), 2579–2587. https://doi.org/10.1002/jsfa.7176

Sissons, M. J. (2016). Pasta. In C. Wrigley, H. Corke, K. Seetharaman & J. Faubion (Eds.), *Encyclopedia of food grains* (2nd ed., pp. 79–89). Academic Press.

Sissons, M. J., Egan, N. E., & Gianibelli, M. C. (2005). New insights into the role of gluten on durum pasta quality using reconstitution method. *Cereal Chemistry Journal*, *82*(5), 601–608. https://doi.org/10.1094/CC-82-0601

Smatanová, N., & Lacko-Bartosová, M. (2014). Noodle quality of winter wheat cultivated in sustainable farming systems. *Journal of Central European Agriculture*, *15*(2), 84–94. https://doi.org/10.5513/JCEA01/15.2.1457

Sui, Z., Lucas, P. W., & Corke, H. (2006). Optimal cooking time of noodles related to their notch sensitivity*. *Journal of Texture Studies*, *37*(4), 428–441. https://doi.org/10.1111/j.1745-4603.2006.00061.x

Vernaza, M. G., Biasutti, E., Schmiele, M., Jaekel, L. Z., Bannwart, A., & Chang, Y. K. (2012). Effect of supplementation of wheat flour with resistant starch and monoglycerides in pasta dried at high temperatures: Resistant starch and monoglycerides in pasta. *International Journal of Food Science & Technology*, *47*(6), 1302–1312. https://doi.org/10.1111/j.1365-2621.2012.02974.x

Yan, N., & Chen, X. (2015). Sustainability: Don't waste seafood waste. *Nature*, *524*(7564), 155–157.

How to cite this article: Ainsa, A., Roldan, S., Marquina, P. L., Roncalés, P., Beltrán, J. A., & Calanche Morales, J. B. (2022). Quality parameters and technological properties of pasta enriched with a fish by-product: A healthy novel food. *Journal of Food Processing and Preservation*, 46, e16261. https://doi.org/10.1111/jfpp.16261