



NOVEL FUNCTIONAL PASTA ENRICHED WITH ANDEAN LUPIN, AMARANTH AND ASPARAGUS RESIDUES: AN EVALUATION OF ITS PHYSICAL AND TECHNOLOGICAL PROPERTIES

Luiggui Hernández-Sihuas^{1,2,3}; Ismael Palomino-Lozano^{1,2,3}; Mauro Rojas-Alvites^{1,2,3}; Ronald Rimari-Barzola⁴, Raúl Comettant-Rabanal^{1,2,3*}

¹Instituto de Investigación de Ingenierías, Universidad Privada San Juan Bautista (UPSJB), Carretera Panamericana Sur Ex km 300, La angostura - Subtanjalla, 11004 Ica, Perú.

²Grupo de Investigación en Ciencia, Tecnología e Ingeniería de Alimentos y Procesos (UPSJB - Filial Ica), Carretera Panamericana Sur Ex km 300, La angostura - Subtanjalla, 11004 Ica, Perú.

³Escuela Profesional de Ingeniería Agroindustrial, Facultad de Ingenierías, Universidad Privada San Juan Bautista, Carretera Panamericana Sur Ex km 300, La angostura - Subtanjalla, 11004 Ica, Perú.

⁴Escuela Profesional de Ingeniería Agroindustrial, Facultad de Química e Ing. Química, Universidad Nacional Mayor de San Marcos, Av. German Amezaga 375, 15081 Lima, Perú.

*E-mail para correspondencia: raul.comettant@upsjb.edu.pe

ABSTRACT:

The objective of this study was to incorporate Andean grains and discarded asparagus to enrich traditional pasta and to evaluate their effect on physical and technological properties, such as optimal cooking time (OCT), weight increase (WI), swelling power (SP) and swelling index (SI). A synergistic enhancing effect was observed in the multiple interaction of lupin-asparagus-amaranth on OCT, whilst asparagus and amaranth added independently preserved the technological properties with slight decreases. Therefore, by using unconventional ingredients, it is possible to produce enriched pasta without drastically compromising quality properties.

Keywords: Andean grains, pasta properties, multicomponent pasta, agroindustrial by-products.

1. INTRODUCTION

Pasta is a widely consumed food worldwide and is particularly popular with children due to its soft texture and the fact that it is easy to chew and swallow once cooked; however, these starchy products have a low nutritional profile (Catellani et al., 2025). Furthermore, they are associated with an increased risk of non-communicable diseases such as type 2 diabetes, obesity and certain types of cancer, due to their high carbohydrate and sodium content (Augustin et al., 2025). Against this backdrop, Andean grains have attracted considerable interest as functional ingredients. Among these is Andean lupin (*Lupinus mutabilis*), a legume with high levels of protein (~44.70%) and natural pigments (carotenoids) (Huamán-Meza et al., 2025). Similarly, amaranth (*Amaranthus caudatus*), an ancient pseudocereal recognised for its high-quality proteins in terms of essential amino acids. Furthermore, vegetables such as asparagus (*Asparagus officinalis*), distinguished by its excellent source of bioactive compounds such as flavonoids (rutin and kaempferol), glutathione and chlorophyll, all of which possess high antioxidant power (Chitrakar et al., 2019). Therefore, the aim of this study was to develop multi-ingredient pasta based on durum wheat semolina with the incorporation of Andean lupin, amaranth and discarded asparagus to evaluate its effect on the quality properties of the pasta.

2. MATERIALS AND METHODS

2.1. Raw materials

The durum wheat semolina (SM) was purchased from the Rimancinata Polselli brand (12.5% protein) and the pre-cooked, de-bittered Andean lupin powder (LP) was purchased from Tarwi Corp. The amaranth seeds were purchased from a local shop in the city of Ica and ground using a hammer mill (Vulcano, MV 15-45 I/C, Peru) to obtain amaranth powder (AP). Finally, the green asparagus (AGP),

variety UC-115, category C, was supplied by the Floridablanca S.A.C. farm, where it was first sanitised with 7.5% sodium hypochlorite at a concentration of 15 ppm for 5 min and washed with distilled water, then blanched at 85 °C for 2 min and rapidly cooled with distilled water to 4 °C. It was then dried in a fluidised bed dryer (Galix Tech, SLFRG-2400XC, Peru) at 65 °C for 12 h and pulverised using a grinding module (Galix Tech, MMCDG-500X, Peru). Subsequently, the ground material from both the asparagus and the amaranth was sieved using a 75 µm mesh to obtain fine powders.

2.2.1. Formulations of pasta mixtures

The mixtures consisted of seven formulations based on 80% SM, incorporating 20% LP, AP and AGP as pure additives and their binary (50:50) and ternary (33.33:33.33:33.33) mixtures, each of which was replicated three times.

2.2. Pasta production

The pastas were prepared in an industrial cold extrusion machine (La Parmigiana, D35-2.0, Type MPRE00610005, Italy) equipped with a paddle mixing system featuring a 250.38 mm long, 35.31 mm diameter screw with a constant pitch. The formulations were placed in the machine and mixed for 10 min until a semi-hydrated granular mixture was formed, then extruded using an 87.85 mm die with 12.50 mm linear dies to obtain tagliatelle-shaped products. Subsequently, the pasta samples were pre-dried for 3 h at 45 °C, then dried at 60 °C for 60 min and placed in 20 µm polypropylene bags for further analysis.

2.3. Technological properties

The optimal cooking time (OCT) was determined according to the method AACC (1999), by adding 125 mL of distilled water to a 500 mL beaker and bringing it to the boil using a hotplate (CAT, H3, USA). Once boiling was reached, 12.5 g of dry pasta was added and the time was immediately recorded using a stopwatch. The OCT was recorded when, upon applying pressure with two watch hands to the piece of pasta, no white core or flour granules were observed in the centre, indicating that cooking was complete. Weight increase (WI) was determined using the methodology described by De Rijdt et al. (2025), applying the same OCT conditions established previously, the cooked pasta was weighed on a precision balance (Ohaus, PR822N/E PR series, USA) to establish the difference from the initial weight of the dry pasta. The swelling power (SP) was determined using the method described by Thomas et al. (2022). To do this, 15 g of dry pasta was weighed on a precision balance and added to 300 mL of boiling water for 20 min. Once the set time had elapsed, the water was drained to remove excess surface moisture and the cooked sample was weighed. The swelling index (SI) was determined using the method described by De Rijdt et al. (2025). Once cooking under OCT was complete, the sample was rinsed and weighed on a precision balance to record the weight of the cooked mass. The cooked sample was then placed in an oven (Mettler, SN30, Germany) to dry at 105 °C for 4 h, after which the weight of the dry sample was recorded. All treatments were repeated four times for each dependent variable.

2.4. Statistical analysis

A simplex-centroid mixture design was used to generate the combinations mentioned in section 2.2, where linear, quadratic and special cubic regression models were used for each response variable. One-way analysis of variance (ANOVA) and the LSD-Fisher multiple range test were used to identify significant differences between the 10 treatments and 1 control at a significance level of 95%.

3. RESULTS AND DISCUSSION

The OCT of the enriched pastas ranged from 6.56 to 13.26 min (Table 1), with the results showing that the single incorporation of AGP (F2) and its binary interactions with LP (F4) and AP (F6) resulted in the smallest reductions in OCT ($p < 0.05$). It is worth noting that, among the enriched prototypes,



the ternary formulations F7–F10 showed significant increases in OCT compared to the control ($p < 0.05$), thus demonstrating that the interaction between LP–AGP–AP produced synergy in consistency and strengthened the pastas structure during cooking. With regard to WI, the samples with multiple interaction (F7–F10) and single interaction (F2) exhibited the best values for this property, which measures total weight gain during cooking, ranging from 138.36 to 145.51%. These results suggest that the enriched pasta obtained falls within the category of acceptable compact pasta with good structural retention.

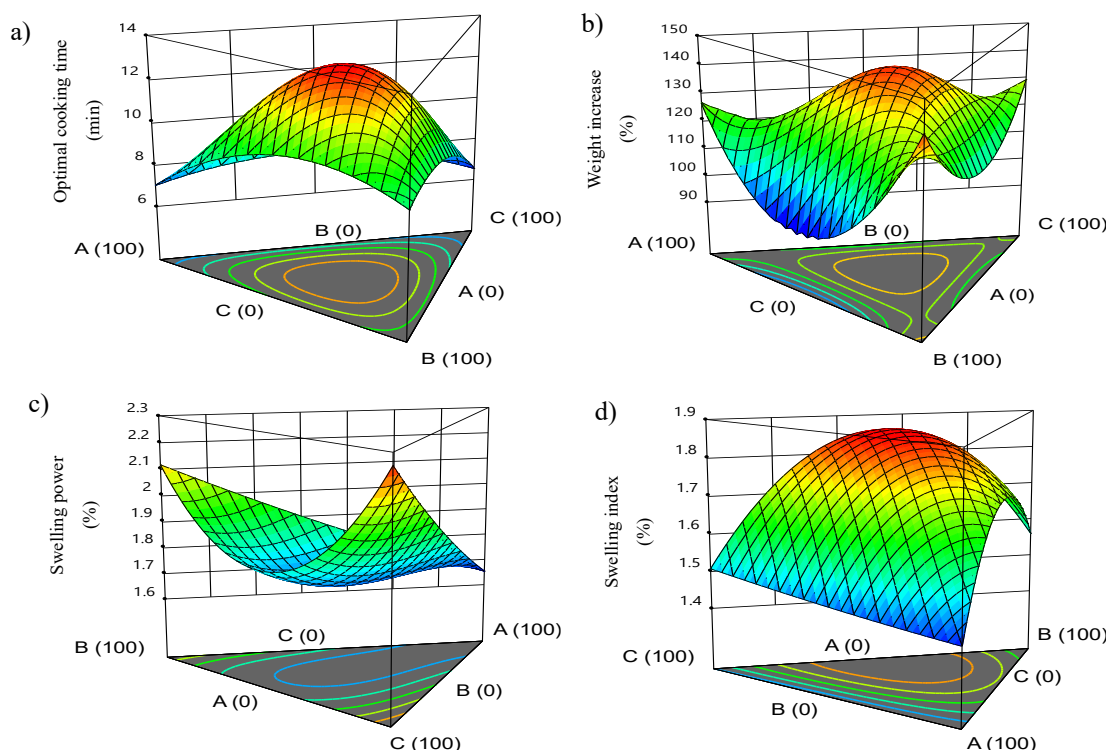
Table 1 – Physical properties of the enriched wheat pasta with lupin, asparagus and amaranth.

Formulation	SM	Experimental design			OCT (min)	WI (%)	SP (%)	SI (%)
		LP (%)	AGP (%)	AP (%)				
Control	100	0	0	0	11.10 ± 0.07^f	182.38 ± 0.33^f	2.44 ± 0.02^g	2.44 ± 0.05^g
F1	80	100	0	0	7.04 ± 0.04^b	126.53 ± 4.56^c	1.66 ± 0.02^a	1.44 ± 0.05^a
F2	80	0	100	0	9.24 ± 0.10^d	139.42 ± 1.27^d	2.12 ± 0.06^c	1.56 ± 0.03^c
F3	80	0	0	100	6.56 ± 0.30^a	129.73 ± 4.41^c	2.26 ± 0.07^f	1.51 ± 0.03^b
F4	80	50	50	0	10.04 ± 0.04^c	91.20 ± 2.31^a	1.87 ± 0.02^d	1.71 ± 0.05^d
F5	80	50	0	50	8.06 ± 0.08^c	113.66 ± 5.03^b	1.92 ± 0.03^d	1.47 ± 0.02^{ab}
F6	80	0	50	50	9.23 ± 0.06^d	110.27 ± 3.88^b	1.81 ± 0.03^c	1.86 ± 0.04^f
F7 (CP)	80	33.33	33.33	33.33	13.26 ± 0.08^g	138.36 ± 4.08^d	1.69 ± 0.03^{ab}	1.80 ± 0.04^c
F8 (CP)	80	33.33	33.33	33.33	13.24 ± 0.05^g	143.94 ± 5.18^{de}	1.71 ± 0.05^{ab}	1.82 ± 0.03^{ef}
F9 (CP)	80	33.33	33.33	33.33	13.23 ± 0.05^g	145.51 ± 4.40^e	1.73 ± 0.03^b	1.81 ± 0.03^{ef}
F10 (CP)	80	33.33	33.33	33.33	13.20 ± 0.06^g	142.29 ± 4.88^{de}	1.70 ± 0.04^{ab}	1.80 ± 0.03^c

Results represent the $M \pm SD$ ($n=4$). Control: 100% Semolina of durum wheat (SM); LP: Lupin powder; AGP: Asparagus powder; AP: Amaranth powder; OCT: Optimal cooking time; WI: Weight increase; SP: Swelling power; SI: Swelling index. CP: Centre Point. Different lowercase letters (a–g) in the same column indicate significant differences between treatments according to LSD Fisher ($p < 0.05$).

The SP values ranged from 1.66 to 2.26% (Table 1) and were lower than those of the control ($p < 0.05$); this was attributed to the use of non-conventional flours that alter the structural matrix of the dough. The highest values for the water-absorption capacity of amaranth starch under hydrothermal cooking conditions were observed in samples F2 and F3 ($p < 0.05$), which contained only AGP and AP, respectively (Kong et al., 2009). It is worth noting that, in terms of this pasta quality property, these prototypes were close to the control, suggesting that these pastas, developed in terms of starch biopolymer hydration, did not drastically alter the gelatinisation process.

Figure 1 – Response surface of the physical properties of optimal cooking time (a), weight increase (b), swelling power (c) and swelling index (d) of enriched wheat-based pasta.



The SI of the enriched pastas ranged from 1.47 to 2.44% (Table 1). F6, composed of 50% AGP and 50% AP, and the treatments involving the interaction of the three substitute components (F7=F10), exhibited the highest SI values among all samples ($p < 0.05$), although these were lower than those of the control. This behaviour suggests that the starch derived from amaranth was able to hydrate more easily, possibly due to the presence of minerals in the asparagus; furthermore, the fibres of this ingredient may have contributed to this swelling property through physical water retention mechanisms (Elleuch et al., 2011). In the multicomponent samples, despite the presence of LP, the aforementioned effect was not significantly affected ($p > 0.05$). The response surfaces for OCT, WI, SP and SI exhibited special cubic behaviour with adjusted coefficients of determination (R^2_{adjust}) ranging from 0.97 to 0.99 (Figure 1a-d).

4. CONCLUSION

The combined incorporation of 20% LP, AGP and AP resulted in enriched multi-component pastas; this demonstrated a synergistic effect that increased the OCT and produced WI values close to those of commercial products, indicating a resilient matrix with good compaction and pasta structure. Furthermore, the inclusion of amaranth performed best in terms of SP, associated with its starch hydration capacity. Meanwhile, the combination of asparagus and amaranth showed the best SI performance, due to greater water retention resulting from the interaction of its components. These results demonstrated that it was possible to incorporate underutilised nutritious Andean grains alongside discarded asparagus as an agro-industrial by-product to develop enriched pastas with excellent technological properties.

REFERENCES

- AACC. (1999). *AACC International Method 66-50.01*. Retrieved Wednesday, May 14, 2025 from <https://www.cerealsgrains.org/resources/Methods/Pages/default.aspx>
- Augustin, L. S. A., Ellis, P. R., Vanginkel, M.-A., & Riccardi, G. (2025). Pasta: Is It an Unhealthy Refined Food? *The Journal of Nutrition*, 155(2), 378-380. <https://doi.org/https://doi.org/10.1016/j.tjnut.2024.11.019>
- Catellani, E., Manfredini, S., Amico, C., Ciccullo, F., & Cigolini, R. (2025). Sustainability on the plate: Unveiling the environmental footprint of pasta supply chain through Life Cycle Assessment. *Environmental Impact Assessment Review*, 112, 107821. <https://doi.org/https://doi.org/10.1016/j.eiar.2025.107821>
- Chitrakar, B., Zhang, M., & Adhikari, B. (2019). Asparagus (*Asparagus officinalis*): Processing effect on nutritional and phytochemical composition of spear and hard-stem byproducts. *Trends in Food Science & Technology*, 93, 1-11. <https://doi.org/https://doi.org/10.1016/j.tifs.2019.08.020>
- De Rijdt, M., Verhaegen, J., Dohogne, D., Brostaux, Y., Haubruge, E., & Goffin, D. (2025). Impact of spirulina biomass physical form on texture, cooking properties, and sensory profile of enriched pasta and meat analogues. *Applied Food Research*, 5(2), 101328. <https://doi.org/https://doi.org/10.1016/j.afres.2025.101328>
- Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., & Attia, H. (2011). Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review. *Food Chemistry*, 124(2), 411-421. <https://doi.org/https://doi.org/10.1016/j.foodchem.2010.06.077>
- Huamán-Meza, K., Gonzales-Pérez, S., Rimari-Barzola, R., Chávez, D. W. H., Carvalho, C. W. P., Silva-Paz, R. J., Elías-Peñafiel, C., Casimiro-Gonzales, S., & Comettant-Rabanal, R. (2025). Nutritious corn extrudates enriched with Andean Lupin and pecan nut: Physicochemical, textural, nutraceutical and sensory properties. *LWT*, 218, 117489. <https://doi.org/https://doi.org/10.1016/j.lwt.2025.117489>
- Kong, X., Bao, J., & Corke, H. (2009). Physical properties of Amaranthus starch. *Food Chemistry*, 113(2), 371-376. <https://doi.org/https://doi.org/10.1016/j.foodchem.2008.06.028>
- Thomas, B., Sudheer, K. P., Saranya, S., Kothakota, A., Pandiselvam, R., & Joseph, M. (2022). Development of protein enriched cold extruded pasta products using hybrid dried processed mushroom powder and defatted flours: A study on nutraceutical, textural, colour and sensory attributes. *LWT*, 170, 113991. <https://doi.org/https://doi.org/10.1016/j.lwt.2022.113991>