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Preparation and evaluation of yam *gnocchi* supplemented with spotted goatfish protein concentrate

Abstract – The objective of this work was to evaluate the physicochemical, nutritional, microbiological, and sensory aspects of yam (*Dioscorea* spp.) *gnocchi* supplemented with spotted goatfish protein concentrate (SPC). Freshly caught fish were processed to obtain meat separated mechanically from the spines, which was subsequently converted into SPC. Yam *gnocchi* with SPC at 0, 7.5, and 15% and evaluated for proximate composition, water activity, color and texture, microbiology, and sensory acceptance. The addition of 15% SPC resulted in a decrease from 69.16 to 65.85 g 100 g^{-1} in moisture, from 28.8 to 20.4 g100 g^{-1} in carbohydrates, from 1.23 to 0.53 N in hardness, from 0.67 to 0.61 in cohesiveness, from 14.60 to 0.61 mm in elasticity, from 5.38 to 1.88 in adhesiveness, and from 64.09 to 57.45 L* in lightness. Sensory scores also dropped from about 6 = "I liked it slightly" to 5 = "I neither liked nor disliked it". Conversely, there was a significant increase from 1.04 to 10.15 g 100 g^{-1} in protein, from 0.20 to 2.16 g 100 g^{-1} in lipids, from 0.80 to 1.47 g 100 g^{-1} in ash, and from 121.20 to 141.50 kcal 100 g^{-1} in caloric value. Microbiologically, the *gnocchi* complies with Brazilian legislation. Supplementing yam *gnocchi* with up to 15% SPC enhances its nutritional quality, without compromising technological or microbiological properties.

Index terms: *Dioscorea* spp., *Pseudupeneus maculatus*, agro-industrialization, alternative consumption, fish coproduct, product development.

Preparação e avaliação de nhoque de inhame suplementado com concentrado proteico de saramunete

Resumo – O objetivo deste trabalho foi avaliar os aspectos físico-químicos, nutricionais, microbiológicos e sensoriais do nhoque de inhame (*Dioscorea* spp.) suplementado com concentrado de proteína de saramunete (CPS). Peixes recém-capturados foram processados, para obtenção de carne mecanicamente separada das espinhas, que foi posteriormente convertida em CPS. Os nhoques de inhame foram preparados com CPS a 0%, 7,5% e 15% e avaliados quanto à composição proximal, atividade de água, cor e textura, microbiologia e aceitação sensorial. A adição de 15% de CPS resultou em diminuição de 69,16 para 65,85 g 100 g^{-1} em umidade, de 28,8 para 20,4 g 100 g^{-1} em carboidratos, de 1,23 para 0,53 N em dureza, de 0,67 para 0,61 em coesividade, de 14,60 para 0,61 mm em elasticidade e de 5,38 para 1,88 em adesividade e de 64,09 para 57,45 L* em luminosidade. As pontuações sensoriais também diminuíram de cerca de 6 = "Gostei um pouco" para 5 = "Não gostei nem desgostei"). No entanto, houve aumento significativo de 1,04 para 10,15 g 100 g^{-1} em proteínas, de 0,20 para 2,16 g 100 g^{-1} em lipídios, de 0,80 para 1,47 g 100 g^{-1} em cinzas e de 121,20 para 141,50 kcal 100 g^{-1} em valor calórico. Do ponto de vista microbiológico, o nhoque está em conformidade com a legislação brasileira.

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A suplementação com até 15% de CPS melhora a qualidade nutricional do nhoque de inhame, sem comprometer suas propriedades tecnológicas ou microbiológicas.

Termos para indexação: *Dioscorea* spp., *Pseudupeneus maculatus*, agroindustrialização, consumo alternativo, coproduto de pescado, desenvolvimento de produto.

Introduction

Regular consumption of fish is associated with nutritional benefits and a reduced risk of chronic diseases. These effects result from a combination of some determinants, as follows: proteins of high biological value, which aids with muscle growth and maintenance, and the presence of polyunsaturated fatty acids as eicosapentaenoic (EPA) and docosahexaenoic (DHA) − essential for proper brain, vision, and heart function (Noreen et al., 2025). Determinants also include the presence of the vitamins D, B12, and A, and the trace minerals iodine, selenium, calcium, magnesium, iron, and other important micronutrients (Torfadottir & Ulven, 2024). Due to these factors, and to other ones such as reduced waste, optimized use of fish, growing demand for fish, and population and economic growth in countries, the global fish consumption has grown at 3% per year between 1961 and 2021 (FAO, 2024).

Fish accounts for 15% of animal protein consumed worldwide. In Brazil, the average apparent consumption ranged from 5 to 10 kg per capita per year, which are values lower than those recommended by the World Health Organization (WHO), which are 12 kg per capita per year (FAO, 2024). This modest consumption, below the dietary recommendation, can be attributed to cultural issues, limited information on nutritional benefits, high prices, high perishability, and low-fish diversity in the market (St. Louis et al., 2022), especially for ready-to-eat products.

Spotted goatfish (*Pseudupeneus maculatus*) occurs along the west coast of the Atlantic Ocean, from the Northeastern USA to Southern Brazil, inhabiting coral reefs at an average depth of up to 90 m (Soares et al., 2020). This fish is a resource of regional importance in Brazil, particularly along the northeastern coast, especially in Pernambuco. It is a marine species caught predominantly through artisanal extractive fishing, with economic and social importance for coastal communities. Although it is not among the top fish species by national catch volume, its exploitation holds local value, particularly in areas where artisanal fishing contributes to food security and income generation (Sá Júnior et al., 2021). The commercial destinations for this species are regional open-air markets, fishmongers, and the export market, mainly to the United States and Europe. This fish is exported whole, gutted, or as fillets, generating waste that could be utilized to prevent pollution, and add value to the fish supply chain (Benevides et al., 2025).

In the area of fish technology, studies have already been carried out using spotted goatfish meat. A spotted goatfish fishburger made with wheat flour, green banana, and eggplant resulted in a high-quality product according to physicochemical analyses and sensory evaluation (Silva et al., 2016). To use waste from spotted goatfish processing, the preparation of silage with the addition of molasses is an excellent alternative, as it provides a shelf life of up to 4 months and good chemical composition (Jatobá & Oliveira Filho, 2017). Spotted goatfish sausages, when subjected to the combination of high temperature (at 80ºC for10 min) and ultrasound (at 37 kHz for 10 min), had a shelf life of 22 days, when stored at 6ºC (Macedo et al., 2021). In a study on snacks fortified with protein concentrate from spotted goatfish and passion fruit (*Passiflora edulis*) shell flour, Benevides et al. (2025) observed that snacks using coproducts from the fish and juice industries resulted in a product with improved nutritional quality as to forms of protein and fiber.

Per capita pasta consumption in Brazil was about 6 kg per capita per year in 2024 (Abimapi, 2025). In addition, pasta is a product that can be nutritionally enriched, increasing biological value, protein content, and digestibility. *Gnocchi* is a fresh potato-based pasta, a typical Italian dish (Merlino et al., 2022), which can also be made from other tubers such as yams (*Dioscorea* spp.), wheat flour, durum wheat derivatives, or derivatives of other cereals, legumes, without fermentation, and can also be presented dry, fresh, pre-cooked, instant or ready to eat (Anvisa, 2022).

Yam (*Dioscorea* spp.) is a tuber rich in carbohydrates (from 12 to 34%), on a wet weight basis), fiber (from 1 to 14%), minerals such as potassium, phosphorus, magnesium, calcium, iron, and zinc, vitamins such as C and E, protein (from 1 to 6%), and a low amount of lipids (< 2%). In addition, it contains nonstarch

polysaccharides, saponins, steroids, dioscorin, phenolics, and other phytochemicals with strong antioxidant, anti-inflammatory, hypoglycemic, and gut microbiome-modulating activity; it is therefore considered a food with functional potential related to cardiovascular protection and glycemic control (Li et al., 2023).

The *Dioscoreaceae* family constitutes an important food source, and it is distributed in tropical and subtropical regions throughout the world (Velázquez-Hernández et al., 2022). In Brazil, cultivation and consumption are concentrated on family production, and the surplus is for direct sale to consumers or intermediaries for sale in urban centers (Siqueira et al., 2014). According to Shinohara et al. (2017), yam represents an alternative food in the diet of vulnerable populations in periods of scarcity, in rural areas of the state of Pernambuco. Although the production and consumption of yam *gnocchi* have increased in Brazil because it is a healthy, nutritious, and versatile product, there are still no official production and consumption figures for Brazil.

Due to the demand for healthy, nutritious, and easy-to-prepare products, studies on pasta enriched with fish protein concentrate (FPC) have been carried out. Pizzas made with common carp flour (*Cyprinus carpio*) replacing wheat flour achieved improvements in chemical, sensory, and texture aspects (El-Beltagi et al., 2017). The addition of FPC from snakehead fish (*Channa striata*) to cookies increased the protein, fat, and moisture content, in addition to improving the appearance, crunchiness, and texture (Ikasari et al., 2020). Pasta enriched with seabass FPC (*Dicentrachus labrax*) resulted in an increase of protein and omega-3 polyunsaturated fatty acids. Furthermore, these products remained stable during frozen storage, and they were well accepted in sensory analyses, especially those in which rosemary extract was added (Ainsa et al., 2021a).

These data indicate the potential of FPC, and the possibility of using it in pasta formulations, adding value and contributing to the increase of fish protein consumption. However, the use of spotted goatfish meat − a species of fish with great technological potential as a protein supplement in yam *gnocchi* − has not yet been investigated.

The objective of this work was to evaluate the physicochemical, nutritional, microbiological, and sensory aspects of yam *gnocchi* supplemented with spotted goatfish protein concentrate.

Materials and Methods

Freshly caught spotted goatfish (of about 126,65±22 g) were purchased (total ca. 35 kg) from artisanal fishermen of the municipality of Recife, in the state of Pernanbuco, Brazil. The fish were placed in thermal boxes with flaked ice, and transported to the Laboratory of Fish Technology of the Department of Fishery and Aquaculture at Universidade Federal Rural de Pernambuco. In the laboratory, fish were washed with chlorinated water (5 ppm) to remove surface mucus, scales, viscera, fillets (yield of 37.53%), skin, and fins were removed, and the spines (yield of 13.61%) were reserved and e kept cooled at 6°C, until obtaining the mechanically separated meat (MSM).

To obtain MSM, spotted goatfish spines were processed by the mechanical deboning machine PV 150 (PV Máquinas, Chapecó, SC, Brazil), and the MSM obtained (yield of 55.55%) was packaged in a low-density polyethylene Ziploc bag (50 μm) of 500 g capacity, and stored at -20° C in a freezer.

Spotted goatfish protein concentrate (SPC) was obtained by defrosting MSM, which was then stirred for 2 min in a planetary mixer Fleetwood of 1/2 hp 4-speed-gearbox, model BPS-12 (Skymsen, Brusque, SC, Brazil), and left to rest for 3 min. Fat from the supernatant was manually removed with a sieve. The material was then filtered through a nylon bag (0.042 mm^2 porosity) and manually pressed until excess water was removed. Moisture was monitored by weighing the product before and after washing the meat. This procedure was repeated once, for two washing cycles. A third washing cycle was performed with 0.05% phosphoric acid solution, to deodorize the product and reach the isoelectric point (pH close to 5.0). Another water washing cycle was performed for four cycles. SPC was then placed on aluminum trays in thin layers and dried in an oven at 65°C for 15 hours. Remaining fat in the dried material was extracted with ethanol (1:2, SPC/ethanol), and the material was then dried in an oven, at 65°C for 3 hours, to remove residual fat. The material was then crushed, sieved through 20- and 35-mesh sieves, packed in Ziploc bags, and stored at -20°C (Amaral et al., 2021) until the *gnocchi* preparation.

Gnocchi was prepared according to the formulations used by Malucelli et al. (2009) with modifications (Table 1). Three treatments were tested, to incorporate SPC − at 0, 7.5, and 15% − into the *gnocchi*, as a substitute for cooked yams; and these percentages were determined through preliminary laboratory tests.

Except for the spotted goatfish protein concentrate (SPC), the following food grade ingredients used to prepare the *gnocchi* were purchased at a local market: yams (purchased at a farmers' market in the Recife metropolitan area); corn starch (Maizena, Unilever Brasil Ltda., São Paulo, SP, Brazil); whole milk Betânia (Alvoar Lácteos, Fortaleza, CE, Brazil); commercial sodium chloride Sal Cisne (Refinaria Nacional de Sal S.A., Cabo Frio, RJ, Brazil); and commercial salted butter Camponesa (Alvoar Lácteos, Lagoa da Prata, MG, Brazil).

Yams were washed with chlorinated water (200 ppm), peeled, and cooked in boiling water for 30-40 min until they reached a soft puree consistency. Subsequently, they were kneaded and manually mixed with the other ingredients according to the treatment. After mixing, 100 g portions were separated and manually shaped into rolls, cut every 2 cm, forming *gnocchi*. *Gnocchi* was cooked in boiling water until they floated, cooled in ice water, dried, packaged in polyethylene bags, and kept frozen (-20°C) for physicochemical, microbiological, and sensory analyses.

The proximate composition of *gnocchi* was determined according to the official AOAC methodology. Moisture content was determined by gravimetry, in an oven with air circulation at 105ºC, until constant weight was attained (Method 926.12) (AOAC, 1996). After the analysis, dry matter was subjected to other proximate composition analyses. Crude protein was determined using the Kjeldahl method (N x 6.25) (Method 991.20) (AOAC, 1994); fat was extracted with petroleum ether in a Soxhlet extractor (Method 920.39) (Cunniff, 1995); and ash content was determined by incineration in a muffle furnace at 550ºC, for 5 hours (Method 900.02) (AOAC, 1996). The carbohydrate percentage of *gnocchi* was determined by subtracting the percentages of moisture, protein, fat, and ash − from 100%, and the caloric value was determined by multiplying the protein and carbohydrate percentages by 4, and fat by 9 (FAO, 2003).

Water activity was determined in pre-homogenized *gnocchi* in a food processor. at 25°C in the Aqualab CX-2 apparatus (Decagon Devices).

The instrumental texture profile was determined using a texturometer (CT3 Texture Analyzer Brookfield). *Gnocchi* was compressed to 50% of the total thickness with pre-test, test, and post-test speeds of 2 mm s^{-1}, at 25ºC, according to Bourne (2002). The analyzed parameters were the following: hardness (g), cohesiveness (admission), and elasticity (mm).

The instrumental color of *gnocchi* was determined by a portable colorimeter (Konica Minolta, model CR – 400), which was previously calibrated with a white standard before each analysis, using a xenon lamp, illuminant C (Y = 92.78; x = 0.3139; y = 0.3200), observation angle of 2º, and measurement area of 8 mm in diameter, at 3 points of three *gnocchi* from each treatment. The color was expressed using the color standards of the CIELAB system: L* [lightness (+) to darker (-)], a* [color intensity from red (+) to green (-)], and b* [color intensity from yellow (+) to blue (-)].

Microbiological analyses of *Staphylococcus aureus*, *Salmonella* sp., *Escherichia coli*, and psychrotrophic aerobes were carried out using CompactDry kits. The results were compared with RDC 331 and IN 60 (Anvisa, 2019a, 2019b).

The sensory evaluation was carried out in the Sensory Analysis Laboratory, provided with individual cabins with white, fluorescent lights. *Gnocchi* were cooked in water, and a sample of each treatment was monadically served in random order, along with tomato sauce, with the aim of simulating a possible residential consumption pattern. To clean the taste buds between

Table 1. Formulation for 1000 g of yam *gnocchi* supplemented with spotted goatfish protein concentrate (SPC) at 0, 7.5, and 15%.

Ingredient (g)	Supplementation of SPC (%)		
	0	7.5	15.0
SPC	-	75	150
Yam	839	764	689
Corn starch (66%)	66	66	66
Whole milk (5.5%)	55	55	55
Commercial sodium chloride (1%)	10	10	10
Commercial salted butter (3%)	30	30	30
Total	1,000	1,000	1,000

one sample and another, water and cream-cracker cookies were served. Affective acceptance tests were carried out by 80 untrained tasters from 18- to 68-year-old fish consumers of both genders − 31 males and 49 females, randomly recruited among students, staff, and professors, using the methodology described by Meilgaard et al. (2025). Sensory attributes were evaluated for color, odor, texture, flavor, and overall acceptance. For this evaluation, the following 9-point hedonic scale was applied: 9, "I liked it extremely "; 8, "I liked it very much"; 7, "I liked it moderately"; 6, "I liked it slightly"; 5, "I neither liked nor disliked it"; 4, "I disliked it slightly"; 3, "I disliked it moderately"; 2, "I disliked it very much"; 1, "I disliked it extremely." The project was previously approved by the Research Ethics Committee of the University Federal Rural de Pernambuco (CAAE: 49517221.8.0000.9547).

The work was designed in a completely randomized arrangement with 3 treatments (0, 7.5, and 15% SPC), and laboratory analyses were performed in triplicate. The results were initially evaluated for normality (Shapiro-Wilk test) and homogeneity of variances (Bartlett test). When prerequisites were met, one-way analysis of variance was used, and the mean comparison post-test (Tukey test) was subsequently applied, at 5% probability. Pearson linear correlation analysis was also performed between the variables under study and SPC concentrations. Analyses were carried out using the Jamovi 2.2.5 statistical software (https://www.jamovi.org/).

Results and Discussion

The average moisture content of *gnocchi* enriched with spotted goatfish protein concentrate (SPC) varied significantly between treatments (Table 2). The lowest-moisture percentage occurred in the treatment with 15% SPC. This may have occurred because SPC is a dry product with high-hydration capacity, absorbing moisture from the other ingredients. Lower humidity may result in greater product stability, which would be a desirable characteristic. In cookies made with different concentrate proportions of fish protein, it was observed that increasing the addition from 5 to 10% also decreased the moisture percentage from 5.6 to 5.1% (Ikasari et al., 2020). The lower-moisture percentage in cookies, in comparison with *gnocchi* in the present work, may be related to the fact that cookies are dry products, and the *gnocchi* was analyzed after cooking. However, pasta enriched with different concentrate proportions (10, 15, and 20%) of tilapia protein did not show significant variations for moisture content (37.3%±1.22) (Goes et al., 2016). These products may have shown lower-moisture percentages because the authors analyzed the products before cooking. In a work with *fusilli*-type pasta, in which seabass protein concentrate was added, Calanche et al. (2019) observed that the product had around 10% moisture content. In another work, fried snacks supplemented with 5% SPC (6.5% of moisture) did not show a significant variation in moisture, in comparison to the control treatment (7.3% of moisture) (Benevides et al., 2025). The moisture percentage in *gnocchi* showed a significant ($p<0.05$) negative correlation with the lipid percentage

Table 2. Moisture, ash, protein, lipid, carbohydrate contents, caloric value, and water activity (mean ± standard deviation) of yam *gnocchi* supplemented with spotted goatfish protein concentrate (SPC) at 0% – control, 7.5%, and 15%.

Physicochemical analyses	Treatments (%)		
	0	7.5	15.0
Moisture (g 100 g^{-1})	69.16 ± 0.57b	70.14 ± 0.12a	65.85 ± 0.32c
Protein (g 100 g^{-1})	1.04 ± 0.04c	6.34 ± 0.18b	10.15 ± 0.52a
Lipid (g 100 g^{-1})	0.20 ± 0.05c	1.02 ± 0.14b	2.16 ± 0.17a
Ash (g 100 g^{-1})	0.80 ± 0.05b	0.84 ± 0.03b	1.47 ± 0.02a
Carbohydrate (g 100 g^{-1})	28.80 ± 0.56a	21.70 ± 0.12b	20.40 ± 0.82b
Caloric value (kcal 100 g^{-1})	121.20 ± 2.02b	121.20 ± 1.19b	141.50 ± 0.87a
Water activity	0.956 ± 0.006a	0.948 ± 0.007a	0.945 ± 0.003a

(1)Means with different letters, on the same row, indicate a significant difference, according to the Tukey's test, at 5% probability.

(r = -0.772). It is important to take into consideration that fish species, type of pasta, and nature of the material under analysis affect the moisture content of products, whether fresh, dried, cooked, or frozen.

The protein content of *gnocchi* increased significantly ($p<0.05$) with the addition of SPC (Table 2). Other authors also found that the FPC addition considerably increased the protein content, observed in the following products: cookies, from 7.36 to 11.4 g 100 g^{-1} (Ikasari et al., 2020); pasta, from 9.7 to 18.28 g 100 g^{-1} (Goes et al., 2015); pizzas, from 11.4 to 15.34 g 100 g^{-1} (El-Beltagi et al., 2017); breads, from 9.73 to 19.26 g 100 g^{-1} (Cercel et al., 2016); *fusilli*, from 13 to 17.5 g 100 g^{-1} (Calanche et al., 2019); and fried snacks, from 2.2 to 5.5 g 100g^{-1} (Benevides et al., 2025). Therefore, the addition of fish protein concentrate to pasta provides high-quality protein rich in essential amino acids (Ryu et al., 2021).

The lipid percentage in *gnocchi* augmented as SPC increased (Table 2). Other studies also reported an increase of lipid content in products with the increase of the FPC percentage, such as those observed in cookies, from 0.49 to 1.33 g 100 g^{-1} (Ikasari et al., 2020); pizzas from 3.93 to 4.31 g 100 g^{-1} (El-Betagi et al., 2017); pasta, from 1.11 to 1.43 g 100 g^{-1} (Goes et al., 2016); and *fusilli*, from 2.83 to 5.95 g 100 g^{-1} (Calanche et al., 2019). Furthermore, seabass protein concentrate supplementation in *fusilli* provided an increase of about 24% in polyunsaturated fatty acids, in comparison with the standard formulation. Among fatty acids, it is important to highlight the incorporation of eicosapentaenoic (EPA) and docosahexaenoic (DHA) fatty acids (Calanche et al., 2019). These results show that the addition of FPC to food products can considerably increase the levels of fatty acids, which are beneficial to human health for their anti-inflammatory and cardiovascular system protection properties.

The addition of 15% SPC increased the ash content of *gnocchi*, in comparison with the other treatments (Table 2). Furthermore, the ash percentage showed a high positive correlation ($p<0.05$) with the percentage of lipids (r = 0.923) and proteins (r = 0.844). This indicates that the addition of SPC improves the nutritional aspects of *gnocchi*. In other works, with different types of masses, an increase of the ash percentage was also observed with increasing FPC levels. For instance, pizzas added with common carp flour from 5 to 10% showed the increase from 0.89 to 0.93 g 100 g^{-1} of the ash percentage (El-Beltagi et al., 2017). Goes et al. (2015) found the increased ash percentage from 1.20 g 100 g^{-1} to 6.62 g 100 g^{-1} by adding up to 30% tilapia PC in fresh pasta. The ash content of *fusilli* enriched with protein concentrate from seabass fillets (0.98 g 100 g^{-1}) was higher than that of the standard formulation (0.51 g 100 g^{-1}) (Calanche et al., 2019); these values are close to those found in *gnocchi* in the present work. In fried snacks supplemented with 5% SPC (0.93 g 100 g^{-1}) (Benevides et al., 2025), the ash content found was close to that of *gnocchi* treated with 7.5% SPC.

The carbohydrate content decreased significantly ($p<0.05$) with the addition of up to 7.5% SPC and remained constant ($p>0.05$) with the addition of 15% SPC (Table 2). The present work corroborates the results by Goes et al. (2016), who observed that fresh pasta added up to 30% tilapia PC reduced the carbohydrate percentage from 50.92 g 100 g^{-1} to 37.63 g 100 g^{-1}. This same trend was observed in pizzas added up to 10% of carp flour, in which a decrease of total carbohydrates was observed (from 81.83 g 100 g^{-1} to 79.42 g 100 g^{-1}) (El-Beltagi et al., 2017). In another work, the carbohydrate content of *fusilli* decreased, when 20% of seabass protein concentrate (62.71 g 100 g^{-1}) was added to the basic formulation (73.00 g 100 g^{-1}) (Calanche et al., 2019). These data indicate that the decrease of carbohydrate concentration is directly related to the replacement of traditional flour, which is rich in carbohydrates, by fish protein concentrate, which contains low levels of this compound. Furthermore, it was observed that the yam *gnocchi* in the present work had lower carbohydrate concentrations than those of the fresh pasta, pizza, and *fusilli* analyzed in the studies above mentioned. This difference is related to the tuber used to make the dough and to the fish species used to develop the protein concentrate.

The caloric value of *gnocchi* increased ($p<0.05$) with the addition of 15% SPC (Table 2). The caloric value, in the present work, showed a positive correlation with the concentration of lipids (r = 0.897) and proteins (r = 0.803), which are important caloric components for the product. In pizzas made with 0, 5, and 7.5% common carp PC, as in the present work, an increase in the caloric value was observed with the increase in the FPC percentage (El-Betagi et al., 2017). Fresh pasta made with wheat flour and 3% seabass PC had 352.95 kcal per 100 g of energy (Ainsa et al., 2021b). In

another work, it was observed that *fusilli* prepared with the addition of 10% seabass PC (*D. labrax*) resulted in 367 kcal per 100 g (Calanche et al., 2019). These values were higher than those of the present work. This may be due to the variation between different types of fish and the PC percentage added to products.

Water activity (a_w) in *gnocchi* did not vary significantly ($p>0.05$) with the addition of spotted goatfish protein concentrate (SPC) (Table 2). Fried snacks supplemented with 5% SPC (0.58) (Benevides et al., 2025) also did not show significant variation in a_w, in comparison with the control treatment. Differently, in pizzas, a_w decreased with the increase of the carp PC percentage in the dough, as follows: 0.987 (0%); 0.908 (5%); and 0.888 (10%) (El-Beltagi et al., 2017). In *fusilli* pasta, there was no significant difference in a_w, when the protein concentrate came from a seabass fillet or skin (Ainsa et al., 2021a). In the present work, the a_w values observed were low (about 0.385) (Table 2), probably because the analysis was performed with dry mass. The variations of the concentrations found in the different results above mentioned may be related to the different types of products under work, such as dry or fresh dough, type of protein product (flour or FPC), and variation between fish species.

The hardness (N) of *gnocchi* samples decreased significantly ($p<0.05$) in response to the increased SPC proportion in the dough (Table 3). The same trend was also observed in other products made with PC from different fish species: fresh pasta without (36.54 N) or with the addition of 10% *Dicentrarchus labrax* PC (31.44 N) (Calanche et al., 2019), and *fusilli* without (2.45 N) or with 3% *Thunnus obesus* PC (1.47 N) (Ainsa et al., 2021b). These results indicate that the addition of fish protein concentrate makes the product softer, regardless of the fish species.

Physical and chemical factors can change the instrumental texture profile of foods. In the case of yam *gnocchi* with the addition of SPC, a strong negative correlation ($p<0.05$) was observed between hardness and the percentage of proteins ($r = -0.941$) and lipids ($r = -0.947$). Washing in the process of obtaining the protein concentrate results in the loss of stromal (collagen and elastin) and myofibrillar (actin and myosin) proteins, which provides consistency and firmness to the cell structure. This new protein configuration can hydrate more easily, when the product is cooked, resulting in lower hardness.

The cohesiveness and adhesiveness of *gnocchi* samples varied with the addition of SPC, but these changes were only significant ($p<0.05$) when the addition was done at the highest-percentage treatment of 15% CPS (Table 3). Furthermore, a strong negative correlation was possible to verify between adhesiveness and protein concentrations ($r = -0.918$) and lipids ($r = -0.929$), which comes from the addition of SPC. However, in pizzas made with the addition of 5, 7.5, and 10% common carp PC, no variation of cohesiveness was observed (El-Beltagi et al., 2017). This difference between results may have originated from the amount of SPC added to formulations − which was higher (up to 15%) in the present work −, or from the differences between the concentrations and compositions of proteins and lipids from spotted goatfish and common carp. However, in general, the results indicate that PC additions equal to or less than 10% would not result in a significant change of cohesiveness or adhesiveness.

Table 3. Results (mean ± standard deviation) for the instrumental texture (hardness, cohesiveness, elasticity, and adhesiveness) of yam *gnocchi* supplemented with spotted goatfish protein concentrate (SPC) at different levels (0% – control; 7.5%, and 15%).

Instrumental texture	Treatments (%)		
	0	7.5	15.0
Hardness (N)	1.23 ± 0.01a	0.97 ± 0.14b	0.53 ± 0.01c
Cohesiveness	0.67 ± 0.01a	0.66 ± 0.01a	0.61 ± 0.12b
Elasticity (mm)	14.60 ± 0.34a	14.31 ± 0.29ab	13.74 ± 0.28b
Adhesiveness	5.38 ± 0.53a	3.97 ± 0.92a	1.88 ± 0.30b

(1)Means with different letters, on the same line, indicate a significant difference according to the Tukey's test, at 5% probability.

The elasticity of *gnocchi* samples decreased as the SPC proportion in the *gnocchi* dough increased (Table 3). A negative correlation (r = -0.778) was observed between elasticity and protein percentage, resulting from the addition of SPC. The same pattern of relationship between elasticity and PC addition was observed in pizzas, with a reduction of elasticity when 10% PC was added (El-Beltagi et al., 2017). Because of the negative relationship between elasticity and protein, as well as the loss of sarcoplasmic proteins during the washing processes to obtain PC, and the replacement of yam by SPC, the resultant product was less elastic.

Lightness (L*) was lower ($p<0.05$) when SPC was added, both 7.5 and 15% SPC (Table 4). SPC is darker in color than yam dough, which would cause the darkening of enriched *gnocchi* samples. The present work corroborates the findings by Benevides et al. (2025), who observed that fried snacks supplemented with 5% SPC exhibited a lower-L* value (64.8) than the control treatment (72.5), and that this lower lightness is due to darkening of proteins during the protein concentrate preparation. Ainsa et al. (2021b) found that the lightness of pasta added with tuna PC was lower than that of nonenriched pasta or enriched pasta with seabass PC, and that there was no significant difference in lightness between the latter two pasta samples. The results above presented indicate that the fish species used influence the lightness of protein concentrate, as it depends on the muscle properties.

The increase of the SPC percentage is associated with a significant increase ($p<0.05$) in the redness (a*) of yam *gnocchi* samples (Table 4). Lightness decrease and redness increase significantly (r = -0.937) were observed with the addition of SPC, which may be related to the fact that spotted goatfish meat is dark and reddish, thus, with a greater addition of SPC, *gnocchi* became redder and less luminous. According to Ainsa et al. (2021b), pasta made with tuna protein concentrate obtained significantly higher-a* values than formulations without PC addition. Higher-a* values were also observed in fried snacks made with 5% SPC (Benevides et al., 2025).

Yellowness (b*) differed significantly ($p<0.05$) between the control and treatments with additions of 7.5 or 15% SPC, which presented yellowness greater than that in the control (Table 4). As with redness (a*), the correlation between yellowness (b*) and lightness (r = -0.987) was also negative. In a work with the addition of 5% SPC to fried snacks, as in the present work, an increase of the b* value was also observed in comparison with the control treatment (Benevides et al., 2025). However, *fusilli* prepared with *Dicentrarchus labrax* and *Thunnus obesus* PC showed b* values like to each other and lower than the treatment without the addition of protein concentrate (Ainsa et al, 2021a).

Therefore, the addition of fish protein concentrate tends to change the color of pasta and derived products. Understanding the PC properties of different species and the degree of modification caused to products, if well managed, can add value according to the preferences of different consumer markets.

Cooked yam *gnocchi* with different SPC percentages were prepared according to the normative instruction n° 60 [Instrução Normativa n° 60, (Anvisa, 2019b)] – for psychrotrophic aerobes – not commented; *Escherichia coli* $<5x10^2$ CFU g^{-1}; coagulase-positive *Staphylococcus* $<5x10^3$ CFU g^{-1}; *Salmonella* – absent. The counts of psychrotrophic aerobes, *Escherichia coli*, and coagulase-positive *Staphylococcus* were less than 2 CFU g^{-1}, and with the absence of *Salmonella*. Therefore, it was possible to verify that the product is safe from a microbiological standpoint and suitable for human consumption.

The microbiological analysis of pasta enriched with up to 30% of tilapia PC also showed the absence of *Salmonella* sp., <3 MPN g^{-1} *Coliform*, and $<1x10^2$ CFU g^{-1} *Staphylococcus* spp. (Goes et al., 2015). This article corroborates the findings regarding cookies (Ikasari et al., 2020), pasta (Goes et al., 2016), pizzas (El-Beltagi et al., 2017), breads (Cercel et al., 2016), *fusilli* (Calanche et al., 2019), and fried snacks (Benevides et

Table 4. Results (mean ± standard deviation) for instrumental color (L*, a*, and b*) of yam *gnocchi* supplemented with spotted goatfish protein concentrate (SPC) at different levels (0% – control, 7.5%, and 15%).

Instrumental color	Treatments (%)		
	0	7.5	15.0
L*	64.09 ± 0.16a	57.89 ± 1.32b	57.45 ± 0.86b
a*	-2.83 ± 0.15c	-0.47 ± 0.33b	0.58 ± 0.26a
b*	3.75 ± 0.15b	14.91 ± 1.54a	15.99 ± 0.67a

(1)Means with different letters, on the same line, indicate a significant difference according to the Tukey's test, at 5% probability.

al., 2025), and also showed that the addition of protein concentrate does not affect the microbiological quality of the product. It is important to take into consideration the fish origin, especially the place of capture, storage, and handling by fishermen/middlemen because if the quality of the raw material is compromised, the quality of the final product will also be compromised.

The sensory evaluation of the color attribute of *gnocchi* samples varied significantly ($p<0.05$) across treatments (Table 5). *Gnocchi* from the control treatment (0% SPC) showed better color acceptance, receiving scores equivalent to "I liked it slightly," whereas *gnocchi* made with 7.5 and 15% SPC received scores equivalent to "I neither liked nor disliked." These scores indicate that color acceptance decreased with the addition of SPC. Furthermore, sensory color showed a highly significant positive correlation ($p<0.05$) for lightness (L* value, $r = 0.925$) and negative correlations for redness (a* value, $r = -0.809$) and yellowness (b* value, $r = -0.889$), indicating that the color acceptance of yam *gnocchi* samples improves when the product is brighter and less red and yellow. Probably, this occurs because these characteristics are close to those of traditional *gnocchi*, which are made from potatoes and wheat flour. In another study, however, the color acceptance of fresh pasta noodles prepared with up to 30% FPC remained unchanged, receiving a score equivalent to "I liked it slightly" (6.74 ± 0.28) (Goes et al., 2015). This result may have been influenced by the mild color of the tilapia fillet (white), making it more difficult for tasters to detect the presence of PC in the product. However, spotted goatfish meat is reddish and oily, producing a protein concentrate with a darker color, which may have been noticed and partially disapproved by tasters.

Odor acceptance was greater in the control treatment (0% SPC) and decreased with the inclusion of up to 7.5 or 15% SPC (Table 5). This attribute showed a negative correlation ($p<0.05$) ($r = -0.679$) with protein percentage. One way to improve *gnocchi* odor could be to carry out more washing procedures when obtaining SPC, although this process may reduce the protein content of the product, which would not be ideal from a nutritional standpoint.

The texture of yam *gnocchi* was the sensory attribute for which the greatest variation was observed regarding the inclusion of SPC. Texture acceptance was greater in yam *gnocchi* without SPC, which received an average score equivalent to "I liked it slightly". However, for *gnocchi* made with the addition of 7.5% SPC, the acceptance changed to "I neither liked nor disliked", and for *gnocchi* with the addition of 15% SPC, the acceptance was "I disliked slightly" (Table 5). This sensory attribute showed a negative correlation ($p<0.05$) with the percentage of proteins ($r = -0.886$) and lipids ($r = -0.947$), which may indicate that the increase of protein and fat from SPC decreased the texture acceptance of *gnocchi* samples. Furthermore, texture acceptance showed a positive correlation ($p<0.05$) with hardness ($r = 0.853$), elasticity ($r = 0.689$), and adhesiveness ($r = 0.835$). Results indicated that tasters preferred *gnocchi* with firmer, more elastic, and adhesive textures. These qualities diminished with the addition of SPC, leading to a product that lacked structural integrity during consumption. The texture of fresh pasta made from wheat flour and supplemented with 20% Nile tilapia

Table 5. Sensory acceptance (mean ± standard deviation) of yam *gnocchi* supplemented with spotted goatfish protein concentrate (SPC) at different levels (0% – control, 7.5%, and 15%).

Attribute	Treatments (%)		
	0	7.5	15.0
Color	6.67 ± 1.90a	5.50 ± 2.09b	5.51 ± 1.98b
Odor	6.35 ± 1.83a	5.03 ± 2.25b	5.39 ± 2.11b
Texture	6.39 ± 1.89a	5.55 ± 2.01b	4.59 ± 2.29c
Flavor	6.13 ± 1.83a	5.47 ± 2.26ab	5.24 ± 2.37b
Overall acceptance	6.41 ± 1.71a	5.55 ± 1.83b	5.15 ± 2.00b

[1]Means with different letters, on the same line, indicate a significant difference according to the Tukey's test, at 5% probability. [2]Nine-point hedonic scale: 9, "I liked it very much"; 8, "I liked it much"; 7, "I liked it moderately"; 6, "I liked it slightly"; 5, "I neither liked nor disliked"; 4, "I disliked it slightly"; 3, "I disliked it moderately"; 2, "I disliked it much"; 1, "I disliked it very much".

protein concentrate obtained a higher score (7.95) than control (7.05), 10% (6.55), and 30% (5.98) of PC inclusion (Goes et al., 2016). The addition of 5 and 10% FPC improved the texture aspects of cookies, in comparison with the control treatment, with reference to which tasters reported that products had a softer texture (Ikasari et al., 2020). However, in noodles made with sago flour (control treatment), and sago flour with the addition of skipjack tuna flour (at 8, 10, 12, and 14%), the texture acceptance was close to five points ("I neither liked nor disliked"), with no significant difference between treatments (Litaay et al., 2022).

The flavor acceptance of *gnocchi* decreased from the equivalent of "I liked it slightly" in the control treatment to the equivalent of "I neither liked nor disliked" for treatments with 7.5 and 15% SPC (Table 5). These results suggest that adding SPC concentrations below 7.5% to yam *gnocchi* can improve the product's flavor. Ikasari et al. (2020) observed that evaluators disliked the taste of cookies made with PC, reporting that they were more bitter than those of the control treatment (without the addition of PC).

The overall acceptance of *gnocchi* decreased with the inclusion of 7.5 or 15% SPC (Table 5). One factor that influences food purchasing is the difference between the idealized image and the product itself. Consumers are used to consuming traditional *gnocchi*, made from potatoes, whose color is yellowish-white, soft in texture, and mild in flavor. A change to this pattern is received with resistance. Suppose the attributes of spotted-goatfish *gnocchi* were closer to traditional ones. In that case, it is likely that the product would be better accepted and could even gain space, opening up the opportunity for possible industrial production. Therefore, to improve the sensory acceptance of this innovative product, future studies should test different formulations using other ingredients.

Conclusions

1. The addition of spotted goatfish protein concentrate (SPC) increases the protein, lipid, and mineral content of yam *gnocchi*, thereby enhancing the product's biological value.

2. The color and instrumental texture of the *gnocchi* are also affected by the addition of SPC.

3. The addition of up to 15% SPC does not compromise the microbiological quality of yam *gnocchi*, and it is considered suitable for human consumption.

4. The sensory acceptance of *gnocchi* supplemented with more than 7.5% SPC is equivalent to a neutral rating ("neither liked nor disliked it"), but lower than that of the control (0% SPC) ("I liked it slightly").

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