



Nutritional Value and Sensory Acceptability of a Food Supplement Based on “Bonito” Fish for Preschool-Age Children

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ABSTRACT

Anemia and child malnutrition are persistent public health issues, particularly affecting the children's population. Despite ongoing efforts, the effectiveness of current interventions remain limited in some countries. In this context, the potential of “bonito” fish as a nutritional resource is being investigated to address these problems and to determine the nutritional value and sensory acceptability of a food supplement based on *Sarda chiliensis chiliensis* (“bonito” fish) for preschool-age children. Two formulations (FA and FB) of fish supplements with different proportions of sweet potato, and variations in some ingredients (“Bellaco” banana in FB) were developed, which were characterized by proximal analysis using AOAC methods and microbiological analysis. The iron and fatty acid content was quantified using validated methods in all cases. The evaluation of sensory acceptability was conducted for children aged 2 and 3 years, using a 5-point facial hedonic scale. Significant differences ($P < 0.05$) were found in calories, proteins, fats, carbohydrates, moisture, and ash. There were no notable variations in iron levels between the formulations tested ($P > 0.05$) ranging 4.96 – 4.98 mg/100g, and in the lipid profile, a higher content of monounsaturated fatty acids was observed, mainly oleic acid ($> 2\%$). Both formulations meet the microbiological standards of acceptance for this type of preparation. FB was significantly more accepted ($P < 0.05$) than FA, although both were rated as “Liked”. Both formulations satisfy the nutritional requirements for preschool-age children, although some nutrients reached the acceptable percentage of adequacy, and were also sensorially accepted.

INTRODUCTION

Anemia is a condition in which the number of red blood cells or the amount of hemoglobin is below normal levels, with nutrient deficiency being the most common cause

(WHO, 2025a). In addition, insufficient iron intake is the main cause of this condition, although low levels of folate, vitamin B12 and protein can also contribute to its onset, particularly affecting children (Latham, 1997; Leung *et al.*, 2023). Likewise, child malnutrition is caused by insufficient food intake in terms of both quantity and quality. If the causes are not addressed, the nutritional situation may worsen, compromising children's survival, cognitive ability and growth. According to the World Health Organization (WHO), anemia and malnutrition are public health problems that affect approximately 40% (WHO, 2025a) and 22% (WHO, 2025b) of children between 6 months and 5 years of age, respectively, and showed signs of stunted growth. This is very relevant because malnutrition compromises children's survival, cognitive ability and growth.

Furthermore, this problem is much more common in developing countries such as Peru, where there is a higher prevalence of anemia and child malnutrition, mainly in rural areas (INEI, 2025). Given this situation, bonito fish emerges as a strategic, relevant and beneficial option due to its high content of high-quality protein, essential vitamins, omega-3 fatty acids and minerals such as iron, calcium, phosphorus and potassium (INS, 2023). These nutrients are essential in preventing iron deficiency and promoting growth and maturation during childhood (Hong, 2025).

The bonito fish (*Sarda chiliensis chiliensis*) is an epipelagic neritic species of the Scombridae family living along the South Pacific, and is distributed from Mancora, Peru, to Talcahuano, Chile (Pepe-Victoriano *et al.*, 2021). From a socio-economic perspective, bonito is one of the most important fishery resources in Peru due to the large volume of fish caught, which is all destined for direct human consumption (IMARPE, 2023). In addition to its significant nutritional value, bonito fish is widely available nationwide. In Peru, its abundance increases during the summer and spring months (January–April), coinciding with the warming of surface waters due to coastal upwelling. Even during the South American summer, there is greater availability for artisanal and small-scale fishing, benefiting the economies of families engaged in this activity. However, its availability may be subject to external conditions. In years when the El Niño phenomenon occurs, bonito tends to move southward and increase its biomass off the Peruvian coast. Conversely, in La Niña years, its presence may decrease (IMARPE, 2023). At the end of 2024, the landing of bonito for direct human consumption reached 131.1 metric tons. It is worth noting that 65.5% of the total catch reached wholesale and retail fish markets for subsequent sale to end consumers (PRODUCE, 2024). In addition, it should be noted that, as of the end of October 2025, bonito landings have reached 109.42 metric tons (PRODUCE, 2025). In line with the above, the Peruvian government promotes fish consumption as part of the basic family food basket, implementing policies to support fishermen and traders, as well as educational activities for the population (PNACP, 2025). These various measures enable familiarity with this food to be recurrent, promoting an affordable price and, above all, efficient use of fishery resources, such as bonito, making it a sustainable alternative in terms of food security.

The development of the bonito fish supplement emerges as an innovative and effective solution to combat these health problems, considering the nutritional deficiency found in most similar commercial preparations and the proven effectiveness of products with similar resources in other studies (**Melina & Cuno, 2016; Bullón-Vela *et al.*, 2018; Sibina & Ordoñez, 2018; Vilca-Cáceres *et al.*, 2020**). Therefore, the idea was to develop a food supplement based on bonito and yellow sweet potato, and also red pepper and olive oil. The choice of this fish is based on its protein, iron and omega-3 fatty acid content, which includes eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (**Sibina & Ordoñez, 2018**). Yellow sweet potato and red pepper, in addition to being nutritionally valuable, provide a sweet flavor that balances the taste and improves sensory acceptability (**Renee Vidal *et al.*, 2018; Kefale *et al.*, 2023**). Finally, olive oil provides monounsaturated fatty acids, while enhancing texture and flavor (**Ramos-Escudero *et al.*, 2015**).

The initial hypothesis addressed the design of a food supplement that is both nutritious and sensorially acceptable to young children. Additionally, the formulation should include foods that are highly nutritious, such as fish, tubers and vegetables. These foods should be easily accessible, seasonal and affordably priced. In this regard, the objective of the present study is to analyze the nutritional value and sensory acceptability of two formulations of a food supplement based on *Sarda chiliensis chiliensis* (bonito) for preschool-age children. This proposal offers a healthy and appealing alternative, designed to provide 10% of children's daily nutritional requirements, facilitating direct consumption and providing convenience for caregivers.

MATERIALS AND METHODS

Collection of samples

The research was carried out using fresh fish (*Sarda chiliensis chiliensis*), yellow sweet potato (*Ipomoea batatas*), carrots, red peppers and virgin olive oil, purchased from a local supermarket in Lima (Peru). To ensure hygienic conditions during preparation, good handling practices were maintained from acquisition to processing of the food supplement, following the Codex Alimentarius General Principles of Food Hygiene (**FAO & WHO, 2022**).

Food supplement processing

Two formulations were elaborated (Table 1), according to the nutritional content data reported in the Peruvian Food Composition Tables (**INS, 2023**), following the steps presented in the flowchart below (Fig. 1). Both formulations addressed the nutritional requirements for preschool children established by the National Institute of Health (Peru) and the recommended daily requirement for the snack mealtime (10% of the total calorific value: 125 kcal) based on Dietary Reference Intakes Energy and, macro and micronutrients (**INS, 2015; National Academies of Sciences, 2023; National Institutes of Health, 2023**). Table (2) shows the nutritional value of each formulation and the percentage of

adequacy according to the nutritional requirements of snack mealtime for pre-school children.

Table 1. Formulations to prepare 120g of food supplement based on “bonito” fish

Formulation	Ingredient	Amount (g)	Proportion (%)
FA	“Bonito” Fish	20	16.6
	Sweet potato	60	50
	Carrot	15	12.5
	Red bell pepper	22	18.3
	Olive oil	3	2.5
	Total weight	120	100
FB	“Bonito” fish	20	16.6
	Sweet potato	15	12.5
	“Bellaco” banana	50	41.7
	Carrot	10	8.3
	Red bell pepper	22	18.3
	Olive oil	3	2.5
	Total weight	120	100

FA: Formulation A; FB: Formulation B



Fig. 1. Flowchart for the production of “bonito” fish-based formulations

Table 2. Nutritional content and nutritional adequacy (%) achieved by the formulations

Formulation	Energy kcal	Protein (g)	Fat (g)	Carbohydrates (g)	Fe (mg)	<i>Omega</i> -3 (mg)
FA	116	6.2	3.8	16.2	0.89	0.52
(%)	93	133	91	94	127	743
FB	124	5.9	3.8	20	0.87	0.52
(%)	99	127	92	117	124	743

FA: Formulation A; FB: Formulation B.

The process of preparing the food supplement began by weighing the ingredients (Table 1) on a digital scale (Soehnle®) followed by being properly cooked (Table 3), The proportions were mixed and crushed manually until a homogeneous, smooth mixture was obtained, and the olive oil was added. The products were placed in hygienic wide-mouth glass containers with a capacity of 200mL, previously washed and sterilized. Subsequently, they were subjected to a thermal sterilization process at 100°C for 25 minutes, thus ensuring their safety. The bottles were kept at room temperature (20- 25°C), ensuring the preservation of the product until the time of analysis. In Fig. (2), the image of the finished product is shown.

Table 3. Cooking parameters of ingredients used in “bonito” fish-based formulations

Food	Time	Temperature (°C)	Method
“Bonito” fish	5-10	63° (internal temperature)	Steamed
Sweet potato	25	100°	Boiled
Carrot	15	100°	
“Bellaco” banana	15	100°	
Red pepper	10	<100°	Poached

**Fig. 2.** “Bonito” Fish-based formulations

Proximate analysis

The formulations were subjected to chemical analysis of proximate composition according to AOAC methods (**Latimer, 2023a**). The protein content was determined using the Kjeldahl method; the fat content was analyzed using the Soxhlet method; the moisture content was determined by oven drying, and the ash content was analyzed using the gravimetric method. Total energy content (kcal) was calculated using the method of **Merrill and Watt (1973)**, based on energy factors of 4 kcal/g for proteins and carbohydrates, and 9 kcal/g for fats, while carbohydrates were determined by difference, subtracting dry matter, protein, lipids and ash. Results were expressed as g/100g of formulation.

Iron

The content of iron was determined according to **NOM 117-SSA1 (1994)** by atomic flame absorption spectrometry, and results were expressed as mg/100g of formulation.

Fatty acid profile

Gas chromatography (GC) was used to characterize the fatty acid profile, following the method described in the ISO 12966-1:2014 guideline (**ISO, 2014**), using a PerkinElmer® Clarus® 500 GC. The compounds were identified by comparing them with standards to determine the composition, and results were expressed in relative frequencies (%).

Microbiological analysis

The microbiological analysis included counts of *Mesophilic aerobes*, *Staphylococcus aureus*, *Salmonella* sp, *Enterobacteriaceae* and *Clostridium perfringens*, as established in the Peruvian Sanitary Technical Standard N°071-2008, which sets out the microbiological requirements for foods established for categories 9.8 (ready-to-eat dietetic products) and 18.1 (semi-preserved food of pH>4.6) (**MINSA/DIGESA, 2008**).

Mesophilic aerobic counts were carried out according to **ICMSF (1988)**, by the plate count method, and results were expressed in CFU/g. For the determination of *Staphylococcus aureus*, the methodology described in AOAC 975.55 (**Latimer, 2023b**) was used by the surface plating method for isolation and enumeration, and the results were presented in CFU/g. The detection of *Salmonella* sp. was carried out by a molecular method (PCR) according to **ICMSF (1988)**, reporting the number of positive samples in CFU/25g. *Enterobacteriaceae* were counted by plate seeding according to the **ICMSF (1988)** standard method, and the results were expressed in CFU/g. Finally, *Clostridium perfringens* counts were performed by plate count technique, as described in AOAC 976.30 (**Latimer, 2023c**). Results were expressed as CFU/g formulation.

Sensory evaluation of acceptability

Once the safety of the formulations was confirmed by microbiological analysis, sensory evaluation was carried out in an environment that ensured optimal conditions for

the evaluation. The study was previously evaluated and approved by the Ethics Subcommittee of the Faculty of Health Sciences of the Peruvian University of Applied Sciences, FCS 797-11-23 PI 527-23. The assessment was carried out using a 5-point Hedonic Facial Expression to evaluate acceptability (Da Cunha *et al.*, 2013) (Fig. 3). This method is primarily used with children, as it involves showing participants images of faces displaying different levels of liking or affection toward the product being evaluated (Huey *et al.*, 2024). The test comprises a scale corresponding to each 'face' scale (Fig. 1) categories ('hated', 'did not like', 'indifferent', 'liked' and 'loved'). The results were then converted into numerical values from 1 to 5 to be analyzed. 20 untrained judges from a pre-school educational institution participated. Selection criteria for participants included: age between 2 and 3 years, no cold, no allergy to fish or any other ingredient in the formulations, no special dietary needs, and informed consent approval by parents or guardians. Participants were selected by non-probabilistic convenience sampling. Before starting the sensory evaluation, the tutors received brief instruction prior to the start of the evaluation. This step was conducted to get familiar with the process and to comprehend how the hedonic scale works.

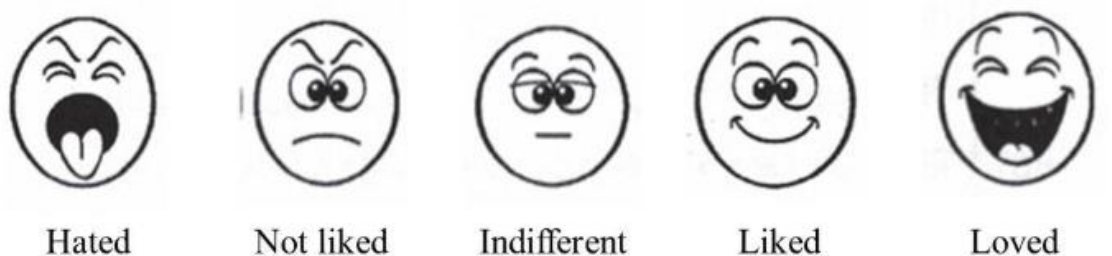


Fig. 3. 5-point Hedonic Facial Expression to evaluate acceptability. Taken from Da Cunha *et al.* (2013)

During the sensory evaluation, the food supplement samples were presented in sterilized jars with a capacity of 30 grams, randomly coded with three-digit numbers to ensure randomization and avoid bias. Each panelist was offered a teaspoon (5 grams) of the first formulation, and the researchers marked the response on the evaluation sheet according to the child's facial expression. After a 5-minute interval, during which the panelists took a sip of water to neutralize the palate, they were given the second sample.

Statistical analysis

All results for proximate analysis, iron and fatty acids were obtained in triplicate ($n=3$), and digitized into a Microsoft Excel spreadsheet to create a database. Averages and corresponding standard deviations were calculated, and significant differences ($P<0.05$) were determined between the values obtained, using parametric and non-parametric tests, as appropriate. On the other hand, the sensory evaluation data ($n=20$) were coded according to the facial hedonic scale which includes the categories: 'hated', 'did not like', 'indifferent', 'liked' and 'loved', with values ranging from 1 to 5, respectively. The mean

and standard deviation of the scores for both formulations were also estimated. Statistical analyses were carried out using RStudio software, version 2024.04.

RESULTS

Proximate analysis and iron content of food supplement

The results of the proximate and iron analysis can be observed in Table (4), showing differences in the values obtained, mainly in the protein content ($P<0.05$). As for iron, the concentrations were similar in both formulations ($P>0.05$).

Table 4. Proximal composition and iron content of fish-based formulations

Component	FA	FB	P-value
Total energy (kcal/100g)	122.84 ± 0.37 ^a	125.72 ± 0.16 ^b	0.009*
Protein (g/100 g)	5.43 ± 0.09 ^a	4.29 ± 0.04 ^b	0.003*
Fat (g/100 g)	4.14 ± 0.06 ^a	4.46 ± 0.07 ^a	0.051*
Carbohydrates (g/100 g)	15.98 ± 0.14 ^a	17.11 ± 0.16 ^b	0.017*
Moisture (g/100 g)	73.60 ± 0.01 ^a	73.32 ± 0.05 ^b	0.016*
Ashes (g/100 g)	0.86 ± 0.00 ^a	0.83 ± 0.00 ^a	0.193**
Iron (mg/100 g)	4.96 ± 0.05 ^a	4.98 ± 0.02 ^a	0.651*

FA: formulation A; FB: formulation B. Mean ± standard deviation (n = 3).

*Values obtained by T-test. **Values obtained by Wilcoxon test.

Fatty acid profile of “bonito” fish-based formulations

As shown in Table (5), there are slight differences in the amounts of fatty acids present in the formulations, with oleic acid being the most abundant unsaturated fatty acid. The major polyunsaturated fatty acids were linoleic>docosahexaenoic>eicosapentaenoic acid, mainly in the FA formulation. In addition, neither of the formulations contained trans-fatty acids. Fig. (4) shows the chromatograms of the fatty acid profile of both formulations.

Table 5. Fatty acid content of “bonito” fish-based formulations

Component*	FA	FB	P-value
Butyric acid (C:1)	1.25 ± 0.02	1.63 ± 0.04	0.005 ⁺
Myristic acid (C14:0)	0.06 ± 0.00	0.08 ± 0.00	0.193 ⁺⁺
Palmitic acid (C16:0)	0.94 ± 0.01	1.24 ± 0.04	0.008 ⁺
Stearic acid (C18:0)	0.22 ± 0.00	0.29 ± 0.02	0.049 ⁺

Arachidic acid (C20:0)	0.02 ± 0.00	0.03 ± 0.00	0.193 ⁺⁺
Oleic acid (C18:1)	2.00 ± 0.07	2.91 ± 0.09	0.008 ⁺
Eicosanoid acid (C20:1)	0.03 ± 0.00	0.05 ± 0.01	0.019 ⁺
Linoleic acid (C18:2)	0.46 ± 0.01	0.70 ± 0.05	0.021 ⁺
Linolenic acid (C18:3)	0.06 ± 0.00	0.08 ± 0.01	0.095 ⁺
Eicosadienoic acid (C20:2)	0.03 ± 0.00	0.03 ± 0.00	NA
Arachidonic acid (C20:4)	0.02 ± 0.00	0.03 ± 0.00	0.193 ⁺⁺
Eicosapentanoic acid (C20:5)	0.14 ± 0.00	0.17 ± 0.01	0.064 ⁺
Docosahexaenoic acid (C22:6)	0.28 ± 0.02	0.35 ± 0.02	0.080 ⁺
SFAs**	1.25 ± 0.01 ^b	1.09 ± 0.01 ^a	0.005 ⁺
MUFAs**	2.17 ± 0.08 ^a	2.10 ± 0.01 ^a	0.364 ⁺
PUFAs**	0.99 ± 0.01 ^b	0.90 ± 0.01 ^a	0.023 ⁺
TFAs**	ND	ND	ND
Unidentified**	0.06 ± 0.02 ^a	0.05 ± 0.03 ^a	0.86 ⁺

FA: formulation A; FB: formulation B; SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids; TFAs: trans fatty acids. *Values are expressed in %. ** Values based on total fat content. ⁺Values obtained by T. Test and ⁺⁺Wilcoxon test. Each value is the mean ± the standard deviation (SD) of triplicate determinations (n = 3).

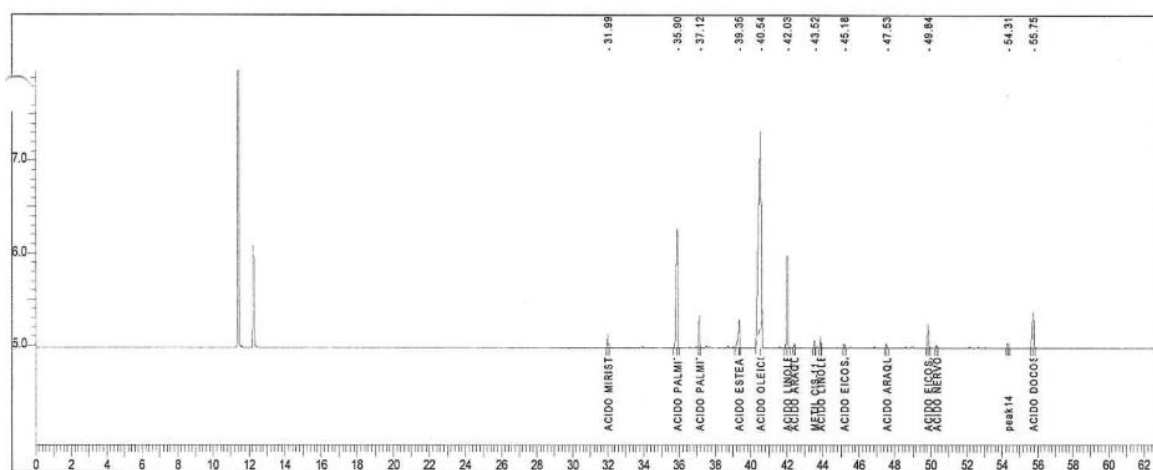


Fig. 4. Fatty acid profile of “bonito” fish-based formulations by GC

Microbiological analysis of fish-based formulations

Both formulations complied with the parameters established in the Peruvian Sanitary Technical Standard N°071-2008, classifying them as safe. Results can be observed in Table (6).

Table 6. Microbiological analysis of “bonito” fish-based formulations

Microbiological group	FA		FB	
	Sample 1	Sample 2	Sample 1	Sample 2
<i>Mesophilic aerobes</i> (CFU/g)	<10 Est	<10Est	<10 Est	<10Est
<i>Clostridium perfringens</i> (CFU/g)	<10	<10	<10	<10
Enterobacteriaceae (CFU/g)	<10	<10	<10	<10
<i>Salmonella</i> (CFU/25 g)	Absence	Absence	Absence	Absence
<i>Staphylococcus aureus</i> (CFU/g)	<10	<10	<10	<10

FA: formulation A; FB: formulation B.

Sensory Evaluation of acceptability of “bonito” fish-based formulations

The group of untrained panelists consisted of 20 children with a mean age of 2.6 years, evenly distributed by gender. The FB formulation scored slightly higher compared to the FA formulation, although based on the values obtained, both formulations were categorized as ‘Liked’ (Table 7).

Table 7. Results of the sensory analysis of fish-based formulations

Sample	Values	P value*
FA	3.60 ± 1.14	0.049
FB	4.25 ± 0.90	

*Values obtained with the Wilcoxon test. Mean ± standard deviation (n=20).

Suitability analysis of “bonito” fish-based formulations

Table (8) presents the nutritional content of both formulations in servings of 120 grams, according to the nutritional requirements for children 2-3 years old established by the National Institute of Health and the RDI for the snack mealtime (10% of the total caloric value). Both formulations meet these requirements; however, the values for protein exceed the minimum recommended percentage of adequacy, which is 90-110% (INS 2015; National Academies of Sciences 2023; National Institutes of Health 2023).

Table 8. Calories, proteins, iron and Omega 3 content provided by 120g of formulations in relation to the dietary requirement for preschool children at snack time

Formulation	Nutrient	Amount (g)	Nutritional requirements* (g)	Adequacy rate in 120 g (%)
FA	Calories (kcal)	147.41	125	118
	Protein	6.52	1.3	502
	Hierro (mg)	5.95	7 mg/day ⁺	85
	Omega 3	0.07	0.7g/day ⁺⁺	10
FB	Calories (kcal)	150.86	125	121
	Protein	5.15	1.3	400
	Hierro (mg)	5.98	7 mg/day ⁺	85
	Omega 3	0.10	0.7g/day ⁺⁺	14

*Nutritional requirements for snack mealtimes. ⁺Based on **National Institutes of Health (2025a)** ⁺⁺ Based on **National Institutes of Health (2025b)**.

DISCUSSION

The purpose of the research was to determine the nutritional value and carry out a sensory evaluation of the acceptability of two formulations of nutritional supplements based on bonito fish (*Sarda chiliensis chiliensis*) for pre-school age children. The results obtained indicate that both formulations met the recommended nutritional requirements for this age group by providing an adequate amount of calories, protein, fat, carbohydrates, iron and omega-3. In addition, both formulations were sensorially accepted.

It is essential to note that both formulations have a similar number of calories. Furthermore, the percentage adequacy in 120g of product exceeded the upper limit of 110% of the RDI for the snack mealtime, indicating that they provide slightly more calories than the recommended nutritional requirement for children of this age. Similarly, when contrasting these results with preparation based on tubers, andean grains and oilseeds for children under 2 years of age, a lower calorie intake (106 kcal) is observed (**Falkon Kaliksztein & Ferrand Ortiz, 2022**) compared to the formulations developed in the present study, whose intake is higher (123 and 126 kcal/100 g, samples FA and FB, respectively). This slight increase in calories in both formulations may be due to the use of higher energy ingredients such as olive oil, sweet potato and “Bellaco” banana,

therefore, including this type of preparation in children's diets could be an effective way to diversify their diets without compromising the nutritional value.

Both formulations show a high protein adequacy for the snack, reaching 500% and 400% in FA and FB, respectively. This protein intake is significant, considering that in rural areas of Latin American countries, the protein requirements are not fully met throughout the day (**Mamani *et al.*, 2016**). It is very important to prepare meals with local foods which contain essential nutrients to prevent chronic malnutrition. Therefore, the high protein content in both formulations could be beneficial in supplementing daily nutritional intake for children, thereby helping to address the challenge of child malnutrition in developing countries. In the same way, the protein of oily fish such as “bonito” is considered complete, a rich source of essential amino acids, such as tryptophan and lysine (**Chamorro *et al.*, 2022**). These amino acids are vital for normal growth and development in children. In fact, a previous study showed that 100g of “bonito” protein contains approximately 40g of essential amino acids and 12.5g of glutamine (**Intarasirisawat *et al.*, 2011**). Therefore, the proposed formulations could be considered an important source of high-biological-value protein from fish, meeting FAO requirements for improving child nutrition. Their ready-to-eat format and ease of preparation make them a practical option for school feeding programs, and their contribution to diversifying the school diet aligns with the objectives of international food security programs.

On the other hand, fats play a crucial role in our bodies, especially during childhood, as they are essential for growth and development. In this context, they act as a major source of energy, which makes them an essential component during the first 2 to 3 years of life (**Frydrych *et al.*, 2025**). In the present study, the food supplement formulations based on “bonito” fish contained higher amounts of fat, compared to only 0.7g in a Hake puree sold in Italy. This puree included other ingredients such as potato, rice flour, extra virgin olive oil and lemon juice (**PLASMON, 2025**). Although both foods contain olive oil, the variation in fat content is mainly attributed to the type of fish used. Despite the fat content, in this study, the formulations remain within the recommended limit for snack mealtime, being mostly unsaturated fatty acids, which is positive given the current exposure to excess saturated fats in the diets of children (**Bavera & Villarroel, 2017**).

About carbohydrates, the presence of this nutrient in “bonito” fish-based preparations is largely due to sweet potato, a common ingredient in Peruvian cuisine. This root not only contributes to carbohydrate content but also provides several nutritional benefits. For example, sweet potato is an excellent source of pro-vitamin A, an antioxidant essential for eye health and the immune system. According to the Food and Drug Administration, sweet potato exceeds the daily requirement for pro-vitamin A in a single 130g serving (**FDA, 2017**). It also contains a significant amount of protein, together with essential amino acids such as leucine, lysine and phenylalanine, which are necessary for cell proliferation and protein synthesis (**Qiu *et al.*, 2020**). On the other hand, the formulation with the highest acceptability score included plantain as one of its key ingredients. Green bananas have also

been identified as a potential solution for tackling child malnutrition due to their high carbohydrate, fibre, vitamin A and potassium content, as well as their abundance of other essential nutrients (**Petr, 2018**).

In proximate analysis, moisture plays an important role. This parameter indicates the amount of water contained in the product, which is directly related to its quality and shelf life (**Thangaraj, 2016**). In this study, it was observed that both formulations have a similar moisture content of around 73%. However, in spite of the high moisture content, both mashes were subjected to a sterilization heat treatment, which guarantees their safety and security. In contrast, a study evaluating three formulations of carrot, zucchini and rice porridge for children over 6 months found that the carrot and zucchini sample achieved a moisture content of 89.96% (**Orantes, 2017**). This can be explained by the specific composition of the formula, in which the food itself has a higher amount of water, as well as the addition of water during processing.

On the other hand, in relation to ash content, which reflects the amount of minerals present in the formulations, it can be seen that the results show that the FA sample contain a greater variety and quantity of minerals in general. However, although the ashes can provide a general indication of the minerals present, including iron, a comprehensive analysis of all minerals would provide a more complete assessment of the formulations. In this context, iron plays a crucial role in several important functions, including the transport of oxygen by erythrocytes. This is essential for proper bodily function and to promote learning in children. Deficiency can lead to anaemia and delays in psychological development, potentially resulting in social isolation and delays in psychological development, potentially resulting in social isolation (**National Institutes of Health, 2025a**). In addition, both formulations contain approximately 6mg/100g of iron, which represents an 85% adequacy without exceeding the upper intake limit (**National Institutes of Health, 2025a**). This value is mainly due to the ‘bonito’ fish content which makes it an ideal choice to cover the requirement of this micronutrient and prevent iron deficiency. Therefore, the inclusion of this supplement in food aid programs around the world could contribute to improving nutritional status and preventing childhood anemia. It is important to note that most children in developing countries do not consume enough iron in their daily diet. Therefore, the contribution of the bonito-based supplement towards meeting the recommended daily intake of iron is significant.

In terms of fatty acids, formulations stands out as a remarkable food due to its nutritional profile, which includes 70 - 100 mg of omega-3 fatty acids per 120 g serving, mainly provided by “bonito” fish and olive oil. In contrast, wild salmon baby food sold in the United States offers a different profile, with approximately 60 mg of omega-3 fatty acids in a 90-gram serving, according to the natural content of this nutrient in salmon (**Serenity Kids®, 2025**). However, the results on the nutritional profiles of the formulations developed in this study reveal a wide variety in their fatty acid profile, which highlights the importance of thoroughly analyzing this composition, as they play an

essential role in health. It should be noted that both fish-based “bonito” formulations supplement the nutritional requirements of omega-3 (ALA) in children. However, when considering the content of the three types of omega-3 (ALA, EPA, DHA), formula A meets almost 83% of the requirement, while formula B exceeds it by 103%. In addition, the EPA and DHA content is derived primarily from bonito fish in both formulations. Therefore, including oily fish, such as “bonito”, in the diet of preschool children is extremely important to meet their essential Omega 3 requirements at this age (**National Institutes of Health, 2025b**). In addition, it is sufficient to acquire the health benefits associated with these nutrients (**Punia et al., 2019**).

On the other hand, the analysis of the formulations reveals that they contain a higher amount of monounsaturated fatty acids. In turn, other fatty acids are also present, such as polyunsaturated fatty acids (PUFAs) which, as well as DHA and EPA acids, play essential roles in brain development and eye health. Conversely, deficiencies in these nutrients can have a direct impact on both cognitive and behavioral performance in children (**Sherzai et al., 2022**). Likewise, in terms of saturated fatty acid content, the values are below the saturated fat limit range established by AESAN for solid products (1.5g/100g product), thus, according to the guideline, both formulations would qualify for the claim ‘Low saturated fat content’ (**European Union, 2006**). Furthermore, as they do not contain trans fats, these formulations pose no health risks associated with this type of fatty acid (**Fernández-Michel et al., 2008**).

Furthermore, both samples fall within the microbiological ranges specified in Technical Standard No. 071-2008. This could be due to adequate heat treatment, which guarantees the elimination of pathogenic microorganisms, and good handling practices implemented during processing. In addition, constant monitoring of sanitary conditions and rigorous quality control were carried out at each stage of the procedure, which has contributed significantly to ensuring the hygiene and microbiological quality of the formulations. Ensuring microbiological quality was essential in order to proceed with the acceptability testing of the bonito-based supplement samples.

Likewise, the characteristic sweet taste of sweet potatoes is due to the breakdown of starch into simple sugars such as glucose, sucrose, and fructose. This natural sweetness apparently improved the sensory profile of the formulations produced, making them more acceptable to children in general. However, as for the results of the sensory analysis, there is a clear preference for formulation 2, which includes the ‘bellaco’ banana, compared to formulation 1, which does not contain this ingredient. Similar results were found in the study conducted by **Vilca-Cáceres et al. (2020)**, who developed three fish-based products: one breaded with banana flour, another with bean flour, and a kamaboko paste. When evaluating the sensory acceptability of these products with children aged 8 to 10, it was observed that the banana flour breading was most popular (86.3%), followed by the kamaboko paste (59.2%), and finally the bean flour breading (26.7%). This may suggest that bananas are a promising ingredient to produce fish-based products aimed at children,

as it improves their sensory acceptability. Similarly, in a previous study in which a purified fish protein mixed into cereal- and pseudocereal-based drinks was administered daily for three months, it was observed that children's acceptance of the food was high (over 90 % of children) (**Bullón-Vela *et al.*, 2018**). On the other hand, although the introduction of solid foods and varied textures is recommended from the age of 2 years (**Escobedo *et al.*, 2021**), the inclusion of fish in foods with a soft texture may contribute to greater acceptability. In addition, **Prell *et al.* (2002)** identified a few barriers to fish consumption, such as aversion to smell and texture, as well as fear of encountering bones, which may influence willingness to consume fish. In this context, **Rozin and Vollmecke (1986)** highlights the importance of textures in food preference or dislike, suggesting that texture may play an important role in the perception of flavor and food acceptability, especially among children. Considering this evidence, the proposed formulation could offer a viable option for introducing fish into children's diets, providing a smoother and more consistent sensory experience and making the strong taste of fish. On the other hand, "bonito" fish-based food supplements could be more affordable and widely available, which could contribute to their lower price compared to wild salmon porridge (**Serenity Kids®, 2025**). Thus, the proposed formulation could be more in line with the preferences and needs of parents seeking a nutritious and affordable alternative.

Affective tests are used to work with individuals who are selected based on the objective of the test and who, based on certain characteristics such as age, may be regular consumers (**Drake *et al.*, 2023**). Therefore, an affective sensory acceptability test based on a 5-point Facial Hedonic Scale was chosen as the evaluation technique, based on the age of the participants (**Davies & Tuleu, 2008; Thompson *et al.*, 2015; Huey *et al.*, 2024**). Another identified strength is that the product is innovative, as there are no previous examples of products with "bonito" fish as the main ingredient. The results obtained from the study will provide relevant data for the scientific community, particularly for child nutrition, by addressing issues considered to be public health problems. In addition, images of the participating children tasting the formulations were shared during the sensory acceptability assessment, offering parents a closer look at their children's experience. Information on healthy eating for preschool children was provided, along with the recipe for the bonito formulation used in the study. This initiative promotes the replicability of the intervention at home while also informing parents about the importance of a balanced diet and promoting fish consumption from an early age.

In terms of the strengths of the study, particular attention was given to including school-age children in the sensory evaluation. This is advantageous, as it allowed us to estimate the acceptability of the formulation with fish inclusion in children aged 2 to 3 years. However, we suggest that in future research, the number of participants should be increased in order to obtain more representative and psychometrically valid results (**Wagner *et al.*, 2020**). Therefore, it is important to recognize sample size as a limitation in our research, which also affects the "generalization of results". For acceptability studies,

the recommendation is to include 10 participants for each evaluation criterion. Consequently, it is recommended that future research utilises a sample size based on a 1:10 ratio (criterion:number of participants) (Wagner *et al.*, 2020).

A further limitation identified in this research is the absence of an analysis of the estimated useful life of the product. A specific shelf-life assessment would be appropriate in order to provide vital information about how stable the product is under specific storage and use conditions, promoting its safety. However, in the present investigation, the shelf-life of the product was therefore determined based on the available scientific evidence regarding sterilized products of a similar nature (Sorică *et al.*, 2022). Furthermore, considering that this product would be intended for consumption by children, its safety was ensured through the respective microbiological analyses.

In the context of future prospects for bonito food supplements with tubers and vegetables aimed at preschool children, it is recommended to proceed with stability and shelf- life studies that evaluate microbiological safety, lipid rancidity, retention of key nutrients, and organoleptic changes in different packaging and temperatures. Concurrently, longitudinal sensory evaluations should be conducted with caregivers and children to ascertain the acceptability of the storage process. From a production standpoint, the development of a pilot line would facilitate the optimisation of formulation, thermal processes, and packaging, as well as the modeling of unit costs. From a production standpoint, the development of a pilot line would facilitate the optimisation of formulation, thermal processes, and packaging, as well as the modeling of unit costs. Future research could consider regulatory requirements for infant foods, nutritional impact studies, and sustainability criteria (responsible fishing practices and environmental footprint) to ensure that the product is safe, economically viable, and socially acceptable.

CONCLUSION

This study highlights that nutritious foods such as “bonito” fish in milder dishes and combining it with other ingredients to mellow its flavor is a safe and suitable snack option for the diet of preschool-age children. The formulations developed in this study exceeded 10% of the energy and protein requirements (snack time) for children aged 2 to 3 years and provided a significant contribution to the daily requirement of iron and omega-3. It should also be noted that, based on their calories, protein, and iron content, they have the potential to prevent and/or counteract child malnutrition and anemia. In addition, monounsaturated fatty acids, mainly omega-3, as well as DHA and EPA, were identified in both formulations. Sensory analysis demonstrated that the proposed formulations were well received by children, especially FB, indicating that the inclusion of fish alongside other ingredients as a snack is an attractive option for children. The study offers an alternative solution to address malnutrition and anemia in countries where children are most affected by these conditions. It also presents itself as a beneficial option for the typical diet of

children. Consequently, the findings would be of significant benefit to health specialists, researchers, and policymakers in the field of child nutrition.

Authors' contributions

M. Anticona and S. Zegarra Samamé designed research; P. Meza Tumialán and A. Prieto Sastre conducted research; P. Meza Tumialán, A. Prieto Sastre and M. Anticona performed statistical analysis; P. Meza Tumialán, A. Prieto Sastre and M. Anticona wrote the paper. All authors read and approved the final manuscript.

Conflicts of interest

The authors declared no conflicts of interest.

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