International Journal of Gastronomy and Food Science 41 (2025) 101216

Contents lists available at ScienceDirect

International Journal of Gastronomy and Food Science

journal homepage: www.elsevier.com/locate/ijgfs

Innovative fortified kale soup formulation designed for the elderly

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ARTICLE INFO

Keywords:
Brassica
Dehydrated
Elderly
Kale
Nutrient-dense
Soup

ABSTRACT

The nutritional needs of the elderly require immediate attention. Strategies to incorporate healthy, high-fibre, protein-rich ingredients into traditional diets have been identified to enhance health benefits. This study aimed to develop a new food product specifically for older adults, using kale (*Brassica oleracea* L. var. *acephala* DC), and to evaluate its nutritional, sensory, and antioxidant properties. Acceptance was assessed among institutionalised elderly individuals in Galicia (Spain) and Northern Portugal. Fresh kale, both blanched and non-blanched, was air-dried at 80 °C for 2 h. The dehydrated kale was then ground into small particles and/or powder. Blanching did not negatively affect the dehydrated samples' protein, fibre, or carbohydrate content. The sensory analysis showed 0.5 %–0.8 % kale enrichment improved taste and texture, balancing appeal without bitterness or roughness from higher concentrations. Incorporating non-blanched dehydrated kale (at concentrations of 0.5 %, 0.8 %, and 1.0 %), pea protein isolate (0.58 %), and calcium lactate (0.25 %) into a traditional soup base resulted in a product with a higher protein content. A 240 g serving of this soup (dehydrated kale 0.8 %: sliced 0.5, and flour 0.3) provided approximately 10 % of the daily dietary fibre recommendation. The nutrient-dense soup was well received (66 %) by the Portuguese and was accepted (52 %) by Galician elders, offering a viable alternative to commercial nutritional supplements and common chewing hard foods rich in fibre and protein.

1. Introduction

Population ageing is a global phenomenon impacting nearly all developed nations, characterised by a simultaneous increase in the quantity and percentage of elderly individuals worldwide. In 2020, 20.6 % of the European Union (EU) population was aged 65 years or over, which is 3 % higher than the corresponding share from a decade earlier (Eurostat et al., 2020). The number of older adults in the EU is projected to peak at 129.8 million inhabitants by 2050, with their relative share of the total population estimated to reach 29.4 % by that time (Eurostat et al., 2020). In 2023, 23.9 % of the Portuguese population was aged 65 years and over, making Portugal the third EU country with the highest proportion of elderly people while in Spain that percentage touches the average of the EU with 20.6 % (Eurostat, 2024).

The nutritional requirements of older individuals demand urgent attention. Their needs can be categorised into two main aspects: those related to the sensory experience of eating (ensuring safe consumption and sensory satisfaction) and those connected to the nutritional requirements associated with the physiological changes that occur with ageing (Aguilera and Park, 2016). Among the older population, the combined effects of physiological ageing, illnesses, and medications often intersect to influence various aspects of oral physiology that significantly impact eating behaviours (Spence and Youssef, 2021; Sulmont-Rossé, 2020; Walker-Clarke et al., 2022). Changes in nutritional needs, along with an increased risk of disease and disability, make older adults vulnerable to disease-related malnutrition (Wendin et al., 2021). While dietary recommendation for older people is generally like that for young adults, the physiological changes associated with ageing introduce additional challenges (Taffet, 2024). Moreover, a study (Pidrafita-Páez et al., 2024) conducted in Portugal and Spain revealed

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https://doi.org/10.1016/j.ijgfs.2025.101216
Received 27 February 2025; Received in revised form 28 May 2025; Accepted 28 May 2025
Available online 28 May 2025

that 35.8 and 20.3 %, respectively, of the care home population sampled have a protein intake below European Food Safety Authority (EFSA) recommendations. The EFSA nutrient intake recommendations for an elder vary accordingly to age and gender, and a full description of Daily Reference Values can be retrieved from the interactive tables at the EFSA website (EFSA, 2024).

Adequate nutrition has the potential to prevent, postpone, or significantly reduce the incidence of chronic diseases affecting the elderly, thereby promoting healthier and more active ageing. Many elderly individuals are particularly susceptible to nutritional deficiencies due to inadequate intake of calories, protein, or other essential nutrients required for tissue maintenance or repair. Specific recommendations have been proposed for this age group (Rusu et al., 2020; Vandenberghe-Descamps et al., 2018). Factors contributing to insufficient nutrient intake among older individuals include age-related appetite decline, shifts in food preferences, such as reduced consumption of protein-rich foods, and challenges related to meal preparation (Beelen et al., 2017; Volpi et al., 2013). Moreover, elderly people often report diminished feelings of appetite and even anorexia, leading to meals becoming more of a discipline than a desire for many (Cox et al., 2020; de Souto Barreto et al., 2022; Straub, 2024).

Enriching foods with nutrients can be an effective strategy to address general nutritional deficiencies, as it is more likely to reach at-risk population segments compared to efforts aimed at altering individual food choices or relying on voluntary supplementation (Mitra and Sharma, 2020; Mohamed et al., 2020). The elderly tend to prefer familiar foods that are easy to consume and prepare without increasing portion sizes (Aguilera and Park, 2016). By enhancing familiar food items, particularly those tailored for individuals with limited dietary preferences or specific nutritional requirements, the elderly can increase their intake of protein or essential nutrients without altering their established eating habits or portion sizes. Soup, owing to its method of preparation and traditional ingredients, holds exceptional nutritional value. In addition to being easy to digest, it is rich in vitamins and minerals. In Portugal, soup remains a staple throughout a person's life cycle, with nutritionists generally recommending daily consumption for a balanced diet (Fonseca et al., 2024; Graça, 2020).

Brassica spp. are cabbages, and kale is a specific type of cabbage grown for their edible leaves that can be collected to the desired needs, without compromising the plant growth and regrows of other leaves. For this reason, they are very common in Portuguese vegetable gardens and remain a prevalent ingredient in Portuguese soups. It is cultivated and widely consumed in rural communities in Portugal and is a traditional component of the Southern European Atlantic Diet (Graça, 2020). Additionally, this vegetable has garnered significant attention due to its health-promoting properties. Regular consumption is associated with health benefits (Ashfaq et al., 2020), such as a reduced risk of chronic diseases, particularly cardiovascular diseases (Huang et al., 2016) and various types of cancer (Abdumannabovna and Zakirjonovna, 2022), and type II diabetes (Uuh-Narvaez and Segura-Campos, 2021). The health benefits of kale vegetables are partly attributed to their antioxidant capacity, which has been the focus of extensive research into their secondary metabolite content (Moreb et al., 2020; Neugart et al., 2018). Similarly, phenolic compounds are believed to be the primary phytochemical constituents responsible for the antioxidative activities in plants particularly in cabbages (Favela-González et al., 2020; Javanmardi et al., 2003).

The high moisture content in fresh cabbage promotes enzymatic, chemical, and microbial reactions, potentially affecting product longevity and quality (Ramjan and Ansari, 2018). Consequently, various food processing methods, such as cooking, drying, and blanching, are required to enhance product quality and extend shelf life (Gaudham et al., 2021; Xu et al., 2020). Drying is a critical stage in the production of kale flour, optimising the use of cabbage by-products. A meticulous outline of the entire processing sequence is essential to achieve the desired standards of both physical and nutritional quality. The resulting powder demonstrates notable water retention and swelling capabilities, making it an appealing choice for various culinary applications (Nilnakara et al., 2009). It is also important to consider the significant potential of kale production by-products, such as outer leaves and surplus production that is typically discarded, to create value-added products.

The objectives of our study were to evaluate the nutritional and antioxidant properties of a kale soup, as well as perform a sensory analysis and an acceptance assessment among institutionalised seniors in Northern Portugal and the region of Galicia in Spain.

2. Materials and methods

This study involving aged individuals in Portuguese and Spanish care homes was approved by the Ethics Committee of the Santa Casa da Misericórdia do Porto (reference Nutriage5set2023-ata 34) and by the Central Ethics and Research Committee of the Galicia Autonomous Community (Reference, 2023/542).

For the tasting panel, no human ethics committee or formal documentation process is available. However, the appropriate protocols for protecting the rights and privacy of all participants were utilised during the execution of the research. Participants received no coercion to participate and were provided with full disclosure of the study requirements and risks. Written consent of participants was obtained from the participants, no release of participant data was conducted without their knowledge, and the participants were informed they could withdraw from the study at any time.

2.1. Elderly nutritional status assessment

Information from a nutritional status assessment, included a care home institutionalised group of N = 186 elderly individuals aged over 65 years from the North of Portugal (n = 68) and from Galicia, Spain (n = 118), was obtained after the 'sister' study conducted by Pidrafita-Páez and colleagues (Pidrafita-Páez et al., 2024), using the same group of individuals we are using in the present study.

The sample size calculation was based on power analysis, considering an average BMI for the entire population of 29.1 and a standard deviation of 4.8 (Correia et al., 2020), and a found mean BMI for the study group of 28. The calculation of the sample size for a type I error with alpha = 0.05 and a type II error with a power of 80 %, gives a minimum sample size of N = 149.

The residential care homes selected for this research are situated within major urban centres. Those located in Galicia are operated under public administration, whereas the facilities in Portugal receive mixed funding, combining public and private sources. All establishments, except for one in Portugal, maintain their on-site kitchen. Residents across all homes are provided with breakfast, lunch, and evening meals; additionally, in the Portuguese facilities, morning and afternoon snacks, as well as a light supper, are also offered. Individuals were excluded from participation based on the following criteria: presence of advanced terminal organ failure, severe dysfunction across multiple organ systems, ongoing cancer treatment, a life expectancy estimated at less than one month, inability to complete the questionnaires, diagnosed psychiatric conditions involving disordered eating (such as anorexia or bulimia), acquired brain injuries, or a prior history of alcoholism.

2.2. Raw materials and reagents

Fresh kale, locally known as 'couve Galega' (*Brassica oleracea* L. var. *acephala* DC), cultivated in the Póvoa do Varzim area of Northern Portugal, was supplied by the company UPN, Lda. (Portugal). Pea protein isolate (88 %, Pisane® M9) was purchased from Cosucra (Belgium), and calcium lactate pentahydrate (13.2 %, CLPRL5H) from Galactic (Belgium). The remaining soup ingredients (carrots, potatoes, chickpeas, onion, garlic, olive oil, and salt) were obtained locally.

Active chlorine (Glow Professional) was supplied by InterHigiene (Guimarães, Portugal). Folin-Ciocalteu reagent, 3,5-dinitrosalicylic acid (DNS) reagent, hydrogen peroxide, Kjeldahl catalyst, potassium hydroxide, potassium sulphate, sodium hydroxide, and anhydrous sodium carbonate were purchased from Panreac (Barcelona, Spain). Acetone, hydrochloric acid (37 %), boric acid, methanol, petroleum ether, and sulphuric acid were supplied by Fisher Scientific (Leicestershire, UK). Glucose was purchased from Riedel-Haën™ (Seelze, Germany). Fatty acid methyl ester (FAME) reference standard mixture 37 (standard 47885-U) and 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) were obtained from Sigma Aldrich (St. Louis, Missouri, USA). 2,2-diphenyl-1-picrylhydrazyl (DPPH) was supplied by Sigma Aldrich (Steinheim, Germany), and Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was purchased from Sigma Aldrich (Buchs, Switzerland). Gallic acid was obtained from Acros Organics (Geel, Belgium). All reagents were of analytical grade.

2.3. Kale pretreatments and drying methods

Before drying, the following preliminary treatments were performed: removal of the central leaf vein of the kale; disinfection with 44 % active chlorine; washing with tap water; and slicing into pieces measuring 5 cm × 0.5 cm (length × width). For the drying process, two types of samples were considered: blanched and non-blanched. Blanching was carried out in hot water at 95 ± 2 °C for 2 min, using a weight ratio of kale leaves to water of 1:7. After blanching, the leaves were immediately cooled in cold water (4 °C). These pre-treatment conditions were established based on peroxidase inactivation through standard blanching procedures.

Blanched and non-blanched samples were spread in a single layer on a tray and subjected to convective air-drying in a laboratory-scale hot air oven (Fagor, Visual Plus, Spain) at 80 °C, with a constant air velocity of 0.5 m/s, until a final moisture content of less than 4 % was achieved. The dehydrated kale was then ground into small particles (6 s at 500 rpm) or powder (10 s at 10,200 rpm) using a food processor, and vacuum packed in bags (PA/PE 20/70; thickness 90 μm, O_2 permeability 50 cm^3/m^2 dbar, WVTR 2.8 g/m^2/d; Termofilm, Portugal) stored at room temperature in the dark until further analysis.

2.4. Proximate composition

Moisture, ash, protein, fat, and fibre contents were analysed using Association of Official Analytical Chemists (AOAC) procedures: moisture content by a gravimetric method at 103 °C (AOAC 930.04); ash content by incineration at 550 °C (AOAC 930.05); crude protein content (N x 6.25) by the Kjeldahl method (AOAC 978.04); crude fat by extraction with petroleum ether using a Soxhlet apparatus (AOAC 920.39); and crude fibre by the ceramic fibre filter method (AOAC 962.09). Total carbohydrates were determined by the 3.5-dinitrosalicylic acid reaction, measuring reducing sugars present in the sample after hydrolysis with hydrochloric acid and subsequent neutralisation. The energy value was estimated using the conversion factors: 4 kcal/g for protein; 4 kcal/g for carbohydrates; 9 kcal/g for lipids; and 2 kcal/g for fibre. The samples were analysed in triplicate.

2.5. Total phenolic content and antioxidant activity

2.5.1. Sample extraction

Sample extraction was based on Porter's methodology (Porter, 2012). Each sample was extracted with 15 mL of 80 % methanol and homogenised for 20 s. The extracts were centrifuged (FINSEN-R, BUNSEN, Spain) at 2000 g for 20 min, and the supernatant was filtered. Another 15 mL of 80 % methanol was added to the residue, centrifuged, and filtered again. This procedure was repeated twice. The final supernatant was adjusted to a final volume of 50 mL with 80 % methanol. Final extracts were stored at 3 °C for four weeks.

2.5.2. Total phenolic content

The total phenolic content (TPC) was estimated using the Folin-Ciocalteau colourimetric assay, according to the modified Gutfinger method. A volume of 0.5 mL of each extract stock solution was mixed with 0.5 mL of Folin–Ciocalteau (0.2 M). After 3 min, 0.5 mL of aqueous sodium carbonate solution (7 %) was added. The mixture was then diluted to a final volume of 10 mL with distilled water. Samples were kept in the dark at room temperature for 90 min, and the absorbance was measured at 725 nm (VWR, UV-3100 PC, USA). Gallic acid was used as the standard for preparing the calibration curve, which ranged from 5 to 160 mg/L. Results were expressed as mg of gallic acid equivalents per g of dry sample.

2.5.3. Antioxidant activity

The antioxidant activity of each sample was determined by the DPPH radical scavenging assay based on Brand-Williams et al. (1995). A volume of 0.3 mL of extract stock solution and diluted extracts (in methanol) was mixed with 2,7 mL of DPPH (60 μM) in methanol and let to stand at room temperature, in the dark, for 30 min before measuring the solution at 515 nm using the spectrophotometer (Varian Cary 50, California). The control was a DPPH solution containing absolute methanol instead of the sample.

The antioxidant activity of each sample was also determined by the DPPH radical scavenging assay. A volume of 25 μL of diluted extract stock solution (in methanol) was placed in a clear 96-well microplate with 200 μL of ABTS in methanol and allowed to stand in the dark for 6 min before measuring the absorbance of the solution at 735 nm on the Varioskan LUX Multimode Microplate Reader (Thermo Scientific, Vantaa, Finland). Methanol was used as the blank to calibrate the spectrophotometer. The control was an ABTS solution containing absolute methanol instead of the sample.

2.6. Formulation and preparation of an enriched soup

A traditional recipe was used for the soup base formulation. This base formulation underwent nutritional composition evaluation using the Food Composition calculation tool – Portfir INSA, which provides food information to consumers according to the EU regulation 1169/2011.

After defining the soup base formulation (Control, Table 1), different amounts of calcium lactate (ranging from 0.25 to 1.30 %) and pea protein isolate (ranging from 0.25 to 1.80 %) were added to the base formulation for enrichment, and the sensory properties of the various formulations were evaluated. Three proportions of dehydrated kale (0.5 %, 0.8 %, and 1.0 %) were tested. The ingredients were then added to water in a weight ratio of 30:70. The soup matrix formulations are shown in Table 1.

The inclusion of pea protein isolates and calcium lactate in the soup formulations aims to provide additional sources of protein and calcium.

Table 1
Soup matrix formulations enriched with pea isolate (0.58 %), calcium lactate (0.25 %), and dehydrated kale (0.5 %, 0.8 % and 1.0 %).

	Soup formulations (g/100 g)			
Ingredients	Control	0.5 %	0.8 %	1.0 %
Water	69.10	67.70	67.50	67.00
Carrots	12.50	12.50	12.50	12.50
Potatoes	8.30	8.30	8.30	8.30
Chickpeas (canned)	6.67	6.67	6.67	6.67
Onion	2.50	2.50	2.50	2.50
Pea isolate (88 %)	–	0.58	0.58	0.58
Dehydrated kale small particles	–	0.25	0.50	0.50
Garlic	0.42	0.42	0.42	0.42
Olive oil	0.33	0.33	0.33	0.33
Dehydrated kale powder	–	0.25	0.30	0.50
Calcium lactate (13,2 %)	–	0.25	0.25	0.25
Salt	0.17	0.17	0.17	0.17
Total	100	100	100	100

Pea protein isolates have the additional advantage of acting as an emulsifier and thickener. The population being studied was identified as consuming below the desirable level in terms of protein, and additionally, calcium is an important mineral for the elderly.

Dehydrated kale was added in the form of powder to mix thoroughly in the food matrix and in the form of small particles, visible in the soup. The final soup was cooled at room temperature, further frozen in individual packages (100 mL) and stored at −18 °C before analytical measurements. The sensory analysis and the consumers' acceptability tests were conducted after cooking.

The recipe is simple, vegetables are chopped into small pieces and boiled in water with all the other ingredients, saving the olive oil and the kale. When cooked, mill with an immersion blender while adding the olive oil to create an emulsified cream. Add kale and let it cook for another 10 min. Remove from the heat and let it rest for 15 min before serving.

2.7. Sensory analysis

A trained panel of six members in a fully equipped sensory analysis laboratory conducted sensory analysis. The panel was a convenience sample selected among adult individuals, three from each gender and with ages ranging between 34 and 63 years old. This panel underwent prior training, which focused on developing the panellists' ability to objectively describe the sensory attributes of the product using standardised descriptive terminology. The panellists' perceptions were calibrated using reference samples in a practice session of 2 h to ensure consistent evaluation. An assessment sheet was developed in advance by the panel. Panellists reached a consensus on the meanings of the attributes and the anchors of the evaluation form.

During their evaluation, the panellists were asked to score their preferences according to the four attributes related to the relevant senses: visual appearance, smell, texture, flavour, to which we add saltiness and fattiness, perceived as important attributes to control. For this purpose, they used a Likert scale ranging from 1 (extremely unpleasant) to 5 (extremely pleasant) (Negrea et al., 2021). The highest-scoring formulation of kale soup was selected for subsequent consumer acceptability testing.

2.8. Fatty acid composition of the selected kale soup formulation

The fatty acid methyl esters (FAME) profile was obtained following the transesterification of the lipid fraction attained by Soxhlet extraction, followed by gas-liquid chromatography with flame ionisation detection (Srigley and Mossoba, 2017). This was performed using a YOUNG IN Chromass 6500 GC System instrument equipped with a split injector set at 250 °C, with a split ratio of 1:50, a flame ionisation detector (FID) set at 260 °C, and a Zebron-Fame column (30 m × 0.25 mm ID × 0.20 μm df, Phenomenex, Lisbon, Portugal).

The following oven temperature programme was used: an initial temperature of 100 °C, held for 2 min, increased at 10 °C/min to 140 °C, followed by a ramp of 3 °C/min to 190 °C, and then a ramp of 30 °C/min to 260 °C. The carrier gas (hydrogen) flow rate was set at 1.2 mL/min, measured at 250 °C. Fatty acids were identified and quantified by comparing the relative retention times of FAME peaks from samples with those of standards (standard mixture 47885-U, Sigma, St. Louis, USA). Results were recorded and processed using the Clarity DataApex 4.0 Software (Prague, Czechia) and expressed as a relative percentage of each fatty acid.

2.9. Consumer acceptability

A consumer acceptability test was conducted with 83 elderly residents from care homes in Portugal and Galicia. Table 2 provides the demographic distribution. The participants were asked to evaluate the soup prototype enriched with 0.8 % dehydrated kale.

Table 2
The ages of the care home residents in Portugal and Galicia (Spain) were selected for the acceptability test.

Characteristics	Category	Galicia (*n*)	Portugal (*n*)
Gender	Female	30	23
	Male	18	12
	Total	48	35
Age	50–60	–	3
	60–70	1	1
	71–80	12	3
	81–90	28	20
	91–95	5	8
	>95	2	–

Participants were informed about the sensory analysis procedures and asked to evaluate their preferences regarding the chosen soup formulation on an enquiry form, using nine preference category scores ranging from extremely unpleasant to extremely pleasant. This scale was chosen as acceptance as an affective component (Negrea et al., 2021). Additionally, respondents were asked if they were regular soup consumers and about their willingness to purchase the product. Participants could also add comments on the enquiry form. The test was conducted using the final soup prototype.

2.10. Statistical analysis

Data were analysed using IBM Corp.® SPSS® Statistics, version: 29.0.2.0 (20), Armonk, NY, USA. Descriptive statistics were calculated, and differences between variables were assessed using an ANOVA test and the least significant difference (LSD) test as a post hoc. The prerequisites of the ANOVA, namely normal distribution of the residuals and homogeneity of variances, were checked respectively via Kolmogorov-Smirnof test and Levene's test. The level of significance was set at 0.05 for all statistical tests. The ANOVA tests were used: to test the effects of kale dehydration on its proximate composition, phenolic, and antioxidant contents, and to test the effects of the addition of pea protein isolate and calcium lactate on the proximate composition of the soup.

The sensory analysis results, for the different kale percentages (0.5, 0.8, and 1 %), and each of the sensory factors (visual aspect, texture, flavour, smell, saltiness, and fatness), were tested via Kruskall-Wallis with pairwise comparisons obtained after the Bonferroni correction. The test was applied after transforming the nominal variable from very bad to very good into an ordinal variable from one to five. As the panel of evaluators contained only six members, we used a Monte Carlo simulation to extend the sample to 1000 members, as previously used by Ferreira et al. (2021) and Frascolla et al. (2022).

In the acceptability test, the comparison between Portugal and Spain was conducted by transforming the nominal scale from extremely unpleasant to extremely pleasant in an ordinal scale from one to nine and applying a Mann-Whitney *U* test.

3. Results

3.1. Results of the elderly nutritional status assessment

The nutritional status of the elders institutionalised in care homes in Northern Portugal and Galicia, Spain and conducted by Pidrafita-Páez and colleagues (Pidrafita-Páez et al., 2024) showed that 58.6 % present normal nutritional status, 37.6 % are at risk of becoming undernourished and 3.8 % are undernourished. Among the residents, 20.3 % in Spain and 35.8 % in Portugal had protein intakes below the EFSA recommendations. Additionally, lipid intake fell below the recommended range for 46.2 % of Portuguese residents and 44.9 % of Spanish residents. Carbohydrate intake met the recommended range for 45.5 % of Portuguese residents, compared to 66.9 % of Spanish residents. Salt consumption exceeded the recommended levels in 67.0 % of Spanish residents and 32.3 % of Portuguese residents.

3.2. Effect of blanching and drying on proximate composition of kale samples

The proximate composition of both, fresh and dehydrated kale (expressed on dry matter), is shown in Table 3.

The moisture content of fresh kale was 82.84 %. Drying led to a 98 % and 97 % reduction in moisture content of blanched and non-blanched samples, respectively. An increase in carbohydrates was observed after the drying process. The effect of blanching was not significant in protein content. In the case of carbohydrates, the content was higher in the non-blanched sample. We also observed significant effects, with a decrease in ash and fibre after drying, and blanching). Fat was lower in non-blanched samples.

3.3. Effect of blanching and drying on total phenolics content and antioxidant activity

The effect of blanching and drying on kale's total phenolic content and antioxidant activity values are presented in Table 4. Losses of 2.9 % and 9.6 % in total phenolic content occurred in blanched and non-blanched dried samples, respectively.

Fresh kale samples presented antioxidant activity values of 19.14 ± 0.03 and 120.45 4.41 μMtrolox/g sample dry matter for the DPPH and ABTS assays, respectively. After drying, losses of approximately 52 % were observed in both non-blanched and blanched samples by DPPH assay. With the ABTS assay, even greater differences of 36 % and 19 % were found in the blanched and non-blanched samples, respectively.

3.4. Proximate composition of enriched soup prototypes

Given the better performance of non-blanched samples, regarding the total phenolic content and the antioxidant activity, no pre-treatment was considered in the development of the soup prototypes.

The final proximate composition of the soup prototype is shown in Table 5.

The moisture content of the base soup formulation (without kale added) was 97.57 %. The moisture content decreases as the dehydrated kale concentration (0.5, 0.8, 1 %) increases, 92.21 %, 86.89 %, and 88.05 %, respectively, which was expected given the percentage of water used in the formulations which were dependent on the amount of dehydrated kale added. The addition of dehydrated kale significantly impacts the nutritional composition. The highest values of protein and fibre were found in the 0.8 and 1 % soup formulations, with a 4-fold and a 1.5-fold higher than the control formulation for protein and fibre, respectively. The same results were obtained for ash content, where values were 2-fold (0.8 %) and 1.8-fold (1 %) higher than in the control samples.

3.5. Sensory analysis

The results of the sensory analyses are shown in Fig. 1. The panel evaluated the different formulations of soup enriched with dehydrated kale allowing them to determine their preference.

The soup enriched with 0.5 % and 0.8 % dehydrated kale obtained higher scores in appearance, texture and flavour attributes. In contrast, the soup enriched with 1.0 % had the least favourable appreciation. Fig. 2 represents the acceptability scores for visual appearance, texture and flavour.

The preference scores for visual appearance, texture and flavour were higher in the 0.5 % and 0.8 % kale concentrations and no significant differences were observed in scores regarding saltiness and fattiness. Although the 0.5 % and 0.8 % samples had the same scores in terms of preference, the 0.8 % formulation was selected to carry out the acceptability test for the final phase, due to its higher nutritional content.

The results of the statistical analysis are presented in Table 6.

3.6. Final soup prototype formulation, proximate information and antioxidant potential

The maximum acceptable amounts, i.e., those not negatively affecting the sensory properties of the soup base (score below 3 in a 5 point Likert scale), were 0.25 g of calcium lactate and 0.58 g of pea isolate, respectively, per 100 g of soup, as previously found by Vieito (2021). Although no calcium quantification was performed in this study, it is relevant to note that, based on the Food Composition calculation tool, Portfir INSA, this base formulation contains approximately 12 mg of calcium per 100 g of soup.

The final soup prototype (0.8 % kale) formulation is shown in Table 7. Table 8 provides the proximate analysis. According to the EU Dietary Reference Values (DRV), a serving (240 g) of this soup provides 6.0 % and 10.0 % of elderly requirements of protein and fibre requirements, respectively.

Despite being mainly originated in the olive oil, the results regarding the fatty acids composition in the soup prototype formulation are given in Table 9.

Monounsaturated fatty acids (MUFA) were the major group, followed by polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA). MUFA corresponds to 51.2 ± 0.4 % of the fatty acids present in the soup prototype formulation, mainly due to the high content of oleic acid (49.8 ± 0.3 %), as expected, due to the presence of olive oil. PUFA is the second group of fatty acids (27.4 ± 0.3 %), largely due to the high content of linoleic acid (24.8 ± 0.2 %).

Regarding antioxidant activity, measured by the ABTS and DPPH assays (Fig. 3), the soup enriched with dehydrated kale presented higher activity than the control soup without kale.

3.7. Consumer acceptability test

The results from the acceptability test are shown in Fig. 4.

As can be observed, the soup was positively appreciated by Portuguese (66 %) and Galician (52 %) participants. The Portuguese participants evaluated the soup as extremely pleasant (2.9 %), very pleasant (17.1 %), pleasant (37.1 %) and slightly pleasant (5.7 %). Concerning Galician participants, 4.2 % evaluated the soup as extremely pleasant, 8.3 % as very pleasant, 27.1 % as pleasant and 10.4 % as slightly pleasant. More than half (57 %) said that they would buy this product. In Galicia, only 29 % of the elders stated that they usually consume soup,

Table 3
Proximate composition of fresh and dehydrated kale (on a dry matter basis).

Sample	Ash (%)	Protein (%)	Fiber (%)	Carbohydrates (%)	Fat (%)
P-values	<0.01	>0.05	<0.001	<0.05	<0.05
Fresh	13.25 ± 0.27[c]	26.50 ± 0.60	11.50 ± 0.10[b]	40.14 ± 1.06[a]	9.20 ± 0.73[b]
AD-B	10.32 ± 0.35[b]	27.78 ± 0.99	10.70 ± 0.19[a]	42.29 ± 0.29[b]	9.09 ± 0.47[b]
AD-NB	9.83 ± 0.28[a]	27.74 ± 0.88	10.76 ± 0.25[a]	44.23 ± 0.38[c]	7.98 ± 0.03[a]

Notes: Different letters in superscript in the same column are indicative of significant differences ($p < 0.05$) after the least significant differences post-hoc test. Type of product: AD-B: Air-drying/blanched; AD-NB: Air-drying/non-blanched.

Table 4
Effect on total phenolic content and antioxidant activity (ABTS and DPPH assays) of fresh and dehydrated kale (on a dry matter basis).

Samples	Total Phenolic Content (mg GAE/g sample)	Antioxidant Activity (μM trolox/g sample)	
		DPPH	ABTS
P-values	<0.05	<0.05	<0.05
Fresh	5.82 ± 0.03^{c}	19.14 ± 0.03^{c}	120.45 ± 4.40^{c}
AD-B	5.26 ± 0.06^{a}	10.78 ± 0.02^{b}	84.69 ± 4.74^{a}
AD-NB	5.65 ± 0.04^{b}	10.69 ± 0.05^{a}	104.53 ± 2.69^{b}

Notes: Different letters in superscript in the same column are indicative of significant differences ($p < 0.05$) after the least significant differences post-hoc test. AD-B – Air-dried/blanched; AD-NB – Air-dried/non-blanched; DPPH – (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay; ABTS – (2,2′-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid)) radical scavenging assay.

Table 5
Effect on proximate composition of soup formulations enriched with pea isolate (0.58 %), calcium lactate (0.25 %) and dehydrated kale (0.5 %, 0.8 % and 1.0 %).

Nutrients (%)	P-value	Control	0.5 %	0.8 %	1 %
Moisture	<0.001	97.57 ± 0.06^{d}	92.21 ± 0.88^{c}	86.89 ± 0.22^{a}	88.05 ± 0.34^{b}
Protein	<0.001	0.23 ± 0.00^{a}	1.05 ± 0.05^{b}	2.36 ± 0.22^{c}	2.44 ± 0.19^{d}
Fat	<0.01	0.52 ± 0.01^{a}	0.78 ± 0.01^{b}	0.80 ± 0.03^{c}	0.81 ± 0.04^{d}
Carbohydrates	<0.05	1.51 ± 0.03^{a}	2.91 ± 0.25^{b}	4.17 ± 0.42^{c}	5.44 ± 0.57^{d}
Fibre	<0.01	0.24 ± 0.09^{a}	0.43 ± 0.04^{b}	0.99 ± 0.21^{d}	0.92 ± 0.08^{c}
Ash	<0.01	0.21 ± 0.03^{a}	0.73 ± 0.04^{c}	1.26 ± 0.28^{d}	0.98 ± 0.05^{b}
Energy (Kcal/100g)	<0.05	11.64 ± 0.01^{a}	24.21 ± 1.14^{b}	36.76 ± 0.26^{c}	40.76 ± 2.78^{d}

Note: Different letters in superscript in the same row are indicative of significant differences ($p < 0.05$) after the least significant differences post-hoc test.

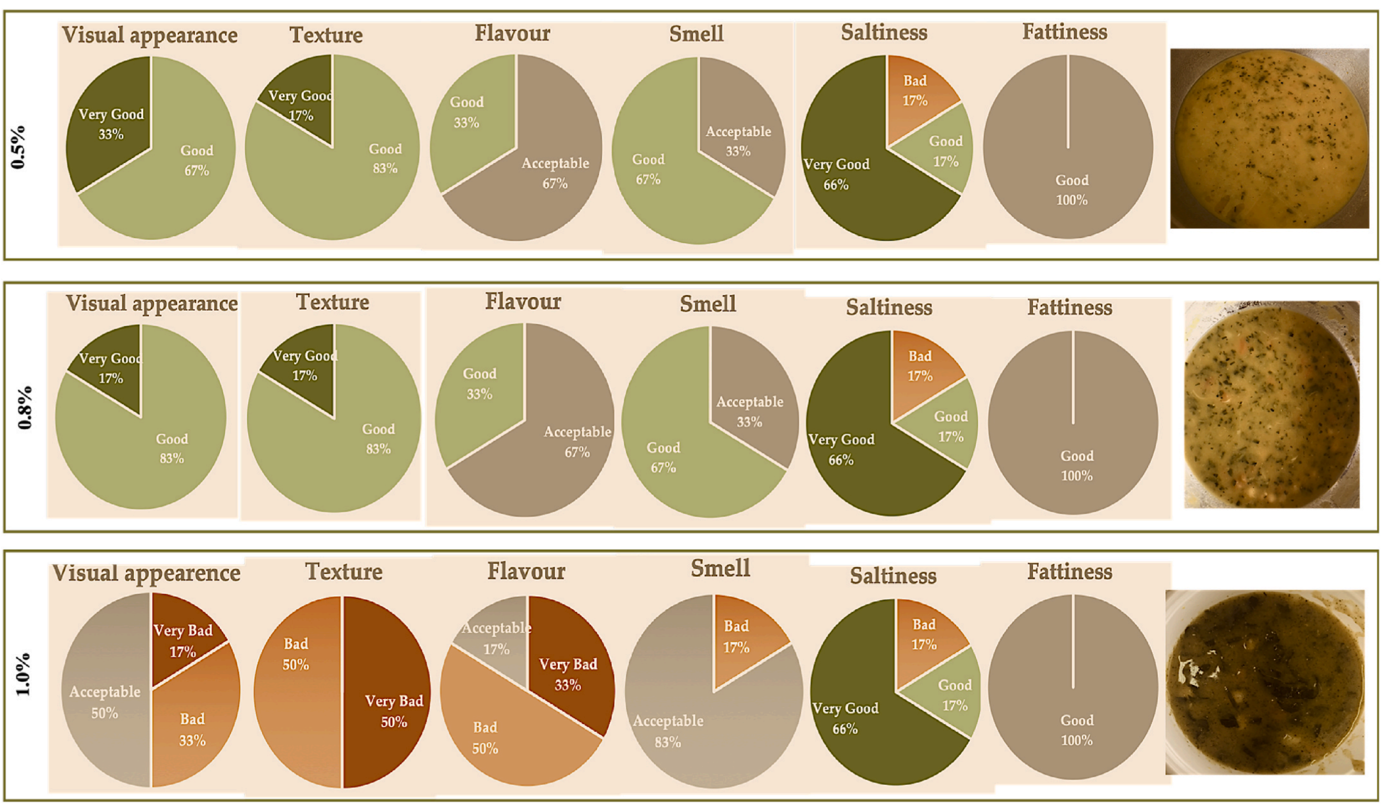

Fig. 1. Sensory analysis of the enriched soup formulations with pea isolate (0.58 %), calcium lactate (0.25 %), and dehydrated kale (0.5 %, 0.8 %, and 1.0 %). The percentages relate to the number of panel members in each rating, in each of the attributes. Photos of the final product are also shown (Source: the authors).

and 33 % showed interest in buying this product. The appreciation differences between Portuguese (Median = 7, pleasant)) and Galician participants (Median = 5.5, indifferent to slightly pleasant) were not statistically significant ($U = 684$, $p = 0.142$).

4. Discussion

4.1. The elderly nutritional status assessment

The main reason to institutionalise the elderly is their physical and/or mental vulnerability (Bosch-Farré et al., 2020). The screens for malnutrition or risk thereof, highlighted the importance of maintaining adequate nutrient intake in older adults. Addressing malnutrition often

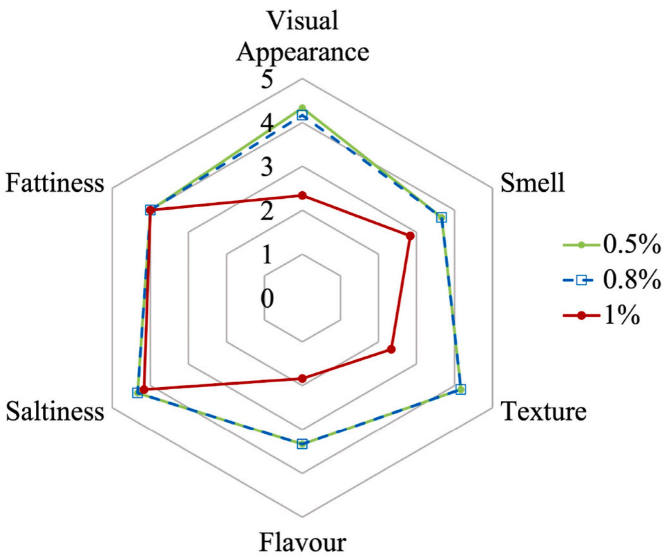

Fig. 2. Sensorial scores of the different enriched soup formulations with pea isolate (0.58 %), calcium lactate (0.25 %) and dehydrated kale (0.5 %, 0.8 % and 1.0 %).

involves enriching foods familiar to the elderly, which can support adequate protein and energy intake without altering eating habits or portion sizes.

Research has shown that incorporating enriched foods, such as protein-fortified soups or nutrient-dense drinks, effectively helps institutionalised elders meet nutritional recommendations (Norton et al., 2022). Enrichment strategies are particularly effective because they increase nutrient density without requiring significant dietary adjustments, thus promoting better overall compliance. Ensuring that enriched items are familiar and acceptable enhances the likelihood that elderly individuals will consume these foods willingly, making enrichment a practical strategy for preventing malnutrition and its associated risks, such as frailty and functional decline, in this vulnerable population. Previous nutritional study in this sample [9] showed that 38.4 % of the elderly are at risk of becoming undernourished, and 4.1 % are malnourished. These results are slightly above the 25 % reported by other authors (Crichton et al., 2019; Leij-Halfwerk et al., 2019) for older European adults.

4.2. *Effect of drying and blanching on proximate composition of kale samples*

The lower TPC found in blanched samples is likely due to phenolics leaching into the water. Leafy vegetables are highly sensitive to the effects of blanching, mainly due to their larger exposed surface area per unit of mass. Chemical oxidation by polyphenol oxidase, which catalyses the oxidation of flavonoids, may justify the slight decrease in TPC in non-blanched samples. These results align with findings from other studies on the effects of drying and related pre-treatments (Dibanda et al., 2020; Korus, 2011; Yamaguchi et al., 2003).

Drying led to a slight decrease in TPC across all kale samples.

Table 7
Final soup prototype formulation (0.8 %) and composition per serving.

Ingredients	%	g per serving (240g)
Water	67.50	162
Carrot	12.50	30
Potato	8.30	19.9
Chickpeas (cooked)	6.67	16
Onion	2.50	6
Pea Isolate (88 %)	0.58	1.4
Dehydrated kale sliced	0.50	1.2
Garlic	0.42	1
Olive oil	0.33	0.8
Dehydrated kale flour	0.30	0.7
Calcium lactate (13.2 %)	0.25	0.6
Salt	0.17	0.4
Total	100	240

Table 8
Proximate analysis of the final soup prototype formulation (0.8 %) (mean ± SD).

Component	Content (g)
Protein	2.36 ± 0.22
Fat	0.80 ± 0.03
Carbohydrates	4.17 ± 0.42
of which sugars	0.70 ± 0.019
Fibre	0.99 ± 0.21
Ash	1.26 ± 0.28
Salt	0.41 ± 0.01
Energy (Kcal/100 g)	36.76 ± 0.26

Table 9
Fatty acid composition of the prototype soup formulation (mean ± SD, *n=3*). These are mainly sourced by the olive oil in the soup.

Fatty acids		Relative percentage (%)
C14:0	Myristic	0.160 ± 0.009
C16:0	Palmitic	13.7 ± 0.1
C16:1	Palmitoleic	0.96 ± 0.01
C17:0	Margaric	0.141 ± 0.003
C18:0	Stearic	2.25 ± 0.04
C18:1n9c	Oleic	49.8 ± 0.3
C18:2n6c	Linoleic	24.8 ± 0.2
C18:3n3	Linolenic	2.6 ± 0.1
C20:0	Arachidic	0.82 ± 0.02
C20:1	Paullinic	0.47 ± 0.04
C22:0	Behenic	0.49 ± 0.01
C23:0	Tricosylic	0.123 ± 0.003
C24:0	Cerotic	3.59 ± 0.02
SFA	Cn:0	21.3 ± 0.1
MUFA	Cn:1	51.2 ± 0.4
PUFA	Cn:>1	27.4 ± 0.3

Table 6
Medians of the sensory evaluation of the different factors for the different contents of dehydrated kale (0.5, 0.8 and 1 %).

	Visual	Smell	Texture	Flavour	Saltiness	Fatiness
Kruskal-Wallis H	13.236	13.857	10.436	7.511	0	0
df	2	2	2	2	2	2
Assymptotic p-value	<0.01	<0.01	<0.01	<0.05	>0.05	>0.05
Monte Carlo p-value	<0.01	<0.01	<0.01	<0.05	>0.05	>0.05
Median 0.5 %	4^{b}	4^{b}	3^{b}	4^{b}	5	4
Median 0.8 %	4^{b}	4^{b}	3^{b}	4^{b}	5	4
Median 1 %	2.5^{a}	1.5^{a}	2^{a}	3^{a}	5	4

Note: Tested with Kruskall-Wallis tests, applied to each of the sensory factors analysed. The pairwise comparisons were performed after the Bonferroni correction. The sample was extended with a Monte Carlo simulation. Different letters in superscript in the same column indicate significant differences between medians ($p < 0.05$).

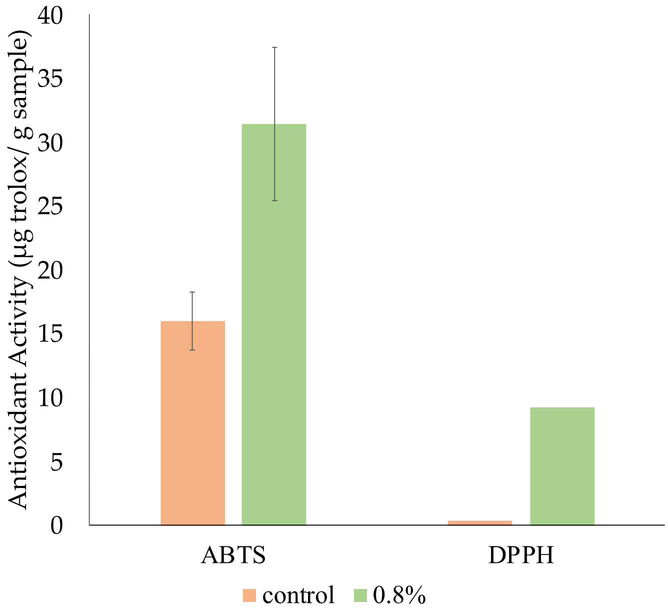

Fig. 3. Antioxidant Activity (µg trolox/g sample) of the soup prototype formulation (0.8 %) (DPPH and ABTS assays).

Phenolics may be affected by drying temperatures, likely due to changes in their chemical structure, resulting in compounds that cannot be extracted and quantified by the methodology used, or due to binding with other compounds, such as proteins (Antony and Farid, 2022; Belwal et al., 2022). In general, the use of elevated temperatures in air drying methods hurts phenolic content. However, in some cases, subjecting materials to high temperatures for short periods during air drying has resulted in higher levels of total and free polyphenols. This phenomenon may be due to the enhanced release of compounds from the matrix, making them more accessible for extraction and reducing drying times that lower thermal stress (Hameed et al., 2023; Korus, 2022). In this study, however, the chosen time-temperature combination (air drying at 80 °C for 2 h) did not drastically impact total phenolic content, with only a slight decrease observed.

The ABTS cationic radical is soluble in both organic and aqueous media, while the DPPH radical dissolves only in organic media (Bibi Sadeer et al., 2020). As expected and consistent with the behaviour of phenolic content, blanching had a negative effect on AA values. Although drying reduced the antioxidant activity of vegetables, results indicated that dehydrated kale without blanching pre-treatment remains a good source of bioactive compounds.

4.3. The proximate composition of enriched soup prototypes

The results were compared with the EU DRV for elderly individuals over 70 years of age (Agostoni et al., 2010; EFSA Panel on Dietetic ProductsN. and A., 2012). In terms of DRV for protein (96.7 g/day) and fibre (25.4 g/day), 100 g of each soup (control, 0.5 %, 0.8 %, and 1 %) provided 0.24 g, 1.09 g, 2.44 g, and 2.52 g of protein and 0.96 g, 2.60 g, 3.96 g, and 3.68 g of fibre, respectively, based on daily requirements.

The enhanced protein content in the developed soup formulations can be attributed to the incorporation of both pea isolate and dehydrated kale. The latter addition substantially increased protein levels. Epidemiological studies and clinical trials emphasise the importance of increased protein intake for elderly adults, as adequate protein consumption has been linked to numerous health benefits in this population (Wirth et al., 2020). Specifically, higher protein intake is associated with improved bone mineral density, reduced bone loss, and enhanced muscle mass and strength, which are crucial for reducing age-related frailty and supporting overall physical functionality (Aggarwal and Bains, 2022; Fagundes Belchior et al., 2020; Webster et al., 2023).

These findings suggest that the soups, especially those with higher protein and fibre concentrations, could serve as valuable dietary supplements to support the health and nutritional needs of older adults. By providing essential nutrients in easily consumable portions, these soups can contribute meaningfully to daily dietary intake and promote better health outcomes in the elderly.

4.4. The sensory analysis

The sensory analysis results align with findings from other studies (e.g. (Rathore, 2021), where moderate enrichment with greens or vegetables enhances sensory appeal without overpowering the product. Soups with 0.5 % and 0.8 % dehydrated kale received higher ratings in appearance, texture, and flavour, likely due to an optimal balance that highlighted the benefits of kale without introducing overly strong flavours or textures. Similar studies report that moderate vegetable enrichment enhances flavour complexity and visual appeal (Hoppu et al., 2021; Islam et al., 2023) while avoiding any potential bitterness or rough texture, as seen in formulations with higher concentrations. In contrast, the control soup may have lacked sensory depth, and the soup with 1.0 % kale likely had a more pronounced bitterness, as flavour was penalised as bad or very bad by 50 % of the panellists. The control soup may also be penalised by the panellists (50 rating very bad and 50 % bad) due to its thicker texture, which is a common challenge noted in

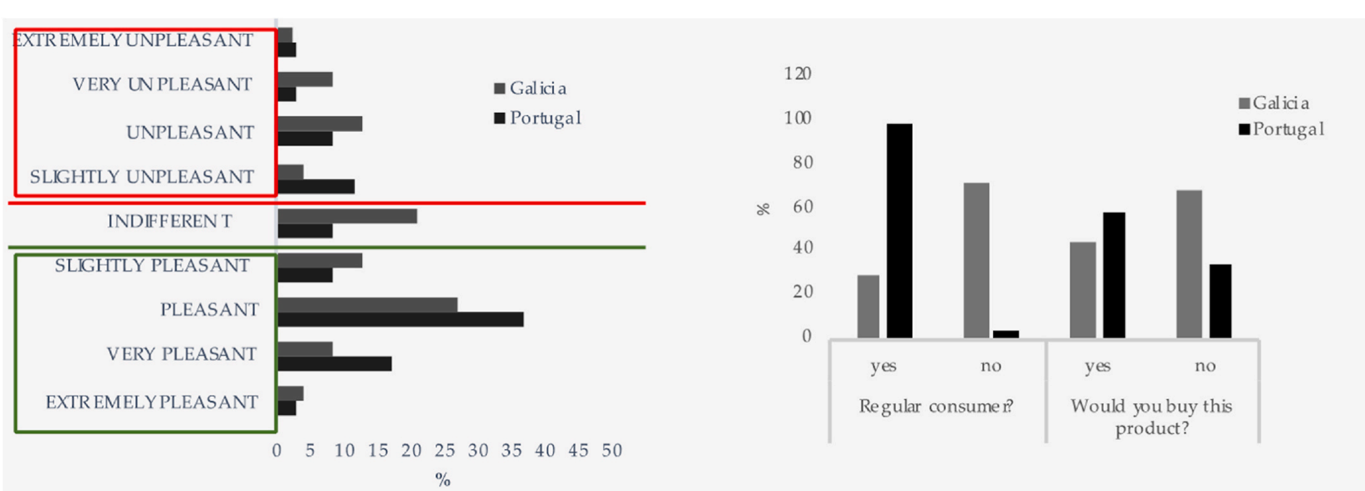

Fig. 4. Results of consumer acceptability of the soup enriched with pea isolate (0.58 %), calcium lactate (0.25 %) and dehydrated kale (0.8 %).

high-vegetable formulations that can detract from consumer acceptance (Hoppu et al., 2021). This suggests that moderate kale enrichment, as used here, is effective for improving sensory qualities without compromising taste.

4.5. Final soup prototype formulation, proximate information and antioxidant potential

The high antioxidant activity observed in the final soup prototype is largely due to the inclusion of kale, rich in antioxidant compounds such as polyphenols, resulting in counteracting oxidative stress (Michalak-Tomczyk et al., 2024; Ortega-Hernández et al., 2021). The soup prototype, developed with enriched protein and fibre content, offers nutritional benefits that support the dietary needs of older adults. The lipidic content of the prototype has an excellent quality, with MUFA and PUFA (51.2 %, and 27.4 %, respectively) deriving mainly from the olive oil added. Given its nutrient density, this soup could serve as an effective alternative or complement to traditional nutritional supplements, providing essential nutrients in a familiar form. Nevertheless, the quantities of lipids in a soup serving of 240 g (1.9 g) are well below the average daily consumption of Portuguese and Spanish elders of respectively 40 and 45 g reported by Pidrafita-Páez et al. (2024). In terms of the balance between the different types of fatty acids, this soup prototype has a composition favouring MUFA and PUFA in comparison to the recommendations suggested by Schwingshackla et al. (Schwingshackl et al., 2021), of respectively 10–25 and 6–11 % of the daily energetic content recommended. As such, this soup prototype, has the potential to balance the composition of the lipidic intake of the elders.

For elderly individuals, meeting protein and fibre requirements is often challenging due to dietary restrictions or lack of appetite (Nishimura et al., 2023). Particularly in Portugal and Spain, deficiencies in protein and lipids intake have been identified in care homes (Pidrafita-Páez et al., 2024). The formulation developed in this study allows the elderly to boost intake without altering portion sizes or eating habits. By delivering key nutrients in an easy-to-consume format, the prototype aligns well with the dietary guidelines for ageing populations, potentially improving health outcomes through enhanced antioxidant intake and balanced macronutrients.

4.6. The consumer acceptability test

Both the Portuguese and Galician participants in the acceptability test provided comments on the prototype soup's sweetness and lack of salt, with many finding it "very sweet" and "unsalted." This feedback is significant, as salt reduction was a goal in all formulations but may have negatively impacted consumer perception, especially given the crucial role of flavour in elderly dietary acceptance. Salt intake has been identified as being above recommendations for 67 % and 32.2 % of care home residents, respectively in Spain and Portugal (Pidrafita-Páez et al., 2024).

In Portugal, where 97 % of elderly respondents confirmed they regularly consume soup, this product is more likely to be successfully integrated into care home meal plans. Soup is traditionally served daily at both lunch and dinner, making it a familiar and well-accepted option. Introducing a fortified soup in Portuguese care homes would likely support elderly nutrition with minimal resistance, leveraging established dietary habits. Nevertheless, no differences were found in the acceptability between Portuguese and Galician elders.

4.7. Study limitations

This present study presents some limitations. Firstly, the sample size for the sensory evaluation and acceptability testing was relatively small and limited to institutionalised elderly individuals in specific regions of Galicia and Northern Portugal, which may affect the generalisability of the findings. Cultural food preferences and regional dietary habits could influence the results, potentially limiting wider applicability. Secondly, while nutritional composition and antioxidant properties were thoroughly assessed, long-term health outcomes and the actual impact on nutritional status were not evaluated. The study also did not account for individual variations in dietary requirements, medical conditions, or medication interactions that may affect nutrient absorption.

5. Conclusion

This study highlights the potential benefits of developing fortified soup prototypes to support the nutritional needs of elderly populations, particularly those at risk of malnutrition. The nutritional assessment revealed that a significant portion of elderly individuals are at risk of undernutrition, underscoring the need for targeted dietary interventions. By enriching soups with kale, the prototypes provided increased protein, fibre, and antioxidant content, addressing essential dietary needs without requiring changes in eating habits or portion sizes. The sensory analysis demonstrated that moderate kale enrichment (0.5 % and 0.8 %) positively impacted taste and texture.

The results of this study have also emphasised the importance of cultural acceptance in product development. The soup is likely to integrate well into Portuguese and Galician care homes. Future interventions should consider cultural nuances to enhance adoption and compliance. Overall, this fortified soup offers a practical, culturally adaptable option to improve elderly nutrition and reduce malnutrition risks, ultimately supporting healthier ageing.

Implications for gastronomy

Kale (*Brassica oleracea* L. var. *acephala* DC), known in the Iberian peninsula as "couve galega", is present in many vegetable gardens. This cabbage has the advantage of continuous plurilingual growth, allowing the collection of leaves inserted in a central stem without compromising posterior plant survival. This cabbage, however, is not frequently found in food stores as it is not commonly produced in commercial farming. Nevertheless, it is widely used in the Portuguese traditional soup "caldo verde". Portugal has an ageing population, and the nutritional needs of the elderly require close attention. Using kale, a strategy to incorporate healthy, high-fibre, protein-rich ingredients into traditional diets can be followed, enhancing health benefits for the elderly.

CRediT authorship contribution statement

Cristina Duarte: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Rita Pinheiro:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Fernando Mata:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Elisabete Pinto:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Ângela Fernandes:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Manuela Vaz-Velho:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Funding sources

This research was funded by the project "NUTRIAGE – Soluciones avanzadas para un envejecimiento saludable através de la nutricíon en el marco de la Eurorregíon Galícia/Norte de Portugal." 0359_NUTRIAGE_1_E. INTERREG V A España Portugal (POCTEP).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Centre for Research and Development in Agrifood Systems and Sustainability is supported by Fundação para a Ciência e a Tecnologia FCT, Portugal) (UIDB/05937/2020 DOI:10.54499/UIDB/05937/2020 and UIDP/05937/2020 DOI:10.54499/UIDP/05937/2020). Centro de Investigação em Montanha is supported by FCT (UIDB/00690/2020 and UIDP/00690/2020) and SusTEC (LA/P/0007/2020). In addition, financial support is obtained from FCT for the contracts of Â.F. and F.M.

Data availability

The data that has been used is confidential.

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