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Effect of spirulina (*Arthrospira platensis*) powder addition on nutritional and sensory attributes of chicken mortadella

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PAPER

Abstract

The main objective of the present investigation was to evaluate the nutritional and sensory impacts of mortadella supplemented with various levels of Spirulina (*Arthrospira platensis*) powder (SP). Spirulina powder was investigated for its chemical composition, energy value, micronutrient concentration (mg/100 g), and functional qualities. The total amount of carotenoids, phenolics, flavonoids and antioxidant activity were assessed in chicken breast flesh and SP. Different SP (0–5.0%) proportions were integrated to mortadella recipes. The formulated mortadella samples were investigated for their proximate composition, mineral content, total carotenoids, total phenolics, total flavonoids, antioxidant activity, and sensory properties. SP possesses proteins, carbohydrates, crude fiber, ash, and lipids at 63.70, 15.84, 7.60, 7.49 and 5.37 g/100 g of dry sample, respectively. Water absorption capacity (WAC) and oil absorption capacity (OAC) of SP were 1.77 g and 1.65 mL/g of the sample, respectively. The results of the current study revealed that the antioxidant activity and total phenolic content of SP were significantly higher than those of chicken breast by 71.29- and 15.38-fold, respectively. Crude protein content of the mortadella control sample (SP0) was 13.58%, which increased to 14.17%, 14.72%, 15.33%, 15.95% and 16.49% for mortadella samples enhanced with 1%, 2%, 3%, 4% and 5% SP, respectively. Calcium, phosphorus, potassium, sodium, magnesium, iron, zinc, and selenium contents in mortadella samples, partially replaced with 5% SP, were approximately 2.27-, 1.21-, 1.28-, 1.02-, 1.46-, 3.91-, 1.21- and 1.08-fold higher, respectively, compared to the control sample without SP addition. The highest levels of total carotenoids, total phenolics, total flavonoids and antioxidant activity were found in the mortadella samples integrated with 3%, 4% and 5% SP. In contrast, the control sample and those supplemented with 1% and 2% SP were absolutely low in these constituents. The highest results (8.06–8.07) for overall acceptance were observed in mortadella samples with 2% and 3% SP.

Keywords: Food intake, Food processing, Antioxidant Activity, polyphenols, public health, Dietary supplements, Fatty acid

Introduction

Currently, a sizable number of studies focus on the development of healthier foods in an effort to comply with the demands and preferences of increasingly health-conscious consumers (Ali *et al.*, 2020; Doménech-Asensi *et al.*, 2013; Santos *et al.*, 2020). In this regard, a lot of studies have been done to develop novel meat product formulations. More precisely, such innovation initiatives focus on the development of items that can be categorized as functional, that is, foods that have bioactive components and positive health impacts as well as can be utilized as valuable alternatives in the prevention and treatment of diseases (Câmara *et al.,* 2021). Therefore, the food industry invests a lot of time and money in enhancing the nutritional value of foods (Decker and Park, 2010).

Microalgae are believed to be a significant component of aquatic biodiversity; they could be cultivated in a variety of settings, including freshwater, seawater and even the desert (Stengel *et al*., 2011). Algae have recently been utilized in animal feed additives, dietary supplements to improve nutrient benefit, and even therapeutic applications (Navacchi *et al.,* 2012; Shahidi, 2009). In this scenario, microalgae (i.e., spirulina and chlorella) are novel natural ingredients that can be employed to produce healthy diets (Freitas *et al.,* 2019). Historically, people from all over the world have accepted *Arthrospira platensis,* a member of the spirulina family. It grows naturally as an alga in alkaline waters of some tropical lakes (Kent *et al.,* 2015; Khan *et al.,* 2005).

Owing to its great nutritional values, spirulina has been served as a food for centuries in Africa and is now utilized extensively as a nutraceutical food supplement worldwide (Deng and Chow, 2010). It also contains high levels of protein (approximately between 60% and 70% dry weight [DW]), vital amino acids profile, pigments, dietary fiber, essential fatty acids, minerals, vitamins (B1, B2, B3 and B12) as well as omega-3 fatty acids, such as gamma-linolenic and linoleic acids. In addition, spirulina may be a rich source of phenolic molecules (Raczyk *et al.,* 2022). Spirulina contains phycobiliprotein substances, including phycocyanin, allophycocyanin and phycoeritrin as well as chlorophyll and carotenoids (Hidayati *et al.,* 2020).

Meat products are important dietary components for different populations because they contain vital elements, such as proteins, vitamins, and minerals (Saldaña *et al.,* 2018). Globally, mortadella is among the most popular processed meat items (Tóldrá *et al.* (2010). Mortadella is extremely popular because of its high lipid content, which contributes crucial organoleptic characteristics, such as taste, mouthfeel, and a desired level of juiciness. Because of evidence linking unhealthy lifestyle choices and a meal high in saturated fats, cholesterol and salt to the risk of heart disease, consumers are becoming increasingly aware of fat intake and the foods they consume (Trindade *et al.*, 2010). Mortadella is prepared from a meat emulsion containing meat and other ingredients, such as soya protein powder, starch, sodium chloride (NaCl), phosphate, ascorbate and spices mixtures. This emulsion is wrapped in natural or artificial casings, formed and subjected to appropriate heat treatment (Al Marazzeq *et al.,* 2015). To improve the nutritional and functional properties of mortadella products, different trials are carried out, for which numerous innovative non-meat components are used, including yacón meal (Santos Junior *et al.,* 2018), quinoa (Vargas Zambrano *et al.*, 2019), *smallanthus sonchifolius* meal (Santos Júnio *et al.,* 2020) and fish protein hydrolysate (Hamzah *et al.,* 2021). Therefore, the aim of the current study was to assess the nutritional and sensory qualities of mortadella supplemented with various levels of spirulina (*Arthrospira platensis*) powder (SP).

Material and Methods

Spirulina powder was purchased from MRM Nutrition (www.mrmnutrition.com). Chicken breast meat (skinless and boneless fillets) and chicken skin were acquired from a commercial meat processing plant in Buraydah, Qassim, Saudi Arabia. Soy protein, potato starch, sodium nitrite, spices (ginger, white pepper, chili and garlic) and salt (NaCl) were purchased from a local market (Uyun Al Jiwa, Qassim, Saudi Arabia).

Preparation of chicken mortadella

The formulas are shown in Table 1 (approximately 20-kg batches). Mortadella formulas were prepared on a pilot scale at a commercial chicken meat processing plant in Buraydah, Qassim, Saudi Arabia. The treatments comprised addition of SP to different mortadella formulas at the following six levels: SP0 (mortadella without SP addition); SP1 (mortadella supplemented with 1% SP); SP2 (mortadella supplemented with 2% SP); SP3 (mortadella supplemented with 3% SP); SP4 (mortadella supplemented with 4% SP) and SP5 (mortadella supplemented with 5% SP). First, cold chicken breast samples were ground using a grinding machine (Moedor de Carne CAF 8 Inox, Grinders, Molino para Carne, Barazil) with grind plates of 5-mm disks. Immediately, other ingredients were weighed and mixed in a multiprocessor (Moulinex, Model No. 3016661149214, 1,500 W) for 6 min to ensure a complete mixing of all ingredients. The dough was stuffed (approximately 500-g per unit) into 90-mm wide polyamide casings. The samples were cooked in a Dubnoff water bath at 80°C until the core temperature of mass reached 74°C. Mortadellas were then cooled in a shower until the interior temperature reached 40°C, and divided, labeled and stored at 4±0.5°C for additional analysis.

Determination of proximate composition and energy value

The nutritional contents of the samples were assessed using standard procedures of the Association of Official Analytical Chemists (AOAC, 2012). An air draft oven (89511-408/89511-414, VWR International, USA; AOAC method 925.09B) was used to measure the moisture content. Ash content was assessed by dry ashing method in

Table 1. Formulations of chicken mortadella prepared with different levels of spirulina powder (SP).

Ingredients	Quantity (%)					
	SP0	SP1	SP2	SP3	SP4	SP5
Breast chicken fillet	70	70	70	70	70	70
Chicken skin	15	12.9	11.0	9.00	7.0	5.00
SP	0	1	2	3	4	5
Ice	3	4.1	5.00	6.00	7.0	8.00
Sunflower oil	2	2	2	2	2	2
Salt	1.2	1.2	1.2	1.2	1.2	1.2
Corn starch	3	3	3	3	3	3
Curing salt (nitrite)	0.25	0.25	0.25	0.25	0.25	0.25
Sugar	0.1	0.1	0.1	0.1	0.1	0.1
White pepper	0.15	0.15	0.15	0.15	0.15	0.15
Cinnamon	0.10	0.10	0.10	0.10	0.10	0.10
Cardamon	0.10	0.10	0.10	0.10	0.10	0.10
Garlic powder	0.20	0.20	0.20	0.20	0.20	0.20
Onion powder	0.10	0.10	0.10	0.10	0.10	0.10
Sodium triphosphate	0.30	0.30	0.30	0.30	0.30	0.30

SP0: mortadella without SP addition; SP1: mortadella supplemented with 1% SP; SP2: mortadella supplemented with 2% SP; SP3: mortadella supplemented with 3% SP; SP4: mortadella supplemented with 4% SP; SP5: mortadella supplemented with 5% SP.

a muffle furnace at 550°C in accordance with the procedures described in AOAC method 930.22. The Soxhlet method (AOAC method 963.15) was used to determine the quantity of fat in the sample, with diethyl ether as a solvent. Protein content was determined using the Kjeldahl method (with correction factor of 6.25) according to AOAC method 950.36. Using a digestion technique, the crude fiber content was assessed in accordance with AOAC method 950.37. The carbohydrate content (nitrogen free extract [NFE]) was calculated by deducting the total of fat, crude protein, ash and crude fiber from 100%. According to the method described by Ali *et al.* (2020), total energy (kcal/100 g sample) was theoretically computed using the conversion factors of 4.0, 4.0 and 9.0 kcal g^{-1} for proteins, carbohydrates and fat, respectively.

Elemental composition

According to the procedure described by Mohammed *et al.* (2022), the elemental composition of samples was identified using flame atomic absorption spectroscopy (3300 Perkin-Elmer). The colorimetric method was applied to determine phosphorus content in accordance with the procedure described by Winiarska-Mieczan and Kwiecien (2011).

Cholesterol measurement

The cholesterol content of mortadella samples was assessed using the procedure described by El-Anany *et al.* (2020). The cholesterol content of mortadella samples was calculated as mg/100 g of DW.

Phenolic compound extraction

Phenolic compounds (PCs) were extracted from the sample using the procedure described by Machado et al. (2022), with some modifications. Briefly, 2 g of sample were mixed with 25 mL of aqueous methanol (80% methanol–20% water), containing 1% HCl, for a period of 24 h at room temperature (25°C). Methanolic extract was subsequently centrifuged at 5,000×g for 20 min, and the solvent was evaporated in a rotary evaporator at 50°C. The extract was filtered through a Whatman No. 41 filter paper, transferred to a 50-mL volumetric flask, completing the final volume with deionized water.

Measurement of total phenolic content

A freshly prepared Folin–Ciocalteu reagent (5 mL) was mixed with 0.5 mL of methanolic extract. After waiting for 5 min, 4 mL of sodium carbonate solution (75 g/L) was added. The mixture was incubated for 2 h in complete darkness at room temperature (25°C). A UNICO UV/VIS-2100 series spectrophotometer (Dayton, USA) was used to measure absorbance at 765 nm. Total phenolic content (TPC) was assessed as milligram of gallic acid equivalent to per gram of dried powder.

Determination of flavonoid contents

The Dowd method was used to determine the amount of total flavonoids (Mohammed *et al.,* 2022). The total quantity of flavonoids is expressed as milligram of catechin equivalent (CE)/g DW.

Determination of antioxidant activity by DPPH radical scavenging activity assay

1,1-Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity of sample extract was assessed using the recent techniques described by Juntachote and Berghofer (2005). Aliquot (100 μL) of methanolic extract was mixed with 5 mL of 6×10^{-3} M methanolic solution of DPPH radical. The mixture was vortexed thoroughly and kept at room temperature for 30 min. Mixture's absorbance was determined spectrophotometrically at 517 nm. Butylated hydroxytoluene (BHT) served as the standard. The following equation was used to compute the percentage of DPPH radical scavenging activity:

DPPH radical scavenging activity (%) = (1 − absorbance of sample ÷ absorbance of blank) × 100.

Determination of total carotenoids

Total carotenoids were determined by using the method described by Yuan *et al.* (2009). Using a mortar and pestle, 5 g of samples were ground and extracted with a 1:1 v/v solution of petroleum ether–acetone to produce a colorless residue. After being continually washed with water, the upper layer was recovered and mixed with crude extracts. The extracts were diluted with petroleum ether to a known volume. Using a spectrophotometer to measure absorbance at 451 nm, the total amount of carotenoids was calculated as mg/100 g DW.

Functional properties of SP

Water and oil capacity

The capacity of SP to absorb water and oil was measured according to the procedure described by Cruz-Solorio *et al.* (2018): 5 g of SP was mixed with either 5 mL of water or oil for 5 min, and the mixture was allowed to stand for 30 min. The mixture was centrifuged at 3000 rpm for 30 min. Then the excess liquid was removed carefully. The following formulas were used to calculate water absorption capacity (WAC) as well as oil absorption capacity (OAC):

WAC (%) = (Absorbed water [mL] ÷ Original sample weight [g]) ×100.

OAC (%) = (Absorbed oil [mL] ÷ Original sample weight [g]) × 100.

Foaming capacity (FC)

Foaming capacity (FC) was assessed according to the method described by Cruz-Solorio *et al.* (2018). SP sample, 1 gm, was mixed with 25 mL of deionized water. The pH was adjusted to 6.8, and the mixture was homogenized for 5 min at 3,000 rpm. The mixture was then transferred to a 100-mL test tube. FC was determined using the following equation:

FC (%) = ([Volume after homogenization − Volume before homogenization] ÷ Volume before homogenization) × 100.

Emulsifying activity (EA)

Emulsifying activity was assessed as described by Yasumatsu *et al.* (1972). A sample of spirulina (0.5 g) was suspended in 3 mL of distilled water in a graduated tube prior to adding 3-mL sunflower oil. The mixture was then shaken vigorously for 5 min, and the produced emulsion was centrifuged at 2,000×g for 30 min. EA (mL/100 mL) was calculated as follows:

(Volume of emulsified layer ÷ Volume of the entire slurry) × 100.

Sensory assessment

The sensory assessment was performed to determine the effect of SP on the sensory qualities of chicken mortadella. To evaluate the organoleptic properties of mortadella items, a private company in Qassim, Saudi Arabia, dealing in chicken products, hired 25 well-trained employees (10 females and 15 males, aged 25–50 years) having knowledge of sensory characteristics of mortadella samples. Using a nine-point Hedonic scale, where 1 represented extreme dislike, 5 represented neither like nor dislike, and 9 represented an extreme like, mortadella formulations were assessed for appearance, color, odor, flavor, taste, and overall acceptance. Unsalted crackers and water were used to keep the mouth clean between the sensory tests of different mortadella samples.

Statistical analysis

Obtained data were analyzed according to the method described by Gomez and Gomez (1984), and statistically examined in a randomized design using Excel (Microsoft Office 2007; Microsoft Corporation, Redmond, WA, USA) and SPSS version 18.0. Mean values and standard deviation were used to describe the results. Mean values of various treatments were compared using Fisher's least significant difference test (SPSS Inc., Chicago, IL, USA).

Results and Discussion

Proximate composition, energy Value, micronutrient content (mg/100 g), and functional properties of spirulina powder

Proximate composition, energy value, micronutrient content (mg/100 g) as well as functional properties of SP are presented in Table 2. Moisture content of SP was 8.04±0.28%. The initial moisture content of ground particles is a critical factor in protecting the product's physical characteristic during storage. Excessive moisture content could impact the rheological characteristics of ground particles, particularly its bulk density and flow ability. Furthermore, it could impact the physical and chemical features of the particles during the storage process (Maltini *et al.,* 2003). The protein content of SP was 63.70±2.18% DW. This finding indicates that protein is the major constituent of SP. This matched the protein percentage value (71.34%) reported by Raczyk *et al.* (2022).

Table 2. Proximate composition (g/100g), energy value, micronutrient content (mg/100 g) and functional properties of spirulina powder.

Sample	SP (DW)
Moisture	8.04 ± 0.28
Protein	63.70 ± 2.18
Ash	7.49 ± 0.41
Fat	5.37 ± 0.51
Crude fiber	7.60 ± 0.67
Total carbohydrate	15.84 ± 0.81 (g/100g)
Energy	366.49 ± 0.86 (kcal/100 g)
Micronutrient content (mg/100 g)	
Calcium	589 ± 4.90
Phosphorus	1009 ± 8.09
Potassium	1598 ± 6.08
Sodium	641 ± 5.89
Magnesium	307 ± 1.85
Iron	92.6 ± 0.70
Zinc	4.57 ± 0.05
Selenium	29.5 ± 0.13
Manganese	3.79 ± 0.09
Copper	0.58 ± 0.05
Functional properties	
WAC (%)	177 ± 1.85
OAC (%)	165 ± 1.47
FC (%)	205 ± 2.63
EA (%)	61.9 ± 1.05

Values are mean ± SD of five replicates.
WAC: water absorption capacity; OAC: oil absorption capacity; FC: foaming capacity; EA: emulsifying activity; ND: not detected.

Ash content of SP was 7.49±0.41% DW. This finding indicate that SP is a considerable source of elements. Spirulina had a substantial amount of ash (5.93%), which significantly enhanced the nutritive benefits of fortified products (Raczyk *et al.,* 2022). SP had a moderate fat content (5.37±0.51 g/100 g), which was markedly higher than the 0.4% fat content reported by Raczyk *et al.* (2022). This difference could be due to the manufacturer's method of extraction and purification of spirulina extract.

Spirulina powder was found to contain a significant amount of fiber (7.60±0.67 g/100 g; Table 2). Various nutritional benefits of eating dietary fiber include lowering cholesterol level and maintaining lower blood sugar level (Fuller *et al.,* 2016). SP contained 15.84±0.81 g/100 g total carbohydrates. The total carbohydrate content in SP ranged from 3% to 20% (Fradinho *et al.,* 2020). Energy content in SP was 366.49±0.86 kcal/100 g. Spirulina's low-fat content contributed to its low energy (333.4 kcal/100 g DM) (Raczyk *et al.*, 2022). Table 2 illustrates the following mineral contents as DW of SP: potassium (K) (1,598 mg/100 g), phosphoru (P) (1,009 mg/100 g), sodium (Na) (641 mg/100 g), calcium (Ca) (589 mg/100 g), magnesium (Mg) (307 mg/100 g), iron (Fe) (92.6 mg/100 g) and selenium (Se) (29.5 mg/100 g).

Spirulina powder is a significant source of minerals for fortified products to achieve the proper balance of micro- and macro elements. Spirulina is among the most significant microalgae groups containing both macro- and micronutrients, such as high-quality protein molecules, minerals, vitamins, lipids, carbohydrates as well as other bioactive compounds (Masten Rutar *et al.,* 2022).

Table 2 shows the result of some functional properties of SP. The hydrophobicity of flour/powder is assessed by WAC, which was 177% for SP. In this regard, Guarda *et al.* (2004) demonstrated that spirulina is a cyanobacterium that lacks a rigid cell wall, resulting in higher proportion of water absorption because of its hydrophilic cellular components, primarily proteinaceous structures. The OAC of SP was 165%. These findings were in agreement with the results shown by Bashir *et al.* (2016). Protein molecule has both hydrophobic and hydrophilic attributes, which affect its interaction with lipids and polar molecules in different foods. WAC and OAC assess the physicochemical interaction of proteins with other food components (Bashir *et al.,* 2016). The ability of a protein to form stable foam with air is referred to as foaming. Solubilized protein is responsible for FC.

The FC of SP was 205%. In addition, the EA of SP was 61.9%. Spirulina improves whipping properties and foam stability, contributes smoothness of body and texture, acts as a stabilizer, and assists in fat emulsification. This is due to spirulina's higher FC and EA, which help in the formation and stabilization of dispersed gas or incorporated air. Spirulina has an EA of 1.13 mL fat/g protein, with a foaming stability of 27% (Robinson *et al.,* 2000).

Total carotenoids, total phenolics, total flavonoid and antioxidant activity by DPPH of chicken breast meat and spirulina powder

Table 3 presents the total carotenoids, total phenolics, total flavonoid and antioxidant activity by DPPH of chicken breast meat and SP. Carotenoids are a type of natural lipid-soluble pigments responsible for red, yellow and orange colors present in different organisms and plants. They mainly perform as photosynthetic pigments and play a role in photoprotection process. Carotenoids are not synthesized by humans or other animals but only obtained through diet.

Carotenoids are used as colorants and flavorings in food and feed as well as a source of provitmin A in nutritional supplements (Kim, 2015). These were not found in chicken breast meat. SP contained a high concentration of total carotenoids (5.095 ± 0.14 mg/100 g). Inclusion of phenolic compounds in functional food items has many benefits, including ability to prevent or delay spoilage of food, as chicken breast had a total phenolic content of 0.364 mg GAE/g sample. SP contained a high concentration of total phenolics (25.95 0.18 mg GAE/g), approximately 71 times found in chicken breast. This finding is consistent with the findings of Hidayati *et al.* (2020), who reported that the phenolic content in SP extract was 26.640.16 mg GAE/g sample.

Flavonoids are a significant group of natural products; specifically, they are a type of plant's secondary metabolites with a polyphenolic configuration and are widely available in fruits and vegetables. They have a number of biochemical and antioxidant effects (El-Anany *et al.*, 2020). Flavonoids were not discovered in chicken breast meat. On the other hand, SP has a high level of flavonoids (6.76±0.12 mg/g). The aqueous extract of SP contained a high concentration of flavonoids (1.047 mg/g), while the ethanolic extract contained a low concentration (0.568 mg/g) (Kumar *et al.,* 2022).

SP has a significantly ($p \leq 0.05$) greater DPPH radical-scavenging activity (92.79%) than chicken breast meat extract (6.03%). This finding shows that the DPPH radical-scavenging activity of SP extract was approximately 15.4-fold that of chicken breast meat extract. The antioxidant protective effects of SP are mediated by phycocyanin, b-carotene, other vitamins and minerals (Kumar *et al.*, 2022).

Proximate composition and mineral content of chicken mortadella prepared with different levels of spirulina powder

Table 4 illustrates the proximate composition and mineral content of chicken mortadella prepared with different levels of SP. Mortadella samples had a moisture content ranging from 60.25% to 62.19%. The addition of SP to investigated mortadella samples significantly increased their moisture content. The moisture content of mortadella samples fortified with 1%–5% SP increased to 60.59%, 61.09%, 61.42%, 61.82%, and 62.19%, respectively. The improved capacity of SP to absorb and maintain more water as well as oil could have contributed to the higher moisture content of fortified mortadella (Table 4). The table shows that fortified mortadella samples had high protein, ash as well as fiber contents. Protein levels in mortadella samples varied from 13.58% to 16.49%; protein levels in fortified mortadella formulas increased significantly ($p \leq 0.05$) with increasing SP levels. Crude protein content of the mortadella control sample (SP0) without addition of SP was 13.58%, which increased with 1%–5% SP to 14.17%, 14.72%, 15.33%, 15.95% and 16.49% of mortadella samples, respectively. Protein is a predominant component of SP, accounting for 63.70% of the chemical composition (Table 2). Spirulina has been reported to contain 60%–70% DM crude protein (Raczyk *et al.*, 2022).

Table 3. Total carotenoids, total phenolics, total flavonoids and antioxidant activity by DPPH of chicken breast meat and spirulina powder.

Sample	Total carotenoids (mg/100 g)	Total phenolics (mg GAE/g sample)	Total flavonoids (mg/g)	Free radical scavenging (%)
Chicken breast meat	ND	$0.364^{b} \pm 0.08$	ND	$6.03^{b} \pm 0.09$
Spirulina powder	$5.095^{a} \pm 0.14$	$25.95^{a} \pm 0.18$	$6.76^{a} \pm 0.12$	$92.79^{a} \pm 5.14$

Values are mean ± SD of five replicates.
Values with different superscript letters in the same column are significantly different ($p \leq 0.05$).
ND: not detected.

Table 4. Proximate composition and mineral content of chicken mortadella prepared with different levels of SP.

Component	Mortadella formulas					
	SP0	SP1	SP2	SP3	SP4	SP5
Moisture (%)	60.25^{c} ± 0.56	60.59^{b} ± 0.42	61.09^{b} ± 0.63	61.42^{ab} ± 0.85	61.82^{a} ± 0.73	62.19^{a} ± 0.68
Protein (%)	13.58^{cd} ± 0.37	14.17^{c} ± 0.46	14.72^{b} ± 0.26	15.33^{ab} ± 0.29	15.95b ± 0.18	16.49^{a} ± 0.65
Ash (%)	2.98^{c} ± 0.03	3.07^{bc} ± 0.05	3.14^{b} ± 0.08	3.21^{a} ± 0.09	3.29^{a} ± 0.04	3.31^{a} ± 0.09
Crude fiber	ND	0.09^{d} ± 0.01	0.17^{c} ± 0.05	0.24^{bc} ± 0.09	0.31^{b} ± 0.08	0.39^{a} ± 0.03
Fat	9.75^{a} ± 0.18	8.39^{ab} ± 0.25	7.11^{b} ± 0.39	5.79^{c} ± 0.31	4.52^{cd} ± 0.11	3.23^{d} ± 0.07
Total carbohydrate	13.44^{a} ± 0.27	13.69^{a} ± 0.21	13.77^{a} ± 0.26	14.01^{b} ± 0.31	14.11^{b} ± 0.21	14.39^{c} ± 0.32
Energy value (kcal/100 g)	195.83^{a}	187.13^{b}	178.29^{c}	169.95^{cd}	161.54^{d}	153.37^{e}
Cholesterol (mg/100 g)	113.40^{a} ± 1.23	95.73b ± 1.17	82.09^{c} ± 0.86	66.81^{d} ± 0.94	51.62^{e} ± 1.43	36.77^{f} ± 1.56
Mineral (mg/100 g)						
Calcium	23.16^{d} ± 0.17	29.05^{cd} ± 0.23	34.99^{c} ± 0.12	40.87^{b} ± 0.10	46.75^{ab} ± 0.16	52.61^{a} ± 0.21
Phosphorus	235.08^{e} ± 5.06	245.14^{d} ± 6.06	255.18^{cd} ± 4.02	265.27^{b} ± 7.03	275.36^{ab} ± 6.23	285.45^{a} ± 6.45
Potassium	282.00^{e} ± 1.75	297.98^{d} ± 1.82	313.96^{cd} ± 1.37	329.94^{c} ± 1.88	345.92^{b} ± 1.43	361.90^{a} ± 1.97
Sodium	1184.03^{c} ± 5.99	1190.41^{b} ± 4.76	1196.82^{b} ± 7.13	1203.23^{b} ± 5.82	1209.64^{a} ± 5.77	1216.05^{a} ± 8.09
Magnesium	33.12^{d} ± 0.07	36.19^{c} ± 0.09	39.26^{bc} ± 0.18	42.33^{b} ± 0.06	45.40^{ab} ± 0.12	48.47^{a} ± 0.17
Iron	1.59^{e} ± 0.05	2.52^{d} ± 0.11	3.44^{c} ± 0.06	4.37^{b} ± 0.04	5.29^{ab} ± 0.10	6.22^{a} ± 0.09
Zinc	1.06^{d} ± 0.05	1.11^{c} ± 0.02	1.15^{bc} ± 0.04	1.20^{b} ± 0.06	1.24^{a} ± 0.03	1.29^{a} ± 0.08
Selenium	18.21^{b} ± 0.16	18.51^{b} ± 0.18	18.80^{ab} ± 0.23	19.10^{a} ± 0.19	19.39^{a} ± 0.14	19.69^{a} ± 0.22
Manganese	ND	ND	0.09^{c} ± 0.00	0.13^{bc} ± 0.03	0.16^{b} ± 0.02	0.19^{a} ± 0.01
Copper	ND	ND	ND	ND	ND	0.06 ± 0.00

Values are mean ± SD of five replicates.
Values with different superscript letters in the same row are significantly different ($p \leq 0.05$).
ND: not detected.

Fortified mortadella samples supplemented with 5% SP enrichment had the highest ash content (3.31%). This increase could be due to the high ash content (7.49±0.41%) of SP (Table 2). Spirulina contained a significant quantity of ash (5.93%) that significantly increased the nutritive value of fortified products (Raczyk *et al.*, 2022).

The crude fiber content of mortadella samples under investigation ranged from undetectable quantity to 0.39±0.03%. The dietary fiber content of mortadella samples supplemented with SP increased dramatically ($p \leq 0.05$), with increase in SP replacement level. The crude fiber content of mortadella samples fortified with SP increased significantly from a undetectable level in SP0 to 0.24%, 0.31% and 0.39% in SP3, SP4 and SP5 samples, respectively. SP was observed to have a considerable amount of fiber (7.60%±0.67) (Table 2).

The fat content of mortadella samples ranged from 3.23% to 9.75%. However, the addition of SP significantly reduced the fat content of mortadella chicken samples. Fat content was significantly reduced when chicken skin was replaced with different levels of SP. Mortadella samples complemented by 3, 4, and 5% SP had fat content that was approximately 3.01, 2.15, and 1.68 times lower than the control sample, respectively. The quantity of fat recovered from chicken skin fluctuated depending upon the extraction conditions, and ranged from 22.6% to 38.9% of the initial weight of skin (El-Anany et al., 2020). No significant difference was observed for carbohydrate content between the control sample and those fortified with 1% and 2% SP. However, a significant increase was observed in mortadella samples supplemented with 3%–5% SP. The energy values of mortadella samples varied from 153.37 kcal/100 g to 195.83 kcal/100 g. The energy values of mortadella samples fortified with SP were significantly ($p \leq 0.05$) lower than those of the control sample without addition of SP. The control sample had the maximum energy level of 195.83 kcal/100 g sample. At the same time, the lowest energy levels of 169.95, 161.54 and 153.37 kcal/100 g were observed in mortadella samples enhanced with 3%–5% SP, respectively. Calorie values (kcal) of chicken mortadella samples supplemented with 5%, 4%, 3% and 2% SP were approximately 1.27,1.21, 1.15, and 1.09 times lower than in the control sample, respectively. Food products with a lower content of lipids generally have fewer calories than food products with a higher fat content. This is due to the fact that 1 g of fat contains 9 kcal energy, whereas

1 g of protein or carbohydrates contains 4 kcal of energy (El-Anany *et al.*, 2020).

The concentration of cholesterol in the analyzed mortadella samples ranged from 36.77 to 113.40 mg/100 g. The highest cholesterol levels were observed in the mortadella control sample (113.40 mg/100 g). Several studies for comparing chicken meat or fat with chicken skin showed that chicken skin contained higher concentration of cholesterol (El-Anany *et al.,* 2020). Mortadella samples formulated with differing amounts of SP had significantly ($p \leq 0.05$) lower cholesterol concentrations than the control sample without SP. Cholesterol levels of the formulated mortadella samples could be placed in the descending order as follows: SP0 > SP1 > SP2 > SP3 >SP4 >SP5. Result of a study indicated that the inclusion of vegetarian food in diet could lower the risk of cholesterol and heart disease (El-Anany *et al.,* 2020).

As the levels of partial replacement increased, the mineral content of mortadella samples fortified with SP increased significantly ($p \leq 0.05$) (Table 4). This finding could be attributed to the high mineral content of SP. Spirulina has been recognized to be high in elements such as iron, magnesium and potassium (Janda-Milczarek *et al*., 2023). The highest content of micro- and macroelements was observed in SP4 and SP5 samples, while the lowest content was found in the control sample. Table 4 shows that the content of Ca, P, K, Na, Mg, Fe, Zn, and Se in mortadella samples partially replaced with 5% SP were approximately 2.27-, 1.21-, 1.28-, 1.02-, 1.46-, 3.91-, 1.21- and 1.08-fold higher, respectively, compared to the control sample. This finding confirmed the results of Raczyk *et al*. (2022), who found that semolina-based fresh pasta enriched with SP contained more minerals than the control pasta sample without addition of spirulina.

Total carotenoids, total phenolics, total flavonoids and antioxidant activity by DPPH of chicken mortadella prepared with different levels of spirulina powder

Table 5 shows the effect of enhancing chicken breast meat with different amounts of SP on the total carotenoids, total phenolics, total flavonoid and antioxidant activity by DPPH of produced chicken mortadella. Mortadella samples incorporated with 3%–5% SP had the highest content of total carotenoids, total phenolics, total flavonoids and antioxidant activity. However, the control sample and those supplemented with 1% and 2% SP lacked total carotenoids, total phenolics, total flavonoid and antioxidant activity.

The total carotenoid content of mortadella samples enhanced with 5% SP was approximately 1.33 and 1.84 times higher than that of samples supplemented with 3% and 4% SP, respectively. A similar pattern was observed for total phenolics, total flavonoids and antioxidant activity. Spirulina is classified as a safe food for human consumption by the US Food and Drug Administration (FDA) and the Dietary Supplement Information Expert Committee (DSI-EC). Spirulina has recently gained popularity as a functional food because of its cholesterol-lowering properties, immune system modulation and antioxidant properties (Kumar *et al.,* 2022). Spirulina platensis has antioxidant activity and free radical scavenging properties because it possesses natural pigments, such as chlorophyll, beta-carotene, phycoerythrin and phycocyanin (Hidayati *et al*., 2020; Kumar *et al*., 2022).

Sensory quality of chicken mortadella prepared with different levels of spirulina powder

Table 6 shows the results of sensory analysis of chicken mortadella prepared with different levels of SP. The appearance scores of fortified samples varied from 6.64% to 7.90%. The mortadella samples enhanced with 1% and 2% SP, as well as the control sample, had the highest appearance values. On the other hand, attractiveness scores dropped significantly with increase in addition of SP. Mortadella samples prepared with 5% SP received the lowest appearance score. No significant ($p \leq 0.05$) difference in mortadella color was observed between the control sample and those incorporated with 1% SP. In addition, higher amounts (4% and 5%) of SP significantly reduced ($p \leq 0.05$) color scores. The color of mortadella samples enhanced with 5% SP had the lowest liking score.

Odor scores in mortadella samples varied from 7.50% to 8.70%. The highest scores of odor were observed for the samples formulated with 3% and 4% SP. However, additional higher amount (5% SP) caused significant ($p \leq 0.05$) reduction in odor scores. Mortadella samples enhanced with 5% SP received the lowest odor score (7.50%).

In general, incorporation of SP into mortadella recipes results in a significant ($p \leq 0.05$) increase in the flavor scores of formulated mortadella samples. Mortadella samples fortified with 2–5% SP had the highest flavor score ($p \leq 0.05$). The acceptability of new products depends critically on taste. The taste scores of mortadella samples ranged from 7.00 to 8.15. Compared to the control sample without addition of SP, the flavor of mortadella samples was significantly ($p \leq 0.05$) improved by addition of 2% and 3% SP. On the other hand, mortadella samples with 4% and 5% SP had the lowest taste scores.

In terms of overall acceptance, there was no significant difference ($p \geq 0.05$) between the control sample and those with 1% SP. The highest scores (8.06–8.07) for overall acceptance were observed for mortadella samples

Table 5. Total carotenoids, total phenolics, total flavonoids and antioxidant activity by DPPH of chicken mortadella prepared with different levels of SP.

	Mortadella formulas					
Parameter	**SP0**	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**
Total carotenoids (mg/100 g)	ND	ND	ND	$0.13^{c} \pm 0.02$	$0.18^{b} \pm 0.06$	$0.24^{a} \pm 0.08$
Total phenolics (mg GAE/g sample)	ND	$0.18^{e} \pm 0.02$	$0.37^{d} \pm 0.09$	$0.58^{c} \pm 0.07$	$0.76^{b} \pm 0.10$	$0.93^{a} \pm 0.11$
Flavonoids (mg/g)	ND	ND	$0.11^{c} \pm 0.02$	$0.19^{b} \pm 0.04$	$0.25^{ab} \pm 0.05$	$0.32^{a} \pm 0.08$
Free radical scavenging (%)	ND	ND	$1.56^{d} \pm 0.09$	$2.63^{c} \pm 0.12$	$3.71^{b} \pm 0.10$	$4.58^{a} \pm 0.13$

Values are mean ± SD of five replicates.
Values with different superscript letters in the same column are significantly different ($p \le 0.05$).
ND: not detected.

Table 6. Sensory quality of chicken mortadella prepared with different levels of SP.

Treatment	Sensorial parameters					
	Appearance	**Color**	**Odor**	**Flavor**	**Taste**	**Overall acceptance**
SP0	$7.90^{a} \pm 0.89$	$7.55^{a} \pm 0.66$	$8.00^{c} \pm 0.42$	$7.50^{c} \pm 0.45$	$8.00^{b} \pm 0.29$	$7.79^{b} \pm 0.54$
SP1	$7.88^{a} \pm 0.54$	$7.53^{a} \pm 0.70$	$8.00^{c} \pm 0.80$	$7.90^{b} \pm 0.28$	$8.00^{b} \pm 0.38$	$7.85^{b} \pm 0.56$
SP2	$7.88^{a} \pm 0.43$	$7.45^{b} \pm 0.68$	$8.65^{b} \pm 0.99$	$8.25^{a} \pm 0.24$	$8.10^{a} \pm 0.56$	$8.06^{a} \pm 0.60$
SP3	$7.85^{b} \pm 0.54$	$7.45^{b} \pm 0.48$	$8.70^{a} \pm 0.82$	$8.20^{a} \pm 0.66$	$8.15^{a} \pm 0.23$	$8.07^{a} \pm 0.54$
SP4	$7.00^{c} \pm 0.77$	$7.05^{c} \pm 0.55$	$8.70^{a} \pm 0.65$	$8.20^{a} \pm 0.39$	$7.50^{c} \pm 0.36$	$7.69^{c} \pm 0.56$
SP5	$6.64^{d} \pm 0.73$	$6.50^{d} \pm 0.40$	$7.50^{d} \pm 0.32$	$8.20^{a} \pm 0.22$	$7.00^{d} \pm 0.26$	$7.16^{d} \pm 0.47$

Values are mean ± SD of 25 determinations.
Values with different superscript letters in the same row are significantly different ($p \le 0.05$).

with 2% and 3% SP. On the other hand, the lowest score of overall acceptance (7.16) was observed for mortadella sample supplemented with 5% SP.

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References

Ali R.F., El-Anany A.M., Mousa H.M. and Hamad E.M. 2020. Nutritional and sensory characteristics of bread enriched with roasted prickly pear (Opuntia fcus-indica) seed four. Food Funct. 11(3):2117–2125. https://doi.org/10.1039/C9FO02532D

Al Marazzeq A.K., Haddadin M., Abdullah, M.A.L. and Angor, M. 2015. Effect of nitrite substitution with olive oil leaves extract on color and sensory properties of beef mortadella. J Agric Sci. 7:120-128. https://doi.org/10.5539/jas.v7n12p120

Association of Official Analytical Chemists (AOAC). 2012. Official Methods of Analysis, 19th ed. AOAC, Rockville, MD.

Bashir S., Sharif M.K., Butt M.S. and Shahid M. 2016. Functional properties and amino acid profile of spirulina platensis protein isolates. Pak J Sci Ind Res Biol Sci. 59(1):12–19. https://doi.org/10.52763/PJSIR.BIOL.SCI.59.1.2016.12.19

Câmara J.S., Albuquerque B.R., Aguiar J., Corrêa R.C.G., Gonçalves J.L., Granato D., et al. 2021. food bioactive compounds and emerging techniques for their extraction: polyphenols as a case study. Foods. 10:37. https://doi.org/10.3390/foods10010037

Cruz-Solorio A.R., Villanueva-Arce M.E., Garín- Aguilar H., Leal-Lara G. and Valencia-del T. 2018. Functional properties of flours and protein concentrates of 3 strains of the edible mushroom *Pleurotus ostreatus*. J Food Sci Technol. 55(10):3892–3901. https://doi.org/10.1007/s13197-018-3312-x

Decker E.A. and Park Y. 2010. Healthier meat products as functional foods. Meat Sci. 86:49–55. https://doi.org/10.1016/j.meatsci.2010.04.021

Deng R. and Chow T. 2010. Hypolipidemic, antioxidant and antiinflammatory activities of microalgae spirulina. Cardiovasc Ther. 28(4):e33–e45. https://doi.org/10.1111/j.1755-5922.2010.00200.x

Doménech-Asensi G., García-Alonso F.J., Martínez E., Santaella M., Martín-Pozuelo G., Bravo S., et al. 2013. Effect of the addition of tomato paste on the nutritional and sensory properties of mortadella. Meat Sci. 93:213–219. https://doi.org/10.1016/j.meatsci.2012.08.021

El-Anany A.M., Ali R. F.M. and Elanany A.M.M. 2020. Nutritional and quality characteristics of chicken nuggets incorporated with different levels of frozen white cauliflower. Ital J Food Sci. 32(1):45. https://doi.org/10.14674/IJFS-1550

Fradinho P., Niccolai A., Soares R., Rodolfi L., Biondi N., Tredici M.R., et al. 2020. Effect of *Arthrospira platensis* (spirulina) incorporation on the rheological and bioactive properties of gluten-free fresh pasta. Algal Res. 45:101743. https://doi.org/10.1016/j.algal.2019.101743

Freitas B.C.B., Santos, T.D., Moreira J.B., Zanfonato K., Morais M.G. and Costa J.A.V. 2019. Novel foods: a meal replacement shake and a high-calorie food supplemented with spirulina biomass. Int Food Res J. 26(1):59–65. http://www.ifrj.upm.edu.my

Fuller S., Beck E., Salman H. and Tapsell L. 2016. New horizons for the study of dietary fiber and health: a review. Plant Foods Hum Nutr. 71:1–12. https://doi.org/10.1007/s11130-016-0529-6

Gomez K.A. and Gomez A.A. 1984. Statistical Procedures for Agricultural Research, 2nd ed. IRRI, New York, NY; 680 p. ISBN: 10:0471879312.

Guarda A., Rosell C.M., Benedito C. and Galotto, M.J. 2004. Different hydrocolloids as bread improvers and anti-staling agent. Food Hydrocolloid. 18:241–247. https://doi.org/10.1016/S0268-005X(03)00080-8

Hamzah M., Shaik M.I. and Sarbon N.M. 2021. Effect of fish protein hydrolysate on physicochemical properties and oxidative stability of shortfin scad (*Decapterus macrosoma*) emulsion sausage. Food Res. 5(3):225–235. https://doi.org/10.26656/fr.2017.5(3).354

Hidayati J.R., Yudiati E., Pringgenies D., Oktaviyanti D.T. and Kusuma A.P. 2020. Comparative study on antioxidant activities, total phenolic compound and pigment contents of tropical Spirulina platensis, Gracilaria arcuata and Ulva lactuca extracted in different solvents polarity. In: E3S Web of Conferences; EDP Sciences, Les Ulis, France, vol. 147: 03012. https://doi.org/10.1051/e3sconf/202014703012

Janda-Milczarek K., Szymczykowska K., Jakubczyk K., Kupnicka P., Skonieczna-Zydecka K., Pilarczyk B., et al. 2023. Spirulina supplements as a source of mineral nutrients in the daily diet. Appl Sci. 13:1011. https://doi.org/10.3390/ app13021011

Juntachote T. and Berghofer E. 2005. Antioxidative properties and stability of ethanolic extracts of holy basil and ga langal. Food Chem. 92(2):193–202. https://doi.org/10.1016/j.foodchem.2004.04.044

Khan Z., Bhadouria P. and Bisen P.S. 2005. Nutritional and therapeutic potential of spirulina. Curr Pharm Biotechnol. 6(5):373–379. https://doi.org/10.2174/138920105774370607

Kent M., Welladsen H.M., Mangott A. and Y. Li. 2015. Nutritional evaluation of Australian microalgae as potential human health supplements. PLoS One. 10(2): 1–14. https://doi.org/10.1371/journal.pone.0118985

Kim S.K. 2015. Handbook of Marine Microalgae: Biotechnology Advances. Academic Press, Waltham, MA; 300 p.

Kumar A., Ramamoorthya D., Verma D.K., Kumar A.R., Kumar N., Kanak K.R., Marweina B.M. and Mohan K. 2022. Antioxidant and phytonutrient activities of Spirulina platensis. Energy Nexus. 6(100070):1–9. https://doi.org/10.1016/j.nexus.2022.100070

Machado A.R., Silva P.M.P., Vicente A.A., Souza-Soares L.A., Pinheiro A.C. and Cerqueira M.A. 2022. Alginate particles for encapsulation of phenolic extract from spirulina sp. LEB-18: physicochemical characterization and assessment of in vitro gastrointestinal behavior. Polymers. 14:4759. https://doi.org/10.3390/polym14214759

Maltini E., Torreggiani D., Venir E. and Bertolo G. 2003. Water activity and the preservation of plant foods. Food Chem. 82(1):79–86. https://doi.org/10.1016/S0308-8146(02)00581-2

Masten Rutar J., Jagodic Hudobivnik M., Neˇcemer M., Vogel Mikuš K., Arˇcon I. and Ogrinc N. 2022. Nutritional quality and safety of the spirulina dietary supplements sold on the Slovenian market. Foods. 11:849. https://doi.org/10.3390/foods11060849

Mohammed A.M., El-Anany A.M., Althwab S.A., Alhomaid R.M., Alharbi H.F., Algheshairy R.M., et al. 2022. Nutritional and quality attributes of bread fortified with cheese weed mallow leaves powder. Nutr Food Sci. 53(6): 1045–1058. https://doi.org/10.1108/NFS-03-2022-0094

Navacchi M.F.P., De Carvalho J.C.M., Takeuchi K.P. and Danesi E.D.G. 2012. Development of cassava cake enriched with its own bran and Spirulina platensis. Acta Scientiarum Technol (Maringa). 34(4):465–472. https://doi.org/10.4025/actascitechnol.v34i4.10687

Raczyk M., Polanowska K., Kruszewski B., Grygier A. and Michałowska D. 2022. Effect of spirulina (Arthrospira platensis) supplementation on physical and chemical properties of semolina (*Triticum durum*)-based fresh pasta. Molecules. 27(2):355. https://doi.org/10.3390/molecules27020355

Robinson., R.K., Carl, A. B. and Pradip, D. P., 2000. Encyclopedia of food microbiology. In: Single- Cell Protein/The algae. Academic press, A Harcourt Sc. and Tech. Company. 3: 2025–2026.

Saldaña E., de Oliveira A., Selani M.M., Haguiwara M.M.H., Aurelio de Almeida M., Siche R. and Contreras-Castillo C.J. 2018. A sensometric approach to the development of mortadella with healthier fats. Meat Sci. 137:176–190. https://doi.org/10.1016/j.meatsci.2017.11.027

Santos Junior A.C., Maia Junior J., Henry F.D.C., Oliveira R.F.D., Quirino C.R., Leal Martins M.L, Moreira Moulin M. and Cabral N.O. 2018. Preparation and physico-chemical characterization of mutton mortadella supplemented with yacón meal. Revista Electrónica de Veterinaria. 18(7):1–10.

Santos Junior A.C., Oliveira R.F.D., Henry F.D.C., Maia Junior J., Moreira Moulin M., Della Lucia S.M., et al. 2020. Physicochemical composition, lipid oxidation, and microbiological quality of ram mortadella supplemented with *Smallanthus sonchifolius* meal. Food Sci Nutr. 8:5953–5961. https://doi.org/10.1002/fsn3.1880

Shahidi F. 2009. Nutraceuticals and functional foods: whole versus processed foods. Trends Food Sci Technol. 20(9):376–387. https://doi.org/10.1016/j.tifs.2008.08.004

Stengel D.B., Connan S. and Popper Z.A. 2011. Algal chemodiversity and bioactivity: sources of natural variability and implications for commercial application. Biotechnol Adv. 29(5):483–501. https://doi.org/10.1016/j.biotechadv.2011.05.016

Tóldrá F., Mora L. and Flores M. 2010. Cooked ham. In: Tóldrá, F. (Ed.), Handbook of Meat Processing (pp. 301–312). Wiley-Blackwell, IA.

Trindade M.A., Thomazine M., Oliveira J.M., Balieiro J.C.C. and Favaro-Trindade C.S. 2010. Estabilidade oxidativa, microbiológica e sensorial de mortadela contendo óleo de soja, armazenada a 0°C durante 60 dias. Brazil J Food Technol. 13(03):165–173. http://dx.doi.org/10.4260/BJFT2010130300022.

Vargas Zambrano P., Riera González G. and Cruz Viera, L. 2019. Quinoa as gellingagent in a mortadela formulation. Int Food Res J. 26:1069–1077.

Winiarska-Mieczan A. and Kwiecieṅ M. 2011. Evaluation of the mineral composition of breadstuff and frequency its consumption among students of Lublin universities. Acta Sci Pol Technol Aliment. 10:487–495.

Yasumatsu K, Sawada K, Maritaka S, Toda J, Wada T, Ishi K (1972). Whipping and emulsifying properties of soy bean products. Agri. Biol. Chem. 36: 719–727.

Yuan G.-F. Sun B., Yuan V. and Wang Q.M. 2009. Effects of different cooking methods on health-promoting compounds of broccoli. J Zhejiang Univ B. 10(8):580–588. https://doi.org/10.1631/jzus.B0920051