Impact of the soy protein replacement by legumes and algae based proteins on the quality of chicken rotti

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Abstract The addition of different protein sources (soy, bean, lentil, broad bean, *Spirulina*, and *Chlorella*) on nutritional, physicochemical and sensory properties of chicken rotti was evaluated. Significant changes were observed in physicochemical composition, textural properties and amino acid content of chicken rotti after adding the proteins from different sources, thus influencing the sensory acceptance and preference. *Spirulina* and *Chlorella* rotti presented a slight increase of pH and seaweed caused a decrease in some colour parameters. The highest lipids contents were found in chicken rotti added of with *Spirulina* and lentil proteins. Chicken rotti prepared with lentil protein also showed the highest values for ash content. Chicken rotti enriched with seaweed protein presented the highest total amino acid content. Principal component analysis showed that broad beans and lentils proteins as interesting ingredients to replace soy protein in chicken rotti.

Keywords Functional foods · Meat analogues · *Spirulina* · *Chlorella* · Amino acid profile · Sensory analysis

Introduction

The main source of protein in the entire world diet is of animal origin and scarcely from plant sources (Neacsu et al. 2017). Animal protein is considered to be of high quality as it contains all the essential amino acids closely resembling the human body (Lorenzo et al. 2014). However, recent discussions on the sustainability of food production/consumption have focused on the role of products of animal origin (Vainio et al. 2016; Seves et al. 2017). Similarly, more and more people have adapted to a vegetarian diet, which has demanded a sharp increase of vegetable sources of protein. Meat analogues are becoming popular because of their healthy image (cholesterol free), simulation of meat-like texture and low cost. Moreover, some studies have shown the beneficial effects of a diet rich in vegetables because it leads to a decreased risk of cancer, coronary heart disease (CHD), and/or many other non-communicable diseases (Bazzano et al. 2001; Rochfort and Panozzo 2007).

Legumes and pulses, such as beans, soybeans, lentils, peas, and chickpeas, are among the most nutritious and accessible protein sources, representing about 20% of dry weight in pea and beans, whereas higher amounts (around 38–40%) were observed in soybean and lupine (Neacsu et al. 2017). However, animal meat presents specific functionalities and has intrinsic sensory attributes (Gómez and Lorenzo 2013). Mimicking meat protein functionality by any other protein source is a technological hurdle (Arora et al. 2017). Soy-based texturized proteins have been used as common meat replacement. However, many people are

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allergic to soy (Boye et al. 2012). In addition, there has been a growing interest in developing products with algal proteins (Bleakley and Hayes 2017) which are an excellent nutrient source, containing high amounts of macro- and micronutrients (Lorenzo et al. 2017), as well as bioactive compounds (e.g., catechins such as gallocatechin, epicatechin and catechingallate, flavonols, and flavonol glycosides) with high antioxidant and health beneficial properties (Agregán et al. 2017a, b, c; 2018).

From both environmental and public health perspectives, it would be beneficial to reduce the quantity of meat and increase the intake of plant and algae-based foods. Therefore, the aim of this work was to investigate the effect of the partial replacement of animal proteins by plant and algae-based proteins on physicochemical composition and amino acid profile of chicken rotti.

Materials and methods

Experimental design and chicken rotti manufacture

Chicken meat was provided by Coren SCG (Ourense, Spain). All the used spices and additives were of food grade. Different vegetable protein (soy, bean, lentil and broad bean) were supplied by VitessenceTM Pulse Proteins, seaweed proteins (*Spirulina*, *Chlorella*) sources were supplied by Algaenergy (Madrid, Spain). All the chemicals used for the analysis were of analytical grade.

Six batches of chicken rotti enriched with different protein sources were manufactured. Formulations for obtaining the different meat products are given in Table 1. Each batch was enriched with 1% of protein corresponding to that particular protein batch (soy (control), pea, lentil, broad bean, *Chlorella* and *Spirulina*). Chicken meat was grounded using a 8 mm diameter mincing plate in a refrigerated mincer machine (La Minerva, Italy) and minced (Fuerpla, Spain) for 60 min together with chicken breast and all additives (except for the protein extract). Six batches are made and the amount of protein needed is added to each one of them. Mince chicken meat was wrapped in the whole chicken breast. Rotti samples were stuffed into grid casing and then they were cooked in an oven (Rational, Germany) at 180 °C until an internal temperature of 60 °C (Fig. 1).

Physical parameters

Physical parameters were analysed according to method previously reported by Pateiro et al. (2013). The pH of the rotti was measured using a pH-meter (HI 99163-Hanna Instruments, Spain). Colour CIELAB parameters (L^* , a^* ,

Table 1 Formulation to elaborate the chicken rotti

Ingredients	Concentration (%)
Chicken meat	50.0
Chicken breast	35.0
Protein*	1.0
Water and Ice	8.5
Potassium lactate	1.7
Potato starch	1.5
Salt	0.75
White wine	0.4
Dextrose	0.4
Sodium acetate	0.2
Sodium citrate	0.2
Sodium ascorbate	0.1
Yeast extract	0.1
White pepper	0.05
Crushed onion	0.05
Garlic	0.05

*Respective protein content in each batch

and b^* values) were measured using a portable colorimeter (CM-600d-Konica Minolta, Japan) with pulsed xenon arc lam, 0° viewing angle geometry and 8 mm aperture size. The colour was measured in three different points of each sample in homogeneous and representative areas, free of fat. Textural profile analysis (TPA) test was conducted using a texture analyser (TA-XT2, Stable Micro Systems, UK).

Chemical composition

Lipids were extracted according to the AOCS Official Procedure Am 5-04. Samples were subjected to a liquid-solid extraction using petroleum ether in an extractor apparatus (Ankom^{HCl} Hydrolysis System, USA) at 90 °C during 60 min. Moisture was quantified according to ISO 1442:1997 (ISO 1997). Protein was quantified according to ISO 937:1978 (ISO 1978), in which samples were subjected to a reaction with sulphuric acid in a digester (Gerhardt Kjeldatherm KB, Bonn, Germany). For the final protein content, a conversion factor of 6.25 was used.

Amino acid composition

Hydrolyzed amino acid composition was estimated using the procedure previously described by Lorenzo et al. (2011). Amino acids derivatization was conducted using the 6-aminoquinolyl-N-hydroxysuccinimidyl carbamate (Waters AccQ-Fluor reagent kit) and determined by RP-

Fig. 1 Chicken rotti elaborated with different protein sources

HPLC (Waters 2695 Separations Module+Waters 2475 Multi Fluorescence Detector+Waters AccQ-Tag amino acids analysis column). The amino acids content was expressed in mg/100 g of meat.

Sensory analysis

Sensory analysis was conducted with sixteen trained panellists (9 females and 7 males) selected from the Meat Technology Center of Galicia. Sensory evaluations were held in closed individual booths according to the Regulation UNE-EN ISO 8589:2010 (Anonymous 2007), under white light. Samples were coded with 3-digit number drawn from a table of random numbers. Water and unsalted toasted bread were used between samples to clean the palate. An acceptance test using a 9-point structured scale (1-dislike extremely to 9-like extremely) was also conducted. A preference test was conducted using a 6-point structured scale (1-most favorite to 6—least favorite).

Statistical analysis

Data were presented as means of 5 replicates followed by the standard deviation. Inferential analysis (one-way

ANOVA + Fisher LSD test) was performed to check for differences between chicken rotti manufactured with different plant-based proteins (Granato et al. 2014). The obtained data of preference test were analyzed using Friedman two-way ANOVA (protein source and panellists as factors). Aiming to reduce the number of variables and gain a better understanding of the data, principal component analysis (PCA) was conducted in auto-scaled data. Factor loadings higher than 0.60 were used to project the samples in a two-dimensional factor plane (Granato et al. 2018). Statistica v.7 (Statsoft, USA) was used for the statistical analysis.

Results and discussion

Physicochemical properties

The mean values of pH, color parameters, and chemical composition of the different chicken rotti formulations are presented in Table 2. Overall significant differences ($P < 0.01$) were found in pH values among the different batches of chicken rotti samples ranging between 6.43 and 6.64. *Spirulina* and *Chlorella* rotti presented a slight

Table 2 Proximate composition, pH values, colour parameters and textural properties of chicken rotti with different protein replacements by pulses and algae proteins

	Soy	Pea	Lentils	Broad beans	<i>Spirulina</i>	<i>Chlorella</i>	Sig.
pH	6.48 ± 0.03 ^{bc}	6.44 ± 0.08 ^c	6.43 ± 0.04 ^c	6.47 ± 0.06 ^{bc}	6.64 ± 0.13 ^a	6.58 ± 0.11 ^{ab}	**
<i>Colour parameters</i>							
L*	72.76 ± 1.29 ^a	74.55 ± 1.99 ^a	73.31 ± 2.3 ^a	73.10 ± 0.70 ^a	58.05 ± 3.58 ^b	56.37 ± 2.75 ^b	***
a*	5.36 ± 0.67 ^a	5.00 ± 0.58 ^a	5.16 ± 0.60 ^a	5.03 ± 0.18 ^a	− 2.33 ± 0.59 ^c	− 0.92 ± 0.47 ^b	***
b*	23.36 ± 0.95 ^a	23.63 ± 0.76 ^a	23.89 ± 1.40 ^a	23.33 ± 0.45 ^a	16.58 ± 0.31 ^c	21.31 ± 0.65 ^b	***
<i>Composition (%)</i>							
Moisture	67.91 ± 0.65	69.14 ± 0.70	66.34 ± 1.80	67.89 ± 0.96	67.00 ± 0.94	68.03 ± 0.70	ns
Lipids	5.04 ± 0.43 ^b	5.50 ± 0.23 ^{ab}	5.60 ± 0.30 ^{ab}	5.61 ± 0.44 ^{ab}	5.82 ± 0.45 ^a	5.55 ± 0.85 ^{ab}	***
Proteins	21.56 ± 0.97 ^{ab}	19.32 ± 0.44 ^c	22.06 ± 0.90 ^a	20.48 ± 0.26 ^b	21.43 ± 0.49 ^{ab}	20.54 ± 1.30 ^b	***
Ash	2.97 ± 0.10 ^{bc}	2.87 ± 0.09 ^c	3.22 ± 0.10 ^a	2.91 ± 0.18 ^{bc}	3.06 ± 0.08 ^b	2.85 ± 0.85 ^c	***
<i>Textural parameters</i>							
Hardness (N)	33.94 ± 2.70 ^a	20.00 ± 6.40 ^b	17.61 ± 3.20 ^{bc}	12.73 ± 2.40 ^{cd}	14.81 ± 2.55 ^{cd}	10.61 ± 1.66 ^d	***
Adhesiveness (g.sec)	48.7 ± 31.2	− 38.9 ± 29.2	− 16.3 ± 9.8	− 17.7 ± 19.5	− 18.39 ± 15.27	− 13.07 ± 7.463	ns
Elasticity (mm)	0.76 ± 0.04 ^{ab}	0.77 ± 0.02 ^a	0.72 ± 0.03 ^{bc}	0.76 ± 0.03 ^{ab}	0.72 ± 0.01 ^{bc}	0.67 ± 0.05 ^c	***
Cohesiveness	0.43 ± 0.03 ^a	0.37 ± 0.03 ^b	0.31 ± 0.04 ^c	0.31 ± 0.01 ^c	0.32 ± 0.03 ^c	0.29 ± 0.03 ^c	***
Gumminess (N)	14.87 ± 1.50 ^a	7.41 ± 2.5 ^b	5.74 ± 1.6 ^c	3.91 ± 0.8 ^{cd}	4.89 ± 1.16 ^{cd}	3.21 ± 0.79 ^d	***
Chewiness (N.mm)	11.35 ± 0.80 ^a	5.66 ± 1.90 ^b	4.18 ± 1.20 ^c	3.02 ± 0.60 ^{cd}	3.50 ± 0.82 ^{cd}	2.13 ± 0.58 ^d	***

Sig significance; ns not significant

*** ($P < 0.001$); ** ($P < 0.01$)

All the data are expressed as mean ± standard deviations. Means with the different superscript letters in a row are differ significantly

increase compared to the other batches with values of 6.64 and 6.58, respectively. However, other authors reported a pH reduction with the addition of *Himanthalia elongata* to a meat product (Cofrades et al. 2008, 2017; López-López et al. 2009). Concerning the color parameters (L*, a* and b*), the highest values were found in chicken rotti samples enriched with pea, lentil and broad beans protein and no significant differences were observed compared to control samples. However, color parameters were significantly affected by incorporating seaweed protein ($P < 0.001$). The green and blue-green pigments of *Spirulina* and *Chlorella* caused a decrease in these parameters. L* values was lower in rotti with added *Chlorella* (56.37) followed by *Spirulina* (58.05) proteins than in the control samples (72.76). Redness (a*) values of control group were observed to be ≈ 5.36 , showing a significant decrease in these values after replacement of soy by *Chlorella* (− 0.92) and *Spirulina* (− 2.33) proteins, which is mainly due to chlorophyll pigments. Regarding b* values, *Spirulina* (16.58) and *Chlorella* (21.31) enriched samples also presented different values from that obtained for the control group (23.36).

On the other hand, adding different protein sources did not affect moisture content of chicken rotti, showing values between 66.34 g/100 g and 69.14 g/100 g for lentils and

pea groups, respectively. On the contrary, significant differences ($P < 0.001$) were found in lipids, proteins and ash contents. The highest lipid contents were found in samples supplemented with *Spirulina* protein (5.82 g/100 g) and the lowest in the control group (5.04 g/100 g). In this regard, López-López et al. (2009) reported a slight increase of fat content in frankfurters elaborated with *Himanthalia elongata* compared to the control group. Protein content ranged from 19.32 (rotti with pea protein) to 22.06 g/100 g (rotti with lentil protein). These values were higher than those reported by Arnaud et al. (2013) for refrigerated chicken rotti (12.8%). Therefore, adding vegetable or seaweed protein into chicken rotti increase their nutritional values. Finally, chicken rotti elaborated with lentil protein also showed the highest ash content (3.22 g/100 g), whereas the lowest values were found in chicken rotti with pea protein (2.87 g/100 g).

Textural parameters

Regarding textural properties, all parameters showed significant differences ($P < 0.001$) except for adhesiveness (Table 2). Hardness, cohesiveness, gumminess, and chewiness were higher (33.94 N, 0.43, 14.37 N, and 11.35 N.mm, respectively) in chicken rotti with soy protein

than in the other samples. Chicken rotti with pea protein presented the highest elasticity values (0.77 mm). The replacement of soy protein by the other vegetable and seaweed protein decreased the maximum force of compression, being rotti with *Chlorella* protein which showed the lowest hardness values (10.61 N). Moreover, rotti supplemented with *Chlorella* protein also presented the lowest values of elasticity (0.67 mm), cohesiveness (0.29), gumminess (3.21 N) and chewiness (2.13 N.mm). Although, López-López et al. (2009) and Cofrades et al. (2008) reported an increase in hardness and chewiness values after adding of *Himanthalia elongate* in frankfurters and meat gel/emulsion, similar results to ours were found by Choi et al. (2012), who observed a reduction of hardness, gumminess and chewiness in pork patties containing *Laminaria japonica*.

Amino acids profile

Table 3 shows the hydrolyzed amino acid content of chicken rotti and significant differences were observed among the studied batches. Seventeen amino acids out of

the 20 amino acids were included in the essential amino acid fraction (Domínguez et al. 2015). Chicken rotti enriched with seaweed protein presented the highest total amino acid content (22.88 g/100 g and 22.89 g/100 g for *Spirulina* and *Chlorella* groups, respectively), whereas rotti with pea protein showed the lowest values (11.45 g/100 g). These results are consistent with the studies previously reported by others authors (Fleurence 1999; Dawczynski et al. 2007; López-López et al. 2009), who noticed that the addition of seaweeds caused some increase in the amount of several amino acids. In *Spirulina* and *Chlorella* proteins enriched chicken rotti, the ratio of essential and non-essential amino acids was greater than 1, which indicated that these seaweeds are good sources of essential amino acids. The ratio of essential and non-essential amino acids (Lorenzo and Pateiro 2013) of rotti with pea and lentils protein was equal to 1.

Glutamic acid was the highest non-essential amino acid in all samples with values ranging between 3.58 g/100 mg in rotti with *Chlorella* protein and 1.84 g/100 g in rotti with pea protein followed by aspartic acid in batch with *Chlorella* protein and 1.05 g/100 g in rotti with pea

Table 3 Amino acid content (expressed as g/100 g) of chicken rotti with different protein replacements by pulses and algae proteins

	Soy	Pea	Lentils	Broad beans	<i>Spirulina</i>	<i>Chlorella</i>	Sig.
Asp	1.53 ± 0.31 ^{ab}	1.05 ± 0.61 ^b	1.90 ± 0.20 ^a	1.73 ± 0.43 ^a	2.04 ± 0.25 ^a	2.10 ± 0.68 ^a	*
Ser	1.00 ± 0.14 ^a	0.51 ± 0.29 ^b	0.90 ± 0.10 ^a	0.87 ± 0.15 ^a	1.03 ± 0.15 ^a	1.07 ± 0.31 ^a	*
Glu	2.57 ± 0.59 ^{ab}	1.84 ± 1.06 ^b	3.20 ± 0.30 ^a	3.00 ± 0.69 ^a	3.52 ± 0.44 ^a	3.58 ± 1.17 ^a	*
Gli	0.82 ± 0.14 ^{bc}	0.58 ± 0.33 ^c	1.02 ± 0.10 ^{ab}	0.93 ± 0.14 ^{ab}	1.17 ± 0.20 ^a	1.20 ± 0.34 ^a	**
Hys	0.55 ± 0.10 ^{bc}	0.39 ± 0.22 ^c	0.67 ± 0.10 ^{ab}	0.66 ± 0.13 ^{ab}	0.78 ± 0.12 ^a	0.51 ± 0.37 ^{bc}	*
Arg	1.43 ± 0.33 ^{bc}	1.10 ± 0.64 ^c	1.84 ± 0.20 ^{ab}	1.84 ± 0.34 ^{ab}	2.15 ± 0.35 ^a	2.25 ± 0.74 ^a	*
Thr	0.78 ± 0.14 ^{bc}	0.56 ± 0.32 ^c	0.96 ± 0.10 ^{ab}	0.93 ± 0.17 ^{ab}	1.12 ± 0.17 ^a	1.16 ± 0.37 ^a	*
Ala	1.08 ± 0.18 ^{ab}	0.72 ± 0.41 ^b	1.27 ± 0.10 ^a	1.16 ± 0.24 ^{ab}	1.46 ± 0.19 ^a	1.23 ± 0.87 ^{ab}	**
Pro	0.70 ± 0.14 ^{bc}	0.49 ± 0.28 ^c	0.87 ± 0.10 ^{ab}	0.80 ± 0.19 ^{ab}	1.04 ± 0.18 ^a	1.01 ± 0.31 ^a	**
Cis	0.14 ± 0.03 ^{bc}	0.10 ± 0.06 ^c	0.20 ± 0.02 ^{ab}	0.17 ± 0.05 ^{ab}	0.22 ± 0.04 ^a	0.23 ± 0.09 ^a	*
Tyr	0.63 ± 0.12 ^{bc}	0.42 ± 0.24 ^c	0.72 ± 0.10 ^{ab}	0.70 ± 0.14 ^{ab}	0.84 ± 0.13 ^{ab}	0.89 ± 0.30 ^a	*
Val	0.78 ± 0.15 ^{bc}	0.54 ± 0.31 ^c	0.95 ± 0.10 ^{ab}	0.91 ± 0.18 ^{ab}	1.14 ± 0.16 ^a	1.15 ± 0.36 ^a	**
Met	0.13 ± 0.03 ^{ab}	0.08 ± 0.05 ^c	0.17 ± 0.04 ^a	0.15 ± 0.05 ^{ab}	0.20 ± 0.03 ^a	0.18 ± 0.13 ^a	**
Lys	1.52 ± 0.36 ^{ab}	1.08 ± 0.63 ^c	1.91 ± 0.20 ^a	1.14 ± 0.77 ^c	2.11 ± 0.29 ^a	2.17 ± 0.71 ^a	*
Isoleu	0.73 ± 0.15 ^{bc}	0.52 ± 0.30 ^c	0.91 ± 0.10 ^{ab}	0.87 ± 0.19 ^{ab}	1.10 ± 0.16 ^a	1.10 ± 0.35 ^a	**
Leu	1.33 ± 0.29 ^{bc}	0.96 ± 0.55 ^c	1.66 ± 0.20 ^{ab}	1.59 ± 0.34 ^{ab}	1.97 ± 0.28 ^a	2.00 ± 0.63 ^a	*
Phe	0.67 ± 0.14 ^{bc}	0.50 ± 0.29 ^c	0.85 ± 0.10 ^{ab}	0.83 ± 0.16 ^{ab}	1.00 ± 0.16 ^a	1.05 ± 0.33 ^a	*
Total	16.39 ± 3.13 ^{bc}	11.45 ± 6.59 ^c	20.0 ± 1.7 ^{ab}	18.30 ± 2.82 ^{bc}	22.88 ± 3.26 ^a	22.89 ± 7.47 ^a	*
E	7.91 ± 1.66 ^{bc}	5.74 ± 3.31 ^c	9.90 ± 0.90 ^{ab}	8.94 ± 0.82 ^{ab}	11.56 ± 1.70 ^a	11.56 ± 3.48 ^a	**
NE	8.47 ± 1.47 ^{bc}	5.71 ± 3.28 ^c	10.10 ± 0.80 ^{ab}	9.36 ± 2.01 ^{ab}	11.32 ± 1.56 ^a	11.33 ± 4.00 ^a	*
E/NE	0.93 ± 0.04 ^c	1.00 ± 0.02 ^b	1.00 ± 0.020 ^b	0.97 ± 0.106 ^c	1.02 ± 0.01 ^a	1.04 ± 0.07 ^a	*

E essentials amino acids; NE non essential amino acids; Sig significance

** ($P < 0.01$), * ($P < 0.05$)

All the data are expressed as mean ± standard deviations. Means with the different superscript letters in a row are differ significantly

protein. In the case of essential amino acids, arginine was the predominant in all batches with values ranging from 2.25 g/100 g (rotti enriched with *Chlorella* protein) to 1.10 g/100 g (rotti enriched with pea protein), followed by lysine with values between 2.17 and 1.08 g/100 g in rotte supplemented with *Chlorella* and pea proteins, respectively. Furthermore, the content of all hydrolyzed amino acids was increased in chicken rotte containing *Chlorella* and *Spirulina* proteins, showing values higher to those found in the available literature (Cofrades et al. 2017).

Sensory scores

Figure 2, shows that soy chicken rotte has the highest ($P < 0.05$) acceptability scores, followed by the chicken rotte prepared with pea and lentils/broad beans proteins. The products made with *Chlorella* and *Spirulina* proteins presented the lowest ($P < 0.05$) sensory acceptability scores. The average percentage of preference of 16 panellists obtained from the six chicken rotte is shown in Fig. 3 and the total scores of preference obtained to ranking test are given as numbers in brackets in Table 4. The results indicated that rotte control were the most chosen for the panellists (62%) with 27 points followed by rotte supplemented with broad bean and lentil protein (13%) with 43 and 44 points. On the other hand, rotte manufactured with *Chlorella* protein did not like any panellist. Friedman's test indicated that there were significant difference among studied samples ($F_{\text{test}} > F_{(\alpha=0.05)}$). The results of the LSD test (Table 4) showed that rotte samples enriched with protein from broad beans and lentils had the same preference and non-significant differences were found compared to the control group. The other group of samples was composed by rotte manufactured with *Spirulina* and *Chlorella* proteins, whereas samples elaborated with pea protein had the same preference in both groups. The order of global score of all the different protein enriched rotte was observed in the sequence of soy > broad

Fig. 2 Sensory acceptability of chicken rotte using a 9-point hedonic scale. Different letters for the formulations represent statistically different results ($P < 0.05$)

Fig. 3 Percentage of sensory preference (%) of elaborated chicken rotte

beans > lentils > pea > *Spirulina* > *Chlorella*. This result was probably due to certain dry feeling and the characteristic taste of the seaweed (O'Sullivan et al. 2016). As it is well known, free amino acids contribute to the taste. In such a manner, alanine, glycine, proline, serine, and threonine provide a sweet taste, whereas histidine, allo-isoleucine, isoleucine, leucine, methionine, phenylalanine, tryptophan and valine are related to a bitter taste. On the other hand, aspartic acid and glutamic acid are correlated to the umami taste. Rotte supplemented with *Spirulina* and *Chlorella* proteins increased amino acids, thus increasing umami and bitter taste, which most probably, the panelists were not accustomed. In this line, De Boer et al. (2013) observed that fish consumers were more likely to choose the snack from seaweed than meat consumers. Future studies should focus on the sensory optimization of sensory acceptability of chicken rotte made with these algae as the formulation tested here did not present positive results and, in addition, consumer education is need and background works such as dissemination of information on the nutritional values would increase the possibility of product trial.

Principal component analysis

PCA separated the chicken rotte according to a wide variety of quality traits and the 2-dimensional projection was able to explain more than 80% of data variability (Fig. 4). *Chlorella* and *Spirulina* chicken rotte tended to have a higher content of lipids and most amino acids, including alanine, lysine, arginine, methionine, serine, and histidine. Additionally, these samples had the highest adhesiveness and pH values compared to the other samples. Soy protein chicken rotte was associated with higher sensory acceptability, cohesiveness, chewiness, gumminess, a^* and b^* values, and elasticity, while the pea protein chicken rotte presented the highest moisture levels and the lowest pH values and protein contents. On the other hand, samples manufactured with broad beans and lentil proteins

Table 4 Total preference values and LSD results obtained to chicken rotti with different protein source

Sample most favorite				Sample least favorite	
Soy (27)	Broad bean (43)	Lentil (44)	Pea (54)	Pea (54)	<i>Spirulina</i> (79)
				<i>Spirulina</i> (79)	<i>Chlorella</i> (89)

Samples in the same row not have significant differences ($P > 0.05$) and samples in different row show significant differences ($P > 0.05$)

Numbers in brackets are $\sum$ score

Fig. 4 Principal component analysis showing the projection of samples (a) manufactured with different plan-based proteins according to the centesimal and texture properties and acceptability (b)

presented intermediate values. Food companies may use these results to improve specific quality parameters of chicken rotti prepared using these ingredients: while soy had the best sensory attribute, it did not have important protein/amino acids profile. On the contrary, the chicken rotti made with algae protein had the best aminogram but the lowest sensory acceptability. In terms of balance between chemical composition and sensory acceptability, broad beans and lentils proteins seem to be interesting ingredients to manufacture chicken rotti.

Conclusion

The different protein-enriched chicken rotti samples exhibited significant changes in the physicochemical and chemical composition, textural properties, and amino acid content which have influence in acceptance and preference. Chicken rotti enriched with seaweed protein presented the highest total amino acid content and showed the best ratio of essential and non-essential amino acids. As for the sensory analysis, the soy protein chicken rotti presented the highest means for acceptability and preference followed by

broad bean and lentil proteins rotti. PCA showed that broad beans and lentils proteins as interesting ingredients to replace soy protein in chicken rotti.

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