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Effect of different protein sources (plant, cricket powder and microalgae) on the technological and functional properties and sensory characteristics of pork meatballs

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ABSTRACT

This study demonstrates the potential use of soy flour, spirulina powder, cricket powder, buckwheat flour and lupin flour as alternative protein sources in a minced meat product (meatballs) by comparing the reformulated meatballs with control meat-only samples. We analysed the use of the same amount of each of the selected protein sources on the technological and functional characteristics and the sensory perception of raw and cooked meatballs. Higher pH and better emulsion stability was observed in the soy flour, spirulina and cricket powder samples compared to the meat-only sample. In the texture profile, greater hardness and springiness of the samples made with buckwheat flour, soy flour and spirulina powder was found compared to the meat-only sample, but lesser values for the same parameters when cricket powder or lupin were added. The results obtained indicated that spirulina and cricket powder are promising ingredients for the innovative formulation of meat products and are suitable for application in a mixed design approach.

1. Introduction

Consumer interest in healthy and nutritionally complete foods, both of animal and plant origin, is constantly growing. Simultaneously, in the context of resource scarcity, global climate change, environmental pollution and increasing food demand, the strategies for more efficient and sustainable agri-food systems have prompted researchers and producers to explore different protein sources that could be used for obtaining new, healthy, sustainable and natural foods with a balanced nutritional composition (*Markard et al.,* 2012; *Velasco-Muñoz et al.,* 2021). Meat products, being both sources of a wide variety of important nutrients (proteins, lipids, minerals and vitamins) (*Jiménez-Colmenero and Delgado Pando,* 2013*; Lorenzo and Pateiro* 2013*; Lorenzo et al.,* 2014) and recognisable, widely consumed and valued foods due to their taste qualities, can be seen as a suitable object of composition modification with a view to the manufacture of innovative products with improved nutritional benefits (*dos Santos et al.,* 2016*; Lorenzo et al.,* 2016; *Domínguez et al.,* 2017; *Heck et al.,* 2017). Meat product reformulation through the addition of various plant products and proteins is not a new invention; however, this trend is nowadays oriented to the technical and economic benefits but also to the enrichment of the finished products with various natural sources of biologically active compounds (*Eisinaite et al.,* 2016) that reduce the risk of a number of socially

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significant diseases (*Neuhouser,* 2019). Out of all plant proteins, soy protein products are the most widely used in the food industry, the meat industry in particular (*Asgar et al.,* 2010). Regardless of all proven technological and health benefits of soy protein preparations (isolates, concentrates, texturisers, granules and flours), they are classified as allergenic foods (*Spychaj et al.,* 2018). Furthermore, there have been concerns in recent years that soy production is one of the causes of deforestation in South America's rainforests, and that it is one of the infamous genetically modified foods rejected by many consumers in Europe. These are the reasons for the growing number of studies searching for other, more sustainable meat alternatives (*Altmann et al.,* 2019*; Grahl et al.,* 2018).

Lupin flour (hereafter called lupin) and buckwheat flour are possible sources of plant protein in the technology of various meat products owing to their similarities with soy (*Danowska-Oziewicz and Kurp,* 2017) and their good emulsifying and gelling properties (*Yang et al.,* 2021*; Janssen et al.,* 2007). Buckwheat has been recognised as a promising functional food source and is cultivated in various countries worldwide (*Ohsawa et al.,* 2020*; Pinski et al.,* 2023). Therefore, incorporating buckwheat in product formulations can make them attractive to the food market on account of their health benefits, and these products can become suitable food for people with gluten intolerance (*Sofi et al.,* 2022). The addition of lupin to foods can enhance their nutritional value by improving their protein content and well-established sustainability parameters, which is regarded as a crucial factor in the promotion of healthier food environments (*Abreu et al.,* 2023). Other foods rich in high-quality proteins and referred to as "foods of the future" for their potential to address the challenge of feeding the world's growing population are insects and microalgae (*Koyande et al.,* 2019*; Ruskova et al.,* 2023). Both of them fall within the scope of the so-called "novel foods", thus attracting growing interest not only from a nutritional perspective, but also from the point of view of the European Union's circular economy strategy and the reduction of greenhouse emissions, since they offer a way of securing a sufficient supply of protein in a sustainable manner.

This study demonstrates the potential use of soy flour, buckwheat flour, lupin (lupin flour), cricket powder and spirulina powder as alternative protein sources in a minced meat product (meatballs) by comparing the reformulated samples with control, meat-only samples. We aimed to compare the use of the same amounts of each of the five selected meat protein substitutes on the technological and functional characteristics of raw and cooked meatballs and on their sensory perception.

2. Materials and Methods

Six different meatball types were prepared for the study. The following recipe was used as the basic formulation: lean pork meat (shoulder blade): 50%; semi-fat pork: 50%; potable water: 20%; sodium chloride: 1.8%. The formulation without additives was used as a control. Soy flour, buckwheat flour, lupin flour, cricket powder and dry spirulina powder were added in 1% concentrations to the other five meatball types, respectively. Before the addition, the dry additives had been hydrated in water in a 1:3 w/v ratio. The protein additives were purchased from retail shops, cricket powder was supplied by EntoSynergy Ltd (Bulgarevo, Bulgaria), and the meat raw materials were supplied by the AGO–MES meat manufacturing company (Asenovgrad, Bulgaria).

The samples were prepared in the following production sequence: the meat was ground using a meat grinder with a grid diameter of 6 mm and divided into six equal parts; the necessary salting materials, water, and a protein supplement were added to each part in a mixer as indicated in Figure 1; 0.060 kg meatballs were formed from each obtained meat batter and were then packed on polyvinyl chloride plates and stored at 4±1 °C. At 24 h after the meatballs were prepared, the raw meatballs were analysed according to the following physicochemical parameters: pH, emulsifying capacity and colour characteristics. After roasting the meatballs to a temperature of 72°C in the centre, they were examined to determine their thermal weight loss (cooking yield) and textural parameters and were subjected to sensory evaluation.

pH analysis

The pH determinations were carried out on a prepared aqueous extract of the sample (1:9 w/v), using a pH meter (MS 2004, Microsyst, Bulgaria).

Colour analysis

The colour parameters lightness, (L*), redness, (a*), yellowness, (b*), chroma (C), and hue (h) were determined spectrophotometrically using a Minolta Chroma meter (model CR 410, Osaka, Japan) in the CIELab system.

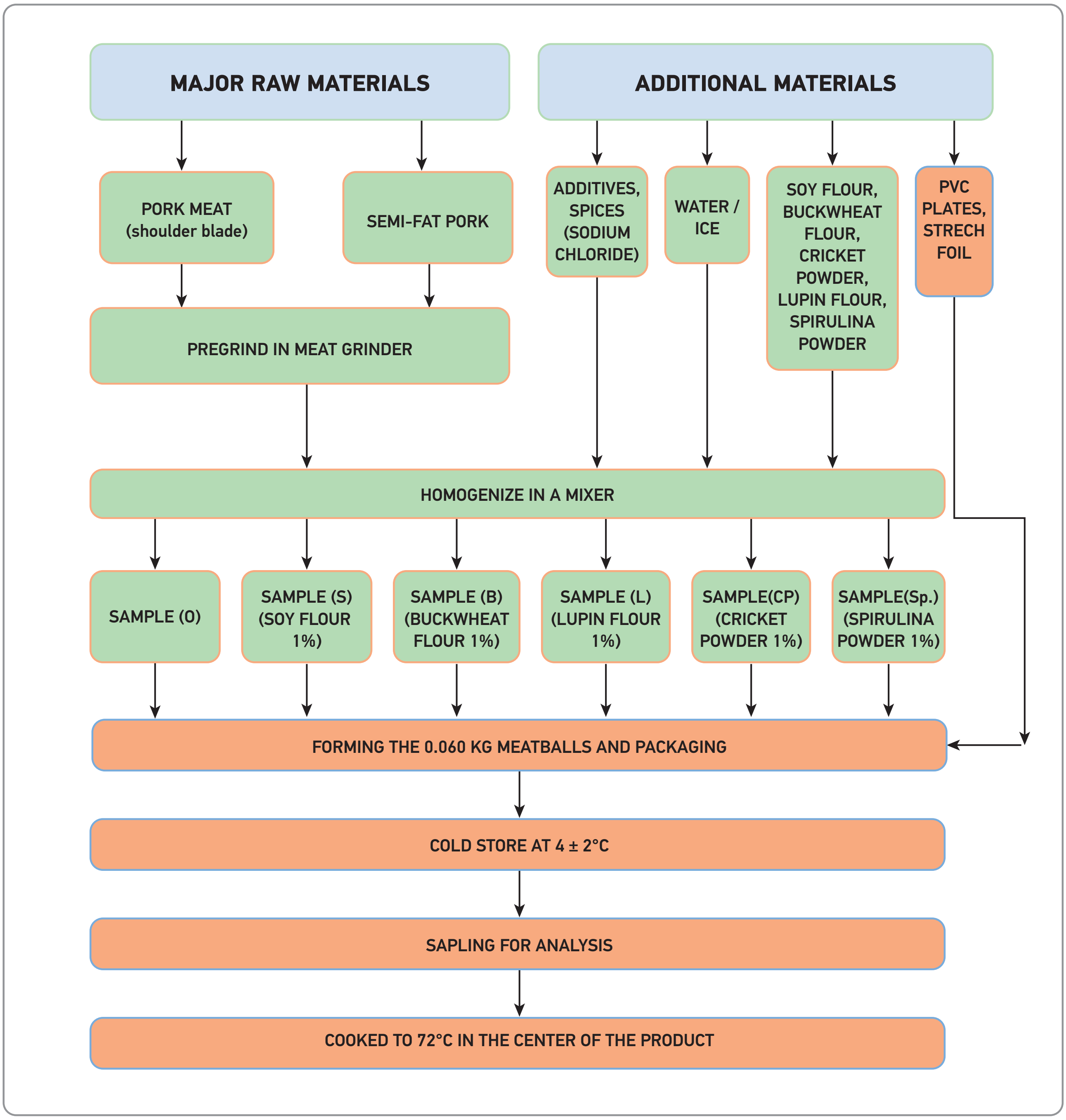

Figure 1. Flow chart of the meatball preparation with the addition of different protein sources to the samples

Emulsion stability

For determination of the emulsion stability, the method described by *Zorba and Kurt* (2006) was used. Thirty grams of each sample before and after heat treatment were weighed into a centrifuge tube and heated in a water bath at 70 °C for 30 minutes. Immediately after heating, the tubes were centrifuged at 2000 rpm min^{-1} for 10 minutes, and the separated water and oil were weighed and used to calculate the emulsion stability (ES).

Cooking yield

The cooking yield was determined as the percentage of weight loss in the samples after cooking according to the method described previously (*Murphy et al.*, 1975).

Texture profile analysis (TPA)

A TA-XT Plus texture analyser (Stable Micro Systems, Surrey, UK) was used to analyse the texture profile of the finished heat-treated meatballs under the following measurement conditions: sample size: 40±2 mm in diameter and 25±2 mm in height; diameter of the compression cylinder: 50 mm, compression speed: 2 mm s^{-1}; degree of deformation: 8 mm; and relaxation time between two compressions: 5 s. The hardness, springiness, cohesiveness, gumminess, chewiness and adhesiveness of the samples were calculated on the basis of the obtained values (*Bourne,* 1978*; Bourne,* 2002; *Kim et al.,* 2009).

Sensory evaluation

The sensory evaluation was performed in a sensory laboratory, with precautions taken to ensure that each panellist would make an independent evaluation. The analysis was performed on six meatball samples, each sample designated by a 3-digit number and randomly assigned to trained panellists. The meatballs were evaluated for appearance, colour, aroma, consistency, taste, aftertaste, saltiness and overall sensory evaluation. Each sensory parameter was rated along a structured 7-point scale with values ranging from *dislike extremely* (1), *dislike very much* (2), *dislike* (3), *acceptable* (4), to *like* (5), *like very much* (6) and *like extremely* (7) (*Kırkın et al.,* 2019).

Statistical analysis

All the data obtained were statistically analysed by one-way analysis of variance (ANOVA) using the Statgraphics 16 software product. Significant ($p \leq 0.05$) differences between the treatments were determined using Duncan's post hoc test. All experiments were performed in triplicate, and the data presented in the tables and figures were expressed as means±standard deviation (SD).

3. Results and Discussion

The addition of the different protein sources, although in small amounts (1%), had a significant effect on the pH values of the meatballs (Table 1). The highest pH values were measured in the soy samples, followed by the spirulina and cricket powder samples ($p<0.05$). In contrast, the addition of the other two plant flours, buckwheat and lupin, led to lower pH values of the samples, even below the measured value for the meat-only control sample. An increase in pH with the addition of spirulina, soy or insect powder was also reported by other authors who studied the effect of such additives following their addition to sausages (*Kim et al.,*2016*; Marti-Quijal et al.,* 2019). The changes in the pH values could have resulted directly from the pH of the individual ingredients, but it is important to point out that the use of additives that can increase the pH of the meat batter is desirable from the point of view of the water holding capacity of the meat product; hence, a higher yield and better consistency during heat treatment are obtained. In contrast, a low pH can cause protein denaturation which affects protein solubility, water holding capacity and colour (*Cornfort,* 1994).

Each one of the additives used, due to its own colour and its hydration before being added to the meat batter, led to changes in the general colour characteristic of the meatballs with the additives compared

Table 1. Effect of the addition of different protein sources on the pH value and the colour characteristics of raw pork meatballs

Sample	Parameter					
	pH	lightness (L*)	redness (a*)	yellowness (b*)	chroma (C)	hue (h)
O	6.16 ± 0.01^{c}	52.89 ± 7.48^{b}	10.72 ± 1.12^{b}	5.73 ± 0.54^{ab}	12.18 ± 0.88^{b}	28.32 ± 4.19^{a}
S	6.36 ± 0.01^{f}	60.82 ± 6.20^{c}	10.91 ± 3.66^{b}	7.23 ± 1.97^{bc}	13.10 ± 4.11^{bc}	33.97 ± 2.23^{ab}
B	6.12 ± 0.01^{a}	55.51 ± 2.61^{bc}	12.11 ± 1.08^{b}	7.93 ± 0.98^{c}	14.37 ± 1.31^{bc}	32.41 ± 2.93^{ab}
L	6.14 ± 0.01^{b}	56.31 ± 6.49^{bc}	11.89 ± 1.30^{b}	8.76 ± 0.97^{c}	14.77 ± 1.39^{bc}	36.41 ± 3.27^{b}
CP	6.23 ± 0.01^{d}	53.68 ± 6.86^{bc}	12.19 ± 1.44^{b}	8.79 ± 1.78^{c}	15.09 ± 1.74^{c}	35.69 ± 5.60^{ab}
Sp	6.30 ± 0.01^{e}	33.55 ± 3.12^{a}	-1.14 ± 1.03^{a}	4.87 ± 0.73^{a}	5.08 ± 0.79^{a}	102.97 ± 10.96^{c}

Note: Results are mean values for the respective samples after triplicate measurements of the individual parameters.

a-e: Values bearing the same superscripts were not statistically different ($P > 0.05$).

Sample description: sample O: control meatballs without additives; sample S: soy flour sample; sample B: buckwheat flour sample; sample L: lupin flour sample; sample CP: cricket powder sample; sample Sp: spirulina powder sample.

to the meatballs without additives (Table 1). Thus, for instance, the highest L* values were recorded for the soy and lupin samples while the lowest lightness was observed for the spirulina sample, where, despite its good hydration, the dark green-blue colour of the spirulina strongly affected all colour parameters of the end product. The negative a* and b* values measured in these meatballs were attributed to the presence of phycocyanin (blue colour) and chlorophyll pigments (green colour) in the composition of *Spirulina platensis* (*Danesi et al.,*2004*; Marrez et al.,* 2013; *Marti-Quijal et al.,* 2019).

The cricket powder sample also showed higher *L**, *a** and *b** values compared to meatballs without additives (Table 1), and this was consistent with the results obtained by *Smarzyński et al.* (2019), who observed higher *L*, a*, b** when cricket powder was used in pork pâté. Although the values obtained for the red colour component remained statistically indiscernible (p>0.05) except for the spirulina sample, the highest a* values were measured in the cricket powder (12.19±1.44) and buckwheat (12.11±1.08) samples. This was in conformity with the results reported by other researchers who studied the effect of the addition of insect powder (*Kim et al.,* 2016*; Han et al.,* 2023) and buckwheat flour and flakes (*Shin et al.,* 2017*; Salejda et al.,* 2022) in the production of pork or poultry sausages. On the basis of the comparison of the *C* and *h* values of the meatballs, they were arranged in the following order with regard to the degree of colour changes in relation to the control meatballs without additives: buckwheat < soy < cricket powder < lupin < spirulina.

The emulsion stability of the meatballs prior to their heat treatment is presented in Table 2. The lowest emulsion stability values were reported for the lupin flour (78.23±1.14) and buckwheat flour (79.70±3.35) samples, which led to significant water losses during the subsequent heat treatment. The low pH values of these samples were a good indicator of the stability of the meat emulsions obtained (*Ho et al.,* 2022). The best emulsion stability was observed in the meat batter of the soy (85.78±1.27) and spirulina (85.32±1.24) samples, without any statistically significant difference between them (p>0.05). This corresponds to the high gelling and emulsifying capacity reported for proteins in spirulina (*Hamed et al.,* 2015*; Bernaerts et al.,* 2019), which makes the latter a competitive technological and functional ingredient compared to some commercial proteins used as emulsifiers in meat products, such as sodium caseinate, whey proteins and soy protein preparations (*Teuling et al.,* 2019).

Regarding the weight losses after heat treatment, represented via the finished product yield (Table 2), the investigated protein sources led to differences in this parameter as well. The lowest losses were found for the meatballs without a hydrated additive, followed by the samples with spirulina, cricket powder and lupin. The higher protein content in the additives used was probably one of the reasons for the differences in the yields (*Kolb et al.,* 2004*; Christaki et al.,* 2011). According to *Kim et al.* (2016), the higher yield obtained when using insect powder in meat products is due to the lower moisture content and higher protein content in

Table 2. Effect of the addition of different protein sources on the emulsion stability, textural parameters and cooking yield of pork meatballs

Sample	Parameter							
	Hardness (N)	**Springiness**	**Cohesiveness**	**Gumminess**	**Chewiness (N)**	**Adhesiveness (N mm)**	**Emulsion stability, %**	**Cooking yield, %**
O	52.23±17.22^{ab}	6.52±2.15^{ab}	0.55±0.02^{a}	33.53±7.46^{cd}	29.93±7.21^{cd}	−0.03±0.00^{b}	82.27±3.69^{bc}	60.51±2.56^{d}
S	65.58±18.45^{bc}	7.80±2.31^{bc}	0.54±0.06^{a}	30.43±3.00^{cd}	27.22±2.30^{cd}	−0.08±0.05^{ab}	85.78±1.27^{c}	58.63±3.21^{bc}
B	76.82±20.83^{c}	9.58±2.58^{c}	0.49±0.02^{a}	39.92±7.22^{d}	35.56±7.97^{d}	−0.08±0.10^{ab}	79.7±3.35^{ab}	54.39±3.32^{a}
L	43.21±6.31^{ab}	5.39±0.78^{ab}	0.54±0.03^{a}	23.39±4.45^{bc}	21.22±4.78^{bc}	−0.13±0.08^{ab}	78.23±1.14^{a}	58.63±1.69^{bc}
CP	41.75±14.07^{a}	5.21±1.76^{a}	2.43±2.69^{ab}	18.23±11.35^{ab}	16.69±10.27^{ab}	−0.17±0.20^{a}	82.43±1.18^{bc}	59.01±2.10^{b}
Sp	55.07±19.75^{ab}	6.87±2.47^{ab}	4.35±3.74^{b}	13.81±9.46^{a}	12.94±8.41^{a}	−0.97±0.05a	85.32±1.24^{c}	60.22±1.76^{cd}

Note: Results are mean values for the respective samples after triplicate measurements of the individual parameters.

$^{a-e}$: Values within the same column bearing the same superscripts were not statistically different (p>0.05)

Sample description: sample O: control meatballs without additives; sample S: soy flour sample; sample B: buckwheat flour sample; sample L: lupin flour sample; sample CP: cricket powder sample; sample Sp: spirulina powder sample.

the composition of these products, whereas the lower weight losses in our meatballs containing spirulina could be attributed to this product's high protein and polysaccharide content (*Backers and Noll,* 1998). The use of high protein additives that contain fibre in meat products leads to higher yields due to the improved water immobilisation capacity (*Steenblock et al.,* 2001*; Choe et al.,* 2011). Most probably, the similar technological properties of soy and lupin, related to binding the added water and affecting the texture of meat products (*Asgar et al.,* 2010), made the yields of the samples containing these additives statistically indiscernible. The greatest weight loss, and hence, the lowest yield, was observed in the meatballs made with the addition of buckwheat flour (Table 2). This was consistent with the lowest emulsion stability found for these samples. According to *Pires et al.* (2017), problems in the structure and consistency of finished sausages occurred when the emulsion stability was below 85%, as was the case with our buckwheat flour meatballs.

The texture analysis demonstrated that the buckwheat samples showed the highest hardness, gumminess, springiness and chewiness, together with the lowest values for the cohesiveness parameter (Table 2). Buckwheat proteins have the ability to increase the hardness of the product, similarly to soy proteins (*Bejosano and Corke,* 1998), and in our study, the significant increase in these textural parameters was also a consequence of the deteriorated emulsion stability and the water loss during the heat treatment of these samples. The use of spirulina in the composition (formulation) of the meatballs resulted in numerically lower but statistically indiscernible values for hardness, springiness and adhesiveness, and higher cohesiveness values compared to the soy sample. However, the chewiness and gumminess of the spirulina samples were significantly lower than the soy and all other samples. A similar trend towards a decrease in hardness was also observed by *Marti-Quijal et al.* (2018), who replaced soy with spirulina in the production of cooked turkey breast, as well as by *Parniakov et al.* (2018), who reported a decrease in the values of the textural parameters, with the exception of adhesiveness, in chicken rotti made with the addition of spirulina. Among our meatball types, the lowest hardness and gumminess were observed in the cricket powder sample, which was in contrast to the increase in the hardness of emulsion sausages found by *Kim et al.* (2016). Other researchers, who established a decrease in the hardness and cohesiveness and an increase in the springiness of meat batter after 10% substitution of lean meat with cricket powder (*Ho et al.,* 2022), suggested that different insect protein sources and different meat product preparation technologies could have an impact on the textural properties of the finished products. As a result of incorporating cricket powder in a hydrated state into the meatball batter (as in our study), the higher water content of the product can induce a decrease in the shear force, hardness, springiness and chewiness compared to the meat-only control (*Grahl et al.,* 2018). The highest cohesiveness was obtained

Table 3. Effect of the addition of different protein sources on the sensory descriptors of roasted pork meatballs

Sample	Parameters						
	Appearance	Colour	Aroma	Consistency	Taste	Aftertaste	Saltiness
O	6.7±0.48^{a}	6.7±0.48^{c}	6.2±0.63^{b}	5.4±1.26^{a}	6.6±0.52^{bc}	5.9±1.10^{b}	6.0±0.82^{b}
S	6.3±0.48^{a}	6.2±0.79^{bc}	6.2±1.03^{b}	5.7±0.82^{a}	6.8±0.42^{c}	6.2±1.03^{b}	5.9±0.57^{b}
B	6.4±0.70^{a}	5.8±0.79^{b}	5.0±0.82^{a}	5.9±0.74^{a}	5.8±1.32^{ab}	6.2±1.15^{b}	5.4±0.97^{b}
L	6.6±0.70^{a}	5.8±0.92^{b}	4.7±1.06^{a}	5.6±0.52^{a}	5.2±1.55^{a}	5.9±0.99^{b}	5.4±0.70^{b}
CP	6.3±0.82^{a}	6.2±0.79^{bc}	6.2±0.92^{b}	5.2±0.79^{a}	6.2±0.79^{bc}	6.1±0.99^{b}	5.5±0.71^{b}
Sp	6.2±0.92^{a}	5.0±1.05^{a}	6.0±0.94^{b}	5.9±0.74^{a}	4.9±0.99^{a}	4.9±0.88^{a}	4.4±0.52^{a}

Note: Results are mean values for the respective sample after five measurements of the individual parameters.

a-c: Values within the same column bearing the same superscripts are not statistically different (P > 0.05)

Sample description: sample O: control meatballs without additives; sample S: soy flour sample; sample B: buckwheat flour sample; sample L: lupin flour sample; sample CP: cricket powder sample; sample Sp: spirulina powder sample.

in our samples with cricket powder and spirulina, which was in conformity with the results reported by *Kim et al.* (2016), who investigated the addition of new protein sources to emulsion-type meat sausages and also recorded an increase in cohesiveness compared to the control. Gumminess and chewiness parameters give an idea of the structural and mechanical properties that affect performance of the products during consumption. In the soy sample, these parameters were closest to the meat-only sample, whereas the spirulina and cricket powder samples showed the lowest gumminess and chewiness. In view of the fact that the low hardness and springiness of meat products can result in a lower quality product from the consumers' point of view, the cricket powder meatball was the least desirable of our formulations with regard to this parameter. This is consistent with the data of *Han et al.* (2023), who investigated the effect of cricket powder addition to meat sausages on their texture and emulsifying capacity.

Each one of the protein sources added affected the colour, taste and texture of the resultant reformulated meatballs. However, any difference in colour and taste of reformulated products is usually perceived as undesirable by consumers (*Jeon,* 2006; *Prakash and Kumari,* 2011; *Beheshtipour et al.,* 2013). Therefore, the soy and cricket powder samples were evaluated as being the most acceptable in terms of colour and taste (Table 3), due to their score proximity to the meatballs without additives. As had been expected, the spirulina sample received the lowest scores for these parameters because the green colour of microalgae affects consumer perception adversely (*Becker,* 2007; *Fradique et al.,* 2013). Furthermore, heat treatment of spirulina meatballs even increased the darkened colour. In addition to the dark, almost black colour of these meatballs, an earthy aftertaste and musty algae odour were also detected, similarly to the sensory results obtained by *Grahl et al.* (2018). Interestingly, the spirulina sample was rated as the saltiest among our products, probably due to the sodium and potassium ions contained in spirulina (*Janda et al., 2023*), and which are detected by the ion channels on the tongue and amplify the saltiness sensation. Lower aroma and taste grades were also given to the lupin and buckwheat samples, although both were rated positively, as liked and liked very much, respectively.

In terms of the degree of overall liking and acceptance by sensory panellists, the meatballs were ranked in the following ascending order: lupin < buckwheat < spirulina < cricket powder < soy < control. (Figure 2).

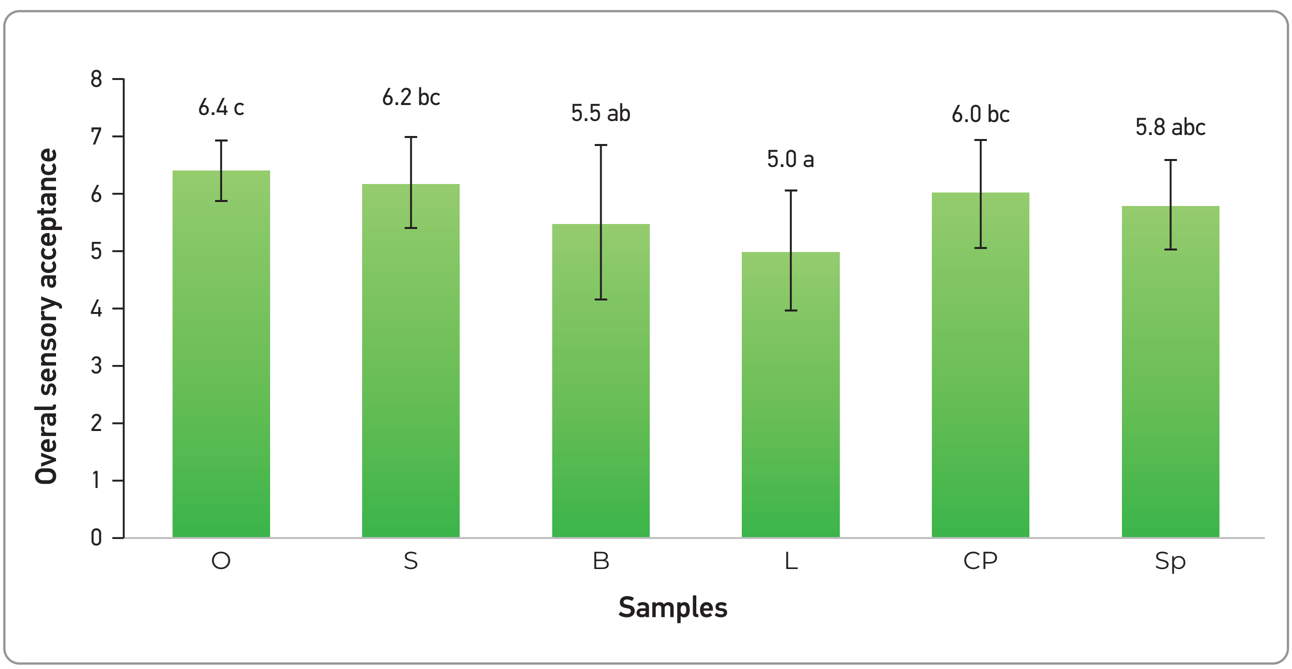

Figure 2. Overall sensory acceptance of the control and reformulated meatballs with different added protein sources

Sample description: sample O: control meatballs without additives; sample S: soy flour sample; sample B: buckwheat flour sample; sample L: lupin flour sample; sample CP: cricket powder sample; sample Sp: spirulina powder sample.

4. Conclusion

The experimental data provides objective evidence that the different protein sources, added in 1% amounts to the meat batter of reformulated pork meatballs, led to different emulsion stability and water holding capacity in the meat batter, as well as to modifications in the textural characteristics of the finished products. The inclusion of soy, spirulina or cricket powder as protein sources contributed to better emulsion stability and lower losses compared to the lupin and buckwheat samples. In the texture profiling, greater hardness and springiness of the buckwheat flour, soy flour and spirulina samples were observed compared to the control meatballs without additives; however, values of the same parameters, compared with the control, were lower with the addition of cricket powder or lupin. Significant differences were recorded regarding the colour parameters (L*, a*, b*, C and h), these colour differences were directly dependent on the protein source used, and they had impacts on the sensory evaluation. The results obtained indicate that spirulina and cricket powder are promising ingredients for the innovative formulation of minced meat products and are suitable for application in a mixed design approach.

Uticaj različitih izvora proteina (povrće, brašna od cvrčka i mikroalge) na tehno-funkcionalna svojstva i senzorne karakteristike svinjskih ćufti

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INFORMACIJE O RADU

Ključne reči:
Spirulina u prahu
Sojino brašno
Brašno lupina
Prah od cvrčka
Parametri boje
Teksturne karakteristike
Stabilnost emulzije
Senzorna procena

APSTRAKT

Ova studija je pokazala potencijalnu upotrebu spiruline u prahu, praha od cvrčka, brašna od heljde i lupine kao alternativnog proteina u proizvodu od mlevenog mesa (mesne ćufti) upoređujući preformulisane uzorke sa kontrolnim uzorcima napravljenim od soje i sa uzorcima samo od mesa. Analizirali smo upotrebu jednake količine svakog od odabranih izvora proteina na tehnološke i funkcionalne karakteristike sirovih i kuvanih ćufti i njihovu senzornu percepciju.Uočeno je povećanje pH vrednosti i stabilnosti emulzije u uzorcima sojinogbrašna, spiruline i praha od cvrčkau poređenju sa uzorkom samo sa mesom. U profilu teksture utvrđeno je povećanje čvrstoće i elastičnosti uzoraka napravljenih od heljdinog brašna, sojinog brašna i spiruline u prahu u poređenju sa uzorkom samo od mesa i smanjenje istih parametara kada su dodani praha od cvrčka i lupina.Dobijeni rezultati ukazuju da su spirulina u prahu i praha od cvrčka obećavajući sastojci za inovativnu formulaciju proizvoda od mesa i pogodni za primenu u mešovitom dizajnerskom pristupu.

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