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Research Article

Evaluation of textural and sensorial properties of burger patties produced with plant-based protein alternatives

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ABSTRACT

Recently, there has been a growing interest in alternative protein sources. This study aimed to determine the textural and sensory properties of vegan burger patties produced with plant-based (soy and pea) protein sources instead of meat protein. For this purpose, 14 different vegan burger patties produced with soy and pea-based protein alternatives were obtained from different brands in the İstanbul market. Burger patties were analysed in terms of moisture content, cooking properties, instrumental colour, texture profile, and sensory properties. According to the results, pea-based burger patties have a higher moisture content and cooking loss and a lower cooking yield than soy-based patties. The L^* and a^* values of the pea-based patties tended to be higher than those of the soy-based patties, while the b^* values were generally higher. In addition, the texture profile analysis of soy and pea-based burger patties shows differences in texture attributes that may affect consumer preference and overall eating experience. In the sensory evaluation, a significant difference between soy and pea-based burger patties was observed only for juiciness and spicy taste characteristics. The research findings shed light on alternative proteins' textural and sensorial properties and their role in the food industry, particularly in developing vegan burger patties. These differences in sensory attributes and colour and texture analysis between soy and pea-based burger patties highlight the importance of ingredient selection and formulation in developing plant-based protein products.

Keywords: Pea-based burger patties, Sensorial properties, Soy-based burger patties, Textural properties

Introduction

Meat, the highest quality protein source among animal-originated food, has an excessively savoury taste and nutritional attributes. Meat proteins are classified into two groups. Some of them have all amino acids essential for the human body, whereas the rest conduce to the food industry via their functional features (Asgar et al., 2010; Piazza et al., 2015; Xiong, 2004). An increasing acceleration has been recorded in global meat production, reaching 357 million tons in 2021 (FAOSTAT, 2023). It is possible to say that this situation occurred initially due to developments in the industry, followed by a hectic work pace and personal preferences (Joseph et al., 2020). On the other hand, the world population seems to be growing rapidly and is estimated to be almost 9 billion by 2050. This means that people will need much more meat resources than humans consume. For this reason, food factories have developed alternative products that can replace meat. However, consumers have become aware of the negative aspects of conventional meat, such as health effects, environmental impacts, animal welfare, ethnical and religious beliefs, personal preferences and habits.

In terms of health impact, the high-fat content of meat, which contains saturated fatty acids, causes serious health problems such as cholesterol, stroke, diabetes type 2, colorectal cancer, cardiovascular (CV) and cerebrovascular diseases (Cengiz & Gokoglu, 2005; Muguerza et al., 2004; Profeta et al., 2021; Richi et al., 2015; Simopoulos, 2002). Excessive intake of red meat and meat products in routine diets seriously threatens human health (Apostolidis & McLeay, 2019). For this reason, the World Health Organization (WHO) recommends that fat is between 15% and 30% of the calories in the diet, while saturated fat should take place less than 10%. Also, it defends that cholesterol intake must be limited to 300 mg/d in protective activity for CV diseases (WHO, 2003).

Livestock are a major part of the ecosystem, and the ecosystem's functional movement relates to these animals' presence. Raising livestock and meat production in recent years seems to have vital effects on the environment, such as greenhouse gas emissions and water pollution, leading to decreased biodiversity and increased climate change (Katare et al., 2022). From this point of view, it is evaluated as a situation that triggers meat consumers to experience anxiety (de Vries et al., 2011; Erisman et al., 2011; Escribano et al., 2021; Profeta & Hamm, 2019).

Animal welfare is another major reason for rejecting meat consumption. The idea of protecting animal rights also supports it. This situation significantly affects people's choice to abandon animal protein and look for new alternatives (Thavamani et al., 2020). Because of this, humans may tend to a flexitarian or vegetarian diet or veganism (Profeta et al., 2021). Moreover, according to ethnic and religious beliefs, meat consumption differs in some geographies. The prohibition of different animal meat products in Muslims, Jews, and Hindus alternative protein sources will fulfil the needs of consumer communities (Asgar et al., 2010). High meat prices are also one of the main reasons forcing food plants to switch to other protein sources (Bhat & Karim, 2009; Boye et al., 2010).

Alternative protein sources are divided into five groups: plant-based alternative proteins, pulses, single-cell protein (algae, mycoprotein) insects, and cultured meat (Onwezen et al., 2021). Plant-based protein sources have the most widespread production and consumption network. Legumes such as soy, peas, beans, lentils, and chickpeas are used for this purpose.

Soybean proteins are the largest source for manufacturing texturized protein products worldwide. Soybean contains 35% to 40% protein, which is high quality due to its relatively well-balanced composition of amino acids, especially lysine (Dubois & Hoover, 1981; Golbitz & Jordan, 2006; Klein et al., 1995). Also, they play a major role in food functionality via some features such as gelling/textural capabilities, water absorption, fat absorption, emulsification, elasticity, and colour control (Singh et al., 2008). Pea protein has become an increasingly preferred protein source in recent years because it is a non-genetically modified organism (GMO), gluten-free, highly nutritious, and low-allergenic (Lam et al., 2018). Pea protein exhibits a balanced amino acid profile, characterized by high levels of the amino acid lysine (Lu et al., 2020). Pea seeds comprise approximately 23.4% protein, 21.2% total dietary fibre and 49.0% starch (Tulbek et al., 2024).

Plant-based meat alternatives reduce the burden by producing less greenhouse gas emission, using less water (Keoleian & Heller, 2018; Tilman & Clark, 2014) and leaving several times less environmental footprint than industrial meat production (Reijnders & Soret, 2003). The fact that it has beneficial aspects in terms of health also causes people to tend towards this direction. Even if consumers are still cautious about the taste and edibility of these products, this can be considered an important transition to sustainable food consumption (Szenderák et al., 2022).

Based on this information, this study was carried out to determine the textural and sensory qualities of vegan burger patties produced with plant-based protein sources such as soy and pea instead of meat protein.

Materials and Methods

Sampling

Fourteen vegan burger patties produced with plant-based protein alternatives (soy and pea) from different brands commercially available in İstanbul, Türkiye were collected from September 2023 – May 2024.

Seven soy-based (SB) and seven pea-based (PB) burger patties from three different batches were obtained from the markets at different times and delivered immediately to the laboratory in their original packaging (-18°C).

Physical and Cooking Properties

The moisture content of burger patties was determined by drying 2 g of homogenised sample in a digital moisture analyzer (Sartorious MA45, Germany) at 105°C to constant weight.

The cooking properties (cooking loss [CL], cooking yield [%], reduction in the diameter of the burger [%], and reduction in burger thickness [%]) of burger patties were calculated using the following equations (Murphy et al., 1975).

Immediately after opening, the raw burger patties were cooked in an electric cooker at 150-170°C for 6 minutes (applying heat to both patty's faces for an average of 3 minutes).

Cooking loss = Weight of raw burger – Weight of cooked burger

Cooking yield % = (Weight of cooked burger / Weight of raw burger) × 100

Reduction in the diameter of the burger % = (Diameter of raw burger – Diameter of cooked burger) / (Diameter of raw burger) × 100

Reduction in burger thickness % = (Thickness of raw burger – Thickness of cooked burger) / (Thickness of raw burger) × 100

Instrumental Colour Analysis

CIE L^* (lightness), a^* (redness) and b^* (yellowness) values of burger patties were determined using the HunterLab Color Flex Colour Measurement System (Hunter Associates Laboratory, Inc., USA). All colour measurements were evaluated in "daylight" mode using diffuse illumination (D65 2° observer) with a viewing aperture of 8 mm and a port size of 25 mm. Five measurements were taken from each sample, and the arithmetic means of the results were calculated (AMSA, 2012).

Texture Profile Analysis

The textural profiles of the vegan burger patties were determined by Instron (Model 3343, Instron, UK) texture profile analyser. For the evaluation of the texture profile analysis (TPA) of the samples, 6 measurements were performed for each burger sample and the arithmetic averages were calculated. Hardness (N), cohesiveness, springiness (mm), chewiness (J), gumminess (N) and adhesiveness (J) properties were used to determine the texture profile of the analysed burger samples. The values of these properties were calculated using the following areas and distances and their related equations (Bourne, 1978).

Sensory Analysis

Twelve trained panellists (5 females and 7 males, aged between 25 and 55) evaluated the sensory properties of the vegan burger patties, serving each one raw or cooked (ISO 8586, 2023).

Raw burger samples were subjected to sensory evaluation immediately after the packages were opened, and cooked burger samples were subjected to sensory evaluation after being cooked in an electric cooker at 150-170°C for 6 minutes.

The samples were evaluated in terms of appearance, colour, odour, texture (both raw and cooked samples) and flavour (cooked samples only) attributes using a 10-point bipolar scale (0: extremely weak; 10: extremely strong) and arithmetic averages were recorded.

Statistical Analysis

The statistical differences between and within soy and pea-based vegan burger patties groups were determined using ANOVA (one-way analysis of variance). Duncan's test was used to control the significance of differences between the groups (SPSS, 2017). The trial was conducted with three replicates at different times.

Results and Discussion

In the last decade, several types of new generations of non-meat protein alternatives with meat-like texture, aspect, dietary facts, aroma, and taste have entered the market (Hu et al., 2019; Lu et al., 2020). With the unique imitation of meat, they are expected to positively impact vegetarians and traditional meat-eaters (Szejda et al., 2020). In this context, the present study aimed to evaluate the textural and sensory qualities of vegan burger patty samples produced with plant-based protein sources such as soy and peas.

The component information given in the label of vegan burgers is given in Table 1. Although the products were produced with the same plant base, it was observed that there were differences in nutrient values from producer to producer. The protein values of soy-based burger patties varied between 12 and 21%. On the other hand, the protein values of pea-based burger patties were detected in a much wider range of 12 to 44%. Despite the differences between the components, the energy values of the products were close to each other, while the energy amount increased in parallel with the increase in protein level.

The moisture content and cooking properties of vegan burger patties are shown in Table 2. Pea-based burger patties' moisture content and cooking loss were higher than soy-based ones. However, the cooking yield of pea-based vegan burger patties was lower than soy-based burger patties. The average moisture content varied between 40-62% (n: 7, ~50%) in pea-based burger patties, while it was around 41-57% in soy-based samples. Since the moisture loss caused by the cooking process was higher in pea-based samples, hardness was observed with increased binding in the products. Meanwhile, the preservation of the raw product form was higher in soy-based vegan burger patties with higher cooking yields. Similarly, Bakhsh et al. (2021) reported the average moisture content of the plant-based meat analogue examined in their study as 51.53±0.54%. Simard et al. (2021), who compared plant-based patties' physicochemical and cooking properties with animal-based burger patties, determined that the proportions of the specified parts were lower in plant-based ones. The same study reported that moisture loss was lower in plant-based burger samples; high protein content and low fat and starch content in the meatball composition helped the product retain water. Studies have shown that moisture retention and cooking loss percentage are inversely proportional. Likewise, Chin et al. (2004) confirmed with their data that soy is another plant-based ingredient that reduces cooking weight loss. It is stated that reduced cooking loss is emphasized in product development to attract consumers who appreciate juicier products (Yi et al., 2012).

Table 1. Label information of proximate properties of soy and pea-based vegan burger patties (n=14)

Origin	Sample	Parameters					
		Protein (%)	Fat (%)	Carbohydrate (%)	NaCl (%)	Energy (kcal)	Dietary fibre (%)
Soy-based vegan burger patties	SB1	13.82	13.47	10.9	1.19	227.48	3.72
	SB2	21.4	13.5	6.7	0.9	235	-
	SB3	14.2	14.9	2.9	1.14	207	-
	SB4	13.5	4.1	73.4	0.3	339	-
	SB5	14.6	13.5	10.9	1.2	231	3.7
	SB6	16.9	12.32	9.37	1,77	224.4	4.22
	SB7	20.59	14.07	8.07	0.8	241	
Pea-based vegan burger patties	PB1	12	12	8	1.5	197	4
	PB2	17.5	13.9	7.6	2.6	225.5	4.4
	PB3	12.7	13.7	8.5	2	209	-
	PB4	34.73	8.44	41.64	2	393.12	-
	PB5	36.16	8.23	43.2	1.8	391	-
	PB6	18	8	6	1.2	168	-
	PB7	44.1	7	33.2	0.6	234.8	9.8

Table 2. Instrumental colour (CIE *L*, a*, b**) and cooking parameters of soy and pea-vegan burger patties (n=14)

Origin	Sample	Parameters							
		*L**	*a**	*b**	Moisture (%)	Cooking Loss	Cooking Yield (%)	Reduction in diameter (%)	Reduction in thickness (%)
Soy-based vegan burger patties	SB1	43.10^{c}±0.27	8.41^{e}±0.05	15.14^{e}±0.23	54.82^{b}±0.04	23.64^{b}±0.04	76.45^{e}±0.20	11.88^{a}±0.02	16.67^{c}±0.04
	SB2	32.55^{g}±0.61	13.33^{c}±0.24	17.79^{d}±0.42	50.75^{e}±0.11	5.44^{d}±0.02	93.84^{b}±0.06	3.26^{f}±0.01	7.14^{e}±0.02
	SB3	56.49^{a}±0.44	7.37^{f}±0.16	27.19^{a}±0.17	52.71^{d}±0.09	5.00^{d}±0.04	94.91^{a}±0.03	6.17^{c}±0.02	25.00^{a}±0.44
	SB4	44.52^{b}±0.27	17.35^{a}±0.31	15.48^{e}±0.35	56.97^{a}±0.13	9.29^{c}±0.04	90.07^{d}±0.03	2.33^{g}±0.09	13.33^{d}±0.15
	SB5	40.16^{e}±0.56	10.06^{d}±0.18	16.96^{d}±0.22	53.60^{c}±0.13	27.90^{a}±0.45	71.67^{f}±0.08	10.00^{b}±0.09	-
	SB6	36.17^{f}±0.68	13.25^{c}±0.28	25.20^{b}±0.53	54.52^{b}±0.18	3.67^{e}±0.09	94.66^{a}±0.15	4.11^{e}±0.05	20.00^{b}±0.45
	SB7	41.64^{d}±0.35	14.02^{b}±0.13	22.52^{c}±0.72	41.17^{f}±0.08	3.79^{e}±0.09	93.39^{c}±0.09	5.41^{d}±0.04	-
	P	***	***	***	***	***	***	***	***
Pea-based vegan burger patties	PB1	50.76^{a}±0.46	10.16^{e}±0.66	18.50^{b}±0.35	51.48^{e}±0.13	17.60^{c}±0.27	81.62^{e}±0.13	7.69^{a}±0.05	-
	PB2	39.79^{e}±0.44	12.88^{c}±0.19	18.17^{b}±0.55	49.75^{f}±0.11	21.77^{a}±0.04	75.53^{g}±0.13	4.17^{b}±0.08	20.00^{a}±0.89
	PB3	44.39^{c}±0.29	18.65^{a}±0.09	13.92^{d}±0.14	59.11^{b}±0.05	3.78^{e}±0.09	89.46^{c}±0.09	1.00^{e}±0.13	1.67^{c}±0.09
	PB4	41.77^{d}±0.29	11.38^{d}±0.25	17.30^{b}±0.55	40.76^{g}±0.09	18.51^{b}±0.09	79.26^{f}±0.12	2.15^{d}±0.07	6.25^{b}±0.11
	PB5	45.21^{c}±0.32	14.97^{b}±0.29	15.64^{c}±0.35	58.06^{c}±0.03	5.58^{d}±0.13	94.42^{b}±0.19	3.45^{c}±0.13	20.00^{a}±0.34
	PB6	48.49^{b}±0.69	18.09^{a}±0.33	22.05^{a}±0.45	51.89^{d}±0.04	17.96^{c}±0.01	83.64^{d}±0.06	4.30^{b}±0.13	5.38^{b}±0.17
	PB7	44.44^{c}±0.45	7.37^{f}±0.15	22.47^{a}±0.34	62.09^{a}±0.04	1.82^{f}±0.05	96.00^{a}±0.45	-	-
	P	***	***	***	***	***	***	***	***

a-g Values within a column with different superscripts differ significantly at $p<0.001$(***)

The instrumental colour values of soy and pea-based burger patties are given in Table 2. The lightness (*L**), redness (*a**), and yellowness (*b**) values of soy-based burger patties ranged between 32.55-56.49, 7.37-17.35 and 15.14-27.19, respectively. *L**, *a** and *b** values of pea-based burger patties ranged between 39.79-50.76, 9.37-18.65 and 13.92-22.47, respectively. The mean *L** and *a** values of pea-based burger patties were higher than soy-based burger patties, while the mean *b** values of soy-based burger patties were higher than pea-based ones (Figure 1). The difference between soy and pea-based samples was significant only in the lightness value. This was due to the darker colour of pea-based burger patties compared to soy-based ones. Bakhsh et al. (2021) reported that the yellowish colour in products is due to the soy protein content. Kyriakopoulou et al. (2019) reported that a yellowish-brown colour directly affects the final product quality. Also, the reason why plant-based burgers showed lesser green-red (*a**) and blue-yellow (*b**) colour is because of the compound which is called "leghemoglobin", known as symbiotic haemoglobin (De Marchi et al., 2021). However, most plant-based burgers on supermarket shelves have soy or pea protein as ingredients, which help create the impression of 'bleeding' to imitate meat better, making these products more attractive to consumers (Slade, 2018).

The texture profile analysis of soy and pea-based vegan burger patties is shown in Tables 3 and 4. The differences in the ingredients of soy and pea-based burger patties with different commercial formulations provided a significant difference in the texture profile analyses of the samples ($p<0.05$). The hardness, cohesiveness, springiness, adhesiveness, gumminess and chewiness properties of vegan burgers were similar in some patty formulations. At the same time, a significant difference was observed in the rest of the vegan burger patties (Table 3-4). The adhesiveness properties of pea-based vegan burger patties were equivalent ($p>0.05$). At the same time, significant differences were observed in all textural properties for both based on vegan burger patties ($p<0.05$). However, the variation in tenderness and juiciness properties depending on the ingredients used in the formulations also affected the chewiness properties of the products ($p<0.001$). Meanwhile, the differences in hardness, springiness, gumminess and chewiness were significant in the raw samples of soy and pea-based burger groups. In contrast, there were significant differences in springiness, adhesiveness and cohesiveness after cooking ($p<0.05$, Figure 2-3). The hardness and chewiness values of cooked soy and pea-based samples that lost moisture after cooking started showing similar characteristics ($p>0.05$). In the study of Forster et al. (2024), most plant-based burger samples were evaluated as high in terms of cohesiveness. Also, all plant-based burgers generally received lower scores for the attributes meaty, sweetness, and umami and showed higher scores for bitterness and lingering spice flavours. Samard et al. (2021) also reported that the adhesiveness, chewiness and hardness of the samples were weaker than the meat-based samples due to the presence of a weaker protein network compared to the structure of meat. In the present study, a significant difference was recorded in the adhesiveness of soy-based burger patties. Mabrouki et al. (2023) also stated that chewing before swallowing was necessary for patties made from beef rather than patties-originated peas. This difference is due to the different binding components used in the product formulation. When considering sensory parameters, no statistical difference was observed in the appearance and colour characteristics of vegan burgers of different brands produced by adding peas. In contrast, a significant difference was found in colour intensity between patties produced with soy. This is thought to be because of different additives or spices used in the composition of the patties, which affect the product's colour.

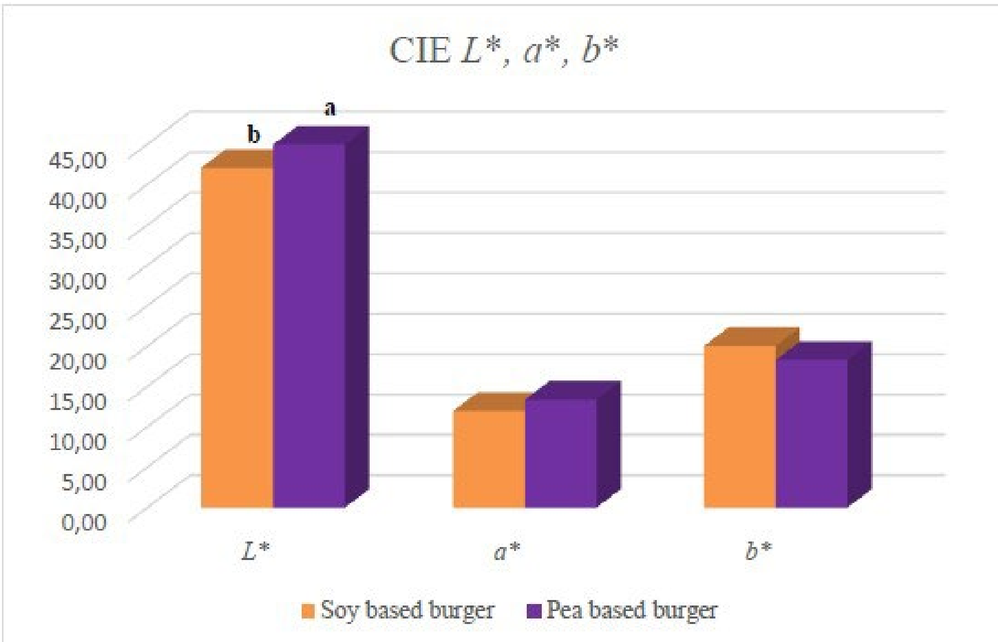

Figure 1. Comparison of instrumental colour values of soy and pea-based burger patties

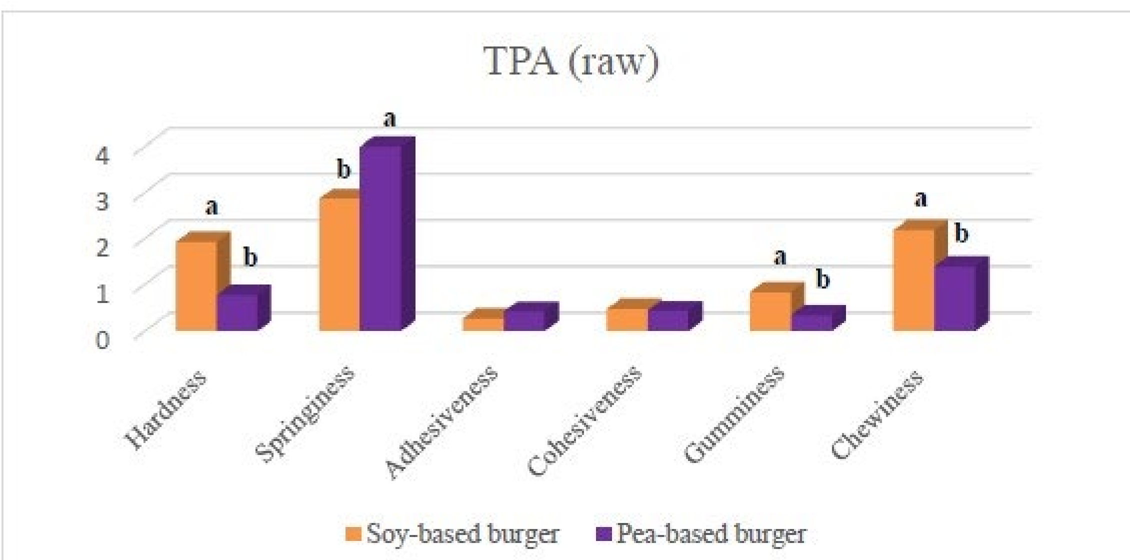

Figure 2. Comparison of texture profiles of raw soy and pea-based burger patties

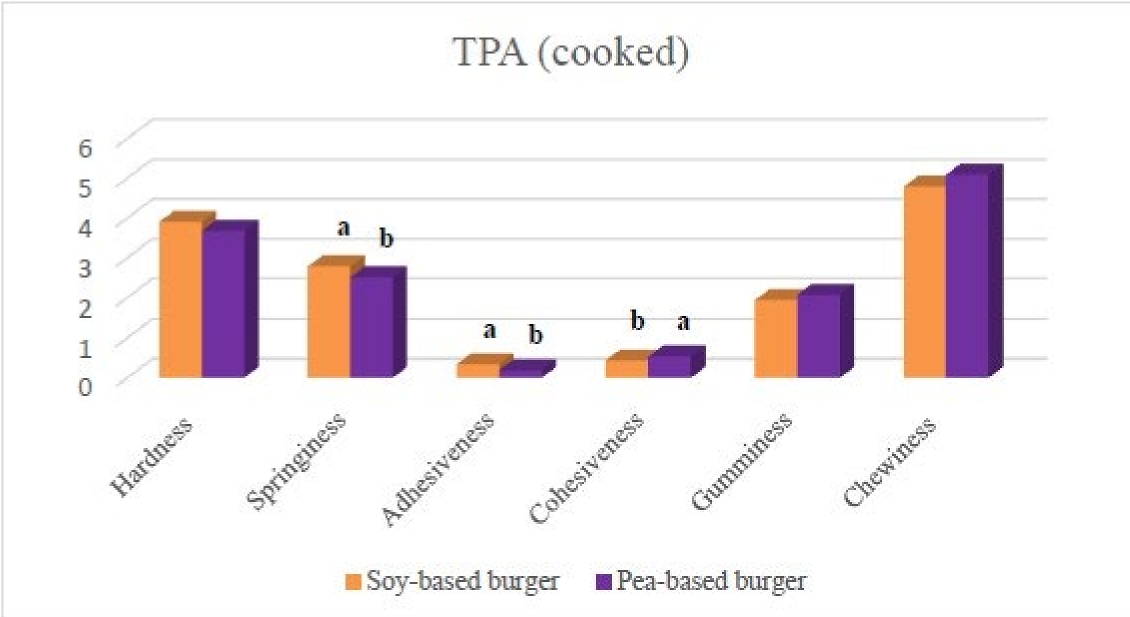

Figure 3. Comparison of texture profiles of cooked soy and pea-based burger patties

Table 3. Means and standard errors (SE) of textural properties of soy-based vegan burger patties (raw/cooked)

	Soy-based vegan burger patties	n	HARDNESS		SPRINGINESS		ADHESIVENESS		COHESIVENESS		GUMMINESS		CHEWINESS	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
RAW	SB1	3	1.078^{de}	0.007	2.583^{cd}	0.112	0.080^{b}	0.025	0.621^{a}	0.008	0.669^{bc}	0.010	1.729^{bcd}	0.079
	SB2	3	1.742^{c}	0.049	3.500^{b}	0.190	0.225^{b}	0.028	0.388^{d}	0.011	0.677^{bc}	0.034	2.367^{bc}	0.163
	SB3	3	0.806^{ef}	0.011	2.209^{cd}	0.081	0.312^{b}	0.159	0.339^{d}	0.005	0.273^{c}	0.008	0.604^{d}	0.033
	SB4	3	2.894^{b}	0.349	2.749^{c}	0.449	0.828^{a}	0.309	0.372^{d}	0.036	1.128^{b}	0.241	3.088^{b}	0.727
	SB5	3	1.349^{cd}	0.026	2.042^{d}	0.032	0.041^{b}	0.011	0.646^{a}	0.008	0.871^{b}	0.019	1.778^{bcd}	0.052
	SB6	3	0.545^{f}	0.034	4.580^{a}	0.201	0.241^{b}	0.046	0.456^{c}	0.015	0.249^{c}	0.020	1.138^{cd}	0.083
	SB7	3	5.027^{a}	0.243	2.375^{cd}	0.081	0.169^{b}	0.014	0.528^{b}	0.023	1.983^{a}	0.413	4.556^{a}	0.906
	P	21	***		***		**		***		***		***	
COOKED	SB1	3	4.754^{c}	0.045	1.667^{d}	0.140	0.139^{c}	0.046	0.625^{a}	0.008	2.972^{b}	0.040	4.959^{c}	0.440
	SB2	3	2.896^{d}	0.175	3.209^{a}	0.110	0.253^{bc}	0.076	0.358^{d}	0.007	1.036^{c}	0.062	3.334^{d}	0.246
	SB3	3	1.289^{e}	0.059	3.084^{ab}	0.227	0.416^{abc}	0.183	0.241^{e}	0.015	0.315^{d}	0.032	0.980^{e}	0.128
	SB4	3	9.173^{a}	0.154	2.750^{bc}	0.220	0.646^{a}	0.139	0.469^{c}	0.016	4.303^{a}	0.142	11.723^{a}	0.700
	SB5	3	7.574^{b}	0.356	2.458^{c}	0.033	0.508^{ab}	0.140	0.568^{b}	0.010	4.289^{a}	0.158	10.536^{b}	0.381
	SB6	3	0.986^{ef}	0.059	3.083^{ab}	0.083	0.204^{bc}	0.042	0.453^{c}	0.009	0.447^{d}	0.032	1.384^{e}	0.120
	SB7	3	0.632^{f}	0.044	3.250^{a}	0.083	0.207^{bc}	0.017	0.372^{d}	0.021	0.191^{d}	0.054	0.607^{e}	0.164
	P	21	***		***		*		***		***		***	

n: number of analyzed samples. *: p<0.05. **: p<0.01. ***: p<0.001.
a-f Values within a column with different superscripts differ significant.

Table 4. Means and standard errors (SE) of textural properties of pea-based vegan burger patties (raw/cooked)

Pea-based vegan burger patties		n	HARDNESS		SPRINGINESS		ADHESIVENESS		COHESIVENESS		GUMMINESS		CHEWINESS	
			Mean	SE	Mean	SE	Mean	SE.	Mean	SE	Mean	SE.	Mean	SE
RAW	PB1	3	0.509^{e}	0.013	3.750^{b}	0.935	0.361^{bc}	0.053	0.500^{b}	0.008	0.254^{de}	0.009	0.988^{c}	0.263
	PB2	3	0.978^{b}	0.037	1.958^{c}	0.193	0.132^{c}	0.036	0.448^{c}	0.015	0.440^{b}	0.027	0.857^{c}	0.087
	PB3	3	0.667^{d}	0.015	4.875^{ab}	0.161	0.481^{b}	0.177	0.442^{c}	0.014	0.294^{cd}	0.007	1.436^{b}	0.074
	PB4	3	0.546^{e}	0.023	4.083^{ab}	0.250	0.289^{bc}	0.024	0.364^{d}	0.019	0.197^{ef}	0.006	0.802^{c}	0.045
	PB5	3	0.816^{c}	0.025	5.167^{a}	0.264	0.942^{a}	0.104	0.419^{c}	0.025	0.339^{c}	0.010	1.764^{b}	0.145
	PB6	3	1.235^{a}	0.050	4.542^{ab}	0.170	0.511^{b}	0.026	0.585^{a}	0.011	0.725^{a}	0.041	3.258^{a}	0.087
	PB7	3	0.654^{d}	0.029	3.626^{b}	0.178	0.252^{bc}	0.053	0.285^{e}	0.023	0.186^{f}	0.016	0.682^{c}	0.078
	P	21	***		***		***		***		***		***	
COOKED	PB1	3	3.842^{c}	0.150	1.750^{e}	0.064	0.176	0.043	0.566^{b}	0.013	2.181^{b}	0.126	3.854^{d}	0.376
	PB2	3	3.909^{c}	0.133	2.417^{cd}	0.124	0.184	0.059	0.585^{ab}	0.010	2.282^{b}	0.057	5.533^{c}	0.371
	PB3	3	2.662^{d}	0.216	2.292^{d}	0.122	0.106	0.035	0.505^{c}	0.009	1.336^{c}	0.087	3.035^{d}	0.192
	PB4	3	3.581^{c}	0.147	2.792^{ab}	0.122	0.223	0.053	0.566^{b}	0.019	2.034^{b}	0.130	5.639^{c}	0.345
	PB5	3	5.718^{a}	0.459	2.750^{bc}	0.135	0.207	0.066	0.570^{b}	0.005	3.260^{a}	0.264	8.903^{a}	0.716
	PB6	3	4.901^{b}	0.244	2.459^{bcd}	0.062	0.173	0.027	0.620^{a}	0.009	3.041^{a}	0.171	7.516^{b}	0.596
	PB7	3	1.112^{e}	0.083	3.125^{a}	0.153	0.275	0.118	0.333^{d}	0.027	0.381^{d}	0.058	1.164^{e}	0.148
	P	21	***		***		NS		***		***		***	

n: number of analyzed samples. NS: Not significant.
a-f Values within a column with different superscripts differ significantly at p<0.001(***)

The sensory properties (appearance, colour, odour, texture and flavour) of soy and pea-based vegan burger patties are shown in Figures 4 and 5. A significant difference was observed in colour intensity between the soy-based burger patties. However, there was no significant difference in the appearance and colour characteristics of pea-based vegan burger patties belonging to different brands. This is thought to be because of different additives or spices used in the composition of burger patties on the product's colour. There was no difference between the odour characteristics of vegan burger patties produced with soy and peas. When soy and pea-based burger patties were compared with each other in terms of odour characteristics, the mealy odour characteristics of pea-based samples were determined to be more intense than soy-based samples, and this difference was found to be significant ($p<0.05$, Fig 4). There was a significant difference in adhesiveness attributes between the vegan burger patties produced with soy ($p<0.01$). This difference is due to the different binding components used in the product formulation (e.g. pea starch, potato starch, methylcellulose, carrageenan). Different spice ratios used in the formulation provided a statistical difference between soy-based vegan burger patties. The difference between pea-based burger patties was significant only in tenderness and juiciness ($p<0.05$). In comparison between the soy and pea-based burger patties, a significant difference was observed in only juiciness and spicy taste attributes ($p<0.01$). Pea-based burger patties were juicier than soy-based ones, while soy-based patties had a more spicy flavour than pea-based patties (Figures 4-5). The difference in juiciness observed between the pea-based vegan patties produced with different ingredients caused the pea-based products to be perceived as juicier than soy-based ones. The soy-based product was reported as a factor that negatively affected the juiciness (Chin et al., 2024). In comparing the taste characteristics of the soy and pea groups, only the difference in spicy taste characteristics was found to be significant. Different spice ratios used in the formulation created a statistical difference between soy-based burger patties. Briefly, food scientists are investigating strategies to improve the quality parameters of meat analogues. In parallel with the increasing consumer demand, all efforts are focused on developing formulations and cooking methods to improve alternative protein sources' colour, flavour, and texture. In this context, it should be noted that the choice of protein source is an important factor to consider, as it can affect the sensory characteristics of the final product (Fiorentini et al., 2020). Also, the textural quality is influenced by many factors. Smaller particles create a smoother texture, while larger particles create a more granular texture. The particle organisation plays an important role in texture perception (Ilic et al., 2024).

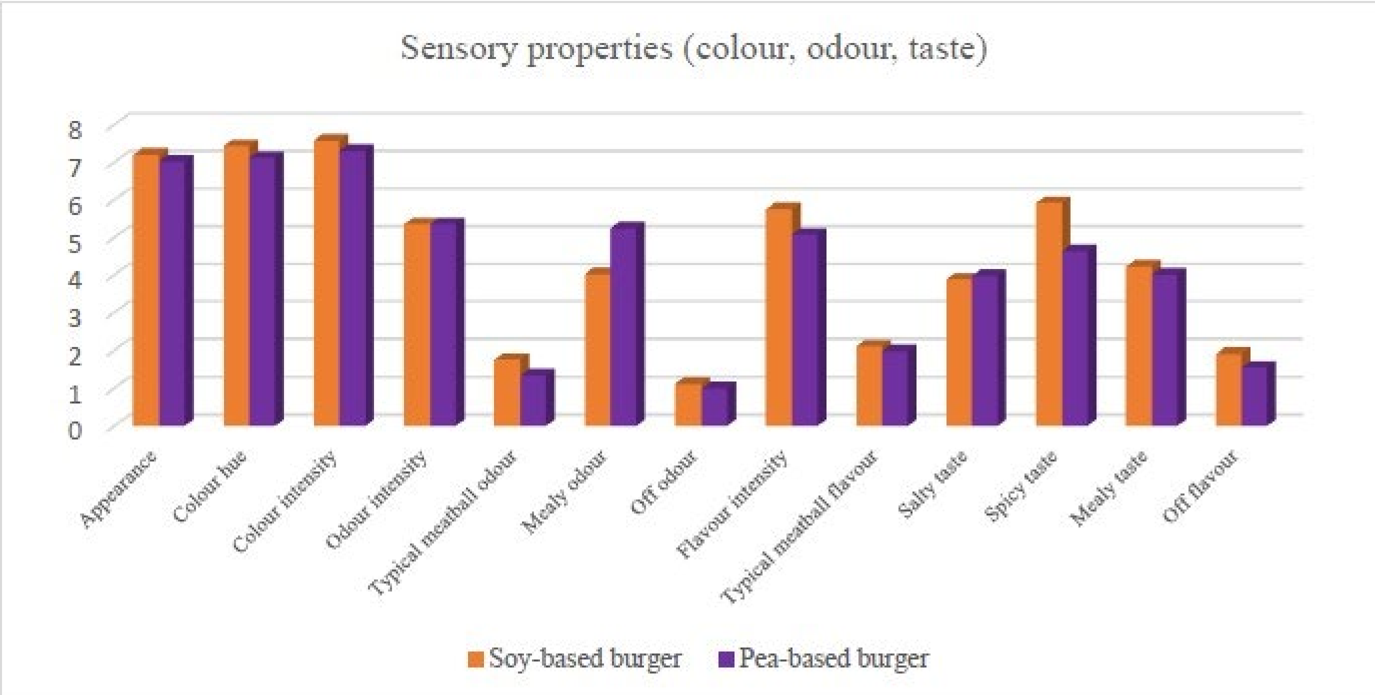

Figure 4. Comparison of sensory properties (colour, odour, taste) of soy and pea-based burger patties

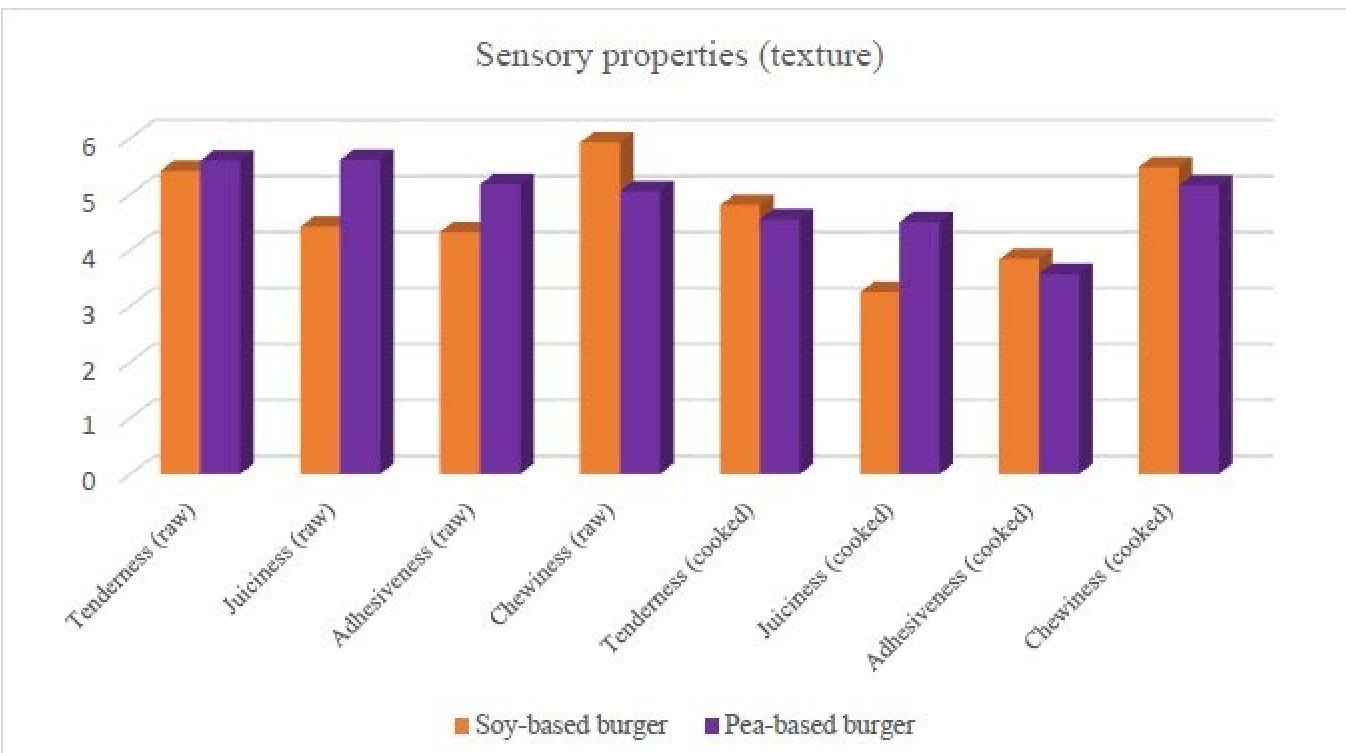

Figure 5. Comparison of sensory properties (texture) of soy and pea-based burger patties

Conclusion

There is a growing trend towards plant-based protein sources due to animal welfare, health effects, environmental impact, and ethnic and religious beliefs. Therefore, patties produced with plant-based protein alternatives can be a good alternative to animal-based patties. To successfully produce meatless plant-based protein patties with a texture that is as close as possible to that of a meat-based burger patty, the textural and sensorial properties of the patties must be well understood. In the present study, texture profile analyses of soy and pea-based burger patties showed differences in texture characteristics, which may affect consumer liking and preferences. Among the sensory characteristics of soya and pea-based burger patties, only the difference in juiciness and spicy flavour was significant. The differences in textural and sensorial attributes between soy and pea-based burger patties highlight the importance of ingredient selection and formulation in developing plant-based protein products. In conclusion, the research findings remark on plant-based protein sources' textural and sensorial quality profiles to understand and meet consumer expectations and demands for these products. Also, it should be added that protein source is an important factor which is decisive over the sensory characteristics of the final product.

Compliance with Ethical Standards

Conflict of interest: The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: The authors declare that this study does not include experiments with human or animal subjects, so ethics committee approval is not required.

Data availability: Data will be made available on request.

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