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COMPARISON OF PATTIES PRODUCED USING MEAT FROM VARIOUS ANIMAL SPECIES WITH BLACK-EYED PEAS AS THE PARTIAL MEAT SUBSTITUTE

(Perbandingan Burger yang Dihasilkan menggunakan Daging daripada Pelbagai Spesies Haiwan dengan Kacang Mata Hitam sebagai Pengganti Separa Daging)

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Abstract

Incorporating plant-based ingredients as meat substitutes can be a strategy to reformulate healthier and more environmentally sustainable meat products. However, meat species variations could lead to different physicochemical and sensory characteristics of the final products. This study aimed to evaluate the physicochemical, sensory, and microstructural properties of patties made from different meat species [chicken (CB), beef (BEB), mutton (MB), and buffalo (BFB)] and substituted with 50% black-eyed peas compared to 100% black-eyed peas (BEP) as the control. An array of physicochemical properties was evaluated, encompassing cooking yield, shrinkage, water holding capacity (WHC), pH, proximate composition, texture, gel strength, and colour. Furthermore, scanning electron microscopy and sensory evaluation were employed to elucidate the microstructural modifications and sensory attributes of the samples. The results reveal significant differences in proximate composition, WHC, and textural properties across the meat species. CB exhibited a higher lightness, cooking yield and softer texture than other samples, which displayed better water retention. Whereas BEB and BFP were harder and chewier. The BEB resulted in lower gel strength and less intact structure, as evidenced by microstructure images and texture profile analysis (TPA) results. No significant difference in sensory traits exists between different meat species. Despite the overall acceptability of BEB being the highest, the MB was the lowest. The composition, texture, and sensory features of chicken and beef with the incorporation of BEP make them viable candidates for use in the development of healthy patties.

Keywords: different meat types, meat analogues, meat emulsion, meat substitute, plant-based protein

Abstrak

Menggabungkan bahan berasaskan tumbuhan sebagai pengganti daging boleh menjadi strategi untuk merumuskan semula produk daging yang lebih sihat dan lebih mampan alam sekitar. Namun, variasi spesis daging boleh menghasilkan ciri-ciri fizikokimia dan deria yang berbeza pada produk akhir. Kajian ini bertujuan untuk menilai sifat fizikokimia, deria rasa, dan struktur mikro burger yang diperbuat daripada spesis daging yang berbeza [daging ayam (CB), daging lembu (BEB), daging kambing (MB), dan daging kerbau (BFB)] yang digantikan dengan 50% kacang mata hitam berbanding dengan 100% kacang mata hitam (BEP) sebagai kawalan. Pelbagai sifat fizikokimia telah dinilai, merangkumi hasil memasak, pengecutan, kapasiti pegangan air (WHC), pH, komposisi proksimat, tekstur, kekuatan gel dan warna. Tambahan pula, penilaian deria dan pengibas mikroskop elektron telah digunakan untuk menjelaskan sifat deria dan pengubahsuaian mikrostruktur sampel. Komposisi proksimat, WHC, pengecutan, kekuatan gel, warna dan profil tekstur adalah berbeza secara signifikan di antara patties yang berbeza. CB menunjukkan nilai kecerahan yang lebih tinggi, hasil masakan yang lebih tinggi, dan tekstur yang lebih lembut daripada sampel lain, yang menunjukkan pengekalan air yang lebih baik. Manakala BEB dan BFP lebih keras dan lebih kenyal. BEB menghasilkan kekuatan gel yang lebih rendah dan struktur yang kurang utuh, seperti yang dibuktikan oleh imej struktur mikro dan hasil analisis profil tekstur (TPA). Tiada perbezaan yang signifikan dalam ciri-ciri deria antara spesis daging yang berbeza. Walaupun penerimaan keseluruhan BEB adalah yang tertinggi, MB adalah yang terendah. Komposisi, tekstur, dan ciri-ciri deria daging ayam dan daging lembu dengan penggabungan BEP menjadikan mereka calon yang berpotensi untuk digunakan dalam pembangunan patties yang sihat.

Kata kunci: analog daging, emulsi daging, jenis-jenis daging yang berbeza, pengganti daging, protein berasaskan tumbuhan

Introduction

According to the United Nations, the world's population has grown more than threefold since the mid-twentieth century, reaching nearly 8 billion by 2022 from 2.5 billion in 1950 [1]. Despite a reduced growth rate, the global population continues to increase. This population growth, along with urbanization and rising incomes in developing countries, has become the main driving force behind the escalating demand for meat products. However, the shift towards a diet dominated by animal products has led to significant external costs. Primarily, the consumption of meat and processed meat products has been directly associated with a higher prevalence of cancer, including colorectal, pancreatic, and prostate cancer [2]. Additionally, these products are major contributors to weight gain due to their cholesterol and saturated fatty acid content [3]. Moreover, meat consumption, particularly from ruminant animals, is a significant source of greenhouse gas emissions, deforestation, and global biodiversity loss [4]. It also contributes to local pollution of water, soil, and air [5]. Furthermore, a substantial portion of the land, energy, and water used to grow feed crops for animals could be more efficiently utilized to produce plant-based foods directly consumed by humans [6]. The rearing conditions of animals for meat production also indirectly contribute to global threats such as antibiotic resistance and zoonotic diseases [7]. In addition to environmental concerns, society is increasingly showing heightened awareness and concern for animal suffering and welfare in the farming industry. This growing concern is reflected in the rising number of vegetarian and vegan consumers in affluent countries [8]. As a result, there is a growing demand for alternative and sustainable sources of protein to meet the nutritional needs of the global population while addressing the challenges posed by conventional meat consumption.

There has been a growing interest in developing plant-based meat replacements or incorporating plant-based substitutes with various meat types to improve human health, contribute to environmental sustainability, and address animal welfare concerns [9,10]. In comparison to traditional meat, plant-based meat production boasts significant advantages, utilizing 72% to 99% less water and 47% to 99% less land, while also causing 51% to 91% less water pollution and greenhouse gas emissions [11]. Recognizing the growing demand for meat alternatives, various companies in Europe and the United States have introduced plant-based meat products, such as Impossible Burger®, Beyond Burger®, and Schnitzel® [12]. By processing ingredients like wheat gluten, soy protein, mushrooms, rice, legumes, and flavour additives, plant-based meat can closely mimic the aesthetic qualities and nutrient content of real meat [13]. Studies indicate that plant-based proteins are particularly favoured among consumers as an alternative to conventional meat [11, 14, 15].

However, despite the potential benefits and consumer interest, the development of plant-based meat products that truly resemble and rival conventional meat in appearance, flavour, and texture remains a significant challenge for food producers [16]. Achieving the desired texture, water-holding capacity, and mouthfeel akin to real meat is particularly complex, as the microscopic structure of plant-based proteins differs from that of animal muscle fibres [13]. The use of various additives to enhance flavour, texture, and juiciness has raised concerns regarding nutrition, food safety, cost, and consumer acceptance [17]. Therefore, while plant-based meat holds tremendous promise as a sustainable and ethical alternative to conventional meat, overcoming challenges related to texture, flavour, nutrition, and food safety will be crucial to its widespread acceptance and successful integration into global diets.

Black-eyed peas, a highly nutritious legume, are increasingly considered a promising option for a meat substitute in various food products due to their rich composition and health benefits [18]. These legumes belong to the Fabaceae/Papilionaceae family and are characterized by their diversity across four cultivar groups: Unguiculata, Biflora, Sesquipedalis, and Textilis, which vary by seed size, colour, flavour, yield, and maturity [19]. Cultivated widely across warm regions like Southeast Asia, Africa, the Southern United States, and Latin America, black-eyed peas thrive in warm climates with adequate rainfall [20]. Nutritionally, black-eyed peas are laden with both soluble and insoluble dietary fibres, essential minerals, vitamins, particularly those of the B group, and other beneficial compounds such as phenolic acids that are known for their antioxidant properties [21]. These components are crucial not only for general health but also offer preventive benefits against chronic diseases such as cardiovascular diseases, hypercholesterolemia, obesity, diabetes, and various cancers due to their bioactive compounds [22-27].

In addition to health benefits, black-eyed peas contain a significant concentration of bioactive compounds like polyphenols, carotenoids, vitamins, and omega-3 fatty acids that have attracted attention for their potential to prevent several chronic illnesses [28, 29]. The resistant starch and dietary fibre content of seeds contributes to their low glycemic index, beneficial for diabetes management and weight control, by slowing digestion and reducing the intake of glucose by intestinal cells [30, 31]. Moreover, the phenolic content of black-eyed peas, particularly abundant in the seed coat, exhibits strong antioxidant activities, which help mitigate oxidative stress, thus providing further health advantages [32, 33].

The textural properties of black-eyed peas also make them particularly suitable for meat substitution. When cooked, their firm texture and mild flavour allow them to blend seamlessly into dishes traditionally dominated by ground meat [34, 35], making them an ideal ingredient in patties, meatballs, and other textured protein products. Their capacity to absorb flavours and spices used in meat preparations enhances their appeal, providing a satisfying culinary experience for both meat-eaters and vegetarians alike [36]. Given these nutritional, health, and functional advantages, black-eyed peas stand out as a promising option for developing healthier and more environmentally sustainable meat alternatives.

Recent research indicates that partially (10-50%) substituting meat with pulses (including chickpeas, lentils, black beans, or green peas) not only enhances the nutritional profile of meat products but also improves their environmental footprint and potentially reduces production costs. Importantly, these benefits are achieved without compromising the sensory and physical properties of the meat products [36-39]. Building on these findings, this study aims to assess the physicochemical, sensory, and microstructural properties of patties made with different meat species (chicken, beef, mutton, and buffalo) and partially substituted with black-eyed peas, compared to patties made entirely of black-eyed peas as a control. The goal is to maximize the retention of the physicochemical properties and sensory qualities of meat products while developing healthier and more environmentally sustainable alternatives. The findings of this research can contribute to the growing body of knowledge surrounding sustainable protein sources and aid in creating consumer-directed strategies to promote the adoption of plant-based meat substitutes, thereby further reducing the environmental impact of meat consumption.

Materials and Methods

Materials

Frozen deboned beef, beef fat, frozen deboned buffalo, buffalo fat, frozen deboned mutton, mutton fat, and breast chicken with chicken skin were procured from the wholesale market (Seri Kembangan, Selangor, Malaysia). Black-eyed peas, salt, sugar, garlic, black pepper, sodium tripolyphosphate (STPP), shortening, and isolated soy protein (ISP) 90% were purchased from the local market. Four different species of meat (chicken, beef, mutton, and buffalo) were selected as raw materials based on considerations of diversity in consumer preferences, textural variations, nutritional profiles, and environmental impact considerations.

Preparation of patties

The basic formulation of the patties was from the study conducted by Kahar et al. [40], based on the Malaysian Food Regulations 1985, where the amount of meat should be not less than 65% and fat not more than 30%. Nevertheless, this study modified the formulation to incorporate black-eyed peas as the meat substitute. Black-eyed peas were washed, soaked in potable water for 30 minutes, and subsequently boiled for 45 minutes. The boiled black-eyed peas were mechanically crushed into small pieces using a food processor (Panasonic MK-5087M, Malaysia). Meat from beef, chicken, buffalo, and mutton were cut into small pieces and washed separately under running water. Each species of meat was minced individually for approximately 5 minutes by a meat mincer machine (H.L TJ12-A, Henglian, China). The patties were produced following distinct formulations listed in Table 1. The minced meat was placed in a bowl cutter (Mainca CM-21, Spain), and ice water and salt were incrementally added to the mixture, followed by a 2-minute mixing process. Subsequently, all other ingredients were homogeneously mixed for an additional 8 minutes. The resulting mixture was shaped using a patty's moulder, resulting in uniformly sized patties weighing 70g each.

Table 1. Formulation of black-eyed peas patties with partial replacement of meat from different species

Ingredients	Amount (%)				
	BEP	CB	MB	BEB	BFB
Black-eyed peas	75	37.5	37.5	37.5	37.5
Chicken	-	37.5	-	-	-
Mutton	-	-	37.5	-	-
Beef	-	-	-	37.5	-
Buffalo	-	-	-	-	37.5
Chicken fat	-	15	-	-	-
Mutton fat	-	-	15	-	-
Beef fat	-	-	-	15	-
Buffalo fat	-	-	-	-	15
Shortening	15	-	-	-	-
Black pepper	0.5	0.5	0.5	0.5	0.5
Ice water	4	4	4	4	4
Isolated Soy Protein (ISP)	2	2	2	2	2
Salt	1.5	1.5	1.5	1.5	1.5
Sugar	1	1	1	1	1
Crushed garlic	0.75	0.75	0.75	0.75	0.75
STPP	0.25	0.25	0.25	0.25	0.25

BEP: black-eyed peas patties; CB: chicken with black-eyed peas patties; MB: mutton with black-eyed peas patties; BEB: beef with black-eyed peas patties; BFB: buffalo with black-eyed peas patties.

Cooking yield and shrinkage

The patties underwent a cooking process in an electric oven set at 150°C for 10 minutes. Subsequently, the individual patty samples were weighed both before and after cooking. The percentage change in weight from the original weight was computed to determine the cooking yield, following the methodology outlined by Ramle et al. [41] as expressed in Equation 1. Furthermore, the shrinkage of the patties was determined using the approach proposed by Kahar et al. [42], and the corresponding calculation is represented by Equation 2.

$$Cooking\ yield\ (\%) = \frac{Weight\ of\ cooked\ \ patty}{Weight\ of\ raw\ patty} \times 100 \qquad (1)$$

$$Shrinkage(\%) = \frac{(Raw\ thickness - Cooked\ thickness) + (Raw\ diameter - Cooked\ diameter)}{Raw\ thickness + Raw\ diameter} \times 100 \qquad (2)$$

Water holding capacity (WHC)

Patty samples (1.5g) were placed with absorbent paper in centrifuge tubes, which were then subjected to centrifugation at 4000 ×g at 20 °C for 15 minutes using a Kubota 3740 centrifuge (Japan). The absorbent paper effectively absorbed the water in the centrifuge. WHC was expressed as the amount of retained water per 100 g of water present in the sample before centrifuging (Equation 3) [43].

$$WHC(\%) = \frac{Weight\ before\ centrifugation - Weight\ after\ centrifugation}{Original\ sample\ weight} \times 100 \qquad (3)$$

pH measurement

The pH of each 10g sample was measured by homogenizing it with 100 mL of distilled water for five minutes, followed by pH measurement using a Model HI 84530 pH meter (Hanna Instruments Co., USA).

Proximate analysis

Moisture content, ash content, protein content, fat content, and fibre content of the patties were determined using the Association of Official Analytical Chemists (AOAC) techniques [44].

TPA and gel strength

The TPA and gel strength of the cooked patties were determined using specific equipment and procedures. The TPA analysis was conducted using a texture analyser XT Plus (Stable Micro Systems Ltd., Godalming, Surrey, UK) with the P75 probe [43]. The parameters assessed included hardness, gumminess, chewiness, and cohesiveness. For the TPA analysis, a flat square surface probe and a 75 mm probe were utilized, and a 25 kg load cell was employed. The compression test was performed in one cycle, with the pre-test speed set at 1.00 mm/s, the test speed at 0.8 mm/s, and the post-test speed at 5.00 mm/s. The distance for compression was set at 8.00 mm, and the auto-trigger type was set at 5.0 g.

To determine the gel strength of the patties, a texture analyser (TA-XT2, Stable Microsystem System Ltd., UK) was used. The patties were cut into cylindrical shapes with dimensions of 30 mm in height and 30 mm in diameter. A spherical probe of 5 mm (P/5S) was employed for the analysis, with a test speed of 1.1 mm/s, a force of 10 g, and a distance of 5 mm applied to the sample. In the context of TPA, hardness is defined as the peak force observed at the first compression, while the maximum force required to break the polymer matrix in the stressed region is characterized as gel strength. Cooked patty samples were utilized for both TPA and gel strength analyses, and they were cut into square shapes with dimensions of 30 mm in height and 30 mm in diameter.

Colour parameter

The colour of cooked and uncooked patties was evaluated in terms of lightness (L*), redness (a*), and yellowness (b*) using a chromameter (CR-410, Konica Minolta, Japan) [41].

Microstructure evaluation with scanning electron microscopy (SEM)

Small pieces (10mm×10mm) of uncooked patties were horizontally cut, and thin layers were examined and photographed using a scanning electron microscope (LEO 1455 VPSEM, Cambridge, UK) at 250× magnification.

Sensory evaluation

Fifty untrained panellists participated in sensory evaluation, rating different samples of patties based on texture, aroma, colour, flavour, and overall acceptability using a nine-point hedonic scale.

Statistical analysis

All the experiments were performed in triplicate (n=3) except for sensory tests (n=50). They were analysed using one-way ANOVA and Tukey's test with a confidence level of 95% (p <0.05). All data were analysed using Minitab Statistical Software version 19 (MiniTab Inc., USA).

Results and Discussion

Proximate analysis

Table 2 shows the proximate composition of the various patties produced with black-eyed peas and different meat species. The moisture content of the patties showed significant differences (p <0.05). The patties containing chicken breast (CB) exhibited the highest moisture content (62.99%), likely due to the inherent higher moisture content of chicken breast meat (77.19%) [45]. On the other hand, black-eyed peas influenced the moisture content in all patties, with values ranging from 46.69% in black-eyed peas patties (BEP) to 57.04% in mutton patties (MB).

Regarding the ash content, BEP (2.93%), CB (2.96%), and BFB (2.77%) did not show significant differences (p >0.05), but they were lower than BEB (3.11%) and higher than MB (2.68%), which might be attributed to the variations in meat species and the presence of spices and condiments used in the patties [46]. The protein content in the different patties also displayed significant variations (p <0.05). CB (15.41%) exhibited the highest protein content compared to BFB (14.75%), MB (14.12%), BEB (13.53%), and BEP (10.19%). The higher protein content in CB patties can be attributed to chicken meat being a lean source of protein with less fat than red meats, which are relatively higher in fat and calories.

The fat content in BEP patties (19.20%) was the highest among all the patties, likely due to the addition of shortening. On its own, BEP has a low-fat content (1% on a dry basis of average black-eyed peas) [47]. Shortening is a solid fat derived from liquid vegetable oil, processed through hydrogenation, partial-hydrogenation, fractionation, and interesterification [48]. The fibre content in all the patties showed no significant difference (p >0.05), possibly due to the presence of black-eyed peas in all formulations. Legumes like black-eyed peas are known to contain dietary fibre, which can influence the physical, rheological, and sensory properties of food systems based on their physicochemical properties [49]. Mallillin et al. [50] reported 34% dietary fibre (TDF) in cowpea/black-eyed peas, which is comparable to other legumes, supporting the consistent total fibre content observed in all the patties.

Water holding capacity, cooking yield, shrinkage, pH value, and gel strength analysis

Table 3 presents the results of the water holding capacity (WHC), cooking yield, shrinkage, pH value, and gel strength for the various patties prepared with different meat species. Notably, the cooking yield and pH value showed minor differences among the patties, while WHC, shrinkage, and gel strength exhibited more significant variations. CB (29.53%) exhibited the highest WHC (p < 0.05), followed by BFB (24.21%), BEB (22.80%), MB (20.4%), and BEP (15.66%), which had the lowest WHC. The contribution of dietary fibre to higher WHC has been reported in the literature [51]. However, in this study, BEP exhibited the lowest WHC, possibly due to its lower moisture content.

Table 2. Proximate analysis of black-eyed peas patties with partial replacement of meat from different species

Proximate Composition (%)	BEP	CB	MB	BEB	BFB
Moisture content	46.69±0.45^{d}	62.99±0.15^{a}	57.04±0.12^{b}	56.45±0.24^{b}	55.77±0.07^{c}
Fat content	19.20±3.3^{a}	12.13±0.54^{c}	7.80±1.45^{bc}	13.05±3.63^{ab}	13.89±0.44^{ab}
Protein content	10.19±0.03^{d}	15.41±0.30^{a}	14.12±0.15^{bc}	13.53±0.31^{c}	14.75±0.27^{b}
Ash content	2.93±0.03^{ab}	2.96±0.07^{ab}	2.68±0.25^{b}	3.11±0.12^{a}	2.77±0.10^{ab}
Fiber content	0.56±0.02^{ab}	0.57±0.02^{a}	0.56±0.03^{ab}	0.53±0.03^{ab}	0.51±0.01^{b}

The values represent means ± SD. Small letters that do not share the same letter are significantly different ($p < 0.05$) in the same row

Cooking yields were consistently high for all patties ($p < 0.05$), ranging from the highest in BEP (92.70%) to CB (92.23%), BEB (91.44%), MB (90.87%), and BFB (89.02%). The low cooking yield reported in some studies can be attributed to moisture and fat loss, as well as the denaturation of meat proteins [52]. In contrast, the higher cooking yield observed for BEP could be attributed to its lower moisture content and the distinctive properties of black-eyed pea protein compared to animal protein. Pea fibre addition to meat products has been found to increase cooking yield without affecting sensorial properties [53,54]. The shrinkage values were lower for BEP (5.02%) compared to CB (11.71%), MB (14.79%), BEB (12.95%), and BFB (13.09%). Heating during the cooking process causes moisture loss and protein shrinkage in the patties [55]. The meat patties tend to shrink due to the loss of water and fat during cooking [56].

The pH values exhibited no significant difference ($p < 0.05$) between BEP (6.53), CB (6.49), and BFB (6.40). MB (6.28) and BEB (6.32) displayed lower pH values ($p > 0.05$). CB (395.14 N/m²) and MB (423.53 N/m²) had higher gel strength compared to BEP (324.80 N/m²). Gel strength is influenced by the molecular weight distribution in the gelatin [57,58], and the lower gel strength of gelatin restricts its application areas in biomaterials [59]. The increase in gel strength could be attributed to the formation of higher molecular weight structures resulting from cross-linking reactions between protein molecules (gelatin components) and polyphenols [60].

Table 3. Water holding capacity, cooking yield, shrinkage, pH value and gel strength of black-eyed peas patties with partial replacement of meat from different species

Properties	BEP	CB	MB	BEB	BFB
Water Holding Capacity (%)	15.66±1.25^{c}	29.53±1.73^{a}	20.42±1.17^{bc}	22.80±2.74^{b}	24.21±2.12^{b}
Cooking yield (%)	92.70±0.28^{a}	92.23±0.20^{ab}	90.87±0.26^{b}	91.44±0.09^{ab}	89.02±1.09^{c}
Shrinkage (%)	5.02±0.38^{c}	11.71±0.54^{b}	14.79±0.67^{a}	12.95±0.46^{b}	13.09±0.59^{b}
pH value	6.53±0.03^{a}	6.49±0.05^{a}	6.28±0.04^{b}	6.32±0.10^{b}	6.40±0.03^{ab}
Gel strength (N/m²)	241.8±32.05^{c}	395.14±58.25^{ab}	423.53±10.78^{a}	324.80±9.74^{bc}	313.44±14.7^{bc}

The values represent means ± SD. Small letters that do not share the same letter are significantly different ($p < 0.05$) in the same row

Colour parameter and TPA

Table 4. presents the colour parameters of uncooked and cooked patties, as well as the results of the TPA for patties with partial replacement of meat with black-eyed peas from different species. The colour traits of cooked meat products are influenced by the formulation additives and the inherent pigmentation of the meat [61]. Figure 1 illustrates the comparison of colour parameters for uncooked patties. In terms of lightness (L*), BEP (64.14) exhibited a lighter colour ($p < 0.05$) compared to other patties, followed by CB. This distinction can be attributed to the natural colour of black-eyed peas, while chicken meat is known for its lighter colour compared to other meat species. The L* value reflects the paleness of the meat, and chicken breast, characterized by its light and pale nature [62], exhibited the highest value. The redness (a*) of BEB (6.35), BFB (6.10), and MB (5.23) was significantly higher than CB (3.43) and BEP (3.45). This observation is consistent with the known fact that red meats, such as goat, beef, and buffalo, have higher redness due to the presence of myoglobin [63]. For the yellowness (b*), BEP (18.70) had the highest value, followed by MB (12.70), CB (12.30), BEB (11.21), and BFB (11.03). The vibrant yellow colour of the black-eyed peas used in all patties likely contributed to their yellow appearance.

Regarding the lightness (L*) of cooked patties, BEP (47.58) and CB (44.77) showed similar values ($p > 0.05$) but were lighter ($p < 0.05$) than MB, BEB, and BFB. This finding is consistent with the raw patties, except for CB. In terms of redness (a*), BEB (8.06) displayed the highest redness and was significantly higher than CB. The higher myoglobin content in BEB could account for its greater red colour compared to meat with lower levels of myoglobin. The yellowness of cooked patties was highest in BEP (19.94), followed by CB (15.43), MB (10.47), BEB (10.34), and BFB (9.36). The Maillard reaction, occurring during the cooking process, produces brown pigments by rearranging amino acids and certain sugars, leading to the formation of ring structures that reflect light and give the meat a brown appearance. The protein denaturation during cooking causes the patties to darken in colour. Cooked meats typically have a dull-brown colour due to heat-induced denaturation of myoglobin, the water-soluble sarcoplasmic heme protein responsible for the red colour of fresh meat. Consequently, the biochemistry of cooked colour differs from that of fresh meat colour, where the heme protein is in its original state. However, there is a strong relationship between the chemistry of myoglobin in raw meat and the cooked product, and both are affected by various factors (endogenous and exogenous) [64–66]. Figure 1. provides a more detailed comparison of colour parameters for the cooked patties of different samples.

As for the TPA, no significant differences ($p > 0.05$) were observed between BEP, CB, MB, BEB, and BFB for the hardness, gumminess, chewiness, and cohesiveness of the patties. However, the hardness of BFB was higher compared to other patties. The increased hardness during cooking can primarily be attributed to the denaturation and aggregation of myosin and actin, leading to protein matrix shrinkage and fluid expulsion [67]. This observation also aligns with the gumminess and chewiness of BFB, which were the highest compared to BEB, MB, CB, and BEP [68]. The cohesiveness of the patties was influenced by sarcoplasmic and myofibrillar proteins [69]. BEP exhibited low cohesiveness, while BEB displayed high cohesiveness.

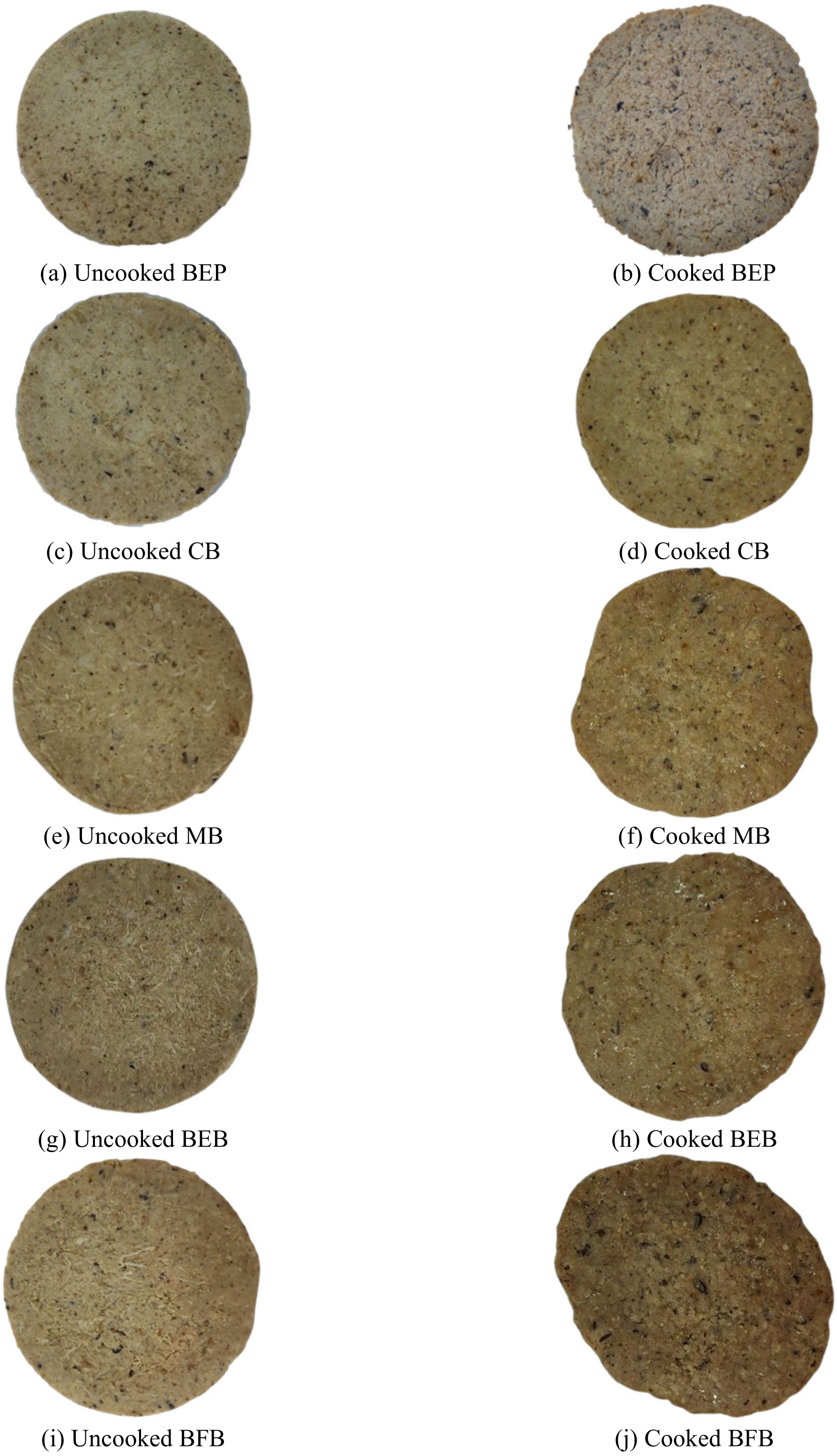


Figure 1. The visual appearance of raw and cooked BEP, CB, MB, BEB, and BFB

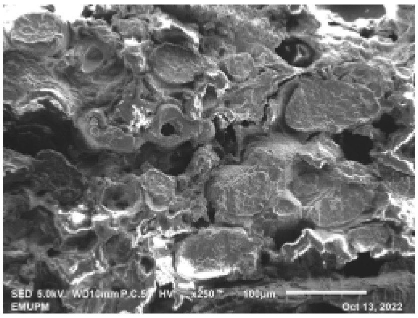
Table 4. Colour parameter of uncooked and cooked patties and textural profile analysis of black-eyed peas patties with partial replacement of meat from different species

Properties		BEP	CB	MB	BEB	BFB
Colour Un-cooked	L*	64.14±0.57^{a}	54.36±1.55^{b}	47.22±0.61^{c}	48.43±2.19^{c}	45.91±1.64^{c}
	a*	3.45±0.07^{c}	3.43±0.10^{c}	5.23±0.42^{b}	6.35±0.57^{a}	6.10±0.59^{ab}
	b*	18.70±0.27^{a}	12.30±0.19^{bc}	12.70±0.24^{b}	11.21±0.38^{c}	11.03±1.03^{c}
Colour Cooked	L*	47.58±0.68^{a}	44.77±2.06^{a}	35.10±0.44^{b}	35.19±0.79^{b}	32.40±0.85^{b}
	a*	6.61±0.17^{ab}	5.36±0.15^{b}	6.83±0.33^{ab}	8.06±1.27^{a}	7.17±0.84^{ab}
	b*	19.94±0.30^{a}	15.43±0.82^{b}	10.47±0.41^{c}	10.34±0.25^{c}	9.36±1.17^{c}
TPA	Hardness (g)	11280±2041^{a}	11876±5721^{a}	13328±11676^{a}	13757±1521^{a}	27202±4507^{a}
	Gumminess (g)	3000±690^{a}	7344±2958^{a}	8468±7400^{a}	8804±627^{a}	11309±1193^{a}
	Chewiness (J)	1226±322^{a}	5638±2362^{a}	6513±5693^{a}	6480±651^{a}	8260±662^{a}
	Cohesiveness	0.27±0.03^{a}	0.63±0.05^{a}	0.42±0.37^{a}	0.64±0.03^{a}	0.42±0.03^{a}

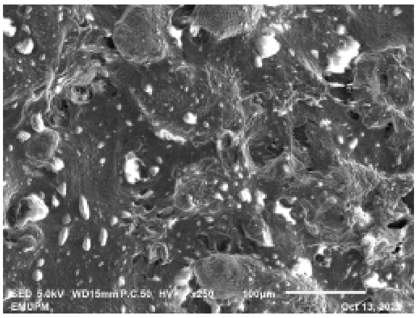
The values represent means ± SD. Small letters that do not share the same letter are significantly different (p <0.05) in the same row

SEM

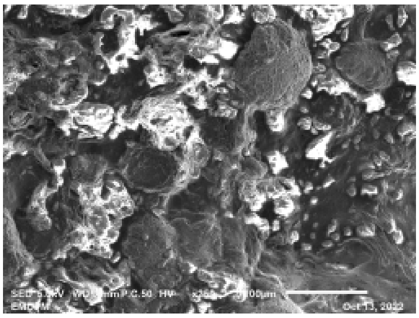
Figure 2. presents the microstructure of the cooked BEP, CB, MB, BEB, and BFB (the magnification scale used was 250× for all samples). Overall, the microstructures of CB, MB, BEB, and BFB exhibited certain similarities. In contrast, the protein matrix of CB is more compact compared to that of BEP. This difference likely results from higher protein content of CB, which enhances the density of the matrix [70]. The protein content in meat formulations significantly affects the texture by influencing the density and cohesion of the protein matrix. Higher protein contents lead to denser and more cohesive structures, which explains the observed difference in the SEM images of the patties [71]. Additionally, BEP exhibited a less intact structure, as evidenced by the presence of several gaps observed in the microscopic image. This observation aligns with the gel strength results, where BEP had the lowest gel strength compared to the other meat species. It indicates that the protein matrix in BEP patties was less cohesive, resulting in a patty with a less structurally compact composition. Studies on the impact of dietary fiber (chickpea fiber) on meat proteins, also reveal that fiber can fundamentally alters the three-dimensional network of myofibrillar protein [72]. This effect of dietary fiber is critical in modifying the structural integrity of patties, influencing their ability to form a cohesive network, which in turn affects their textural properties and gel strength. These findings imply that disparities in protein composition and structural attributes between black-eyed peas and meat-based patties played a pivotal role in determining their capacity to form a cohesive and integral network, thereby influencing both microstructural integrity and gel strength outcomes.



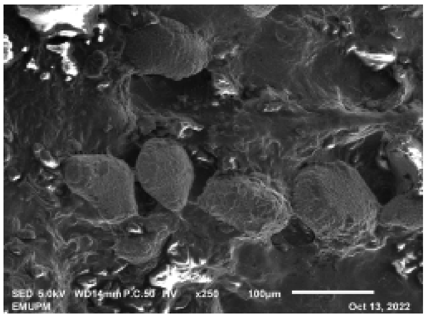
(a) BEP



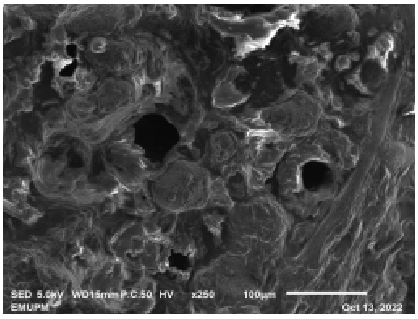
(b) CB



(c) MB



(d) BEB



(e) BFB

Figure 2. The microstructure images of BEP, CB, MB, BEB, and BFB

Sensory evaluation

The results of the sensory evaluations for black-eyed peas (BEP) patties with partial replacement of meat from different species are presented in Table 5. The sensory attributes examined included texture, aroma, colour, flavour, and overall acceptability for BEP, CB, MB, BEB, and BFB. Based on the sensory analysis, no significant differences (p >0.05) were observed in the texture, aroma, colour, flavour, and overall acceptability among the patties prepared with different meat species. However, BEB patties received higher overall acceptability scores compared to the other patties, likely due to favourable evaluations in terms of texture, aroma, and colour. The unique taste characteristics of beef may have been recognized by the panellists during the evaluation, and they may have appreciated the combination of beef with black-eyed peas.

In contrast, the control patty, BEP, received less favourable ratings for texture, aroma, colour, flavour, and overall acceptability (p <0.05) compared to the other patties. These results are in line with the findings from the texture profile analysis, where BEP showed lower values in hardness, gumminess, chewiness, and cohesiveness. The inferior ratings could be attributed to the lower moisture content and reduced gel strength of BEP, as evidenced by the less intact structure observed in Figure 1 and Figure 2.

Table 5. Sensory evaluation of black-eyed peas patties with partial replacement of meat from different species

Properties	BEP	CB	MB	BEB	BFB
Texture	2.90±1.73^{b}	6.78±1.80^{a}	6.52±1.47^{a}	7.08±1.55^{a}	6.50±1.61^{a}
Aroma	3.98±1.78^{b}	6.32±1.97^{a}	6.18±1.72^{a}	6.44±1.85^{a}	6.24±1.65^{a}
Colour	4.02±2.20^{b}	6.10±2.04^{a}	6.10±1.73^{a}	6.58±1.84^{a}	6.46±1.80^{a}
Flavour	3.26±2.13^{b}	6.96±1.81^{a}	6.96±1.81^{a}	6.92±1.69^{a}	6.72±1.64^{a}
Overall acceptability	3.10±1.71^{b}	6.82±1.84a	6.40±1.85^{a}	7.04±1.64^{a}	6.68±1.65^{a}

The values represent means ± SD. Small letters that do not share the same letter are significantly different (p <0.05) in the same row

To sum up, the sensory evaluation revealed that the panellists supported the utilization of black-eyed peas in combination with different meat species as a meat substitute. The patties prepared with partial meat replacement using black-eyed peas received favourable evaluations compared to those with 100% meat replacement by black-eyed peas. These findings indicate the feasibility and acceptability of incorporating black-eyed peas into meat products, offering a promising approach to enhance nutritional value and sustainability in meat-based formulations. However, further studies are warranted to optimize the formulation and processing techniques to ensure the best sensory attributes and consumer acceptance of these innovative patties.

Conclusion

In summary, this study explored the feasibility of using black-eyed peas as a partial meat substitute in various patties containing different meat species. Black-eyed peas significantly influenced the moisture content of the patties, leading to higher moisture levels in chicken breast (CB) patties due to the inherent moisture content of chicken meat. However, all patties incorporated with black-eyed peas demonstrated variations in protein, fat, and fibre content, reflecting the diverse composition resulting from the incorporation of this legume. In terms of sensory evaluations, the patties with partial meat replacement using black-eyed peas received more favourable ratings compared to the control patty made entirely of black-eyed peas (BEP). Specifically, beef patties (BEB) stood out with higher overall acceptability, potentially due to the unique taste of beef combined with black-eyed peas. On the other hand, the control patties (BEP) were perceived less favourably, with lower scores in texture, aroma, colour, flavour, and overall acceptability, aligning with the textural analysis results showing lower hardness, gumminess, chewiness, and cohesiveness. Microstructure analysis revealed differences in the protein matrix, with black-eyed pea patties displaying a less compact structure compared to those with meat species. These differences negatively implicated the overall sensory attributes and acceptance of the patties. Overall, the study suggests that incorporating black-eyed peas as a partial meat substitute offers a promising pathway to enhance the nutritional value and sustainability of meat-based products. By improving the sensory qualities and addressing potential challenges, the food industry can potentially promote the adoption of black-eyed pea-based patties as an environmentally friendly and nutritionally enriched alternative to traditional meat products. In light of these findings, future research should focus on expanding the variety of legumes used as meat replacers and optimizing processing methods to enhance the sensory and nutritional qualities of these products. This approach will not only cater to the growing market for sustainable and healthy food options but also contribute to environmental conservation and public health improvements.

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