A comparative study on physicochemical, textural, and sensorial characteristics of a plant-based meat analog as it relates to beef and pork meats

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Abstract
Background: The global modern population nowadays attempts to diminish their meat consumption in their daily diet, due to the growing awareness of healthy sustainable foods. Meat analogues are vegetable-based protein products that consist of highly beneficial essential amino acids, low saturated fat, and no cholesterol. Meat analogues are receiving attention from various customers who are highly aware of their wellbeing and health and the ecological, ethical and social aspects of consuming animal’s meat, as well as from people who are unable to consume animal meat because of cost considerations, health problems and/or religious restrictions.

Methods: This explores the physicochemical, textural, and sensorial properties of a plant-based meat analog (PBMA) as compared to beef and pork meats. The data were analyzed by one-way analysis of variance (ANOVA). Comparisons of means were carried out using post-hoc Tukey’s test.

Results: Results illustrate that PBMA patties had lower moisture, fat, and protein content, as well as higher ash and crude fiber than beef and pork. Likewise, PBMA patties had a higher pH, lightness (L*), and redness (a*) than either beef or pork meat. Pork meat exhibited the highest released water (RW) and cooking loss (CL) values, followed closely by PBMA with beef displaying the lowest values. However, the Warner-bratzler shear force (WSBF), hardness, chewiness, and gumminess of beef was significantly higher than that of either pork or PBMA. With regard to sensory parameters, PBMA demonstrated the highest values for appearance and firmness, followed by beef and pork respectively.

Conclusions: Therefore results indicated that physicochemical, textural, and sensorial characteristics of PBMA are comparable to that of pork and beef.

Keywords: Texture vegetable protein, Plant-based meat analog, Beef meat, Pork meat, Methylcellulose.
1. INTRODUCTION

Historically, meat has been considered an indispensable part of the human diet. The consumption of meat has likely been vital for human evolution, providing a concentrated source of both protein and most notably lipids that are associated with brain growth and development [1]. Over time, a surging world population and industrial development has created a massive demand for animal protein and food production expansion. However, animal-derived products, particularly meat, have a significant impact on the environment via greenhouse gas production, land-water usage, and extensive energy consumption [2]. The production of meat also requires the additional production of significant quantities of plant proteins. For instance, based on the feed conversion ratio of ruminants, 7 kg of plant-based feed is needed to yield 1 kg meat for human consumption [3]. Furthermore, extensive animal product production has resulted in a serious loss of biodiversity over time. Currently, roughly 30% of land globally is used to produce animal products; this has resulted in increased deforestation to expand livestock production areas and soil erosion in cleared areas due to overgrazing [4].

Concerning human health, plant-based protein consumption has been shown to reduce body weight, high blood pressure, and blood cholesterol levels, which ultimately lowers the prevalence of heart disease and stroke [5]. Soy and pea proteins are the two principal sources of proteins utilized for the manufacturing of nonmeat products due to their abundant availability and low cost. Consequently, recent academic and industrial research has focused on the partial or complete replacement of meat with plant proteins.

Textured vegetable protein (TVP) is a plant-based protein product with excellent nutritional qualities, including low saturated fat, a high concentration of essential amino acids, and is cholesterol-free [6]. The low/intermediate moisture TVP also has advantages in handling, storage, and shelf stability, but requires time to hydrate before consumption. The manufacturing process of TVP involves a high-pressure extrusion process and a final spinning or extraction of the finishing product, which can then be used to create meat analogs. During the production of meat analogs made with TVP, the manufacturer faces difficulties in retaining sensory and textural properties that resemble red meat. In red meat, textural and taste parameters are essential to consumers and represent high economic value as some cuts bring exorbitant prices. In contrast, meat analogs lack these features and are generally regarded as substandard to even the cheapest meats [7].

Moreover, meat analogs are known as faux meat or veggie meat; these mock meats made from non-animal protein only mimic the appearance, taste, and texture of red meat [8]. Protein from various sources has been reformed to mimic the texture and taste of meat, though it has been noted that some of these plant proteins are incomplete, lacking in essential amino acids, and cannot be classified as meat substitutes. Based on nutritional qualities, soya, quinoa, chia, and hemp possessed complete protein profiles and could be used for the preparation of meat analogs [8]. The new generation of meat analogs, including Beyond Meat, Impossible Burgers, and Gardein, are examples of successful productions from such proteins. The growth of the plant-based meat market is projected to increase from $4.6 billion in 2018 to $85 billion in 2030 and, as a milestone by the year 2026, reaching $30.9 billion [9]. Hence, plant-based meat alternatives, substitutes, or replacements represent a primary sector in this emerging and rapidly evolving industry. Thus, the objective of the current study was to compare the physicochemical, textural, and sensory properties of plant-based meat analogs with those of beef and pork meat.

2. MATERIALS METHODS

2.1 Materials

Textured vegetable protein (TVP) (Anthony’s goods, Glendale, CA, USA) was selected as the base for plant-based meat analog (PBMA), and methylcellulose (high viscosity, Modernist Pantry, Eliot ME, USA) was incorporated as a binder. Other ingredients, including molasses, yeast seasoning, umami seasoning, coconut oil, canola oil, garlic powder, and black pepper, were used as described in Table 1. Beef round steak and pork loin were obtained from regional supermarkets in Jinju, Korea.
2.2 Sample preparation and processing
The flow diagram for processing meat analog is described in Figure 1. For the manufacturing and production of the meat analog, TVP was used as a base for the meatless patties. For a single patty preparation, an aggregate of 50 g of TVP was mixed with ddH₂O (2 times in volume) and allowed to hydrate for 1 hour at 4°C. After that, the hydrated TVP was mixed with the ingredients listed in Table 1 using a Kitchen Aid mixer (Classic Plus Stand Mixer, St Joseph, MI, USA). The 50 g mixture was then shaped into patties using a patty press. Likewise, 50 g of beef round and pork loin and were sliced, chopped, and mixed equivalently, before being formed into patties using a patty press. In total, fifty-four patties (twenty-seven cooked and twenty-seven raw) were prepared, with PBMA, beef, and pork having nine cooked and nine raw patties each. By using a non-stick pan with dry heat, the patties were cooked at 150°C for 5 minutes on each side. The patties were flipped three times until the internal temperature reached 75°C as measured by a probe thermometer. Before measuring the physicochemical, textural, and sensorial attributes, the patties were allowed to cool at room temperature for 30 minutes.

![Flow diagram for manufacturing the meat analog](image)

**Figure 1.** Flow diagram for manufacturing the meat analog. TVP: Textured vegetable protein. PBMA: Plant-based meat analog

2.3 Proximate chemical composition
Based on the standard of AOAC [10], the proximate compositions of patties were examined. Moisture content was determined by drying a 5 g sample at 105°C for 16 hours using an automatic oven (BioFree, BF-150C, Buchen Korea). The protein content was determined via the standard Kjeldahl using N analyzer (B-324, 412, 435 and 719 S Titrino, BU-CHI, Flawil, Switzerland) (N × 6.25).

### Table 1. Treatment and formulation of plant-based meat analog, beef, and pork meat

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Treatment</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Lean beef</td>
<td>Beef</td>
<td>83.33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lean pork</td>
<td>Pork</td>
<td>-</td>
<td>83.33</td>
<td>-</td>
</tr>
<tr>
<td>TVP</td>
<td>PBMA</td>
<td>74.90</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Methylcellulose</td>
<td></td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td>Garlic powder</td>
<td></td>
<td>1.50</td>
<td>2.25</td>
<td>2.25</td>
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<tr>
<td>Yeast extract</td>
<td></td>
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</tr>
<tr>
<td>Black pepper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mushroom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt</td>
<td></td>
<td>1.11</td>
<td>1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>Back fat</td>
<td></td>
<td>12.56</td>
<td>12.56</td>
<td>1.11</td>
</tr>
<tr>
<td>Coconut oil</td>
<td></td>
<td></td>
<td></td>
<td>3.75</td>
</tr>
<tr>
<td>Canola oil</td>
<td></td>
<td></td>
<td></td>
<td>3.75</td>
</tr>
<tr>
<td>Beet juice</td>
<td></td>
<td></td>
<td></td>
<td>3.00</td>
</tr>
<tr>
<td>Molasses</td>
<td></td>
<td></td>
<td></td>
<td>1.50</td>
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<tr>
<td>Back fat</td>
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<td>Coconut oil</td>
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<td>Canola oil</td>
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<tr>
<td>Beet juice</td>
<td></td>
<td></td>
<td></td>
<td>3.00</td>
</tr>
<tr>
<td>Molasses</td>
<td></td>
<td></td>
<td></td>
<td>1.50</td>
</tr>
</tbody>
</table>

PBMA: Plant-based meat analog, TVP: Textured vegetable protein
% P = % N × PF
V (1): consumption of titrant, sample (mL) -
V(B1): average consumption of titrant, blank (mL)
F: molar reaction factor (1 = HCl, 2 = H2SO4)
c: concentration of titrant [mol /L]
M(N): molecular weight of N (14,007 (g/mol))
M: sample weight (g)
1000: conversion factor (mL in L)
PF: protein factor

The crude fat content was determined via an extraction process using the Soxhlet apparatus (MS-EAM9203-06, Seoul Korea) with petroleum ether as a solvent through the following formula.

\[
\% \text{Crude Fat} = \frac{(W2 - W1) \times 100}{S}
\]

Weight of empty flask (g) = W1
Weight of flask and extracted fat (g) = W2
Weight of sample = S

Ash was determined after incineration of 2 g of sample in a furnace (CFMD2, Changsin, Korea) at 200°C - 550°C. The crude fiber content was determined using an Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY, USA) by processing a 0.5 g sample with H2SO4 and NaOH. The difference in weight after ashing (2 hours at 600±15°C) was assembled to calculate the crude fiber content (Ankom 2008). The following formula was used to numerically calculate the fiber content.

\[
\% \text{Crude fiber} = \frac{[W3 - (W1-C1)] \times 100}{W2}
\]

Where: W1 = Bag tare weight
W2 = Sample weight
W3 = Weight of Organic Matter (Loss of Weight on ignition of bag and fiber)
C1 = Ash corrected blank bag factor
(Loss of weight on ignition of blank bag/original blank bag)

2.4 Physicochemical analysis
For the determination of pH, three grams of sample was homogenized in 20 ml of double-distilled water. After homogenization, the pH of raw and cooked patties was measured using a digital pH meter (Mettler Toledo, MP230, Switzerland). The external color coordinates of the different patties were measured using a digital colorimeter (Minolta CR-300, MinoltaCo., Japan) with an 8 mm aperture, a D65 illuminant, a 2°C closely matched CIE 1931 Standard observer with a pulse xenon lamp and Φ8 mm/Φ11 mm measurement area. By using a standard white ceramic plate, the device was calibrated (Y= 93.5, X= 0.3132, y= 0.3198), and lightness (L*), redness (a*), and yellowness (b*) values were recorded. Three random measurements of color indices were carried out from different locations on the meat patties. The average value from three different locations from each sample group was used for statistical analysis.

2.5 Water holding capacity and tenderness related measurements
Release water percentage (RW %) was measured based on a method described by [11]. The cooking loss (CL %) was determined as a percentage via the method adopted by [12] using the following formula:

Cooking loss (%) = (Weight of the patties after cooking/Weight of the patties before cooking) × 100.

Warner-Bratzler shear force (WBSF) was determined on the cooked samples using the established AMSA procedure [13]. The percent shrinkage in the patty’s diameter was measured at four different locations both before and after cooking.

2.6 Visible Appearance
The appearance of the beef, pork, and PBMA patties was assessed method followed by [14]. The external and internal appearance was photographed using a digital camera (EOS 700D, Canon, Tokyo, Japan), and various features were distinguished.

2.7 Texture profile analysis
Texture profile analysis (TPA) of the differently prepared patties was performed using a Sun Rheometer (Compact-100 II, Sun Scientific Co., LTD., Tokyo, Japan). Samples were uniformly cut into 1 x 1 x 1 cm
before being axially compressed using a Sun Rheometer with a flat pressure adaptor 25 mm in diameter (No. 1). Subsequently, the samples were compressed at a cross-head speed of 60 mm/min at a final strain of 60% through a 2-cycle sequence with a load cell of 10 kg [15]. The following parameters were determined: hardness, cohesiveness, springiness, gumminess, and chewiness.

2.8 Sensory evaluation
A trained twenty-member panel including students and researchers from the Department of Animal Sciences at Gyeongsang National University, Republic of Korea assessed the sensory characteristics. The panelist assortment was approved according to [16], modified [17]. Small pieces of different samples (2 cm × 2 cm × 2 cm) were prepared, marked, and a random coding was pre-positioned on the glass containers to be presented to the panelists (Pyrex Charleroi, PA, USA). The pieces of samples were permitted to rest for 30 minutes at room temperature and then disseminated among the panelists. For judging each sample in triplicate, fluorescent light was applied. Sensory traits such as appearance, shape, firmness, color, and overall acceptability were measured. The samples were judged using a 9-point hedonic scale ranging from extreme dislike (score = 1) to extreme like (score = 9).

2.9 Statistical analysis
All data were statistically analyzed using the one-way analysis of variance (ANOVA) procedure. Analysis of variance (factorial ANOVA) was carried out using SPSS version 23 (IBM Corp., Armonk NY, USA. For multiple mean comparisons, a Tukey’s post hoc test was performed. A $p$-value $\leq 5\%$ was considered significant.

3. RESULTS AND DISCUSSIONS
3.1 Proximate chemical composition
The proximate compositions of control and PBMA patties are presented in Table 2. PBMA patties were found to have significantly lower moisture, fat, and protein content, and a significantly higher ash and crude fiber content than either beef or pork patties. The lower moisture loss in PBMA patties is likely attributable to the integration of methylcellulose during formulation and preparation as shown in Table 1. The ability of methylcellulose to reduce moisture loss was due to the thermal gelation of methylcellulose; during heating, methylcellulose formed an adhesive layer, which acted as a barrier preventing moisture loss [18]. Similarly, the lower fat content in PBMA patties could be due to the addition of non-polar hexane during the high-pressure extrusion process which likely removed some amount of fat from TVP [7].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatment</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beef</td>
<td>Pork</td>
</tr>
<tr>
<td>Moisture</td>
<td>59.64±0.95$^a$</td>
<td>74.66±0.60$^a$</td>
</tr>
<tr>
<td>Ash</td>
<td>1.55±0.29$^a$</td>
<td>1.51±0.25$^a$</td>
</tr>
<tr>
<td>Fat</td>
<td>19.11±0.56$^b$</td>
<td>20.36±0.27$^b$</td>
</tr>
<tr>
<td>Protein</td>
<td>20.52±0.59$^b$</td>
<td>21.75±0.48$^b$</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>1.56±0.25$^a$</td>
<td>2.63±0.37$^a$</td>
</tr>
</tbody>
</table>

Means with different superscripts within the same row are significantly different ($p < 0.05$)
Data are means ± standard error
The protein content of the three types of patties varied significantly between various protein sources, with pork and beef containing a higher protein content than PBMA patties. These outcomes diverge from Hidayat et al. [19], who described no significant difference in protein content via substitution of beef with different levels of TVP. Regarding crude fiber content, meat lacks fiber as such but the substitute made from vegetable and cereal sources (meat analog) contained about 4-5% fiber. It provided 224 kcal of energy per 100 g and exhibited good textural characteristics [20]. The higher fiber in PBMA patties was probably due to the plants and polysaccharides incorporated into the plant-based patty recipe. Dietary fiber is thought to play an important role in the prevention of large bowel disease, ischemic heart disease, and diabetes mellitus [21]. The variations in chemical composition including moisture, fat, protein, ash, and crude fiber in PBMA are likely the basis for the differences in physical properties that occur when replacing beef and pork with TVP in PBMA patties.

### 3.2 Physicochemical analysis

The physicochemical indicators, including pH and colorimetric evaluation, are given in Table 3. The pH of beef and pork is slightly lower than PBMA both before and after cooking. The high pH in the PBMA patties was likely due to the slight alkalinity of TVP (pH 7.42–7.43) as compared to beef and pork meat [22]. The lower pH value of beef and pork was likely due to the regular glycolytic changes that occur in meat [23]. Previous studies using chicken meat sausage have shown a trend of increasing pH values via the partial or complete replacement of chicken with plant proteins, which aligns well with our findings [22].

Likewise, pH and calorimetric measurements are interconnected with each other. Concerning calorimetric measurements, we found that the addition of plant proteins in PBMA decreased both lightness (L*) and redness (a*) values, followed by beef and pork before after cooking respectively. However, an increase in myoglobin denaturation can be identified in the beef and pork patties by the lower a* value after cooking. In a similar pattern, water and fat can cause more light reflection, which probably contributed to the higher lightness in beef and pork meat as compared to PBMA. Comparable to the present findings, a tendency toward decreasing L* and increasing b* were recorded by [24], who investigated pork burgers modified with soy isolate protein. Additionally, the integration of soy isolate protein and other features such as flavors or fillings of hemeproteins can markedly disturb the color directories of the final product. The yellowish coloration of the PBMA patties can be associated with the yellow color of the soy protein ingredients. Previous studies have found that the yellowish-brown coloration affects the quality of the final product [25].

| Table 3. Physicochemical properties of plant-based meat analog, beef, and pork meat |
|-----------------------------------|----------|----------|----------|----------|
| **Meat**                          | **Treatment** | **Beef** | **Pork** | **PBMA** | **P values** |
| **Parameters**                    |           |          |          |          |            |
| pH before cooking                 | 5.34±0.22 | 5.69±0.13 | 6.50±0.18 | 0.002   |
| pH after cooking                  | 5.62±0.36 | 5.50±0.27 | 6.19±0.27 | 0.000   |
| L before cooking                  | 47.83±0.33 | 50.54±1.21 | 39.94±0.44 | 0.000   |
| a* before cooking                 | 16.05±0.20 | 14.55±0.37 | 12.77±0.35 | 0.000   |
| b* before cooking                 | 11.23±0.18 | 12.26±0.20 | 13.37±0.12 | 0.000   |
| L after cooking                   | 35.46±0.87 | 41.80±0.47 | 31.26±0.35 | 0.000   |
| a* after cooking                  | 8.72±0.23 | 6.85±0.47 | 9.89±1.50 | 0.76    |
| b* after cooking                  | 12.34±0.89 | 13.44±0.27 | 14.69±0.30 | 0.000   |

Means with different superscripts within the same row are significantly different (p < 0.05)
Data are means ± standard error
3.3 Water-holding capacity and tenderness related measurements

In the current study, WHC is expressed in two parts, RW and CL, as shown in Table 4. A substantial difference was detected in RW and CL amongst the different meats, with pork displaying the highest RW and CL followed by PBMA and beef respectively. This implies that the internal structural network of pork was more effective in retaining moisture during cooking when compared to PBMA patties. The complete replacement of beef and pork with TVP causes the WHC to increase. This effect is probably due to the higher concentration of water-soluble proteins in TVP, which can have a better water binding ability than either beef or pork. In addition, the fat content in TVP is lower than beef or pork, and the absence of these fats allows the proteins to more freely bind to water which ultimately causes the WHC to increase. These data are in line with earlier work showing that the complete replacement of meat with soy protein leads to an increase in WHC [26]. WHC mostly reaching the lowest point at IP (Isoelectric Point, approximately 5.2) of meat protein [19]. As mentioned previously, the pH of PBMA patties before cooking was higher than either beef or pork, and a higher pH ultimately causes the PBMA patties to retain more water and present with a higher WHC.

Regardless of patty type, the post-cooking diameter was reduced significantly. Beef and pork meat demonstrated higher shrinkage due to connective tissue denaturation and fluid (moisture and fat) loss; substitution with plant-based protein reduced the shrinkage markedly in PBMA patties. Previous studies have indicated that the addition of fiber and non-meat proteins may reduce shrinkage and weight loss during cooking [27]. The WBSF values indicated that PBMA patties were significantly less tough than pork or beef. The softer textural properties of PBMA significantly affected its shear force values. Previously reports have shown that shear force value was significantly correlated to hardness, springiness, and chewiness [28]. The WBSF of meat is a decent source to measure the primary bite of tenderness. Variations during the cooking process can change the heat-induced alteration of myofibrillar proteins and connective tissue, as cooking solubilizes connective tissue leading to meat tenderization. In contrast, the denaturation of myofibrillar proteins causes meat toughening (Laakkonen et al., 1970). The findings of the current study are in line with [29], who detected lower WBSF values in samples containing soy isolate protein as compared to control (pork patties).

### Table 4. Water-holding capacity and tenderness related measurement of plant-based meat analog, beef, and pork meat

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatment</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beef</td>
<td>Pork</td>
</tr>
<tr>
<td>Release water</td>
<td>1.81±0.97</td>
<td>1.55±0.98</td>
</tr>
<tr>
<td>Cooking loss</td>
<td>6.53±0.41</td>
<td>8.83±0.82</td>
</tr>
<tr>
<td>Diameter before cooking</td>
<td>15.83±0.16</td>
<td>15.33±0.44</td>
</tr>
<tr>
<td>Diameter after cooking</td>
<td>7.30±0.10</td>
<td>9.71±0.43</td>
</tr>
<tr>
<td>Shear force</td>
<td>3.79±0.81</td>
<td>1.91±0.35</td>
</tr>
</tbody>
</table>

Means with different superscripts within the same row are significantly different (p < 0.05)
Data are means ± standard error

3.4 Visible Appearance

The visible (external and internal) appearance of cooked and uncooked beef, pork, and PBMA patties has been shown in Figure 2. The external and internal appearance of beef and pork with natural binding ability more are homogenous than PBMA patties with synthetic binding agents (methylcellulose). The results showed that PBMA patties had more cracks and loose structures before and after cooking. The cracks, with loose structure and moisture in patties with the addition of methylcellulose, could be due to a lower concentration of the binding agent, which consequently leads to rough and spongy structure with higher evaporation from PBMA. Methylcellulose...
lose is essentially incorporated in some modern meat analog due to product consistency and binds all ingredients together to be more intact and stable patties [25]. Methylcellulose is a useful binder, especially on the meat analog that does not require pre-heat for gel formation due to its unique thermal gelling and right emulsifier properties [30]. Previously, it was established that meat analogs prepared with various soy-based TVPs and different concentrations of methylcellulose display a homogenous structure of patties as compared to soy-based TVP with a smaller concentration of methylcellulose showed rough, loose, and more cracks in patties structure [18].

Figure 2. External and internal appearance of plant-based meat with beef and pork meat

3.5 Texture Profile Analysis

The textural parameters including hardness, chewiness, gumminess, cohesiveness, and springiness of beef, pork, and PBMA patties are shown in Figure 3. The hardness, chewiness, and gumminess of beef were significantly higher than either pork or PBMA patties. The higher hardness in beef and pork was expected due to the muscle protein denaturation phenomenon, which increases the hardness in the meat [15]. This is evident from the shrinkage percentage in Table 2, whereby meat protein has a higher degree of shrinkage than plant-based proteins. Previous literature regarding the rheological properties of soy protein meat analogs has confirmed that hardness, cohesiveness, chewiness, and gumminess decrease as moisture content increases [31]. The probable reason that beef and pork had higher values is likely related to the fact that meat contains myofibril proteins, which cause a tougher network formation internally, thereby enhancing the resistance to compression [22]. Furthermore, cohesiveness and springiness varied by patty type, but the difference was not statistically significant. Previously, it was reported that meat substitutes manufactured from low-gelling soy isolate protein could hold more water and fat than high gelling soy isolate protein patties, which ultimately reduces the springiness by filling the interstitial space within the protein matrix with water [32].

Figure 3. Textural properties of plant-based meat along, beef, and pork meat
3.6 Sensory evaluation

The sensory traits of PBMA, beef, and pork are shown in Figure 4. The appearance values of PBMA patties were higher than that of beef and pork patties. Additionally, there were no significant differences in shape or color among different types of patties. PBMA patties had a higher firmness compared to beef and pork meat respectively. Similarly, the overall acceptability of PBMA was comparable to beef and pork but without statistical difference. The vast variability of PBMA patties as compared to controls could be due to the plant-derived proteins (soy protein) in meat analogs expressing more elastic, rubbery, and chewy sensations due to their agglomeration properties [14,18]. Moreover, previous literature has confirmed that incorporating a different type of soy family (soy paste, soy protein isolate, or texture soy protein) generates a unique beany essence in meat products and downgrades sensory scores [29]. Remarkably, in the current study, no beany essence was noticed by any of the panelists. This lack of bean-like flavor could be due to the various types of plant-based ingredients used to mask the beany flavor in PBMA patties. Additionally, plant protein and muscles are considerably different in structure, i.e., in amino acid composition, peptide structure, size and structure of protein molecules, and chemical composition; consequently, it is a challenging task to produce sensory profiles similar to animal meat products.

4. CONCLUSIONS

The final outcomes current study stated that physiochemical characteristics of the meat analog showed higher indices in pH and lower values of lightness and redness. Additionally, the meat analog showed lower values in moisture, fat, and protein than either meat product. Beef and pork, on the other hand, exhibited higher toughness and lower water holding capacities as compared to the meat analog. Consequently, the textural properties of beef and pork had higher hardness, chewiness, and gumminess compared to the soy-based PBMA patties. These data together show that PBMA, while comparable in some respects to its meat-based counterparts, lacks in key areas necessary to generate fully matched hedonic scores.

Author Contributions

All of the authors contributed significantly to the research. A.B wrote the manuscript. Contribution to experimental work by A.B., S.-J.L., and E.-Y.L. S.-T.J. designed experimental work, and the manuscript was reviewed and revised by Y.-H.H. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Not applicable for studies not involving humans or animals.

Conflicts of Interest

The authors declare that they have no conflicts of interest.
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