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ARTICLE

Evaluation of Rheological and Sensory Characteristics of Plant-Based Meat Analog with Comparison to Beef and Pork

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Abstract This study explored the physicochemical, textural, and sensorial properties of a meat analog (MA) as compared to beef and pork meats. Results illustrate that MA patties had lower moisture, fat, and protein content, as well as higher ash and crude fiber than beef and pork. Likewise, MA patties had a higher pH, lightness (L*), and redness (a*) than either beef or pork. Pork meat exhibited the highest released water (RW) and cooking loss (CL) values, followed closely by MA with beef displaying the lowest values. Regardless of patty type, the post-cooking diameter patties were reduced significantly ($p<0.05$). However, the Warner-Bratzler shear force (WBSF), hardness, chewiness, and gumminess of beef were significantly higher than that of either pork or MA. The visible appearance of MA patties had more porous and loose structures before and after cooking. Consequently, based on sensory parameters, MA patties demonstrated the higher values for appearance and firmness, followed by beef and pork respectively, although the difference was not statistically significant. Therefore, the current study demonstrated that some physicochemical, textural, and sensory characteristics of beef and pork exhibited the most similarity to MA.

Keywords textured vegetable protein, meat analog, beef, pork, plant-based ingredients

Introduction

Historically, meat has been considered an indispensable part of the human diet. The consumption of meat has likely been vital for human evolution, meat has been considered a rigorous source of both protein and most notably lipids that are associated with brain growth and development (Williams and Hill, 2017). Over time, a surging world population and industrial development have 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 (Steinfeld et al., 2006). 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 of meat for human consumption (Aiking, 2011). Moreover, extensive animal product production has resulted in a serious loss of biodiversity over time. Recent data showed that globally 30% of the land 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 (Stoll-Kleemann and O'Riordan, 2015). 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 (Tuso et al., 2015).

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 (Alamu and Busie, 2019). 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 (MA; Samard and Ryu, 2019).

Moreover, MA 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 (Mistry et al., 2020). 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 MAs (Mistry et al., 2020). The new generation of MAs, 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 (Sha and Xiong, 2020). 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 MAs with those of beef and pork.

Materials and Methods

Materials

TVP (Anthony's goods, Glendale, CA, USA) was selected as the base for MA, 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.

Sample preparation and processing

The flow diagram for processing MA is described in Fig. 1. For the manufacturing and production of the MA, 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 ddH$_2$O (2 times in volume) and allowed to hydrate for 1 h 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 (MA n=18, pork n=18, and beef n=18) were

Table 1. **Treatment and formulation of meat analog in relation to beef and pork**

Ingredients (%)	Treatment		
	Beef	Pork	MA
Lean beef	75.09	-	-
Lean pork	-	75.09	-
TVP			74.90
Methylcellulose	3.00	3.00	3.00
Garlic powder			2.25
Yeast extract			2.25
Black pepper			1.50
Mushroom			2.25
Salt	1.11	1.11	1.11
Back fat	12.56	12.56	-
Coconut oil	3.75	3.75	3.75
Canola oil	3.75	3.75	3.75
Beet juice			3.00
Molasses			1.50
Umami seasoning	0.74	0.74	0.74

MA, meat analog; TVP, textured vegetable protein.

prepared. By using a non-stick pan with dry heat, the patties were cooked at 150℃ for 5 min on each side. The patties were flipped three times until the internal temperature reached 75℃ as measured by probe thermometer. Before measuring the physicochemical, textural, and sensorial attributes, the patties were allowed to cool at room temperature for 30 min.

Proximate chemical composition

Based on the standard of AOAC (2002), the proximate compositions of patties were examined. Moisture content was determined by drying a 5 g sample at 105℃ for 16 h 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, BUCHI, Flawil, Switzerland) (N×6.25).

$$\%N = \frac{[V(1) - V(B1)] \cdot F \cdot c.F \cdot M(N) \times 100}{M.1000}$$

$$\%\ P = \%\ N \times PF$$

V(1): consumption of titrant, sample (mL)

V(BI): average consumption of titrant, blank (mL)

F: molar reaction factor (1 = HCl, 2 = H_2SO_4)

c: concentration of titrant [mol/L]

M(N): molecular weight of N (14,007 [g/mol])

M: sample weight (g)

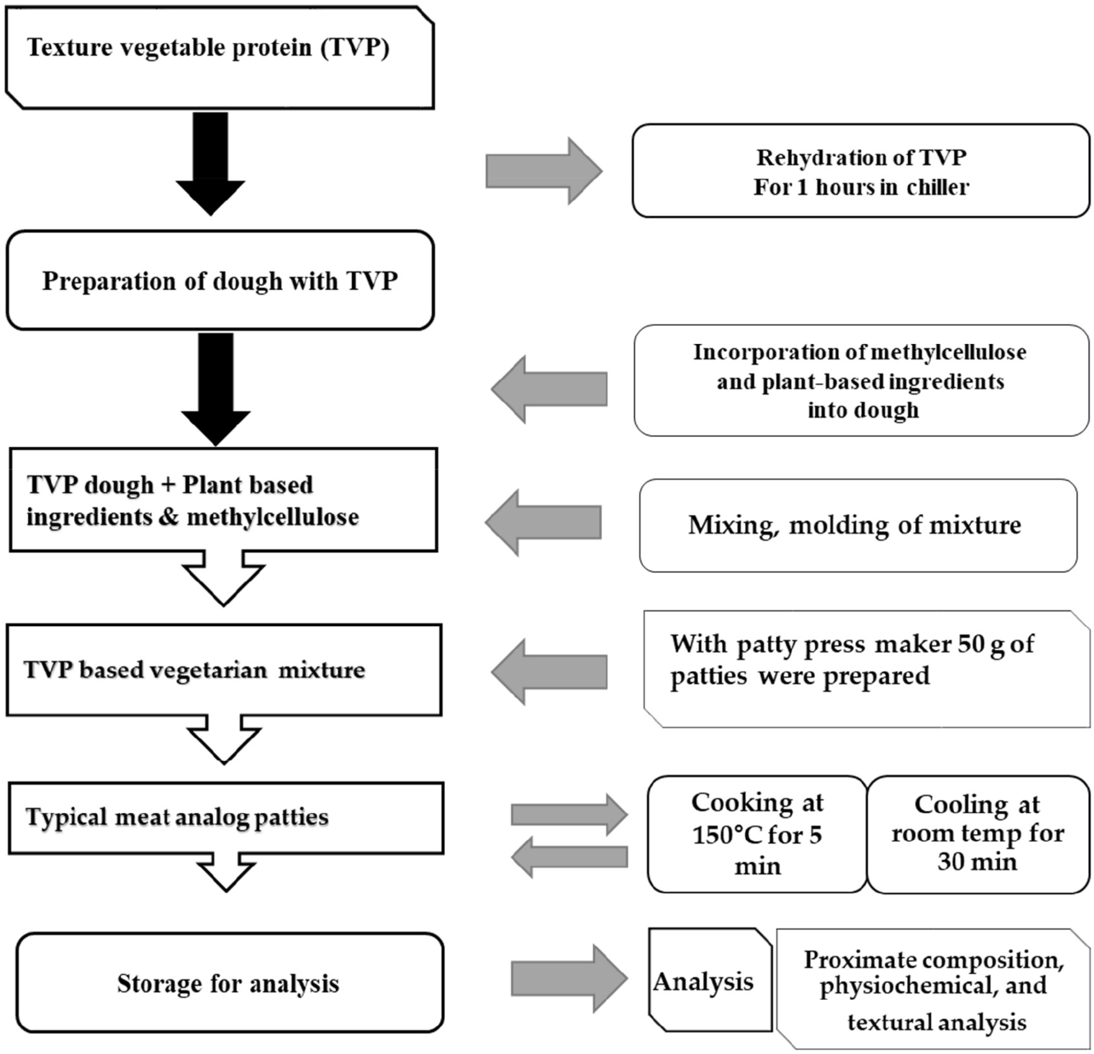

Fig. 1. Flow diagram for manufacturing the meat analog.

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.

$$\% \text{ Crude fat } = (W_2 - W_1) \times \frac{100}{S}$$

W_1 = Weight of empty flask (g)

W_2 = Weight of flask and extracted fat (g)

S = Weight of sample

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 H_2SO_4 and NaOH. The difference in weight after ashing (2 h at 600±15°C) was assembled to calculate the crude fiber content. The following formula was used to numerically calculate the fiber content.

$$\%\text{Crude fiber} = \frac{\left[W_3 - \left(W_1 \times C_1\right)\right]}{W_2} \times 100$$

Where: W_1 = Bag tare weight

W_2 = Sample weight

W_3 = Weight of organic matter (loss of weight on ignition of bag and fiber)

C_1 = Ash corrected blank bag factor (loss of weight on ignition of blank bag/original blank bag)

pH and color attributes

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 (MP230, Mettler Toledo, Greifensee, Switzerland). The external color coordinates of the different patties were measured using a digital colorimeter (Minolta CR-300, Minolta, Japan) with an 8 mm aperture, a D65 illuminant, a 2° 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.

Water holding capacity and tenderness related measurements

Release water percentage (RW %) was measured based on a method described by Joo (2018). The cooking loss (CL %) was determined as a percentage via the method adopted by (Biswas et al., 2006) 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 American Meat Science Association procedure (AMSA, 1995). The percent shrinkage in the patty's diameter was measured at four different locations both before and after cooking.

Visible appearance

The appearance of the beef, pork, and MA patties was assessed method followed by Wi et al. (2020). The external and internal appearance was photographed using a digital camera (EOS 700D, Canon, Tokyo, Japan), and various features were distinguished.

Texture profile analysis

Texture profile analysis (TPA) of the differently prepared patties was performed using a Sun Rheometer (Compact-100 II, Sun Scientific, Tokyo, Japan). Samples were uniformly cut into 1×1×1 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 (Ismail et al., 2019). The following parameters were determined: hardness, cohesiveness, springiness, gumminess, and chewiness.

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 Lawless and Heymann (2013), modified by Rahman et al. (2019). 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 min 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). The Institutional Review Board (IRB) approved the consent procedure for sensory evaluation (nos. GIRB-G16-W-0028). The written consent from all the participants was acquired before conducting the sensory evaluation.

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, Armonk, NY, USA) except for sensory analysis a spider web chart has been adopted. Complete randomized design was adopted for statistical analysis. The error terms used throughout this study are SE. Results are expressed as least square mean values of three independent replications, except for WBSF, for which the average of five measurements was obtained using repeated measurements. For multiple mean comparisons, a Tukey's post hoc test was performed. A p-value ≤5% was considered significant.

Results and Discussion

Proximate chemical composition

The proximate compositions of control and MA patties are presented in Table 2. MA patties were found to have significantly lower moisture loss, low fat, and protein content, and substantially higher ash and crude fiber content than either beef or pork patties. The lower moisture loss in MA 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 (Bakhsh et al., 2021). The mechanism by which MC gelation is achieved between meat protein and plant-based protein is still unclear. Previously one standard theory was adopted that when in solution, hydrophobic methyl groups along the MA polymers are surrounded by cage-like structures of water molecules. With increasing temperature, the cage structure is disrupted, and the polymers gradually lose their hydrated water. At the gelation point, polymers' association occurs due to extensive hydrophobic associations between exposed hydrophobic segments which ultimately causes the food product to loss less moisture content (Sarkar and Walker, 1995). Similarly, the lower fat content in MA patties could be due to the addition of non-polar hexane during the high-pressure extrusion process which likely removed some amount of fat

Table 2. Proximate composition of meat analog in relation to beef and pork

Parameter	Treatment			p-value
	Beef	Pork	MA	
Moisture (%)	59.64±0.95[b]	74.66±0.60[c]	51.53±0.54[a]	0.000
Ash (%)	1.55±0.29[a]	1.51±0.25[a]	3.23±0.144[b]	0.003
Fat (%)	19.11±0.56[b]	20.36±0.27[b]	11.71±1.04[a]	0.000
Protein (%)	20.52±0.59[b]	21.75±0.48[b]	16.77±0.75[a]	0.003
Crude fiber (%)	1.56±0.25[a]	2.63±0.37[a]	6.87±0.93[b]	0.002

Means with different superscripts within the same row are significantly different ($p<0.05$).
Data are means±SE.
MA, meat analog.

from TVP (Asgar et al., 2010).

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 MA patties. These outcomes diverge from Hidayat et al. (2018), 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 (MA) contained about 4%–5% fiber. It provided 224 kcal of energy per 100 g and exhibited good textural characteristics (Ahirwar et al., 2015). The higher fiber in MA 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 (Trowell, 1973). The variations in chemical composition including moisture, fat, protein, ash, and crude fiber in MA are likely the basis for the differences in physical properties that occur when replacing beef and pork with TVP in MA patties.

pH and color attributes

The physiochemical indicators, including pH and colorimetric evaluation, are given in Table 3. The pH of beef and pork is slightly lower than MA patties both before and after cooking. The high pH in the MA patties was likely due to the slight alkalinity of TVP (pH 7.42–7.43) as compared to beef and pork meat (Kamani et al., 2019). The lower pH value of beef and pork was likely due to the regular glycolytic changes that occur in meat (Chauhan et al., 2019). Previous studies using chicken meat sausage have shown a trend of increment in pH values via the partial or complete replacement of chicken with plant proteins, which aligns well with our findings (Kamani et al., 2019).

Likewise, pH and calorimetric measurements are interconnected with each other. Concerning calorimetric measurements, the addition of plant proteins in MA 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 MA. Comparable to the present findings, a tendency toward decreasing L* and increasing b* were recorded by Akesowan (2010), 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 MA 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 (Kyriakopoulou et al., 2019).

Table 3. **pH and color attributes of meat analog in relation to beef and pork**

Parameter	Treatment			
	Beef	Pork	MA	p-value
pH before cooking	5.34±0.22[a]	5.69±0.13[a]	6.50±0.18[b]	0.002
pH after cooking	5.62±0.36[a]	5.50±0.27[a]	6.19±0.27[b]	0.000
L* before cooking	47.83±0.33[a]	50.54±1.21[b]	39.94±0.44[b]	0.000
a* before cooking	16.05±0.20[c]	14.55±0.37[a]	12.77±0.35[b]	0.000
b* before cooking	11.23±0.18	12.26±0.20	13.37±0.12	0.081
L* after cooking	35.46±0.87[a]	41.80±0.47[b]	31.26±0.35[b]	0.000
a* after cooking	8.72±0.23	6.85±0.47	9.89±1.50	0.076
b* after cooking	12.34±0.89	13.44±0.27	14.69±0.30	0.095

Means with different superscripts within the same row are significantly different ($p<0.05$).
Data are means±SE.
MA, meat analog.

Water-holding capacity and tenderness related measurements

In the current study, water-holding capacity (WHC) is expressed in two parts, RW and CL, as shown in Table 4. The WHC including RW and CL% amongst various meats showed differences expressively with MA patties presenting the highest values followed by pork and beef respectively. This implies that the internal structural network of pork and beef was more effective in retaining moisture during cooking when compared to MA patties. This fact was previously well explained by Köhn et al. (2015) who described that myofibrillar protein (actin and myosin), intramuscular connective tissue, and perimysium of meat play a major role to withhold the internal water of red meat which eventually cause to reduce the WHC. The higher WHC in MA patties is probably due to the higher concentration of soy-based water-soluble proteins in TVP, the porosity and air cell size of the TVP structure were highly influenced by WHC (Samard and Ryu, 2019). Moreover, the lower concentration of fat in TVP causes the protein to bind freely to water molecules which ultimately causes the WHC to increase. The current results are in line with earlier work reported which explains that the complete replacement of meat with soy protein leads to an increase in WHC (Das et al., 2008). As mentioned previously, the pH of MA patties before cooking was higher than either beef or pork, and a higher pH ultimately causes the MA patties to retain more water and present with a higher WHC.

Similarly, the patties diameter were reduced significantly post-cooking regardless of patty type. Beef and pork meat demonstrated higher shrinkage due to connective tissue denaturation and fluid (moisture and fat) loss; while MA patties substituted with plant protein showed a reduction in patty diameter markedly. Previous studies have indicated that the addition of fiber and non-meat proteins may reduce shrinkage and weight loss during cooking (Gujral et al., 2002). The WBSF values indicated that MA patties were significantly less tough than pork or beef. The higher hardness in beef and pork was expected due to the muscle protein denaturation phenomenon, which increases the WBSF values in the meat which ultimately caused the meat to be toughened (Ismail et al., 2019). The softer textural properties of MA significantly affected its shear force values. Previously reports have shown that shear force value was significantly correlated to hardness, springiness, and chewiness (de Huidobro et al., 2001). 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,

Table 4. Water-holding capacity and tenderness related measurement of meat analog in relation to beef and pork

Parameter	Treatment			
	Beef	Pork	MA	p-value
Release water (%)	1.81±0.97[a]	1.55±0.98[a]	4.21±0.11[b]	0.000
Cooking loss (%)	6.53±0.41[b]	8.83±0.82[b]	15.68±0.33[a]	0.000
Diameter before cooking (%)	15.83±0.16	15.33±0.44	15.46±0.73	0.775
Diameter after cooking (%)	7.30±0.10[a]	9.71±0.43[b]	10.57±0.55[c]	0.000
Shear force (N)	3.79±0.81[b]	1.91±0.35[a]	2.74±0.58[a]	0.002

Data are means±SE.
[a-c] Means with different superscripts within the same row are significantly different ($p<0.05$).
MA, meat analog.

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 Danowska-Oziewicz (2014), who detected lower WBSF values in samples containing soy isolate protein as compared to control (pork patties).

Visible appearance

The visible (external and internal) appearance of cooked and uncooked beef, pork, and MA patties has been shown in Fig. 2.

Fig. 2. External and internal appearance of meat analog in relation to beef and pork.

The external and internal appearance of beef and pork are more homogenous and finely structured than MA patties before after cooking. The results indicated that MA patties had porous and rough structures before and after cooking. The possible reason could be due to the non-adhesive behavior of plant-based ingredients in MA. Our previous study concluded that the main drawback of using TVP was granular surfaced patties although the external and internal appearance of all parties appeared to be more homogenous and cohesive when the concentration of MC was increased (Bakhsh et al., 2021). Similarly, Wi et al. (2020) confirmed that water-added samples with or without soy protein isolate (SPI) were found to have a rough surface when compared to the other samples due to the high evaporation of moisture on the surface. More research is needed on the structuring potential of new protein sources and their ability to retain water during storage and to release it upon heating and deformation. However, TVP alone, similarly to ground meat, cannot form a coherent MA product, which makes the use of binders unavoidable (Kyriakopoulou et al., 2019). Moreover, methylcellulose is a useful binder, especially on the MA that does not require pre-heat for gel formation due to its unique thermal gelling and right emulsifier properties (Sanz et al., 2005).

Texture profile analysis

The textural parameters including hardness, chewiness, gumminess, cohesiveness, and springiness of beef, pork, and MA patties are shown in Table 5. The hardness, chewiness, and gumminess of beef were significantly higher than either pork or MA patties. The higher hardness in beef and pork was expected due to the muscle protein denaturation phenomenon, which increases the hardness in the meat (Ismail et al., 2019). 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 MAs has confirmed that hardness, cohesiveness, chewiness, and gumminess decrease as moisture content increases (Lin et al., 2000). The probable reason that beef and pork had higher values in (hardness, chewiness, and gumminess) is likely related to the fact that meat contains myofibril proteins, which cause a tougher network formation internally, thereby enhancing the resistance to compression (Kamani et al., 2019). 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 (Youssef and Barbut, 2011).

Table 5. Textural properties of meat analog in relation to beef and pork

Parameter	Treatment			
	Beef	Pork	MA	p-value
Hardness (N)	76.66±1.65^{c}	55.23±1.84^{b}	20.23±1.23^{a}	0.000
Gumminess (N)	13.50±0.77^{c}	6.92±0.82^{b}	3.44±0.85^{c}	0.000
Cohesiveness	0.40±0.038	0.44±0.40	0.37±0.04	0.813
Chewiness (mJ)	6.37±0.46^{b}	3.27±0.17^{a}	1.98±0.48^{a}	0.001
Springiness (mm)	0.48±0.01	0.52±0.23	0.50±0.02	0.715

Data are means±SE.
$^{a-c}$ Means with different superscripts within the same row are significantly different ($p<0.05$).
MA, meat analog.

Sensory evaluation

The sensory traits of MA, beef, and pork are shown in Fig. 3. The appearance values of MA 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. MA patties had a higher firmness compared to beef and pork meat respectively. Similarly, the overall acceptability of MA was comparable to beef and pork but without statistical difference. The vast variability of MA patties as compared to controls could be due to the plant-derived proteins (soy protein) in MAs expressing more elastic, rubbery, and chewy sensations due to their agglomeration properties (Bakhsh et al., 2021; Wi et al., 2020). A common disadvantage of using plant proteins in MAs is the generation of volatile compounds from the lipid oxidation of unsaturated fatty acids that contribute to the formation of unappealing odors and flavors (Asgar et al., 2010). Consequently, a wide array of spices and herbs, including those that are also applied in meat processing, are added to simulate processed meat flavors. However, aftertaste can still be detected in many plant-based alternatives. The characteristic beany odor, thought to be related to the secondary lipid oxidation products or derivatives, such as hexanal and methanethiol (Boatright and Lu, 2007), and the bitter-astringent tastes due to the natural presence of saponins and isoflavones, could be a hindrance to the utility of soy protein as the basic materials for meat alternatives. Therefore, research is necessary to minimize the impact of these undesirable flavors in the preparation of SPI or concentrate. 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 MA 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.

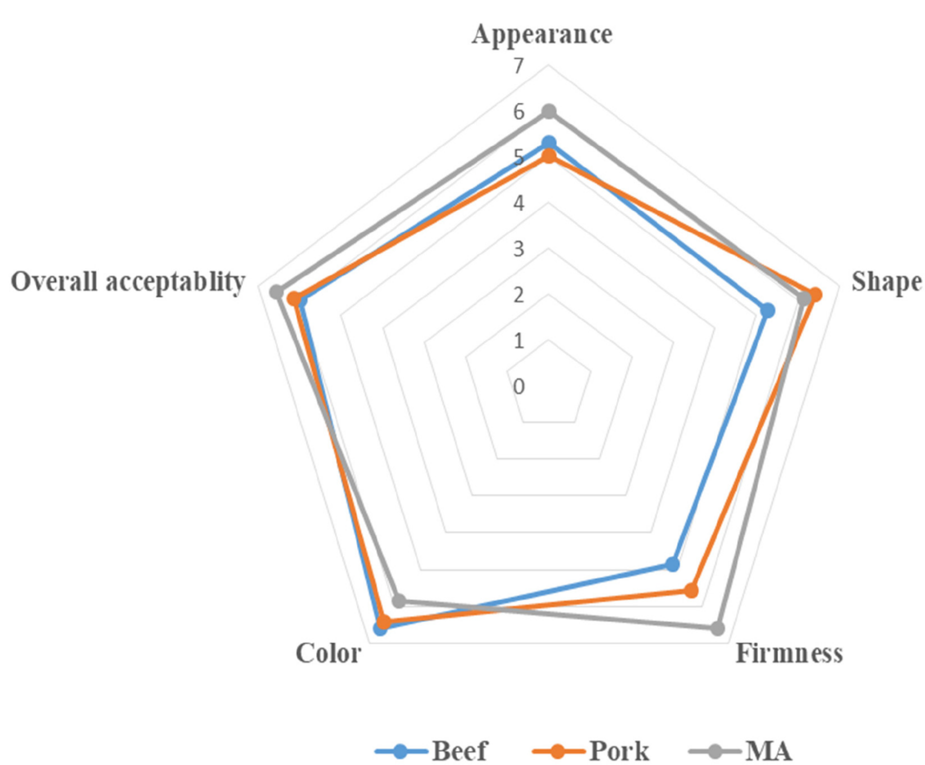

Fig. 3. Sensory properties of meat analog in relation to beef and pork. MA, meat analog.

Conclusion

The outcomes current study stated that physiochemical characteristics of the MA showed higher indices in pH and lower values of lightness and redness. Additionally, the MA showed lower values in moisture, fat, and protein than either meat. Beef and pork, on the other hand, exhibited higher toughness and lower WHC as compared to the MA. Consequently, the textural properties of beef and pork had higher hardness, chewiness, and gumminess compared to the soy-based MA patties. Therefore, in order to produce a quality MA closest to real beef and pork, further investigations of plant based-protein ingredients with combination of different types of TVPs are necessary.

Conflicts of Interest

The authors declare no potential conflicts of interest.

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Author Contributions

Conceptualization: Hwang YH, Joo ST. Data duration: Bakhsh A, Lee SJ. Formal analysis: Bakhsh A, Joo ST. Methodology: Bakhsh A, Lee EY. Validation: Bakhsh A, Hwang YH, Joo ST. Writing- original draft: Bakhsh A, Lee SJ, Lee EY. Writing- review & editing: Bakhsh A, Lee SJ, Lee EY, Hwang YH, Joo ST.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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