COMPARATIVE ANALYSIS OF THE NUTRITIONAL COMPOSITION, PHYSICAL PROPERTIES AND SENSORY PROFILE OF MEAT AND PLANT-BASED BURGERS

Ivica Kos[1] – Veronika Mihovilić[1] – Ivan Širić[1] – Ivan Vnučec[1]

[1] University of Zagreb Faculty of Agriculture, Svetošimunska 25, 10 000 Zagreb, Croatia

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ABSTRACT

This study compared commercially available plant-based (PB) and meat burgers (MB) on the Croatian market in terms of nutritional composition, cooking-induced physical properties, and sensory profile. Nutritional data were obtained from product labels, physical changes during standardised grilling were measured, and sensory characteristics were evaluated using quantitative descriptive analysis. PB had a lower energy value (217 vs 263 kcal·100 g^{-1}) and substantially less saturated fat (2.8 vs 8.23 g·100 g^{-1}) than MB, while MB contained more protein (17.1 vs 14.3 g·100 g^{-1}). Carbohydrate and fibre contents were higher in PB, whereas salt content was similar between categories. During cooking, PB showed greater thickness stability (5.40% vs 11.64% reduction) but higher relative mass loss (24.32% vs 22.63%), indicating limited water-binding capacity. Sensory analysis revealed distinct profiles: MB were characterised by greater firmness, cohesiveness, oily mouthfeel, and meat flavour, while PB had a softer texture and dominant vegetable-related attributes. Plant-based burgers differ fundamentally from meat burgers in nutritional composition, cooking behaviour, and sensory profile, supporting their classification as distinct products rather than direct substitutes for meat burgers.

Keywords: burger, plant-based, nutritional composition, sensory analysis, thermal processing, meat analogues

INTRODUCTION

Burgers are among the most widely consumed processed meat products (Boukid and Castellari, 2021) and have become a central benchmark for the development of plant-based meat analogues. As noted by Szenderák et al. (2022), consumer interest in reducing meat intake is increasingly driven by environmental, animal welfare, and health considerations, a trend further reinforced by life cycle assessments demonstrating substantially lower environmental burdens for plant-based burgers compared with beef (Tang et al., 2024). In this transition, the burger format has emerged as the dominant application for plant-based meat analogues, owing to its standardised shape, familiar consumption context, and technological adaptability (Mercês et al., 2024; Jang and Lee, 2024).

From a nutritional perspective, plant-based burgers are often positioned as healthier alternatives, particularly due to their potential to reduce saturated fat intake and provide dietary fibre (Bohrer, 2019). However, detailed compositional surveys reveal wide variability in nutrient profiles across commercial products, with protein content and quality, carbohydrate levels, and sodium concentration strongly dependent on formulation strategies (De Marchi et al., 2021; Yu et al., 2023). Market-based assessments in Europe further indicate that many plant-based burgers rely on coconut oil and added salt to achieve palatability, resulting in saturated fat and sodium levels that may approach those of processed meat burgers (Astiasaran et al., 2025). These findings show that the nutritional superiority of plant-based burgers cannot be assumed a priori.

Technological innovation has played a critical role in narrowing the sensory gap between plant-based and meat burgers. Nevertheless, fundamental differences in matrix composition persist. While meat burgers undergo dimensional shrinkage driven by myofibrillar protein denaturation and fat melting, plant-based systems often rely on hydrocolloid gelation and protein–lipid interactions to maintain structural integrity during cooking (De Marchi et al., 2021). Sensory quality remains a major determinant of consumer acceptance. Quantitative sensory and consumer studies consistently report that meat burgers are perceived as firmer, juicier, and more cohesive, with stronger meat flavour, whereas plant-based burgers are frequently described as softer and characterised by vegetable-related or beany notes (Sogari et al., 2024; Davis et al., 2021; Correia et al., 2024). Importantly, consumer research indicates that willingness to purchase plant-based burgers is driven primarily by nutritional and sustainability benefits, with sensory performance playing a secondary role in purchase decisions (Sendhil et al., 2024; Pasquariello et al., 2025).

The aim of this study was to conduct a comprehensive comparative analysis of commercially available plant-based and meat burgers on the Croatian market, integrating nutritional profiling, standardised assessment of cooking-induced physical changes, and quantitative sensory analysis to elucidate the key physicochemical and sensory factors differentiating these two product categories.

MATERIALS AND METHODS

Six commercially available burger products were selected to represent meat and plant-based burgers available on the Croatian market. Samples were categorised as meat burgers (MB; n = 3) and plant-based burgers (PB; n = 3) and purchased from major retail outlets representing both premium and mass-market segments in Zagreb. All PB samples and one MB sample were purchased frozen and stored at −20 °C until analysis, while two MB samples were purchased refrigerated and stored at 4 °C in accordance with manufacturer instructions.

Nutritional composition was obtained from mandatory product declarations on the package. The recorded parameters included energy value (kcal/kJ), total fat, saturated fatty acids, carbohydrates, sugars, protein, and salt content per 100 g of raw product. These data were used for comparative evaluation of macronutrient composition between meat and plant-based burger formulations.

To evaluate technological behaviour during cooking, a standardised thermal processing protocol was applied. Prior to thermal treatment, five replicates of each burger type were weighed using a digital scale (Ordning, Ikea, Sweden; accuracy ±1 g). Burger diameter (measured in two perpendicular directions) and thickness were recorded using a digital calliper (Alpha Tools, BAHAG AG, Germany; accuracy ±0.01 mm). Thermal processing was carried out on a preheated electric contact grill (Hendi, model 236907, Netherlands) set to 250 °C. Internal temperature was monitored using a penetration probe thermometer (TFA Dostmann, model 14.1500, Germany), and cooking was terminated when the geometric centre of each patty reached 71 °C, corresponding to microbiological safety standards. After cooking, samples were rested for 3 min at room temperature to allow pressure equilibration. Post-cooking mass and dimensions were then recorded. Cooking loss and dimensional shrinkage were calculated as relative changes, while released fluid was collected and weighed separately to distinguish drip loss from evaporative loss.

Sensory evaluation was conducted in a dedicated sensory laboratory designed in accordance with ISO 8589:2007, under controlled environmental conditions (neutral white lighting at 4000 K and 500 lux, temperature 20–22 °C, relative humidity 50–55%). Quantitative Descriptive Analysis (QDA) was performed by a trained panel of nine assessors selected and trained in accordance with ISO 8586-1 and ISO 8586-2. A consensus lexicon comprising 24 sensory attributes related to appearance, aroma, texture, and flavour was developed during training sessions. Attribute intensities were rated on a 10-point categorical scale (0–9). Samples were served at 45 °C in transparent containers labelled with randomised three-digit codes. Water and bread were provided as palate cleansers between samples. Data acquisition was performed using Compusense sensory software (Compusense Inc., Ontario, Canada).

Statistical analyses were conducted using SAS Studio software (SAS Institute Inc., USA; version 3.8). Descriptive statistics were calculated for all measured variables. Pairwise comparisons between PB and MB were performed on category-level means (n = 3 per group). Results should be interpreted as exploratory due to the limited sample size. Differences in physical properties were evaluated using analysis of variance (ANOVA) with Tukey's post hoc test. Sensory data were analysed using mixed-effects models (PROC MIXED), with sample treated as a fixed effect and assessor as a random effect. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

As shown in Figure 1, the aggregated nutritional profiles revealed clear and systematic differences between PB and MB burgers. MB had a significantly higher mean energy value (263 $kcal \cdot 100\ g^{-1}$) and total fat content (20.7 $g \cdot 100\ g^{-1}$) compared with PB (217 $kcal \cdot 100\ g^{-1}$ and 16.0 $g \cdot 100\ g^{-1}$, respectively). The most pronounced difference was observed for saturated fatty acids, with MB containing nearly three times the level found in PB (8.23 vs 2.8 $g \cdot 100\ g^{-1}$). This finding confirms reduced saturated fat as a principal nutritional advantage of PB, consistent with label-based surveys and compositional analyses of commercial products (Astiasaran et al., 2025; De Marchi et al., 2021; Filip et al., 2025; Yu et al., 2023).

In contrast, PB were characterised by substantially higher carbohydrate content (5.7 $g \cdot 100\ g^{-1}$), whereas these components were negligible in MB (2.1 $g \cdot 100\ g^{-1}$ carbohydrates). These differences primarily reflect the technological requirements of plant-based formulations, where carbohydrates and fibres act as binders, texturisers, and structural stabilisers rather than as nutritionally targeted ingredients (Bohrer, 2019). Sugar content remained low in both categories and was nutritionally marginal as established by Filip et al. (2025).

Protein content was higher in MB (17.1 $g \cdot 100\ g^{-1}$) than in PB (14.3 $g \cdot 100\ g^{-1}$) as similarly established by Filip et al. (2025). Although the quantitative difference was moderate, it is nutritionally relevant when considering protein quality, as meat proteins usually provide higher digestibility and a more balanced essential amino acid profile than most plant protein systems used in PB as observed previously by Cutroneo et al. (2023). However, these authors stated that the differences between these products are mostly dependent on the quality of the raw materials used, rather than on the vegetal or animal protein source.

Salt content did not differ significantly between categories (MB: 1.39 $g \cdot 100\ g^{-1}$; PB: 1.15 $g \cdot 100\ g^{-1}$), indicating that sodium levels are primarily formulation-driven rather than category-dependent. This challenges the perception that plant-based burgers are inherently more sodium-dense than meat burgers and aligns with recent market surveys reporting comparable salt contents across both product types (Astiasaran et al., 2025; Filip et al., 2025).

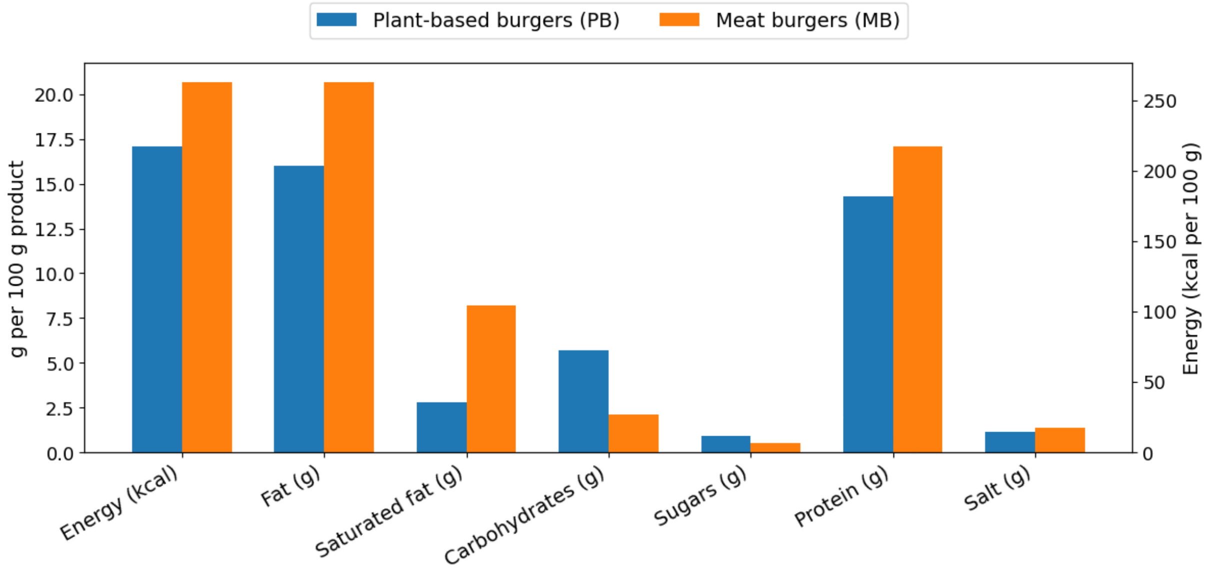

Figure 1: Nutritional composition and energy value of meat (MB) and plant-based (PB) burgers

Cooking-induced changes in physical properties revealed clear differences between plant-based burgers (PB) and meat burgers (MB) (Figure 2), reflecting distinct structural responses to thermal processing. Surface area reduction was comparable between PB (12.71%) and MB (17.25%), suggesting that lateral shrinkage is driven by common mechanisms such as moisture loss and matrix relaxation, regardless of composition. However, thickness reduction differed significantly ($p < 0.05$), with MB exhibiting substantially greater vertical shrinkage (11.64%) than PB (5.40%). This vertical collapse in meat results directly from the thermal denaturation and longitudinal contraction of actomyosin and collagen fibres (Souppez et al., 2025). The superior thickness stability in PB burgers indicates a rigid scaffold, likely mediated by the reversible thermal gelation of plant proteins and hydrocolloids such as methylcellulose, which reinforce the structure during heating (De Marchi et al., 2021).

Mass and fluid loss further distinguished the matrices significantly ($p < 0.05$). MB released significantly more liquid (drip loss) during cooking (8.44%) than PB (5.75%), as the disruption of muscle fibres and adipose tissue promotes the exudation of water and liquefied animal fat (Souppez et al., 2025). In contrast, PB burgers exhibited a higher relative mass loss (24.32%) compared to MB (22.63%), suggesting that weight loss in plant matrices is dominated by evaporative dynamics rather than drip loss. This indicates a decoupling between shape retention and moisture retention: while PB burgers maintain their physical dimensions, they have a limited water-binding capacity relative to the myofibrillar lattice of meat, which traps fluids more effectively (De Marchi et al., 2021). This functional deficiency presents a technological challenge for improving perceived sensory juiciness in meat substitutes (Jang and Lee, 2024).

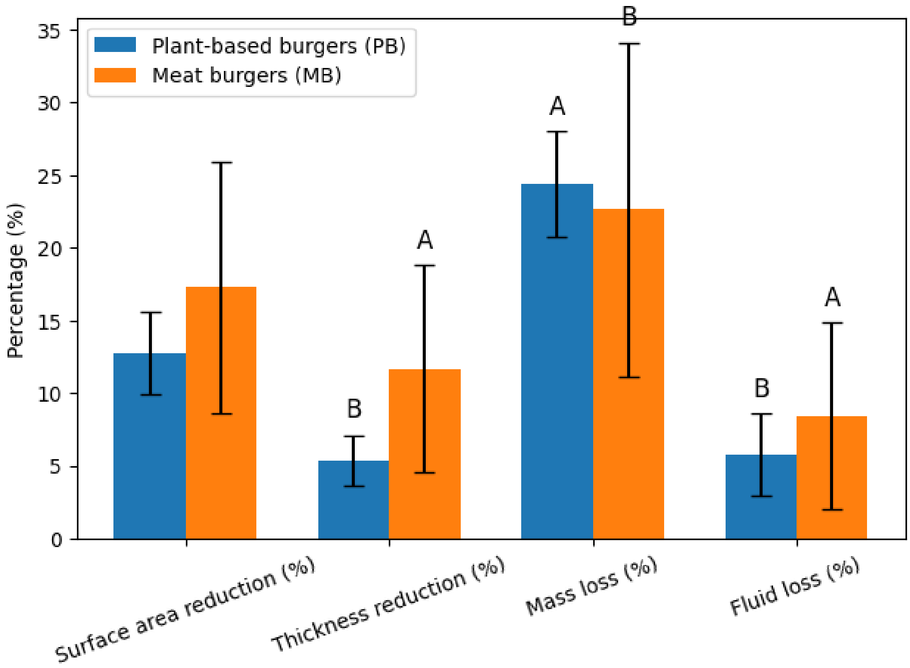

Figure 2: Physical properties of plant-based (PB) and meat burgers (MB), expressed as mean ± SD

Notes: Different superscript letters (A, B) above bars indicate statistically significant differences between groups (p < 0.05)

Quantitative Descriptive Analysis (QDA) revealed fundamental and systematic differences between meat burgers (MB) and plant-based burgers (PB) (Figure 3), confirming that current plant-based formulations do not yet achieve sensory equivalence with animal-derived systems in correspondence with the results of previous research (Abdullah et al., 2024; Davis et al., 2021; Ettinger et al., 2022).

MB were characterised by significantly higher intensities of meat flavour and salty taste ($p < 0.05$), attributes arising from the complex interaction of myofibrillar proteins, endogenous amino acids, and animal fat during thermal processing. In contrast, PB were dominated by vegetable-related, burnt, and spicy odours and flavours, alongside higher perceived sweetness. These sensory signatures are not incidental but reflect persistent formulation constraints within the sector. It is highlighted that achieving visual indistinguishability (mimicking phenotypic characteristics) between meat and analogues may be more feasible than replicating other sensory attributes such as meat taste and animal character (Abdullah et al., 2024). Off-notes commonly described as beany are chemically associated with lipid oxidation products, such as hexanal, inherent to legume-based protein isolates (Jang and Lee, 2024). Although manufacturers attempt to mitigate these attributes through masking strategies, including the use of spices and smoke aromas, as reflected in the elevated spicy odour scores, these approaches tend to overlay rather than eliminate the underlying botanical notes, which remain readily detectable to trained assessors (Sogari et al., 2024).

The presence of intensified burnt notes in PB further indicates a reliance on simplified flavour-generation pathways. These attributes are likely linked to the rapid caramelisation of added reducing sugars (e.g., dextrose) intended to mimic Maillard-derived meat aromas. However, unlike the complex Maillard and lipid–protein reaction network in meat, this strategy tends to produce narrower, less integrated flavour profiles, contributing to sensory imbalance (Sogari et al., 2024; Correia et al., 2024).

Textural profiling revealed a pronounced rheological gap between categories. MB exhibited higher hardness, elasticity, and cohesiveness, reflecting irreversible thermal cross-linking of actomyosin fibres that yields a resilient, fibrous matrix (Souppez et al., 2025). PB, by contrast, were perceived as softer and less cohesive as previously reported by Abdullah et al. (2024), despite comparable graininess scores. This combination suggests that while particle size reduction and comminution may approximate meat-like granularity, insufficient protein fibre alignment during extrusion prevents the formation of a continuous load-bearing network (Zink et al., 2024). The widespread use of methylcellulose provides thermal firmness, yet its reversible gelation leads to structural weakening upon cooling, in contrast to the permanent denaturation of meat proteins (Funami et al., 2007).

Oily mouthfeel further differentiated the categories. MB provided a sustained lubricating sensation due to the gradual melting and redistribution of animal fats, which coat the oral cavity and prolong flavour perception. In PB, due to the differences in the temporal perception (Zhang et al., 2024) plant lipids were possibly perceived as being released too rapidly, producing a transient greasy sensation rather than sustained juiciness.

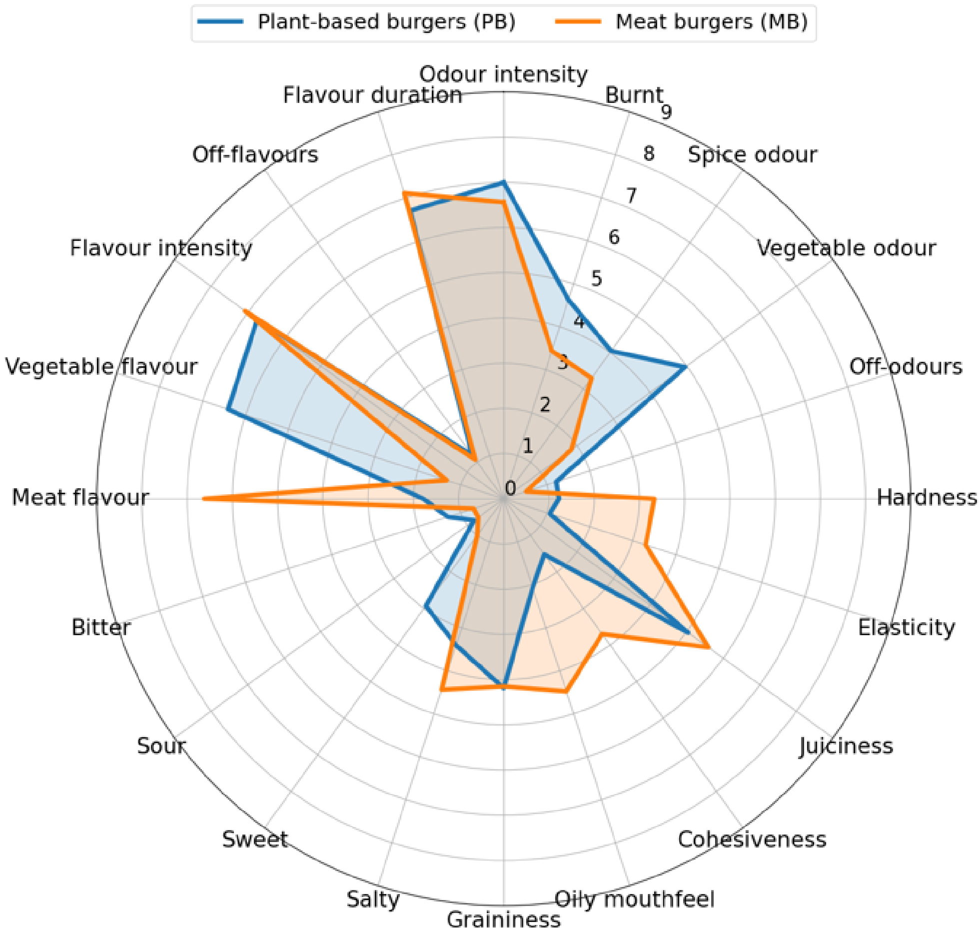

Figure 3: Radar plot of quantitative descriptive analysis (QDA) sensory attributes for plant-based (PB) and meat burgers (MB)

Notes: Values represent mean intensity scores on a 0–9 scale

CONCLUSION

Plant-based burgers (PB) and meat burgers (MB) differ fundamentally in nutritional composition, cooking behaviour, and sensory profile. PB offer advantages through reduced saturated fat and slightly lower energy density, whereas MB retain superior protein quantity and quality, indicating that PB should be regarded as alternative products rather than direct nutritional substitutes for meat. Cooking responses further revealed contrasting matrix behaviour: PB showed greater thickness stability but higher mass loss, while MB exhibited greater deformation and fluid release yet retained more moisture and fat. This decoupling highlights a key technological limitation of PB in moisture retention and juiciness. Sensory analysis confirmed persistent differences, with MB characterised by firmer texture and pronounced meat flavour, and PB by softer texture and vegetable-related attributes. Overall, the findings suggest that improving plant-based burgers will require matrix-level design strategies integrating protein structure, lipid release, and flavour generation, rather than reliance on additive-based correction.

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Contact Information: Invited speaker: Prof. Ivica Kos, PhD, Division of Animal Science, University of Zagreb Faculty of Agriculture, Svetošimunska 25, 10 000 Zagreb, Croatia, e-mail: ikos@gr.hr