

Development of plant sausage utilizing tender jackfruit (*Artocarpus heterophyllus*) and textured Faba bean protein (*Vicia faba*): Evaluation of functional qualities, proximate composition and consumer acceptance.

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Abstract

Advances in plant nutrition and ingredient formulation have led to the development of plant protein ingredients that closely resemble meat characteristics and serve the social demand for nutritious, ethical, and sustainable foods [1].

In this study, a formulation incorporating tender jackfruit and faba bean protein was developed and analyzed for functional and nutritional properties using AOAC methods. Consumer compatibility was assessed through sensory evaluation involving both untrained and trained panelists. The resulting plant sausages exhibited optimal moisture ($62.4 \pm 0.8\%$), pH (6.3 ± 0.1), protein ($18.6 \pm 0.5\%$), and dietary fiber content ($5.2 \pm 0.3\%$). Texture analysis indicated that hardness, chewiness, and cohesiveness were like those of traditional chicken sausages.

Sensory evaluation indicated that the overall acceptability of the plant sausage was significantly higher ($p < 0.05$) than that of traditional chicken sausages for both trained and untrained panelists. The plant sausage's non-greasy, fatty mouthfeel and mild flavors were noted. The meat-like structure of tender jackfruit and the emulsion-binding properties of faba bean proteins led to a complementary interaction, yielding a plant sausage with desirable physicochemical properties and consumer-preferred characteristics.

Introduction

Global demand for plant-based meat alternatives continues to rise, driven by growing environmental, health, and ethical concerns. Recent research emphasizes blending functional plant proteins with fibrous ingredients to replicate both the texture and nutritional profile of conventional meat products [2].

Tender jackfruit (*Artocarpus heterophyllus*) is gaining attention as a natural meat substitute due to its fibrous structure, mild flavor, and ability to absorb seasonings. Its shredded texture resembles muscle fibers, giving a pleasant mouthfeel in vegetarian and vegan recipes. At the same time, faba bean (*Vicia faba*) protein is becoming known as a sustainable, nutritious pulse protein [3–4]. It has excellent emulsifying, gelling, and water-holding properties, making it ideal for textured vegetable protein (TVP) and meat analogues [5].

There is limited evaluation of the combined impact of tender jackfruit and textured faba bean protein in sausage recipes. Most previous research has focused on jackfruit with soy or wheat gluten proteins or on the extrusion and protein functionality of faba bean proteins, rather than their ability to form structured, fibrous products. Few studies have addressed how their combination influences functional aspects such as moisture, pH, acidity, textural, nutritional, and sensory characteristics in sausage formulations [6–7].

Blending fiber-rich jackfruit with protein-rich faba bean could yield a balanced product with a meat-like texture and improved nutritional value. Additionally, farming faba beans promote sustainable agriculture

through nitrogen fixation and adaptability to different climates [8]. Consumer research shows that texture and greasy mouthfeel are major drawbacks of traditional meat sausages.

Materials and Methods

Materials

Sausage Binder Premix: The binder ingredients, potato starch (Ingredion, USA), pea protein isolate (Synthite Industries, Kerala, India), methylcellulose (plant fiber) (Vivapur, J. Rettenmaier & Söhne GmbH, Germany), and kappa carrageenan (Meron Hydrocolloids, India; food grade), were chosen for their proven functionality in improving textural integrity, water-holding capacity, and emulsion stability in meat analogues [9–10].

Tender Jackfruit: Fresh tender jackfruits (*Artocarpus heterophyllus*) were sourced locally from household farms in Kochi, Kerala, during February–April. The fruits were harvested at Stage 1 of maturity (50–70 days), when seed development is absent, and the fibrous texture resembles poultry meat [11].

Textured Faba Bean Protein (TVP) was procured from Beneo India Pvt Ltd, Haryana. The product was stored under ambient conditions until use. Spices (black pepper, salt, garlic, and green chili) were purchased from the local Kochi market, cleaned, and ground prior to formulation.

Pre-processing of materials

For plant sausage formulation, raw materials were preprocessed as follows. First, the binder emulsion was formulated to achieve a uniform, stable emulsion using 35% potato starch, 45% pea protein isolate, 10% methylcellulose, and 10% kappa-carrageenan. These ingredients were homogenized to form a powder binder premix. The emulsion was then prepared by combining the premix with chilled refined sunflower oil (0–4°C) and chilled water (0–4°C) in a 1:1:4 (binder:oil:water) ratio using a high-speed blender, resulting in a stable emulsion.

Tender jackfruit bulbs were selected, peeled, had immature seeds removed, and were cut into 3–4 cm segments. To inhibit enzymatic browning, the pieces were blanched in a 0.1% ascorbic acid solution for 5 minutes, then drained and frozen at –18°C. After freezing, the jackfruit was shredded into fibrous strands using a Robot Coupe cutter.

Textured faba bean protein was rehydrated in chilled water (0–4°C) at a 1:2 ratio (TVP:water) for 30 minutes, then gently pressed to remove excess water [12–13]. Separately, a mild spice mix consisting of ground pepper, salt, green chili, and natural seasonings was prepared to mimic the typical flavor of chicken sausages while ensuring a balanced flavor profile [14].

Plant Sausage Formulation

The final sausage formulation, determined through iterative trials, included 60% binder emulsion, 15% rehydrated faba bean protein, 15% shredded jackfruit, and 10% spice mix. These were combined in a bowl chopper until a homogeneous mass formed. The mixture was cooled to 4–8°C, filled into 15 mm diameter cellulose casings, and manually sealed.

Cased sausages were steamed at 100°C for 20–25 minutes until the core temperature reached 75°C. Next, they were heated at 80°C for 2–3 minutes to enhance flavor [15]. After cooling in chilled water, the casings were removed. The sausages were stored at – 18°C until analysis. For sensory evaluation, samples were pan-sautéed in light oil before serving.

Functional qualities

To evaluate the functional quality of the developed plant sausage, we analyzed pH, salt content, water activity, cooking loss, water-holding capacity (WHC), and shear-force texture, and compared these parameters with those of commercially available meat sausages.

To measure pH and Salt, a 5 g sample was dispersed into 50 ml of deionized water, and the pH was measured using a pre-calibrated portable pH meter (Hanna, HI99163 meat pH meter), and salt with a pre-calibrated digital salt meter (Atago digital PAL-salt). Water activity (a_W) was measured using an industry-standard water activity meter (AQUALAB 4TE) [16–17].

The cooking loss was determined using the following formula, based on pre-cooked weight and post-cooked, cooled weight. The cooked sausages were brought down to room temperature to avoid any weight variations[18–20].

$$\text{Cooking loss (\%)} = [(Weight\ before\ cooking\ (g) - Weight\ after\ cooking\ (g)) / Weight\ before\ cooking\ (g)] \times 100$$

The water-holding capacity (WHC) of the prepared samples was determined by centrifugation. Sample weights were recorded before and after centrifugation to calculate WHC. During centrifugation, highly absorbent paper was used to cover the sausages and collect released water. WHC values were calculated using the following formula.

$$\text{WHC (\%)} = (Weight\ after\ centrifugation / Initial\ sample\ weight) \times 100$$

To determine the cohesiveness and textural integrity of prepared plant sausage, samples were cooked, and shear force (N) was measured using an industry-reliable meat texture analyzer (Ametak TA1Plus Texture Analyzer).

Proximate Composition

The proximate composition of prepared plant sausage was analyzed according to the AOAC (2005) standard methods for crude protein, crude fat, and ash on a dry-matter basis [21].

Consumer acceptance

Sensory analyses were conducted with a trained panel ($n = 15$) and an untrained consumer panel ($n = 30$) using a 5-point hedonic scale for parameters of appearance, texture (bite), mouthfeel (fattiness), flavor, spiciness, saltiness, and overall acceptability. Panelists were provided with 2 sets of coded samples, as prepared plant sausage (P1 & P2) and commercially bought meat sausages (C1 & C2) to evaluate. All sensory tests were conducted in controlled lighting and temperature conditions following ISO 8586:2012 guidelines for sensory testing. Ethical consent was obtained from all panelists [22].

Statistical analysis

All analyses were conducted in triplicate, and the data collected were analyzed using one-way analysis of variance (ANOVA) at a probability level of significant differences between means ($p < 0.05$), and the results obtained are expressed as mean $\pm$ standard deviation [23].

Results and Discussion

Plant Sausage Formulation

The plant-based sausage developed showed significant improvement across all attributes, with results closely comparable to commercial meat sausages. The synergistic effect of pea protein isolates and hydrocolloids, such as methylcellulose and kappa-carrageenan, along with potato starch, significantly improved emulsion stability and enhanced the integrity and cohesiveness of the sausage matrix [24].

Similar findings were reported that plant-based binders containing polysaccharides and proteins significantly improve emulsion-type sausages [25]. The commercial sausage released more fat during cooking than the plant-based emulsion, which maintained structural integrity and minimized fat loss during thermal processing.

Functional Qualities of two identical samples of prepared plant sausage (P1 & P2) were analyzed with two commercially bought brands of chicken sausage (C1 & C2) for data validation. The results obtained are shown. Salt content remained comparable across all samples. Prepared plant sausages showed a pH in the range of 5.80–5.90, whereas the commercial brought meat sausages in the range of 6.24–6.25. The presence of shredded tender jackfruit and textured faba bean protein contributed to slightly lower pH values. A similar reduction in pH was reported in legume-based analogs, due to the presence of organic acids in plant proteins [26].

The water activity (a_w) was slightly higher in sausages, primarily due to the natural moisture content of jackfruit and its limited water-binding compared to muscle protein. The water-holding capacity and cooking loss (%) did not show significant variation, indicating that the prepared plant-based sausage emulsion maintained a good structure. The shear force values were quite comparable to those of the plant formulations, which achieved better structural cohesiveness and chewiness, attributed to the fibrous jackfruit matrix and the emulsifying capacity of faba protein. These results align with the statement that textured legume proteins improve elasticity and bite in plant analogs [27]. The jackfruit fibers enhanced springiness, resembling the fibrous nature of meat, while methylcellulose contributed to juiciness and gel-like structure upon heating.

Table 1

Functional properties of prepared plant sausages and commercially brought meat sausages.

Parameters	*P1	*P2	*C1	*C2	Level of significance
pH	5.82 ^b ± 0.02	5.88 ^a ± 0.01	6.25 ^b ± 0.02	6.24 ^a ± 0.04	p < 0.05
Salt, as NaCl	1.91 ^a ± 0.02	1.87 ^a ± 0.02	1.88 ^c ± 0.01	1.92 ^b ± 0.02	p < 0.05
Water activity (a_w)	0.92 ^c ± 0.01	0.90 ^a ± 0.02	0.89 ^b ± 0.01	0.89 ^a ± 0.02	p < 0.05
Cooking loss (%)	3.48 ^c ± 0.02	3.45 ^b ± 0.02	3.46 ^b ± 0.01	3.44 ^c ± 0.02	p < 0.05
Water Holding Capacity (WHC)	99.52 ^a ± 0.05	99.59 ^a ± 0.05	99.47 ^b ± 0.03	99.69 ^c ± 0.04	p < 0.05
Shear Force (N)	2.88 ^b ± 0.02	2.92 ^a ± 0.01	2.96 ^b ± 0.01	2.94 ^a ± 0.02	p < 0.05
^{a-c} Means in each row having different letters vary significant at 5% level, p < 0.05. Values are presented as mean ± SD					

Proximate analysis results shows that the crude protein content of prepared plant sausages was comparable to that of commercial meat sausages, demonstrating that the incorporation of pea protein isolates and fava bean texture proteins maintained nutritional equivalence. The fat content was substantially lower in plant sausages compared to commercial meat sausages, confirming the formulation's reduced-fat profile.

Prepared plant sausages showed significantly higher crude fiber and ash content, which is primarily composed of minerals like salt and phosphates due to the inclusion of tender jackfruit, plant protein isolates, textured fab bean proteins, and binders in the plant sausage. Meat sausages are naturally low in minerals unless cured and have no fiber.

Table 2

Proximate composition of prepared plant sausages and commercially brought meat sausages.

Parameters	*P1	*P2	*C1	*C2	Level of significance
Crude Protein	12.02 ^a ± 0.02	12.08 ^d ± 0.02	12.87 ^c ± 0.02	14.18 ^a ± 0.02	p < 0.05
Crude Fat	5.71 ^b ± 0.01	5.69 ^c ± 0.02	9.55 ^b ± 0.01	9.42 ^a ± 0.01	p < 0.05
Crude Fiber	1.18 ^a ± 0.02	1.15 ^d ± 0.02	-	-	p < 0.05
Ash	4.23 ^a ± 0.02	4.25 ^d ± 0.02	2.45 ^a ± 0.02	2.48 ^c ± 0.02	p < 0.05
^{a-d} Means in each row having different letters vary significant at 5% level, p < 0.05. Values are presented as mean ± SD					

Consumer acceptance

Sensory results are shown in Graph 1 for appearance, texture (bite), mouthfeel (fattiness), flavor, spiciness, saltiness, and overall acceptability. Samples P1 & P2 received the highest overall acceptability score among the tested samples, surpassing the control in overall flavor balance and texture. However, despite similar salt levels, the plant sausages exhibited a mild astringent taste and lower umami intensity, aligning with the observations [28].

Panelists described the texture as “meat-like,” with good juiciness and clean mouthfeel, while jackfruit fibers and textured faba bean protein contributed to cohesive bite and firmness. These findings support earlier reports confirming that incorporating starches, legume proteins and plant fibers improves the sensory realism of plant-based analogs [29]. The results clearly demonstrate that the combination of textured faba bean protein and tender jackfruit successfully replicates the desirable texture of meat sausages, with enhanced consumer perception and improved nutrition.

Graph 1 Sensory Evaluation of prepared plant sausages and commercially bought meat sausages. (5-point hedonic scale)

Conclusions

This study developed a novel plant-based sausage made with tender jackfruit (*Artocarpus heterophyllus*) and textured faba bean protein (*Vicia faba*), providing a sustainable, healthier alternative to meat sausages. The optimized formulation matched meat sausage in emulsion stability, moisture retention, and textural properties, while offering lower fat, higher fiber, and more minerals. Sensory evaluation showed high consumer acceptance, largely due to improved mouthfeel and reduced greasiness compared to conventional meat sausages.

The uniqueness of this study lies in the synergistic combination of jackfruit and faba bean protein, which has not been previously explored in sausage formulation. However, limitations include the absence of shelf-life evaluation, microbial stability, and detailed amino acid analysis. Future research should focus on optimizing flavor masking of plant notes, enhancing umami perception through natural flavor enhancers, and evaluating stability and scalability of production to support the commercialization of plant-based meat alternatives.

Declarations

Author Contribution

S S wrote the main manuscript text and prepared tables and graph All authors reviewed the manuscript

References

1. Yue F, Annamalai PK, Sangeeta Prakash (2023) Bhesh Bhandari & Characteristics of faba bean protein-based high-moisture meat analogues incorporating brewers' spent grain through extrusion. *Food Res Int*, 170. <https://www.sciencedirect.com/science/article/pii/S1466856425000037>
2. Lin XP et al (2024) Development of Vegetarian Nugget Using Unripe Jackfruit. *Int J Food Sci Nutr*. <https://jurcon.ums.edu.my/ojums/index.php/IJF/article/download/5149/3547>
3. Martineau-Côté, Achouri D, Karboune A, L'Hocine S, Lamia A (2022) Faba Bean: An Untapped Source of Quality Plant Proteins and Bioactives. <https://pubmed.ncbi.nlm.nih.gov/35458103/>
4. Fan Y, Zheng S, Annamalai PK, Bhandari B, Prakash S (2024) Enhancement of the texture and microstructure of faba bean-based meat analogues with brewers' spent grain through enzymatic treatments. *Sustainable Food Technol* 2:826–836. [https://doi.org/10.1039/D4FB00045E\(pubs.rsc.org\)](https://doi.org/10.1039/D4FB00045E(pubs.rsc.org))
5. Taikerd T, Leelawat B et al (2023) Effect of young jackfruit, wheat gluten and soy protein isolate on physicochemical properties of chicken meat analogs. *Agric Nat Resour*, 57. <https://li01.tci-thaijo.org/index.php/anres/article/view/259076>
6. Minh VQ, Thuong TTT, Thuy NM, Giau TN, Hong Van Hao & Ngo Van Tai (2024) Harvesting and Post-Harvest Handling of Jackfruit. *Int J Chem Biochem Sci* 26(20):16–23. <https://doi.org/10.62877/3-IJCBS-24-26-20-3>
7. De Notaris C, Enggrob EE, Olesen JE, Sørensen P, Rasmussen J (2023) Faba bean productivity, yield stability and N₂-fixation in long-term organic and conventional crop rotations. *Field Crops Res* 295. <https://doi.org/10.1016/j.fcr.2023.108894>
8. Palmero F et al (2022) A quantitative review into the contributions of biological nitrogen fixation to agricultural systems by grain legumes. [Full citation details not provided in your original list]
9. Bianchi F et al (2021) Plant-based sausage formulation and comparison with commercial meat sausages; functional, nutritional, and sensory evaluation. *J Food Sci* 86.

<https://doi.org/10.1111/1750-3841.16123>

10. (2024) Composite starch/fermented protein emulsion gels for plant-based cheese applications. *LWT*, 212. <https://doi.org/10.1016/j.lwt.2024.116863>
11. Kaur J, Singh Z, Mazhar MS, Shah HMS, Woodward A (2024) Changes in Physical Attributes, Activities of Fruit Softening Enzymes, Cell Wall Polysaccharides and Fruit Quality of Jackfruit (*Artocarpus heterophyllus* Lam.) as Influenced by Maturation and Ripening. *Horticulturae* 10(12):1264. <https://doi.org/10.3390/horticulturae10121264>
12. Webb D, Dogan H, Li Y, Alavi S (2023) Physico-chemical properties and texturization of pea, wheat, and soy proteins using extrusion and their application in plant-based meat. *Foods* 12(8):1586
13. Ning H, Villota R (2023) Texture and rehydration properties of texturized soy protein: analysis based on soybean 7S and 11S proteins. *Int J Food Sci Technol* 58(1):323–335
14. Yuan J, Qin F, He Z, Zeng M, Wang Z, Chen J (2023) Influences of Spices on the Flavor of Meat Analogs and Their Potential Pathways. *Foods* 12(8):1650
15. Abdulhameed AA, Yang TA, Abdulkarim AA (2016) Kinetics of Texture and Colour Changes in Chicken Sausage During Superheated Steam Cooking. *Journal of Food Technology / Meat Science*.
16. Honikel K-O (1998) Reference methods for the assessment of physical characteristics of meat. *Meat Sci* 49. [https://doi.org/10.1016/S0309-1740\(98\)00034-5](https://doi.org/10.1016/S0309-1740(98)00034-5)
17. Daszkiewicz T, Florek M, Wodzak M, Kubiak D, Burczyk E (2023) Comparison of the quality of selected meat products and their plant-based analogs. *Pol J Food Nutr Sci* 73(2):109–119
18. Shin DJ, Yim DG, Kwon JA, Kim SS, Lee HJ, Jo C (2022) Effect of cutting time and cooking temperature on physicochemical properties of chicken breast meat emulsion sausage with olive oil. *Poult Sci* 101(1):101554
19. Barbera S (2019) WHC trend, an up-to-date method to measure water holding capacity in meat. *Meat Sci* 152:134–140
20. Hong S, Shen Y, Li Y (2022) Physicochemical and functional properties of texturized vegetable proteins and cooked patty textures: Comprehensive characterization and correlation analysis. *Foods* 11(17):2619
21. Mazumder MAR, Sujintonniti N, Chaum P, Ketnawa S, Rawdkuen S (2023) Developments of plant-based emulsion-type sausage by using grey oyster mushrooms and chickpeas. *Foods* 12(8):1564
22. Ruiz-Capillas C, Herrero AM, Pintado T, Delgado-Pando G (2021) Sensory Analysis and Consumer Research in New Meat Products Development. *Foods* 10(2):429
23. Yuan J, Qin F, He Z, Zeng M, Wang Z, Chen J (2023) Influences of spices on the flavor of meat analogs and their potential pathways. *Foods* 12(8):1650
24. (2025) Improving the quality of meat-free sausages using κ-carrageenan, konjac mannan and xanthan gum. *Int J Food Sci Technol*, 52. <https://academic.oup.com/ijfst/article/52/5/1269/7775865>

25. Dekkers J et al (2018) Comparative Evaluation of Polysaccharide Binders on the Quality Characteristics of Plant-Based Patties. *Food Hydrocolloids* 84:1–9.
<https://pubmed.ncbi.nlm.nih.gov/37893624/>
26. Zhang Z, Zhang L, He S, Li X, Jin R, Liu Q, Sun H (2022) High-moisture Extrusion Technology Application in the Processing of Textured Plant Protein Meat Analogues: A Review. *Food Reviews Int* 39(8):4873–4908. <https://doi.org/10.1080/87559129.2021.2024223>
27. Ismail NS, Akila NS (2023) Development of plant-based meat from jackfruit (*Artocarpus heterophyllus*, Lam). Extended abstract of the International Agrotechnology Innovation Symposium (i-AIS), 2nd ed.; Faculty of Plantation and Agrotechnology, Kampus Jasin, Melaka, pp. 103–112. ISBN 978-629-97220-4-5. <https://ir.uitm.edu.my/id/eprint/80813/>
28. Kyriakopoulou M et al (2019) Development of plant-based meat analogues: A review. *Food Res Int* 116:1–10. <https://doi.org/10.1016/j.foodres.2018.08.019>
29. Sha L, Xiong YL (2020) Plant protein-based alternatives of reconstructed meat: Science, technology, and challenges. *Trends Food Science Technology* 99:68–77.
<https://doi.org/10.1016/j.tifs.2020.05.022>

Figures

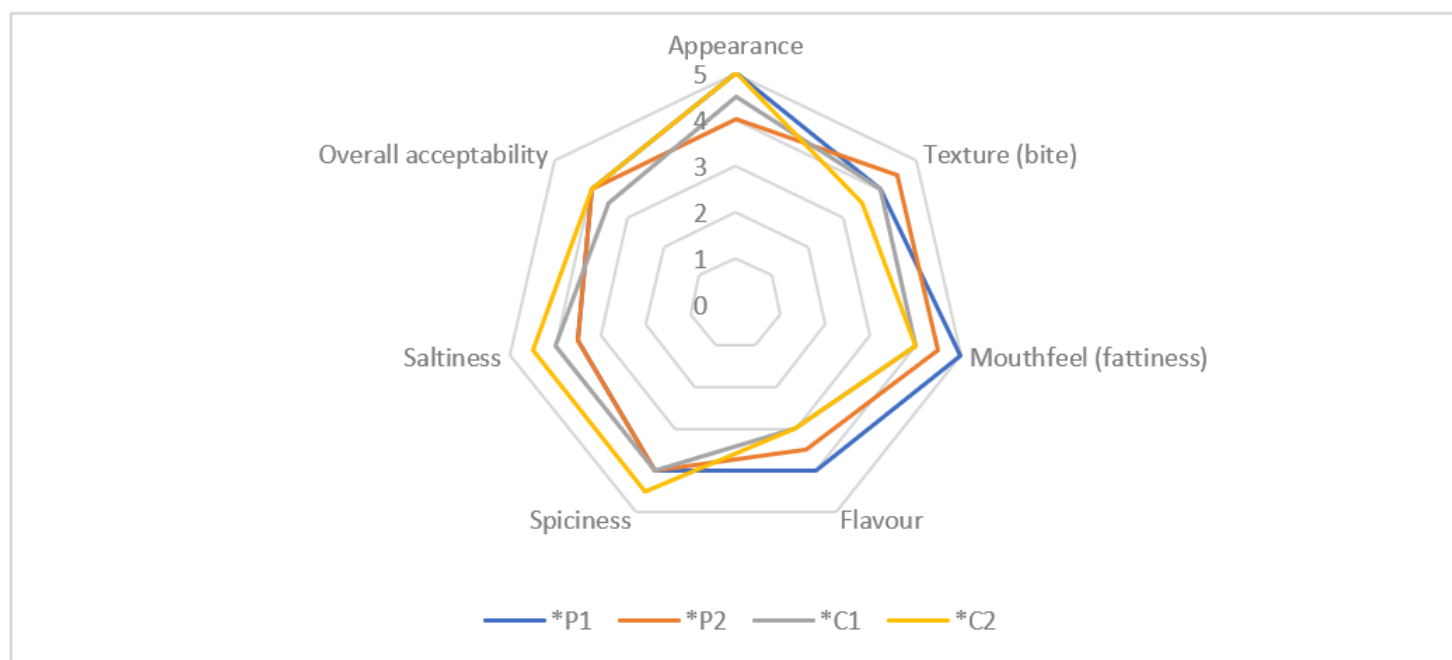


Figure 1

Graph 1 Sensory Evaluation of prepared plant sausages and commercially bought meat sausages. (5-point hedonic scale)