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Sheep cooked hams with the inclusion of gellan gum as a substitute for carrageenan

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Abstract

This study aimed to develop and characterize Pantanal sheep cooked hams using gellan gum. Hams were prepared with gellan gum (0.0, 0.3, and 0.5%) as a substitute for carrageenan. In terms of centesimal composition, the moisture, protein, and ash contents were not affected by gellan gum, but cooked hams with 0.5% inclusion had lower lipid, carbohydrate, and caloric value contents. The parameters of water activity, pH, yellow intensity, hue, shear force, gumminess, and resilience were not different among the cooked hams. However, the water holding capacity was lower in cooked hams with 0.3% gellan gum, leading to greater luminosity, lower red intensity and saturation, and lower hardness compared to the others. Elasticity was higher in the cooked hams with 0.5% gellan gum, which also showed greater chewiness. The different cooked hams were suitable for consumption due to the microbiological results and the same sensory acceptance, with medians of 7 (moderately liked) for color, taste, texture, and overall acceptance. It can be concluded that the inclusion of 0.5% gellan gum reduces the lipid content and calorific value of cooked hams, increasing the elasticity and chewiness of the product, without affecting its sensory profile.

Keywords: hydrocolloids; meat products; development of new products.

Practical Application: Gellan gum can be used as a substitute for carrageenan in sheep cooked hams.

1 INTRODUCTION

Sheep farming is a constantly expanding activity in Brazil. With approximately 22 million heads of sheep, the country ranks 18th in the world in this production chain (Instituto Brasileiro de Geografia e Estatística [IBGE], 2023). Among the indigenous or autochthonous Brazilian sheep breeds, the indigenous sheep genetic group from the state of Mato Grosso do Sul (Pantaneiro sheep) stood out for its good production characteristics (Cansian et al., 2024), with increasing production in the state (IBGE, 2023). Three prominent products are derived from sheep farming: meat from lambs, wethers, and cull ewes (Monteschio et al., 2018).

Meat from wethers and cull ewes has a strong smell and flavor, due to its excess fat and the fact that it is firmer and darker, making it underutilized (Monteschio et al., 2018). Thus, its use in the preparation of meat products could be an interesting economic alternative, requiring studies for the development of these products.

Cooked hams are obtained from meat cuts that were ground, seasoned, and subjected to a specific thermal process (Brasil, 2022). In the formulation of cooked hams, water is an important ingredient, acting as a solvent, carrier, and dispersing agent for salt, nitrate, nitrite, sugar, and phosphates (Sebranek, 2009). The solvent property of water is also essential for the extraction of protein from meat, a critical step for the stability of the meat emulsion, and for the textural properties of the cooked product (Sebranek, 2009).

Added salt and phosphates act to retain water in processed meats (Molina et al., 2023). However, the amount of water retained using these ingredients alone is generally not satisfactory when high levels of brine are added (Prabhu & Sebranek, 1997; Toldrá et al., 2010), as in the case of cooked ham formulations. Therefore, to maintain the water in the meat matrix, the addition of hydrocolloids is necessary.

Hydrocolloids are characterized by their property of forming viscous dispersions and/or gels when dispersed in water, being widely used as thickening agents in foods, given their ability to modify the rheology of the food system, including two basic properties of any food: viscosity and texture (Fang et al., 2020). Carrageenan is one of the most widely used hydrocolloids in meat products, acting mainly on texture, gelling, and viscosity properties (Hotchkiss et al., 2016). However, other hydrocolloids have been prospected for meat products, such as gellan gum.

Prepared by microbial fermentation of the bacterium Sphingomonas elodea, gellan gum is commercially available in two forms, high and low acylation (Zia et al., 2018). It has been used in a wide variety of food, pharmaceutical, personal care, and oral care products as a gelling and texturizing agent due to the need for only a small dosage to achieve the desired effects, and for its diverse textural properties compared to other common polysaccharides (Tong et al., 2018).

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Gellan gum is a linear-chain gel-forming agent made up of glucuronic acid, glucose, and rhamnose. It forms gels at low concentrations (0.05 to 0.40%), has good stability, is easy to use, and has excellent flavor release and clarity (Costa et al., 2020). When compared to carrageenan, it also stands out due to the economic viability of extraction.

Therefore, choosing the ideal hydrocolloid is essential to obtain the performance required to produce a meat product that is acceptable in terms of composition, quality, sensory acceptability, stability, and shelf life (McArdle & Hamill, 2011). Therefore, the aim of this study was to develop and characterize Pantanal sheep cooked hams with the inclusion of gellan gum as a substitute for carrageenan.

1.1 Relevance of the work

The breeding of Pantaneiro sheep has increased in recent years, which led to the need to develop products from older animals, which have less suitable smell and taste. Carrageenan is already well known for its technological improvement characteristics in the development of meat products. However, research on other hydrocolloids, such as gellan gum, could advance in the development of cooked hams with better texture and sensory profile.

2 MATERIAL AND METHODS

2.1 Developing cooked hams

The Pantaneiro sheep meat came from adult cull ewes fattened in confinement at the sheep farming department of the Federal University of Grande Dourados (UFGD).

Pantanal sheep meat cooked hams were prepared with the inclusion of gellan gum (0.0, 0.3, and 0.5%) as a substitute for carrageenan, according to the formulation shown in Table 1.

Initially, the sheep cuts (shank and shoulder) were trimmed to remove fat and nerves. They were then ground in a meat grinder using a 5 mm kidney disk. All the ingredients were homogenized in a mixer (model MJ35, Jamar, Tupã, São Paulo) for 20 minutes until a homogeneous mass was obtained. The doughs were stuffed into packages suitable for ham and then placed in stainless steel molds specifically designed for developing hams. Two hams of around 1 kg each were made for each treatment.

The doughs were cooked in a water bath for 60 minutes at 60°C, 60 minutes at 70°C, and 35 minutes at 80°C, until the internal temperature of the product reached 74°C in the center. The molds were then submerged in ice until the internal temperature reached 15°C. In the end, the cooked hams remained refrigerated (5°C) for 24 hours, when they were unmolded, identified, and sealed in individual vacuum packs, and kept refrigerated (5°C) until analysis.

2.2 Centesimal composition and caloric value

Analyses of centesimal composition were carried out in triplicate per ham, and the moisture and ash contents were determined based on the Association of Official Analytical Chemists (AOAC, 2019) methodology. Crude protein was determined using the semi-micro Kjeldahl method described by Silva and Queiroz (2002). Lipids were measured following the methodology of Bligh and Dyer (1959). The carbohydrate content was determined by the difference between the other constituents (Instituto Adolfo Lutz, 2008). The caloric value was calculated according to Atwater and Woods (1896), where the conversion factors are considered 4 kcal.g−1 for proteins and carbohydrates, 2 kcal.g−1 for total dietary fiber, and 9 kcal.g−1 for lipids. The results were expressed in kcal/100 g.

2.3 Water activity, pH, color, and water holding capacity

The cooked hams were divided into blocks of about 3 cm3 (n = 10 per treatment), each of which was analyzed for water activity, pH, color, and water holding capacity (WHC).

Water activity was measured using the AquaLab CX-2-series 3 equipment.

The pH value of the samples was determined using a digital pH meter (Testo 205, Testo Limited, Hampshire, UK) with a meat insertion electrode.

Instrumental color analysis was carried out using a Konica Minolta Chroma Meter CR 410 portable colorimeter (Konica Minolta Optics Inc., Japan). The parameters L* (luminosity), chroma a* (red intensity), and chroma b* (yellow intensity) were obtained. Saturation (C*) and hue angle (h°) were calculated according to Equations 1 and 2, respectively.

$$C* = \sqrt{a*^2 + b*^2} \quad (1)$$

Table 1. Formulation of sheep cooked hams with gellan gum inclusion.

Ingredients	**Inclusion of gellan gum (%)**		
	0.0	**0.3**	**0.5**
Pantanal sheep meat	69.5	69.5	69.5
1/2 cold water and 1/2 ice	22.0	22.0	22.0
Conamix® (complete seasoning for ham)	3.8	3.8	3.8
Textured soy protein	2.3	2.3	2.3
Cassava starch	1.9	1.9	1.9
Carrageenan (Kappa)	0.5	0.2	0.0
Gellan gum (high acyl)	0.0	0.3	0.5

Conamix: salt (65.5%), sugar, natural flavors, sodium tripolyphosphate, sodium erythorbate, sodium nitrite, and sodium nitrate.

$$h° = tang^{-1}\frac{b*}{a*} \quad (2)$$

For WHC (You et al., 2022), cooked ham samples were weighed at approximately 2 g, wrapped with filter paper (3 layers), placed in a centrifuge, and then centrifuged at 10,000 × g for 10 minutes. The samples were removed from the tube and filter paper and weighed again. The WHC was calculated employing Equation 3.

$$WHC\ (\%) = 100 - \frac{m2}{m1} \times 100 \quad (3)$$

Where:

m1: weight of the sample before centrifugation (g); and

m2: weight of the sample after centrifugation (g).

2.4 Shear force and texture profile analysis

For texture profile analysis (TPA) and shear force, cooked hams were partitioned ($n = 10$ per treatment) into cylinders (20 mm high, 20 mm diameter), according to Rizo et al. (2019). The analyses were conducted on a TA-XT plus texturometer, Stable Micro Systems Ltd. (Surrey, England).

TPA was performed using a 50 kg load cell and a 36 mm cylindrical probe (P/36) at a test speed of 1 mm/s up to 20% compression of the initial height (Rizo et al., 2019). The hardness, fracturability, elasticity, cohesiveness, chewability, and resilience parameters were calculated using the Exponent software package, version 6.1.9.1 (Stable Micro Systems, Surrey, England).

For shear force, the Warner-Bratzler blade was used with a speed of 2 mm/s and a blade displacement of 40 mm to cut the entire sample (Rizo et al., 2019). The cutting force was determined as the maximum force (N).

2.5 Microbiological analysis

The Escherichia coli count (AOAC, method 998.08), coagulase-positive Staphylococcus count (ISO 6888-1:2019), and Salmonella sp (AOAC, 2016) were determined for each treatment as recommended by Agência Nacional de Vigilância Sanitária (ANVISA, 2022).

2.6 Sensory analysis

The sensory analysis was approved by the UFGD Research Ethics Committee (protocol 5,751,599).

The sensory analysis was conducted with 100 untrained tasters (68.4% female and 31.6% male), with a predominant age range (48.5%) between 18 and 24 years. The frequency of consumption of sheep meat reported by the tasters was that 67.4% consume it between 1 and 2 times a year, and for the frequency of consumption of cooked hams, 46.2% reported consuming it at least once a month.

For sensory analysis, chilled (7°C) samples of cooked hams were cut into 25 x 25 x 10 mm cubes (Silva et al., 2021) and identified with three random numbers using disposable material, free of foreign odor. The samples were served randomly to avoid order and transposition effects (MacFie et al., 1989).

For the sensory evaluation of the attribute's odor, color, taste, texture, and general acceptability, the acceptance test was applied using a 9-point structured hedonic scale, anchored between (1) I strongly dislike it and (9) I strongly like it (Dutcosky, 2011). With this data, the acceptability index (AI) of the products was calculated using Equation 4 (Dutcosky, 2011).

$$AI\% = \frac{average\ grade\ of\ product}{maximum\ grade} \times 100 \quad (4)$$

A purchase intention test was also applied using a 5-point hedonic scale, anchored between (1) Certainly would not buy and (5) Certainly would buy (Dutcosky, 2011).

2.7 Statistical procedure

The homogeneity of variances was analyzed using the Shapiro-Wilk test for the physicochemical analysis data. Levene's test was applied to test the normality of the data. The results were then submitted to analysis of variance (ANOVA), followed by Tukey's post hoc test at a 5% significance level, using Statistica 7.0 software (StatSoft, St Tulsa, OK, USA). Results were expressed as mean and standard error.

For the data from the hedonic scales used in the sensory analysis, the non-parametric Kruskal-Wallis test was conducted to identify differences between the treatments, through the JAMOVI software. Data were expressed as medians per treatment. Significant differences were considered when $p < .05$.

3 RESULTS AND DISCUSSION

Moisture, protein, and ash contents were not affected ($p > .05$) by the different levels of gellan gum inclusion in the centesimal composition of the cooked hams (Table 2). However, cooked hams with 0.5% gellan gum had lower levels of lipids and carbohydrates, as well as lower caloric value ($p < .05$). The Technical Regulation of Identity and Quality of Cooked Ham (Ordinance No 701, 17/11/2022) defines a maximum content of 75% moisture, 12% fat, and a minimum of 12% protein (Brasil, 2022).

Fat has an important effect on texture, juiciness, mouthfeel, and flavor in meat products (Sarteshnizi et al., 2015). It is interesting to note that there was a significant decrease in lipid content and an increase in carbohydrate content when carrageenan was completely replaced by gellan gum in the cooked hams.

Among hydrocolloids, gums can form entanglements and cross-links with other food components such as proteins, starches, and emulsion droplets through hydrogen bonds and hydrophobic or electrostatic interactions (Peng & Yao, 2017). In addition, gums can physically trap pieces of fat in the formulation by forming gels, preventing them from leaving the food matrix, thus improving cooking yields (Eghbaljoo et al., 2022). Therefore, gums have been prospected as fat substitutes in meat products, as they can act as a fat imitator due to their ability to control water content by thickening or gelling (Gao et al., 2024). Considering that low-fat meat products are in high demand because they are perceived as healthier by consumers (Rather et al., 2016), cooked hams with gellan gum can meet this demand for lower-calorie products.

The parameters of water activity and pH (Table 3) did not differ between the cooked hams with the inclusion of gellan gum ($p > .05$). In meat products, water activity is highly correlated with salt and moisture content and is a critical parameter for microbial growth (Martuscelli et al., 2017). Like moisture, the water activity of the cooked hams was not affected by the hydrocolloids used, remaining within the expected range for cooked hams, which is 0.90–0.99 (Martuscelli et al., 2017). The pH values were also close to normal for cooked hams, ranging from 5.6 to 6.2 (Danielski et al., 2020).

The WHC determines weight loss and cooking yield in meat products, as well as sensory characteristics after consumption (Warner, 2023). In the present study, the WHC was significantly lower ($p < .05$) in the cooked hams treated with 0.3% gellan gum (Table 3). This treatment also provided cooked hams with greater luminosity (L*), lower red intensity (a*), and lower saturation (C*) than the others ($p < .05$). Yellow intensity (b*) and hue (h°) were not different between the cooked hams ($p > .05$).

It is well known that hydrocolloids improve the emulsion stability and WHC of meat products (Kim et al., 2018). The hydrocolloid's ability to bind with water, thereby increasing the product's WHC, serves to improve important attributes such as reducing cooking losses, which not only affect appearance but also have significant cost implications for producers (Hotchkiss et al., 2016).

However, in this study, the combination of 0.3% gellan gum with 0.2% carrageenan was detrimental to the cooked hams' ability to retain water in the meat matrix, as the WHC was significantly reduced.

The lower ability to retain water in cooked hams with 0.3% gellan gum had a direct impact on the higher luminosity of these cooked hams since there was more water circulating in the meat matrix. In fact, brightness is related to a thin aqueous layer on the surface of the meat product (Yim et al., 2016). Thus, with the higher surrounding water content, the gel network can be destroyed, resulting in greater luminosity in the gels formed (Zhuang et al., 2016).

Water management in meat products such as cooked hams is vital to retain the brine added during processing, making the final products juicy and easy to slice with few breaks (Hotchkiss et al., 2016). In fact, in a meat product emulsified with mutton, the inclusion of guar gum increased the WHC, which can imply significantly greater juiciness (Rather et al., 2016).

The changes in the color parameters of cooked hams may be related to the amount of free water, the interactions between gellan gum and carrageenan, the other ingredients, and the homogeneity of the system, which in turn affect the light reflection of the samples (Majzoobi et al., 2017). Hydrocolloids can form a transparent gel matrix, which affects the amount of light reflected (García-García & Totosaus, 2008). Similar effects to those observed in this study for red and yellow intensities were seen in low-fat chicken meat emulsions, where the addition of gellan gum resulted in higher red and yellow intensity values (Li et al., 2019). In another study, the mixture of konjac and gellan gum increased the red intensity value in pork burgers

Table 2. Proximal composition and caloric value of Pantanal sheep cooked hams with gellan gum inclusion.

Parameters (%)	Inclusion of gellan gum (%)			*p*-value
	0.0	0.3	0.5	
Moisture	68.46 ± 0.36	68.27 ± 0.11	68.46 ± 0.55	.923
Proteins	12.29 ± 0.50	11.34 ± 0.52	11.06 ± 0.62	.303
Lipids	11.87 ± 0.43 a	13.23 ± 0.25 a	9.40 ± 0.49 b	< .001
Carbohydrates	4.30 ± 1.19 b	4.26 ± 0.73 b	8.21 ± 0.86 a	.024
Ashes	3.09 ± 0.12	2.90 ± 0.10	2.86 ± 0.10	.314
Caloric value (kcal/100 g)	173.14 ± 2.02 ab	181.47 ± 1.34 a	161.71 ± 4.57 b	.003

Different letters on the same line indicate a significant difference ($p < .05$) by Tukey's test.

Table 3. Water activity, pH, water holding capacity, and color of Pantanal sheep cooked hams with gellan gum inclusion.

Parameters	Inclusion of gellan gum (%)			*p*-value
	0.0	0.3	0.5	
Aw	0.96 ± 0.00	0.96 ± 0.00	0.96 ± 0.00	.478
pH	6.29 ± 0.01	6.02 ± 0.30	6.29 ± 0.01	.453
WHC (%)	73.48 ± 0.40 a	41.35 ± 5.56 b	72.74 ± 0.45 a	< .001
L*	51.59 ± 0.26 b	53.86 ± 0.24 a	52.45 ± 0.29 b	< .001
a*	16.34 ± 0.21 a	15.35 ± 0.26 b	16.35 ± 0.13 a	.002
b*	8.15 ± 0.21	8.32 ± 0.23	8.26 ± 0.28	.878
C*	18.27 ± 0.14 b	17.47 ± 0.24 a	18.34 ± 0.14 b	.002
h°	1.11 ± 0.01	1.07 ± 0.01	1.10 ± 0.01	.227

Different letters on the same line indicate a significant difference ($p < .05$) by Tukey's test; Aw: water activity; pH: potential hydrogen; WHC: water holding capacity; L*: luminosity; a*: red intensity; b*: yellow intensity; C*: saturation; h°: hue.

(Akesowan, 2011). The inclusion of 1% of various hydrocolloids in beef burgers also increased yellow intensity and brightness (Pematilleke et al., 2021).

The lower intensity of red in ham with 0.3% gellan gum may have negative impacts on long-term acceptance since maintaining an attractive pink color is vitally important because consumers tend to reject discolored meat products (Wu et al., 2024).

The texture of cooked hams depends on several factors, such as the extent of heating (breakdown of the structure), the moisture content, the extent of proteolysis (degree of myofibrillar protein breakdown), and the connective tissue content (Toldrá et al., 2010). In the TPA (Table 4), it was found that cooked hams with 0.3% gellan gum had the lowest hardness among the others ($p < .05$). This may be related to the lower WHC observed in this treatment. The increase in total expressible fluids during the heating process may have induced degradation of the gel structure, decreasing the hardness, elasticity, cohesiveness, and chewiness values, as seen in cooked sausages (Li et al., 2019).

A decrease in WHC in meat products can result in slightly lower textural properties (Kim et al., 2018), including a reduction in juiciness. Cooked sausages with 0.4% gellan gum inclusion showed higher values of hardness, elasticity, and cohesion, which was reported to be a result of better emulsion stability and increased viscosity of the meat patties (Zhou et al., 2010).

For the other texture profile parameters, elasticity was higher in cooked hams with 0.5% gellan gum, which also had a higher average chewiness ($p < .05$). On the other hand, cooked hams without gellan gum (0%) had lower average cohesiveness. The parameters of gumminess and resilience were not different between the treatments, nor was there any difference in the shear strength of the cooked hams ($p > .05$).

Instrumental chewiness is a product of hardness, cohesiveness, and elasticity, so it has a similar pattern to hardness (Pematilleke et al., 2022). Deli meats with complete replacement of carrageenan with gellan gum had greater chewiness, which may also be a result of the lower lipid content found in this treatment. Fat content is known to have a positive influence on some texture and appearance characteristics (Toldrá et al., 2010). The organoleptic qualities of meat products are vital, especially in processed meat products, where the perceived texture, e.g., bite, juiciness, and tenderness, are of extreme importance to the consumer (Hotchkiss et al., 2016).

In the microbiological analysis of the cooked hams, all the treatments showed values of < 1.00 x 102 UFC/g for coagulase-positive Staphylococcus, < 1.00 x 101 UFC/g for Escherichia coli, and no Salmonella sp in 25g. The results are within those recommended for meat products, according to current legislation (ANVISA, 2022), showing good practices in the preparation of cooked hams and that they are fit for consumption.

There were no differences ($p > .05$) between the treatments in the sensory profile of the cooked hams (Figure 1) for the attributes evaluated, with medians of 7 (moderately liked) for the three different cooked hams in terms of color, taste, texture, and overall acceptance. Despite the differences found in the instrumental texture profile, the sensory acceptance of the cooked hams was the same, indicating the viability of making cooked hams with total replacement of carrageenan with gellan gum.

The acceptance index was 70.67, 71.62, and 71.16% for the cooked hams with 0.0, 0.3, and 0.5% gellan gum inclusion, respectively, and these averages were statistically equal ($p > .05$). Considering that acceptance rates above 70% indicate that the product can be well accepted in the consumer market (Dutcosky, 2011), these results indicate the viability of the products developed. This fact is corroborated by the intention to buy, which although it was not different between the treatments ($p > .05$), the medians obtained, between (3) Might buy/might not buy and (4) Possibly would buy, denote good acceptability of the product. Averages like those observed in this study were also obtained in a previous sensory analysis study of Pantanal sheep cooked hams (Monteschio et al., 2018). When comparing cooked hams made from the meat of lambs, rams, and ewes, the authors observed that cooked hams made from the meat of older animals (rams and ewes) did not differ in the attributes of smell, taste, and tenderness, with only color and purchase intention being unfavorable for ewes (Monteschio et al., 2018).

4 CONCLUSION

The combined use of hydrocolloid carrageenan and gellan gum is not recommended in Pantanal sheep meat cooked hams, due to the decrease in the product's water holding capacity, worsening coloration, and hardness. However, the inclusion of 0.5% gellan gum reduces the lipid content and caloric value of cooked hams, increasing the elasticity and chewiness of the product, without affecting its sensory profile, and making it a great potential option to be produced.

Table 4. Texture profile and shear force analysis of Pantanal sheep cooked hams with gellan gum inclusion.

Parameter	Inclusion of gellan gum (%)			*p*-value
	0.0	0.3	0.5	
Hardness	23.85 ± 1.57 a	18.49 ± 1.55 b	25.20 ± 1.04 a	.004
Elasticity	1.07 ± 0.06 b	1.53 ± 0.35 ab	2.39 ± 0.44 a	.040
Cohesiveness	0.36 ± 0.03 b	0.53 ± 0.03 a	0.57 ± 0.04 a	.002
Gumminess	15.15 ± 3.86	9.52 ± 1.22	16.42 ± 2.24	.146
Chewability	15.65 ± 3.77 b	17.66 ± 6.39 b	36.69 ± 6.60 a	.033
Resilience	0.27 ± 0.03	0.30 ± 0.01	0.32 ± 0.02	.212
Shear force (N)	15.25 ± 1.59	13.41 ± 1.14	13.62 ± 0.79	.512

Different letters on the same line indicate a significant difference ($p < .05$) by Tukey's test.

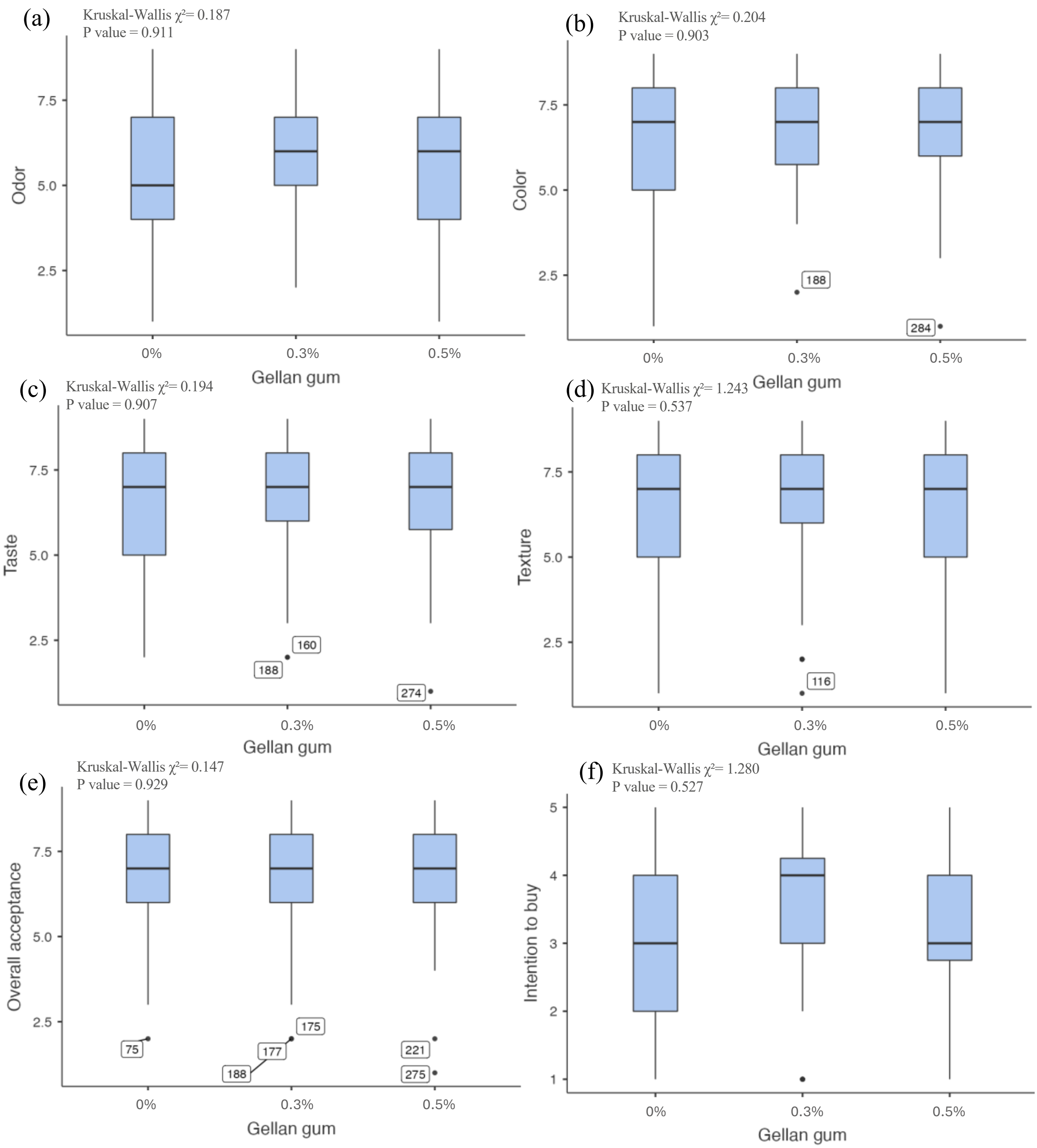

Figure 1. Sensory profile of sheep ham with gellan gum inclusion: **(a)** odor; **(b)** color; **(c)** taste; **(d)** texture; and **(e)** overall acceptance, according to a 9-point hedonic scale (1) Very dislike to (9) Very like; **(f)** intention to buy according to a hedonic scale of (1) Certainly would not buy to (5) Certainly would buy.

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