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Using Generalized Procrustes Analysis for Evaluation of Sensory Characteristic Data of Lamb Meat

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A R T I C L E I N F O

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A B S T R A C T

Generalized Procrustes Analysis (GPA) is a multivariate statistic method that is used at the evaluation of sensory analyses in the food industry. GPA provides benefit in terms of decreasing the difference between the panellists and bringing the data obtained from different panellists together. In this study, the aim was to determine the effect of a pre-slaughter fasting period on sensory characteristics of lambs fed with different rations using GPA. Semi-trained panellists formed from twenty-six persons were requested for evaluation of the meat samples such as tenderness, juiciness, flavour and overall liking rated on a scale of 1(extremely dislike) to 9 (extremely good). The first two factors obtained by GPA explained 66.74% of total variability. As a result of the analysis, it was determined that 12 h and 24 h fasting of lambs fed barley supplemented with alfalfa hay were less preferable when compared to lambs fed alfalfa hay only. In addition, lambs in both groups with 48 h fasting were preferred less by the panellists. In conclusion, GPA analysis provides useful data concerning the sensitivity of each panellist in a sensory panel test.

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Introduction

Many factors such as feeding patterns (socio-cultural effects, lifestyle, etc.), market conditions (price, brand, etc.) and sensory characteristics affect the purchasing patterns of consumers (Font-i-Furnols and Guerrero, 2014). The main sensory characteristics of meat may be specified as appearance (colour, fat content, etc.), texture (tenderness and juiciness) and flavour. Studies have shown that genotype, age, sex, feeding and many procedures before (transportation, fasting period, etc.) and after (storage conditions, ageing period and cooking type, etc.) slaughter have important effects on sensory characteristics of meat (Ferguson and Warner, 2008; Guerrero et al., 2013; Honikel, 2004). As the relevant factors can significantly affect consumer preferences, new information is required to improve these factors in favour of consumer demands.

Sensory analysis is an analytic methodology in which human senses are used to define and measure characteristics of meat (Sanudo et al., 2007). Although sensory analysis is a subjective test, human assessments are important as they allow for a direct measure of consumer perception. Therefore, sensory panel tests are used as a reference method in many studies. But in some cases, the evaluation of panel test results is difficult because of wide variations and differences between panellist assessments (Tomic, 2013).

The sensory panel test is the most effective and appropriate tool used in the determination of the differences between samples subjected to various treatments when evaluated by educated panellists (Rodrigues and Teixera, 2009). The most important problem with sensory analysis is the wide variability in assessments of the same food sample by different panellists. Especially, the most important source of variability is the lack of consensus in describing a sample between panellists (Wu et al., 2003). The Generalized Procrustes Analysis (GPA) is a multi-variate statistical method that is used for the evaluation of sensory analysis in the food industry. GPA is beneficial in terms of decreasing the differences between the panellists and summarizing the data obtained from different panellists (Keskin et al., 2012; Rodrigues and Teixera, 2014).

In recent years, studies are available in which sensory analysis results have been evaluated with the GPA method (Alcalde et al., 2014; Keskin et al., 2012; Rodriquez and Teixeira, 2013). To the best of our knowledge, there is no study concerning the effect of pre-slaughter stress related to feeding system on sensory characteristics that uses the GPA method.

The aim of this study was to determine the effect of pre-slaughter diet/management system and fasting period on sensory characteristics of lambs with Generalized Procrustes Analysis (GPA). Therefore, the aim was to determine the correlation between the effects of pre-slaughter feeding management and assessment by the panellists and review the sensory panel test results from a different viewpoint in more detail.

Materials and Methods

Data Collection

The data for the panel test used in this study was obtained from the study by Karaca et al. (2016). Eighty Norduz lambs at the age of 7 months reared in Yüzüncü Yıl University Research and Application Farm Sheep Breeding Facility were used as the animal material in the study. The lambs were divided into two diet groups of 40 as barley-supplemented alfalfa hay (BAH: 1.250 g alfalfa hay + 500 g barley/lamb/day) and only alfalfa hay (AH: 1.750 g lamb/day) in the short-term finishing period of 21 days. At the end of this period, ram lambs were divided into four groups of 20 with equal head from AH and BAH and were fasted for 0 (0 h), 12 (12 h), 24 (24 h) and 48 (48 h) hours before slaughter. The meat samples were stored at -18°C for the sensory panel test (6 th-12 th *m. longissimus thoracis* (LT) taken from right half carcass) and thawed by being kept at + 4°C for 24 hours. Then meat samples in aluminium foil were cooked in an electric oven at 180°C until their internal temperature reached 80°C. The internal temperatures were monitored by geometrically measuring the midpoint of the meat and using probes connected to a Testo brand 175 T3 model data logger. Each cooked sample was cut into approximately 1 cm^3 piece and kept in aluminium foil at 60°C until they were served to the panellists. Semi-trained panellists comprising 26 individuals were asked to evaluate the samples in terms of tenderness, juiciness, flavor and overall liking, rated on a scale of 1 (extreme dislike) to 9 (extremely good) (Karaca et al., 2016). During the sensory panel, 8 different samples were used in the evaluations and water and unsalted cracker was served to the panellists between samples.

Statistical Analysis Methods

In GPA the matching procedure is based on minimizing the distances between different panellists and the same object. The differences in distances for individual matrices may be stated as mentioned below.

$$\sum_{k<l}^{K} \|\tau(X_k)-\tau(X_l)\| \quad (1)$$

$\tau(X_k)$, $\tau(X_k)$ represent a certain transformation of the matrices (τ) and M is the total of the squares of the elements.

$$\|M\|=tr(M\acute{M})=\sum_{i,j} m_{ij}^2 \quad (2)$$

The points produced by transformation (τ) do not preserve relative distances. Firstly the minimization procedure is performed with the following equations.

$$\sum_{k=1}^{K} \|\tau(X_k)-Y\| \quad (3)$$

and

$$Y=K^{-1} \sum_{k=1}^{K} \tau(X_k)$$

Y is the mean of the transformed individual data matrices ($\tau(X_k)$) and is stated as the consensus matrix. The transformations used in the Procrustes analysis are translation, rotation and scaling. These transformations are stated below.

$$\tau(X_k)=\rho_k X_k H_k+T_k \quad (4)$$

ρ_k, is the isotropic scaling factor, H_k is the rotation matrix and T_k is translation. The minimizing criteria for GPA are the totals of all quadratic distances between the transformed individual matrices and is stated as follows;

$$\sum_{k<l}^{K} \|\rho_k X_k H_k-\rho_l X_l H_l\| =K \sum_{k=l}^{K} \|Y-\rho_k X_k H_k\| \quad (5)$$

(Dijksterhuis, 1996; Tomic, 2013).

To assess the contribution of the transformations to the reduction in total variance, approximate F-tests are used to create Procrustes Analysis of Variance (PANOVA) tables for each of the three transformations (Tomic, 2013).

Data Analysis

In this study, GPA analysis was used for evaluation of sensory panel test results. At the same time, GPA was used to minimize the difference between the panellists. In the first stage, data matrices formed from 4 sensory characteristics and 8 meat samples were obtained for the 26 panellists (configuration). With the aim of reaching a consensus between the panellists with GPA analysis, score values of these matrices were matched by using three different transformations (translation, isotropic scaling and rotation/reflection). XLSTAT package program was used for GPA analysis.

Results and Discussion

The Procrustes Analysis of Variance (PANOVA) is the first step in GPA analysis and the effect of each transformation is obtained in terms of reduction of total variability (Table 1).

According to the PANOVA table, rotation and translation transformations had the highest effect in reducing total variability between the panellists ($P<0.001$). The panellist main effects were removed with the translation procedure and the variation was decreased by pooling them. Thus, the distances between different score values that panellists gave to the same sensory characteristics were minimized with the rotation transformation (Dijksterhuis, 1996). The isotropic scaling transformation did not contribute to reduction of the variability ($P>0.05$). Rodriques and Teixeira (2014) aimed to assess the meat obtained from two different pork breeds with sensory analysis using the GPA method with a data matrix of 4 meat samples, 4 sensory parameters and 10 panellists. The panellists found significant differences between the meat samples from different breeds. The errors of meat samples obtained after translation transformations were similar and low, with differences determined between the panellists.

The residual variance information for each group after rotation and translation transformations is presented in Table 2. As seen in Table 2, the groups which had the lowest residual were groups with most consensus provided by the panellists in terms of sensory characteristics (tenderness, juiciness, flavour and overall liking). Accordingly, while BAH-24 h and AH-12 h groups had the lowest residual and the highest panellist consensus, the highest residual value was obtained from AH-48 h. This indicates that there was no consensus among the panellists for this group (AH-48 h group). However, other groups had similar residuals.

Alcade et al. (2014) in a study researching the effect of breed on sensory characteristics determined that with GPA analysis and 12 panellists, the breed with highest consensus and lowest error was Churra Lebrijana. They also emphasized that the GPA method was the most effective method to differentiate breeds in terms of sensory characteristics. In a study by Kor and Keskin (2011), 12 panellists assessed 10 meat samples with different genotypes and genders, and the lowest error rate was obtained for Angora Late Castrated group with a consensus in terms of sensory characteristics.

The residuals for each configuration (panellist) after transformation, scaling factors and variance changes explained by the first two principal components of GPA are given in Table 3. The residuals obtained from 26 panellists were very close. But panellist 8 (32.142), panellist 13 (32.318), panellist 16 (32.163) and panellist 20 (32.666) had higher residual values, respectively. These results indicate that these panellists had lower consensus when compared to the other panellists. The scaling factors for each panellist are given in the second column of Table 3. Accordingly, the panellists whose scaling factors were higher than 1 (5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21 and 24) used a wider part of the scale, while the panellists whose scale factors were lower than 1 (1, 2, 3, 4, 7, 8, 9, 18, 19, 22, 23, 25 and 26) used a narrow part of this scale. According to Rodriques and Teixeira (2013), some bias may occur as panellists evaluate the scale. Depending on these biases panellists may use a narrower or wider portion of the scale; however they stated that the transformations in GPA analysis easily resolve this situation.

The eigenvalues, variance and cumulative explanation ratios for 4 factors obtained from GPA are given in Table 4. The eigenvalues show the explanatory power of the variance for the sensory characteristics of each factor. According to Table 4, the highest eigenvalue was for the first factor (0.925) and this was followed by the second factor (0.875). At the same time, 100% of the total variability was explained by four factors. The first two factors (i.e. F1 and F2) of the consensus configuration explained 66.74% of total variability between groups. The remaining 33.36% of total variability is explained by the third factor and fourth factor.

Figure 1 represents the correlation between sensory characteristics, groups and the first two factors (i.e., F1 and F2) after principal component analysis (PCA) of GPA. While the first dimension of Figure 1 explains 34.31% of consensus variance, the second dimension explains 32.43% of this variance (Figure 1). There are lower correlations between BAH-12 h, BAH-24 h, BAH-48 h, AH-48 h groups and sensory characteristics when compared to the other groups. Thus, it suggests that a fasting period longer than 24 h and barley-supplemented diet groups were preferred less by panellists. Moreover, while AH-24 h and AH-0 h groups were located in the negative part of F1 and F2, AH-12 h and BAH-0 h groups were located in the positive part of F1. In addition, the flavour was highly correlated with these two groups. AH-0 h group had a higher correlation with tenderness, juiciness and overall liking and AH-24 h had low correlation with these characteristics in the same region.

Table 1 Procrustes analysis of variance for groups of sensory panel test

Source	DF[1]	SSR[2]	MSR[3]	F	Pr [4]
Residuals after scaling transformation	525	767.192	1.461		
Scaling transformation	25	47.182	1.887	1.291	0.158
Residuals after rotation	550	814.374	1.481		
Rotation	150	403.982	2.693	1.843	< 0.0001
Residuals after translation	700	1218.356	1.741		
Translation	100	371.952	3.720	2.545	< 0.0001
Corrected total	800	1590.308	1.988		

[1]DF: Degrees of freedom; [2]SSR: Sum of squares of residuals; [3]MSR: Mean of squares of residuals; [4]Pr.: Significance level

Table 2 Residual variance for each group

Group[1]	Residual
BAH-0 h	101.211
BAH-12 h	95.706
BAH-24 h	86.826
BAH-48 h	90.874
AH-0 h	101.763
AH-12 h	87.815
AH-24 h	92.547
AH-48 h	110.450

[1:] BAH: barley supplemented alfalfa hay; AH: alfalfa hay; fasting periods: 0 h, 12 h, 24 h, and 48 h

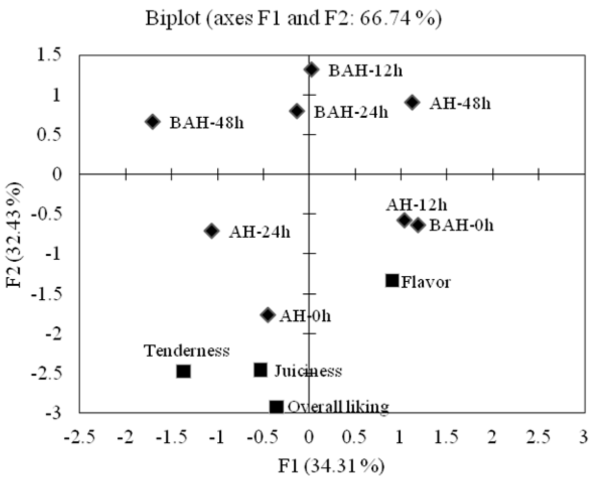
Table 3 Residual variance, scaling factors, and the variation percentage explained by the first two principal components of generalized Procrustes analysis (GPA) for each panellist

Panellists	Residuals	Scaling factors	F1[1],%	F2[2],%
1	26.440	0.870	31.757	36.637
2	26.259	0.673	15.458	6.483
3	27.623	0.677	6.689	10.384
4	30.757	0.790	4.189	59.033
5	28.445	2.065	8.167	51.792
6	29.236	1.274	10.440	31.412
7	28.111	0.919	42.866	4.378
8	32.142	0.782	38.977	35.928
9	29.760	0.983	27.545	12.070
10	29.498	1.494	88.082	1.822
11	29.747	1.380	5.201	71.355
12	28.906	1.385	4.069	70.891
13	32.318	1.605	49.143	8.829
14	29.648	1.258	30.721	1.507
15	30.970	1.219	48.123	25.944
16	32.163	2.141	40.385	12.692
17	30.420	1.172	36.396	34.610
18	25.674	0.668	72.920	6.524
19	28.930	0.779	4.941	71.485
20	32.666	1.326	46.072	44.613
21	29.059	1.199	36.805	38.088
22	26.490	0.914	46.368	11.066
23	31.228	0.738	38.561	57.318
24	30.723	1.312	16.117	58.816
25	28.308	0.715	66.295	9.866
26	31.671	0.966	57.025	17.159

[1]F1: First principal component of GPA; [2] F2: Second principal component of GPA

Table 4 The eigenvalues, variability and cumulative variability

Factors	Eigenvalue	Variability,%	Cumulative, %
Factor 1 (F1)	0.925	34.308	34.308
Factor 2 (F2)	0.875	32.430	66.738
Factor 3 (F3)	0.574	21.261	88.000
Factor 4 (F4)	0.324	12.000	100.000



As a result, 26 panellists evaluated the AH-12 h and BAH-0 h groups as being tastier and they much preferred the AH-0 h group in terms of tenderness, juiciness and overall liking. Rodriques and Teixeira (2013) used the GPA method to evaluate the sensory characteristics of Terrincho lamb meat. Research into the effect of gender and carcass weight on sensory properties (toughness, juiciness, flavour intensity, odour intensity, stringiness, and level of sweetness) found that the two factors explained 72.76% of the total variation. Additionally, the 11 panellists on the panel could not distinguish any gender effect; however, they found the meat of heavier animals was harder and had more intensive odour while the meat of lighter animals was more succulent. Keskin et al. (2012) obtained 6 meat samples from different species (sheep and goats) and feeding (pasture and fattening) systems and completed GPA analysis with 10 panellists and 5 sensory characteristics (colour, texture, odour, taste and acceptability). They found 61.11% of the total variation was explained by the two factors. Additionally, the panellists chose the meat of sheep and goats raised under pasture conditions in terms of sensory characteristics over that of animals raised under fattening conditions.

Conclusion

The evaluation of the sensory panel test using GPA analysis assesses attitudes and behaviour of panellists in a sensory test and reviews the detailed effects of diet and fasting period on sensory characteristics. Longer fasting periods have a negative effect on consensus among panellists. It was determined that barley-supplemented groups were preferred less by panellists. Most of the panellists have a reconciliatory tendency among themselves while evaluating the groups. In conclusion, it is possible to say that GPA analysis is an important method to assess attitudes/behaviour of panellists in a sensory test.

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