Evaluation of sensory characteristics of sheep and goat meat by Procrustes Analysis

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ABSTRACT: Relationships between sensory variables, species, feeding systems, and panelists were examined by Procrustes Analysis. Six meat groups considering species and feeding type combinations were evaluated by ten panelists for five sensory characteristics (colour, texture, odour, taste, and acceptability). These characteristics were assessed using a nine-point hedonic scale (9 = extremely enjoy, 1 = extremely dislike). Generalized Procrustes Analysis was performed and 61.11% of the total variability was explained by the first two dimensions that correspond to Factor 1 and Factor 2. The first one accounted for 33.99% and the second for 27.12%. Results showed that pasture conditions were reflected in all sensory characteristics of meat of Hair goat as well as Karakas sheep. This study concluded that meat of sheep and goats reared in pasture conditions was more preferable as concerns sensory characteristics than that of fattening animals or those reared in intensive conditions.

Keywords: configuration; consensus; dimension; fattening; goat; pasture; rotation; sheep

Meat is a complex and nutritionally significant component of a human diet and foods. Numerous factors including species, gender of the animal, animal growth rate and maturation, diet, genetic factors, diseases status, medication and hormone usage, rearing conditions, temperature, relatively humidity and generally husbandry practices have direct and indirect impact on meat quality (Troy and Kerry, 2010) and lead to changes in the consumption or marketing of meat. Thus, these factors and meat quality are closely related with customers' behaviour as well as with some sensory characteristics such as colour, texture, odour, and acceptability. Therefore, correct determination of the relationships between these variables plays an important role in meat marketing and consumption.

Sheep and goat farming, in other words small ruminant farming, is widespread in Turkey and in the Mediterranean regions. In recent years, quality as well as quantity of animal products has become important both in developed and developing countries, where especially goat meat known for its low fat content has been more preferred. In addition, according to Banskalieva et al. (2000), goat meat contains higher amounts of polyunsaturated fatty acids compared with sheep meat. In recent times, consumers' preferences for a product have determined the process of meat quality improving. The sensory properties like colour or tenderness may have a significant impact on meat quality acceptability. The sensory qualities of meat are one of the primary factors influencing consumers' satisfaction. Sensory analysis performed by trained panelists is the most appropriate tool to explain differences between the treatments as perceived by humans (Rodrigues and Teixeira, 2009).

Generalized Procrustes Analysis (GPA) or in short Procrustes Analysis has largely been used for evaluation of sensory characteristics and food quality. It also examines the relationships between the assessors (experts or panelists) and other concerned variables. Only a few reports have so far documented the relationships between the sensory characteristics (attributes), feeding systems, panelists, and species. The objective of this study was to examine these relationships by means of GPA and to present the results of GPA graphically in two dimensions.

MATERIAL AND METHODS

Samples and panels

Two genotypes of goats (Hair and Norduz) and one sheep genotype (Karakas) were included in the study. Male kids and lambs born in 2009 were raised traditionally, suckling milk from their dams until approximately 2.5–3 months of age. Then the animals were classified into pasture and fattening groups. In the pasture conditions, the animals were reared in grazing areas at the altitudes of 1700–2200 m a.s.l. in the region of Van located in eastern Turkey. The flock was rarely given supplementary foods. On the other hand, in the intensive condition the animals were fed *ad libitum* 85% concentrate feeds and 15% barley hay. The concentrate ration consisted of 2400–2600 ME/kcal energy and 14–16% crude protein. At the end of a 70-day period the animals were slaughtered after a 24 h fast. The carcasses were chilled at 4°C for 24 h. The laboratory samples for the sensory analysis were taken carefully from the right side of the carcass. Long muscles (*m. longissimus dorsi*) were divided into approximately 2 × 2 × 2 cm subsamples which were cooked in a pressure cooker for 30 min. Then the samples were coded and serving sequence was randomized. Each sample was evaluated by ten panelists using a 9-point hedonic scale (9 = extremely enjoy, 1 = extremely dislike) (Pena et al., 2009). The panelists had at least a five-year experience in sensory evaluation. Of the sensory characteristics, colour, texture, odour, taste, and acceptability were evaluated.

Statistical analysis

It is assumed that for k panelists or assessors $\mathbf{X}_k$ matrix represents the data matrix with $n \times m$ dimension where n, m are numbers of products (objects) and characteristics (attributes), respectively. Thus each panelist's data matrix $\mathbf{X}_k$ consists of n rows of scores on m characteristics. GPA is the technique of matching two configurations of n points in k dimensions by translation, rotation/reflection, and possibly an isotropic scaling. The main parts of the Procrustes Analysis are two-dimensional transformation, rotation/reflection, and isotropic scaling. The rotations or reflections are computed for all $\mathbf{X}_k$ matrices to fit the group average matrix. The computation results are denoted in the rotation matrix $\mathbf{H}_k$. After each individual rotation matrix is computed, the new rotated individual matrix ($\mathbf{X}_k\mathbf{H}_k$) and the group average matrix are recomputed for all the k sets. After these computations, isotropic scaling factors (ρ_k) are computed for each $\mathbf{X}_k$ matrix. A configuration (k) is shrunk when $0 < \rho_k < 1$ and stretched when $1 < \rho_k$. At this step, the iteration method is used. Mathematically, matching process is expressed by minimizing the distances between the same objects for different panelists, under the conditions that distances between objects of one expert may not change (Dijksterhuis, 1996). GPA uses the ANOVA to identify significant effects of the transformations. After completing the analysis, the dimension should be reduced to 2 for the convenient presentation of the objects' configuration. For the dimension reduction, Principal Component Analysis is usually used. Thus, GPA calculates the consensus configuration of the sample and enables us to present the results graphically in two-dimensional maps.

The data matrices of 6 (meat samples) by 5 (attributes) for 10 panelists were matched to find a consensus using the XLSTAT software (XLSTAT Product, Addinsoft). The first two axes obtained in the consensus configuration were interpreted.

RESULTS AND DISCUSSION

The data sets of 6 rows (groups) and from 10 columns (attributes) were analyzed with GPA using XLSTAT software. The first result was the Procrustes Analysis of Variance (PANOVA) table presented in Table 1. The PANOVA table can be helpful in finding out which of the variation sources has a significant effect on the overall consensus solution. In other words, it summarizes the efficiency of each GPA transformation in terms of reduction of the total variability. Table 1 showed that the rotation had the largest effect and the translation step also significantly contributed to reduce the deviations between the panelists' results. Moreover, for the percentage of sum of squares, rotation and translation step accounted for 43.46% and 18.68% of the total variation, respectively. The percentage of 36.49 revealed a lack of homogeneity in the materials or differences in the sensitivity.

Table 1. Procrustes Analysis of Variance (PANOVA) table

Source	DF	Sum of squares	Mean squares	*F*	*P*
Residuals after scaling	126	149.734	1.188		
Scaling	9	5.586	0.621	0.522	0.856
Residuals after rotation	135	155.320	1.151		
Rotation	90	178.330	1.981	1.667	0.004
Residuals after translation	225	333.650	1.483		
Translation	45	76.650	1.703	1.433	0.049
Corrected total	270	410.300	1.520		

DF = degree of freedom

Scaling factors and residual variances between the objects after the transformation are presented in Table 2. This table shows that except for the Karakas fattening group, the residuals of all objects are almost close to each other. The highest residual was found in the Norduz fattening group and the second highest one was detected in the Norduz pasture group. In contrast, the Karakas fattening group had the smallest residual. This indicated a high consensus within this group.

The residuals were very close to each other for the panelists, however, panelists 1 and 2 had the highest residuals. This indicates there was not a matching consensus in the attributes for these two panelists.

Score values higher than 1 indicated that the corresponding panelist used a shorter range of the scale than the others. Whereas, score values lower than 1 indicated that the corresponding panelist used a wider scale than the others. Thus our findings showed that panelists 1, 2, 3, 6, and 7 tend to use a wider scale than the others (Table 2).

Eigenvalues for the 5 factors were presented in Table 3. According to Table 3, the highest eigenvalue (1.50) was found for the first factor and this was followed by the second factor with the eigenvalue of 1.20. Eigenvalues explain how much of the variability corresponds to each axis. Thus, it can be concluded that the first two dimensions (i.e. F1 and F2) with eigenvalues greater than 1 accounted for 61.11% of the variability. While 33.99% of consensus variance was accounted for the first dimension, the second dimension explained only 21.11% of the variance. On the other hand, the variance unexplained by these two dimensions (38.99%) may be moderate. Nevertheless, it can be considered that 61.11% of the explained variance is sufficient for the

Table 2. Scaling factors and residuals for panelists and groups

Group	Residuals	Panelist No.	Residuals	Scaling factors
H. Fatt	22.463	1	16.580	0.785
H. Past	26.495	2	16.017	0.814
K. Fatt	17.935	3	15.408	0.972
K. Past	26.781	4	14.557	1.217
N. Fatt	29.091	5	15.270	1.344
N. Past	26.970	6	13.320	0.956
		7	14.367	0.956
		8	14.863	1.129
		9	14.189	1.084
		10	15.164	1.064

H. Fatt = Hair goat fattening, H. Past = Hair goat pasture, K. Fatt = Karakas sheep fattening, K. Past = Karakas sheep pasture, N. Fatt = Norduz goat fattening, N. Past = Norduz pasture

Table 3. Eigenvalues and correlations between dimensions and factors (F)

	Eigenvalues					Correlations between sensory variables and factors		
	F1	F2	F3	F4	F5		F1	F2
Eigenvalue	1.50	1.20	0.86	0.58	0.28	colour	0.023	0.801
Variability (%)	33.99	27.12	19.44	13.05	6.39	texture	0.038	0.996
Cumulative (%)	33.99	61.11	80.56	93.61	100	odour	0.413	0.901
						taste	0.278	0.942
						acceptability	0.284	0.925

presentation of the objects on a two-dimensional plane. In the study performed by Rodrigues and Teixeira (2009) according to the first two dimensions the accounted variance was found to be 93%. Similarly, Kor and Keskin (2011) reported that the first two dimensions explained 84.29% of the total variance.

According to the two dimensions, correlation coefficients between the sensory characteristics and the factors were illustrated in Table 3. The table shows that all of the correlations between dimensions and sensory characteristics are positive. In addition, all of these characteristics are highly correlated with the only second factor. Similarly, Rodrigues and Teixeira (2009) indicated that juiciness and flavour quality were highly and positively correlated with F2. Of these correlations, the highest one (0.996) is between the texture and the second factor. Although the first factor accounted for 33.99% of variation, the sensory characteristics have not been correlated with the first factor. Only odour is partly correlated with the first factor. Thus, it can be stated that all the sensory characteristics play an important role in formation of the second dimension. The view of the relationships between sensory variables and groups on two-dimensional space was illustrated in Figure 1.

According to the first dimension, Karakas and Norduz pasture as well as Hair goat fattening groups were located in the same region as con-

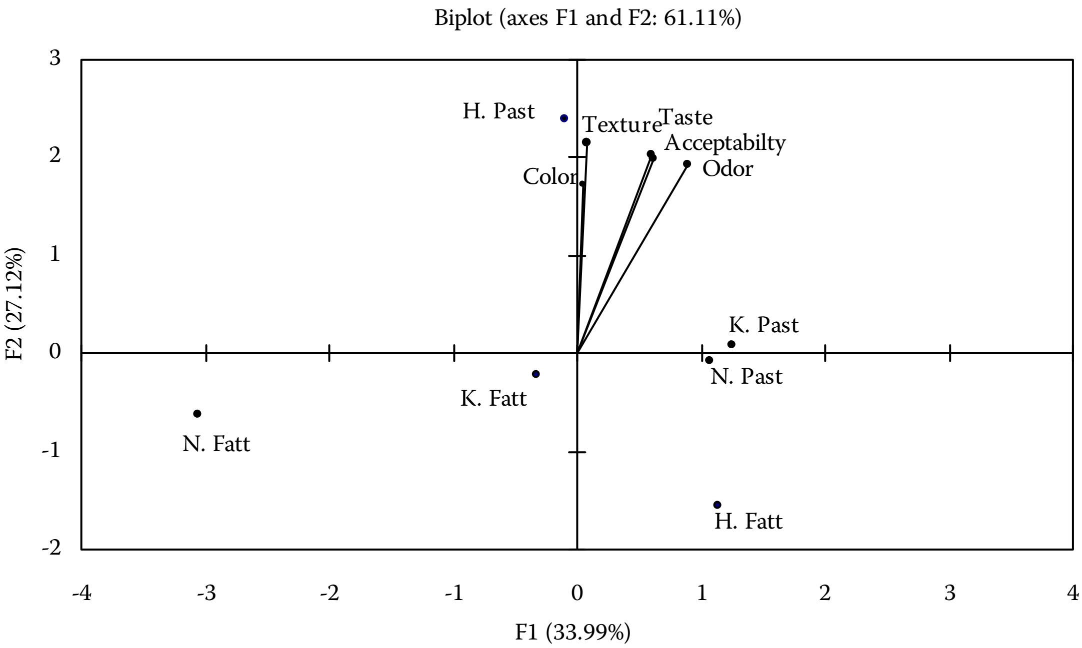

Figure 1. Configuration map of sensory characteristics and groups

H. Fatt = Hair goat fattening, H. Past = Hair goat pasture, K. Fatt = Karakas sheep fattening, K. Past = Karakas sheep pasture, N. Fatt = Norduz goat fattening, N. Past = Norduz pasture
F1, F2 = factors

cerns sensory characteristics. As concerns the first dimension, there is no evident correlation between these groups. Similarly, Norduz and Karakas fattening as well as Hair goat pasture groups were located in the negative region of the first dimension. Furthermore, according to the second dimension there were negative correlations between Hair goat pasture group and Norduz and Karakas pasture groups. When the second dimension is taken into consideration, Hair goat and Karakas pasture groups were located in the positive region, while the other groups were located in the negative region. Hair goat and Karakas pasture groups were located in the positive region of the second dimension and these were negatively correlated with Norduz pasture and other fattening groups. Moreover, Norduz pasture and other fattening groups were located in the negative region according to the second dimension.

As concerns the sensory characteristics, all of them were located in the positive region of both dimensions. Thus, Karakas and Hair goat pasture groups were found highly correlated with sensory characteristics for the second dimension and these two groups may be considered as negatively correlated as to the first dimension. On the other hand, there was no relationship between sensory characteristics and Norduz and Karakas fattening groups. Moreover, these two groups are highly similar to Hair goat fattening and Norduz pasture groups according to the second dimension. For both dimensions, Karakas and Norduz pasture groups were found very similar, in other words, the meat characteristics of these two genotypes were much alike. Hutchison et al. (2010), working with sensory quality of venison, reported that there was a significant difference in the consumers' scores for tenderness. In addition, Jahan et al. (2005) pointed out that differing production regime was based on appearance, texture, aroma, and flavour of chicken breast meat.

Pasture conditions may be favourable for Hair goat and Karakas sheep. Risvik (1994) reported that the consumers generally prefer texture and juicy meat. Highly appreciated sensory characteristics (odour, flavour, and texture) are mostly associated with extensively reared animals. Thus a meat production system based at least partially on pasture may expectedly produce goat meat the consumers would prefer. Although the Norduz pasture group is located in a different area for the second dimension, it can be stated that pasture group of this genotype was also moderately related in sensory characteristics and pasture feeding conditions may also be preferable for this genotype. According to Vipond et al. (1995), in lambs the rearing system affected texture more than odour and flavour (taste). Similarly, Carlucci et al. (1998) emphasized that the rearing system affected texture more than odour and flavour, whereas sex had little effect on textural attributes compared with odour and flavour. Coincidently, Adam et al. (2010) reported that colour is an important sensory characteristics for the consumer. Our study showed that highly assessed colour and other characteristics were related with Hair goat pasture group. Our results largely agree with those of previous studies. However, differently from our results, Summersi et al. (1978) indicated that flavour was more acceptable in concentrate-fed than in non-concentrate-fed lambs.

Rodrigues and Teixeira (2009) investigated the relationships between sex and carcass weight and the sensory characteristics in goats and pointed out that the meat of the males displayed greater juiciness. The authors additionally emphasized that lighter weight carcasses were considered tender with less flavour and odour intensity than heavier carcasses. Moreover, sex and genotype effects in goats were evaluated by Kor and Keskin (2011) who indicated that Angora goat reflected texture, acceptability, and text-odour, while Hair goat reflected colour. The authors further asserted that late castration in Akkeci male may evoke a shift towards femininity, while there are no considerable differences between early and late castrated groups for the Angora goats.

CONCLUSION

In this study, the relationships between panelists, genotypes or species and sensory variables were examined by GPA. Our results showed that two dimensions or factors accounted for 61.11% of the variation and there were considerable correlations between the sensory variables, feeding type, and species. The results also indicated that the investigation of sensory characteristics of small ruminants' meat can provide a useful tool for the meat quality evaluation. However, the findings showed that some difficulties or even a wide disagreement as concerns distinguishing the sensory characteristics may arise among the panelists.

GPA is a fairly straightforward approach to shape correspondence. The algorithms low complexity allows an easy implementation. GPA is a practical solution for very similar object alignment. It is an effective way to correspond shapes and it also enables us to deal with all descriptors and all panelists at once. However, the convergence of means is not guaranteed and therefore convergence is then signified when there is not a significant change in the mean.

It can be suggested that GPA may be successfully used to distinguish genotypes and rearing conditions. GPA is also applicable in modelling the relationships between sensory characteristics and other variables. Thus it may provide the researchers with valuable information. However further investigations are needed to better understand the relationships between sensory characteristics and other variables.

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