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The use of principal component analysis to characterise the retail buffalo meat

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Abstract
The principal component analysis (PCA) statistical method was applied to characterise the 80 retail buffalo meat samples (round muscles) in Thrissur district of Kerala, India, analysed for physio-chemical, compositional and bacterial quality at two different intervals of time 7 AM and 1 PM in a day. Coefficient of variance of the 8 variables in the range from 1.81 to 30.68 per cent. PCA transformed the variables into 2 principal components (PC) based on Eigen value, which explain about 74.798 per cent of total variability. PC1 comprise of pH, Warner-Bratzler shear force, R-value, water holding capacity, total viable count and collagen solubility. PC2 was explained by temperature and collagen content. Component loading plot revealed for high correlation for shelf life and the objective measures meat tenderness. The distribution of objects on the axes of the 2 PC's depicts into two groups, first group had retail buffalo meat analysed at 7 AM and other group 1 PM.

Keywords: Retail buffalo meat, Principal component analysis, Warner-Bratzler shear force, R-value and Total viable count

Introduction
India has principal buffalo population in world by about 56.7 per cent (FAOSTAT, 2014). But domestic consumption, chief source existing from the local butchers because, like commercial chicken or egg markets not existed for the beef or buffalo meat in India. Hence, butchers will vend the meat from early morning until it finishes. Throughout in his shop or stall carcasses was hanged or it was deboned and kept at room temperature by maximum of the butchers, when the consumers arrive, he will sell, hence quality of meat affected by several factors.

Quality of retail buffalo meat was influenced by the temperature at which meat kept, if kept at room temperature, directly influence on fall in pH, activity of endogenous enzymes and different methods of hanging and deboned and keeping meat influence eating quality attributes. Direct exposure to environment would lead to raise in microbial load, attract flies lead to parasite growth either zoonotic and non-zoonotic, hence study the quality of retail buffalo meat was undertaken at different sessions of the day.

Meat quality attributes can be categorized into several physico-chemical, sensory and microbiological parameters. Altogether meat quality traits could be relevant. Thus, comprehensive evaluation of quality traits can yield bulky and complex data which may be very complicated to interpret. Classical approaches of statistical processing of large set of data offer an important procedure to study each single variable. However, these methods may not offer complete indication on the relationships between the variables chosen and also does not permit grouping of samples with homogenous characteristics. Principal component analysis (PCA) is one of the most basic methods of data reduction technique which was developed to analyse bulk data (Naes *et al*. 1996) [12]. PCA explains the variance-covariance structure of a hefty set of data through few linear combinations of the variables. The common way of PCA are data reduction and interpretation (Johnson and Wichern 2007) [9]. PCA linearly transforms the unique set of variables into a significantly lesser set of uncorrelated variables that signify the complete information into unique set of variables. The Principal Components (PC) are ordered with respect to their variations, so that the first few PC infer most of the variation present in the original variables (Dunteman 1989) [4].

In order to infer the new composite variables, we need to study the directions of dissimilar components. These directions denote the rapport amongst the PC and the original variables. The plots of such directions are two-or three-dimensional scale plots, called PC loading plots.

Loading plots elucidate about the association amongst the variables and the score plot elucidate the objects, they were represented in x and y plane. The abscissa parallels to the PC1, the ordinate parallels to the PC2. In loading plots, variables which are distributed on right, left and bottom had highest value and variables close together are positively correlated, while variable lying opposite to each other tend to have negative correlation. The more a variable is away from the axis origin, the better it is appreciated in the considered plane (Naes *et al*. 1996) [12].

The present study has envisioned to apply PCA to analyse different physico-chemical, compositional and bacterial quality of round (*Bicep femoris* and *semimembranosus*) retail buffalo meat at 6-8 AM and 12-2 PM on the same day, collected from culled female spent buffaloes.

Materials and Methods

40 retail buffalo meat stalls or shops in Thrissur district at two different 7 AM and 1 PM on the same day, totally 80 round muscles (*Bicep femoris* and *semimembranosus*) collected from culled female buffaloes were slaughtered by halal method. Muscles collected in high density polyethylene pouches transported immediately during morning and afternoon sessions and analysed for different physico-chemical, compositional and bacterial quality.

Total 8 variables were analyzed

1. pH was measured using Hanna digital pH meter (HI98161 model), FC2023 Food care pH electrode pH range-2.0 to 20.0 pH with accuracy ±0.1 pH, temperature range-20.0 to 120.0 °C with accuracy 0.1 °C with IP67 standards, by inserting the probe directly into meat by avoiding air trapping, as per methods outlined by O’Halloran *et al*. (1997).
2. Temperature of each retail buffalo meat was measured using HM digital TM-1 industrial grade digital Celsius thermometer,-50 to +250 ºC range, 0.1 ºC resolution, thermometer has an accuracy of ± 3 ºC at-50 to-10 C and ± 1 ºC at-10 to +100 ºC, stainless steel probe.
3. R-value of retail buffalo meat estimated as per methods outlined by Honikel and Fischer (1977) [8].
4. Warner-Bratzler shear force (WBSF) of each retail buffalo meat was recorded as per method outlined by Wheeler *et al*. (1997) [19]. Three cores of 1.27 cm diameter were taken from each cooked meat along the longitudinal orientation of muscle fibres. Each core was sheared perpendicular to the muscle fibre on a Texture Analyzer (Model EZ-SX, Shimadzu Corporation, Kyoto, Japan) at a cross head speed of 200 millimeter/min. WBSF was expressed in Newton (N).
5. Water holding capacity (WHC) was estimated using filter paper press method as per Grau and Hamm (1957) [6].
6. Total Viable Count (TVC) of retail buffalo meat was estimated by spread plate method as per APHA (2015) [2].
7. Collagen Content (CC) of each muscle sample was determined as per Stegemann and Stalder (1967) [18].
8. Collagen Solubility (CS) of each beef muscles was determined as per Hill (1996) [7] which was determined from the soluble hydroxyproline content of the sample.
9. Statistical analysis

Data recorded were evaluated statistically using Principal Component Analysis (PCA) for detecting the underlying structure of the variables. PCA with varimax rotation was used for finding unrelated components in the PCA. Data analysis was completed by the dimension reduction procedure of SPSS Software (Version 21.0).

Results and Discussion

Mean, standard error and coefficient of variation (CV) of 8 variables of retail buffalo meat was shown in Table 1. Amongst the variables, TVC had the lowest CV of 1.81 and CS had the highest CV of 30.68 per cent. CV some of variables like TVC, pH, temperature and CC less than 10 per cent, while WBSF, WHC and R-value has 14.34, 15.37 and 19.61 per cent respectively. Similar observations reported by, Destefanis *et al*. (2000) [3] and Kopuzlu *et al*. (2011) [11], Prajwal *et al*. (2019) [15] for beef and Prajwal *et al*. (2017) [14] and Kiran (2019) [10] for buffalo meat.

Correlation coefficients between the variables of retail buffalo meat was shown in the Table. 2. WBSF and WHC is positively and significantly (p<0.01) correlated similar results reported by Prajwal *et al*. (2017) [14] and Kiran (2019) [10] and WBSF and CS was negatively and significantly (p<0.01) correlated, similar results were reported by Prajwal *et al*. (2016) and Kiran (2019) [10] for buffalo meat.

Results of PCA of the 8 variables which offered two principal components (PC) are denoted in Table 3. Out of the variables, the two principal components were extracted using the Kaiser criterion (Johnson and Wichern, 2007) [9] to limit the number of components, retaining only those components which had Eigenvalue more than one (Figure 1). Scree plot can also be used to show the several components and to pick the actual number of components to be included in the analysis, components having Eigen values up to the point “bend of elbow” are usually considered. The two PCs could describe a cumulative variance of 74.798 per cent of the overall variability of the 8 variables measured in the study. Comparable observations were reported by the Destefanis *et al*. (2000) [3] and Kopuzlu *et al*. (2011) [11] for beef and Prajwal *et al*. (2017) [14] and Kiran (2019) [10] for buffalo meat. The first PC accounted for 61.017 per cent of the variation. In a study to characterize buffalo meat from Murrah buffaloes, Prajwal *et al*. (2017) [14] detected the first PC to be explaining about 24.4 per cent of variation of 5 PC’s and Kiran (2019) [10] reported the first PC to be explaining about 46.72 per cent of variance of 4 PC’s. Destefanis *et al*. (2000) [3] observed that the first PC accounted for 33.90 per cent of variation of 6 PC’s in beef. The first PC was denoted by significantly high component loading of pH, WBSF, R-Value, WHC, TVC and CS for retail buffalo meat. The first PC seemed to explain the maximum of objective sensorial attributes and shelf life of retail buffalo meat these are in agreement with findings of Prajwal *et al*. (2017) [14] and Kiran (2019) [10] for buffalo meat they were also reported that objective sensory attributes like WBSF, CC, MFI and WHC. The second PC accounted for 13.781 per cent of variance and represented for temperature and CC of retail buffalo meat.

The loading plot for the first two PCs is shown in (Figure 2). WBSF, WHC and pH are closely grouped placed away from the origin on the left side of the loading plot. The CS, R-value and TVC closely grouped placed away from the origin right side Prajwal *et al* (2017) [14] and Kiran (2019) [10] also reported that objective eating quality attributes like WBSF, MFI and CC, MFI and muscle fiber diameter are clustered placed on the left side respectively and sarcomere length, sensory attributes like tenderness, juiciness, flavour, appearance and overall acceptability are clustered and placed on the right side of the loading plots for buffalo meat. Temperature and CC of retail buffalo meat are placed below and above from the origin in loading plot, hence retail buffalo meat attributes present some substantial findings. The PCs are construed according to the correlations amongst each attribute. Each PC, thus measurements adjacent to each other are positively correlated, measurements detached 180° are negatively correlated, whereas those parted by 90° are independent (Kopuzlu *et al*. 2011) [11]. WBSF, WHC and pH were negatively correlated with the CS, R-value and TVC as these two groups were placed opposite to each other. It points out that one parameter among pH, WHC and WBSF or CS, R-value and TVC may explain the difference in quality of retail buffalo meat at different intervals with respect to the analysed 8 attributes, so we can differentiate quality of meat using either of these two groups. Temperature and CC were not sufficient to explain the variability between the different intervals of retail buffalo meat. Prajwal *et al*. (2017) [14] and Destefanis *et al*. (2000) [3] stated that variables in the loading plot that lie close together are positively correlated while those lying opposite to each other tend to have negative correlation. The more the variables are away from the origin, the better it is represented in the considered plane.

The score plot (Figure 2) shows the location of the objects in the multivariate space of first two principal component vectors. It can be shown that objects are arranged into two groups first includes retail buffalo meat analysed at 7 AM and second group retail buffalo meat analysed at 1 PM. Certainly these two groups exhibits variability, quality attributes of retail of buffalo meat of 7 AM were placed on the left side and 1 PM retail buffalo meat were placed on the right in the score plot hence, retail buffalo meat analysed between of 1 PM had fair eating quality attributes but had slight higher bacterial load compared to former retail buffalo meat, retail buffalo meat of 1 PM had higher CS, low WBSF values hence had higher eating quality attributes. Similar observations were reported by Prajwal *et al*. (2019) [15] who compared meat quality of cross-bred and Indian native cattle breed meat into two groups of cross-bred meat quality and Indian native cattle breeds among former having desirable eating quality attributes. Kiran (2019) [10] who compare the eating quality attributes of young and spent buffalo meat quality attributes and reported that into two groups of young and spent buffalo meat, former having desirable eating quality attributes. Destefanis *et al*. (2000) [3] in bulls who compare the meat quality characteristics between the hypertrophied and normal young bulls and reported two groups first group hypertrophied and second group from the normal bulls.

Table 1: Mean, standard error and coefficients of variation (C.V) of variables

S No	Attributes	Mean	Std. Error	CV
1	pH	5.94	0.03	3.40
2	Temperature	27.03	0.11	3.63
3	Warner-Bratzler shear force	78.48	1.23	14.34
4	R-value	1.05	0.02	19.61
5	Water holding capacity	0.32	0.00	15.37
6	Total viable count	6.51	0.01	1.81
7	Collagen content	0.93	0.01	8.92
8	Collagen solubility	3.10	0.11	30.68

Table 2: Correlation coefficients of physico-chemical attributes of retail buffalo meat

	pH	Temp	WBSF	R-value	WHC	TVC	CC	CS
pH		-0.23*	0.67**	-0.96**	0.92**	-0.62**	-0.14	-0.67**
Temp			-0.16	0.27*	-0.19	0.15	-0.08	0.17
WBSF				-0.72**	0.69**	-0.82**	-0.18	-0.89**
R-value					-0.87**	0.66**	0.14	0.73**
WHC						-0.63**	-0.08	-0.66**
TVC							0.18	0.85**
CC								0.05
CS								

Temp-Temperature, WBSF-Warner-Bratzler shear force, WHC-Water holding capacity, TVC-Total viable count, CC-Collagen content and CS-Collagen solubility. ** $p<0.01$ and * $p<0.05$

Table 3: Results from the PCA for the first two principal components

Components	Eigenvalues	Per cent of Variance	Cumulative variance per cent
1	4.881	61.017	61.017
2	1.102	13.781	74.798

Table 4: Principal component loadings

Attributes	PC1	PC2
pH	-0.91	0.10
Temp	0.24	-0.69
WBSF	-0.90	-0.08
R-value	0.92	-0.11
WHC	-0.88	0.11
TVC	0.85	0.11
CC	0.20	0.76
CS	0.89	-0.01

Temp-Temperature, WBSF-Warner-Bratzler shear force, WHC-Water holding capacity, TVC-Total viable count, CC-Collagen content and CS-Collagen solubility

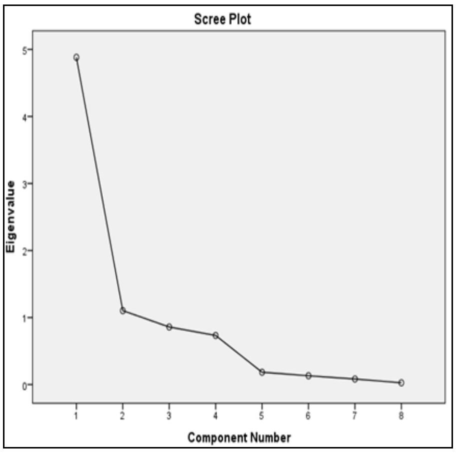

Fig 1: Scree plot

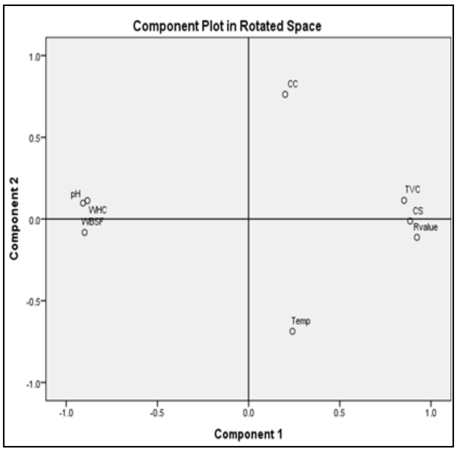

Fig 2: Component loading plot

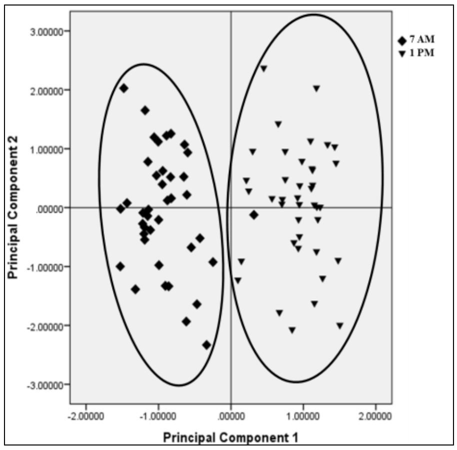

Fig 3: Score plot of the first two PC vectors

Conclusion

The study has shown that PCA can be effectively used to tells difference in the quality of retail buffalo meat by using among the 8 variables, WBSF, pH and WHC or R-value, CS and TVC from loading plots and objects in score plot depicts into two groups of retail buffalo meat analysed at two different intervals. Objects were arranged into two groups first includes retail buffalo meat analysed at 7 AM and second group retail buffalo meat analysed at 1 PM. So PCA help to decide of quality of retail buffalo meat by identifying the groups of variables that determine the nature and extent of variability in buffalo meat by data reduction and visualization.

Conflict of Interest: Not available

Financial Support: Not available

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