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ORIGINAL ARTICLE

Quantitative descriptive analysis and principal component analysis for sensory characterization of Indian milk product *cham-cham*

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Abstract Promising development and expansion in the market of *cham-cham*, a traditional Indian dairy product is expected in the coming future with the organized production of this milk product by some large dairies. The objective of this study was to document the extent of variation in sensory properties of market samples of *cham-cham* collected from four different locations known for their excellence in *cham-cham* production and to find out the attributes that govern much of variation in sensory scores of this product using quantitative descriptive analysis (QDA) and principal component analysis (PCA). QDA revealed significant ($p < 0.05$) difference in sensory attributes of *cham-cham* among the market samples. PCA identified four significant principal components that accounted for 72.4 % of the variation in the sensory data. Factor scores of each of the four principal components which primarily correspond to sweetness/shape/dryness of interior, surface appearance/surface dryness, rancid and firmness attributes specify the location of each market sample along each of the axes in 3-D graphs. These findings demonstrate the utility of quantitative descriptive analysis for identifying and measuring attributes of *cham-cham* that contribute most to its sensory acceptability.

Keywords Quantitative Descriptive Analysis · Principal Component Analysis · *Cham-cham* · Orthogonal contrast

Research Highlights
- A traditional Indian dairy product *cham-cham* was collected from four different locations for sensory quality characterization.
- Quantitative descriptive analysis employed for sensory evaluation of *cham-cham*.
- Principal component analysis employed for statistical analysis of sensory data.
- PCA identified four significant principal components that accounted for 72.4 % of the variation in the sensory data.
- Overall acceptability of all samples varied significantly.

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Introduction

Characterization of optimum sensory attributes is crucial to develop a product which meets the consumer expectations as the sensory quality is driving force for consumer acceptance and demand (Desai et al. 2013). Quantitative descriptive analysis (QDA) approach has been recognized as a tool for measurement and optimization of sensory attributes of various food products (Stone and Sidel 1998). Training the panellist to measure the specific quality attributes of the product to yield quantitative product description which can be analyzed statistically is the main principle of QDA. Under QDA, key product attributes and intensity scales specific to product are identified by employing panellists in a focus group (Murray et al. 2001). Further, this group is trained to consistently identify and score product attributes. Terms generated by the panellists result in some specific description of the attributes which enables precise profiling of sensory attributes and the analysis is efficiently utilized in modeling predictions of consumer acceptability (Young et al. 2004). Results obtained by QDA can be analyzed statistically and then represented graphically for perceptual mapping.

Principal component analysis (PCA) is a widely used multivariate statistical analytical technique (Martinez et al. 1998). It is applied to data to reduce the set of dependent variables (attributes) to a smaller set of underlying variables (called

factors) based on patterns of correlation among the original variables (Lawless and Heymann 1998). Profiling specific product characteristic, comparing and making contrast of similar products based on imperative attributes to consumers and thus increasing market share by altering product characteristics are some of the fates of PCA results.

QDA and PCA has been used to characterize sensorial attributes with great degree of success in many food products e.g. ultra-pasteurized milk (Chapman et al. 2001), Cheddar cheese (Young et al. 2004), chocolate milk (Thompson et al. 2004), soy milk (Keast and Lau 2006), whey and soy proteins (Drake et al. 2007), fermented food products (Ghosh and Chattopadhyay 2010), labneh (Kaaki et al. 2012), yoghurt (Desai et al. 2013) and *doda burfi* (Chawla et al. 2014).

Cham-cham is a popular indigenous dairy product immensely popular in Eastern parts of India. The ingredients for making *cham-cham* are *chhana* (Indian style soft cottage cheese manufactured by direct acidification of milk with dilute organic acid followed by removal of whey by filtration) and sugar. Traditional method of *cham-cham* production involves kneading of *chhana* into pasty consistency and forming cylindrical shaped pieces which are cooked in high concentration sugar syrup which transforms the texture of *chhana* balls to elliptical shaped product having compact and firm structure succulent with sugar syrup. Finally, the product is soaked in low concentration sugar syrup for specific time period followed by drainage of excess syrup without applying external pressure (Aneja et al. 2002). This product has characteristic cylindrical to elliptical shape with colour ranging from off-white to caramel. The manufacture of *cham-cham* has largely been in the hands of traditional sweetmeat makers or local confectioners and due to the differences in manufacturing procedure adopted the organoleptic quality of *cham-cham* varies greatly (Patil 2002). Considering the substantially large domestic market for *cham-cham*, the technology for the production of this delicacy needed to be standardized for making it on commercial scale. Before this the key attributes that contributes the sensory quality of *cham-cham* needed to be identified as they are greatly influenced by the manufacturing process adopted.

Although sporadic information is available regarding manufacturing process and chemical composition of *cham-cham*, practically nothing is known about the sensorial attributes of this delicacy. The objective of this study was to estimate the extent of variation in the product collected from different *cham-cham* producing locations and to find out sensorial descriptors necessary to explain the desirable sensory attributes of *cham-cham* using QDA and PCA.

Materials and methods

Sample collection Twenty samples from four locations of India which are known for their excellence in production of *cham-cham* i.e., seven samples from Chittranjan Park (CR), three from Delhi market (LD), five each from Kolkata city (KC) and other Bengal districts (BD) were collected thrice. Product was procured on the day of manufacture in sterilized rigid containers to retard physicochemical and microbial changes and transported under refrigeration condition to the laboratory and presented for sensory evaluation, so as to minimize the chances of error in the sensory results.

Sensory analyses Attribute terms for sensory evaluation of *cham-cham* samples were developed by a nine member trained sensory evaluation panellist constituted from the faculty of Dairy Technology Division, National Dairy Research Institute, Karnal, India, using QDA methodology (Chawla et al. 2014). The judges had previous experience in sensory evaluation of milk products. The ballot development for sensory evaluation was accomplished in seven working sessions. After the terminology development phase, the panellists were trained for the evaluation of *cham-cham.* Training consisted of evaluating *cham-cham* by use of the descriptive terms developed to describe and quantify appearance, flavour and texture of *cham-cham.* Attributes were quantified with an intensity rating scale from 0 to 10; where 0 = attribute not detected and 10 = attribute extremely strong. Overall quality rating was measured with a scale of 1 to 10, where <6 was considered "poor", 6 to 7 was "fair", and 8 to 10 was "good" (Chapman et al. 2001). This procedure was repeated until panel consensus was achieved. Each sample was served monadically with deionised water.

At each testing period, two intact pieces of samples (tempered to 15 °C) were presented with random three-digit codes in closed glass containers to panel members seated in individual booths. The main descriptors used for evaluating appearance were surface appearance, shape, surface dryness and surface coating, for cross-section appearance, dryness of interior and openness were used. Texture descriptor used in the study was firmness while the flavour was best described using *chhana* solids, cooked, acidic, stale, rancid and sweetness. An additional attribute viz., overall acceptability was added along with other descriptors to judge the extent of liking of the product. Nine panellists provided independent observations on randomized samples of *cham-cham*.

Statistical analyses The data were analyzed with SAS ver. 5.3 (SAS Institute Inc., Cary, NC). Descriptive statistical measures were first calculated for all the attributes using scores from nine panellists. Analysis of variance was used to analyze the descriptive data for difference in means. Duncan post hoc test was used to determine whether the means were different. With the factor analysis PCA was applied to the means of the thirteen attributes. The analysis extracted the most significant variables with minimum loss of information. A combination of Kaiser's criterion i.e., (eigen value >1) and the principal

components that accounted for minimum 70 % of the variance in the data set was applied to retain the number of final factors from the initial ones (Lawless and Heymann 1998). To facilitate interpretation of the results, the factors were orthogonally rotated (which leads to uncorrelated factors), following the 'Varimax' method (Massart et al. 1988).

Results and discussion

Descriptive analyses

The discussion held between trained panellists generated some specific terms to evaluate the samples which were used as basic for QDA. List of lexicons for evaluating the range of *cham-cham* were finally refined after consensus discussion among the panel members. Descriptive vocabulary generated by the panellists to describe the sensory attributes of *cham-cham* is presented in Table 1. Mean panellist ratings of overall quality of market samples of *cham-cham* and attribute intensities for appearance, cross section appearance, textural attributes and taste and flavour for twenty shops are listed in Table 2. Similar to our work concerning characterization of market samples of *cham-cham*, Chawla et al. (2014) conducted descriptive sensory analysis of *doda burfi*, another traditional Indian dairy product. Among the lexicons generated through round table discussion among the panel members only four viz., firmness, cooked, stale and rancid is common with sensory lexicon of *cham-cham*. This reveals thereby the organoleptic differences between *cham-cham* and *doda burfi* and justifies the need for the development of product specific lexicons for describing optimum sensorial quality. Similarly sensorial attributes of Greek yoghurt were different than that of *cham-cham* except for cooked flavours and firmness in texture (Desai et al. 2013).

ANOVA and Duncan test Analysis of variance was carried out on mean sensory scores of *cham-cham* samples collected from four different locations (Table 3). Shape, surface coating, dryness of interior, sweetness and overall acceptability of the samples varied significantly ($p < 0.05$) among the four groups studied. On applying Duncan post hoc test, it was found that sensory scores for "shape" of the sample varied significantly between CR and KC groups. Shape of the product varied from cylindrical to elliptical, elliptical being the most desirable one. Panellists also observed surface coating as one of the major difference in sensory attributes while marking on descriptive scale. "Surface coating" of LD group was significantly different from CR and KC group. Coating ranging from grated *khoa* to sweetened cream and totally absence of coating on product surface made this attribute significantly different among the groups. Practice of garnishing *cham-cham* with grated *khoa* or sweetened cream is done in Bengal districts to maintain the traditional taste of the product, however, few was observed in Delhi markets.

"Dryness of interior" of CR and LD group was different from KC group revealed by significant differences in mean sensory scores. It emerged to be varied significantly probably

Table 1 Descriptors with definition used to explain the desirable quality parameters for *cham-cham*

Descriptor	Definition
Appearance	
Surface appearance	Presence or absence of cracks and bumps on the surface
Shape	Shape of sample ranging from cylindrical to elliptical
Surface dryness	Absence of sugar syrup on the surface of the product
Surface coating	Presence of edible coating material on product's surface for garnishing
Cross-sectional Appearance	
Dryness of interior	Absence of syrup oozing out from interior mass of product
Openness	Appearance of porous structure on breaking
Texture	
Firmness	Force required to compress the product between tongue and palate
Flavour	
Chhana solids	Flavour associated with heat and acid coagulated milk solids (*chhana*)
Cooked	Flavour associated with heated milk
Acidic	A sour, tangy, sharp, citrus-like taste. The fundamental taste sensation of which lactic and citric acids are typical
Stale	Flavour associated with old sample/ingredient
Rancid	The taste associated with hydrolysed/oxidized fats. Having the unpleasant aroma or taste characteristic of oils and fats when no longer fresh
Sweetness	The fundamental taste sensation produced by aqueous sucrose solution
Overall acceptability	The total sensorial likeness or dislikeness of the product based on all the sensorial attributes tested

Table 2 Mean panellists'[a] ratings of market samples of *cham-cham*

Shop codes[b]	Chittranjan Park (CR)							Local Delhi (LD)			Kolkata City (KC)					Bengal Districts (BD)				
	CR1	CR2	CR3	CR4	CR5	CR6	CR7	LD8	LD9	LD10	KC11	KC12	KC13	KC14	KC15	BD16	BD17	BD18	BD19	BD20
Labels for 3-D Graphs[c]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Shape[d]	6.4	6.1	7.1	6.5	6.6	6.1	4.7	7.2	4.0	3.1	8.4	2.9	1.4	1.8	2.6	7.1	7.5	4.2	6.1	1.8
Surface Appearance[e]	6.7	3.9	4.9	4.0	5.4	5.4	4.5	7.4	4.9	7.0	4.4	4.3	6.4	5.9	6.1	5.3	6.1	4.5	5.4	5.9
Surface Dryness	4.3	6.1	4.2	6.4	5.9	5.0	6.1	5.0	5.2	2.9	5.1	5.4	5.6	4.8	4.1	6.0	4.3	6.2	6.1	3.6
Surface Coating	3.7	2.4	1.4	3.0	3.0	2.9	2.5	0.5	1.4	0.1	5.1	5.9	0.0	1.4	0.5	1.5	0.0	3.7	1.5	0.5
Dryness of Interior	1.5	2.2	2.9	3.2	3.3	2.8	2.9	2.7	3.0	2.8	3.4	3.9	5.7	4.6	4.3	4.1	1.6	4.4	4.1	3.3
Openness	4.5	5.1	4.5	5.4	4.8	4.3	2.5	4.3	5.3	5.2	5.6	6.1	6.5	5.1	4.4	4.7	4.5	5.7	4.9	4.4
Firmness	5.2	6.1	5.1	4.1	4.4	4.8	5.8	4.8	5.5	3.1	5.0	3.3	5.4	5.4	3.8	5.4	3.7	4.8	5.5	5.3
Chhana solids	3.7	2.8	3.9	3.4	3.8	3.1	3.3	3.5	3.7	2.2	4.4	4.9	5.3	4.7	2.9	2.1	2.7	2.4	2.3	5.2
Cooked	1.5	3.5	2.7	3.0	2.1	2.9	2.5	2.6	3.2	2.2	2.3	2.1	2.4	2.3	2.4	3.2	1.3	1.5	1.8	3.3
Acidic	0.4	1.6	1.2	1.4	0.8	0.2	0.7	0.4	0.1	0.2	1.4	0.3	0.3	0.4	0.4	0.8	0.5	0.5	0.5	0.5
Stale	0.8	2.0	0.1	0.5	0.5	0.7	1.2	1.4	0.1	0.0	1.1	1.0	1.2	0.1	0.1	0.9	0.1	0.1	0.2	0.0
Rancid	0.4	1.2	0.1	0.5	0.2	0.0	0.1	0.7	0.7	0.0	1.4	0.5	0.9	0.1	0.1	0.5	0.1	0.2	0.3	0.0
Sweetness	7.7	8.0	8.7	8.1	7.8	8.2	7.7	8.6	5.8	7.8	6.9	6.1	6.4	6.0	6.4	7.7	7.7	7.8	7.9	6.5
Overall acceptability[f]	5.3	4.6	5.5	4.5	6.9	4.9	3.4	4.5	5.7	5.1	7.0	7.2	6.6	6.3	5.8	5.3	7.8	6.1	5.9	6.8

[a] No. of panellist =12

[b] New Delhi (CR: Chittranjan Park, LD: Delhi) and **West Bengal** (KC: Kolkata City, BD: Bengal District)

[c] Spikes shown in Figs. 3 and 4 are labelled

[d] Shape of product: 0 = perfect cylinder, 10 = perfect elliptic

[e] Intensity of attribute: 0 = none, 10 = extremely strong

[f] Overall quality rating 1 to 10, where <6 is poor, 6 to 7 is fair, 8 to 10 is good

Table 3 Means sensory scores[1] showing significant differences between groups

Attributes	CR	LD	KC	BD
Surface Appearance	4.96 ± 0.4	6.43 ± 0.6	5.44 ± 0.4	5.4 ± 0.4
Shape	6.2^{a} ± 0.4	4.77^{ab} ± 0.7	3.4^{b} ± 0.5	5.34^{a} ± 0.6
Surface Dryness	5.42 ± 0.4	4.35 ± 0.6	5 ± 0.4	5.21 ± 0.4
Surface Coating	2.69^{a} ± 0.4	0.68^{b} ± 0.3	2.58^{a} ± 0.6	1.43^{ab} ± 0.4
Dryness of Interior	2.66^{b} ± 0.3	2.8^{b} ± 0.5	4.38^{a} ± 0.5	3.5^{ab} ± 0.5
Openness	4.43 ± 0.5	4.9 ± 0.5	5.54 ± 0.4	4.86 ± 0.4
Firmness	5.04 ± 0.3	4.47 ± 0.5	4.58 ± 0.4	4.95 ± 0.4
Chhana solids	3.43 ± 0.4	3.12 ± 0.7	4.45 ± 0.7	2.93 ± 0.7
Cooked	2.58 ± 0.4	2.65 ± 0.7	2.28 ± 0.5	2.2 ± 0.5
Acidic	0.89 ± 0.3	0.24 ± 0.1	0.55 ± 0.2	0.57 ± 0.2
Stale	0.82 ± 0.3	0.52 ± 0.3	0.72 ± 0.3	0.25 ± 0.2
Rancid	0.33 ± 0.1	0.49 ± 0.2	0.6 ± 0.2	0.2 ± 0.1
Sweetness	8.03^{a} ± 0.2	7.4^{a} ± 0.4	6.36^{b} ± 0.2	7.52^{a} ± 0.2
Overall acceptability	5.02^{b} ± 0.4	5.1^{b} ± 0.5	6.56^{a} ± 0.3	6.35^{a} ± 0.4

[1] Means sensory scores of shops of four groups (Mean ± SE)

ANOVA and Duncan post hoc test was applied to the descriptive sensory score data to obtain difference in means

[a, b] Means in the row followed by different letters represents significant differences ($P < 0.05$)

due to varying sugar content of product. *Cham-cham* is prepared by cooking in syrup of high sugar concentration that sometimes leads to crystallization of sugar inside the product in some samples which restricts oozing out of sugar syrup from the interior. All the samples were found to have slight to moderate amount of sugar syrup oozing out from the interior. Higher was the amount of visual sugar crystallization inside the samples, lesser was the leaking of sugar syrup.

The "sweetness" of KC group samples was found to be significantly different than other three groups. This might be due to different concentration of sugar syrup used for cooking as well as differences in duration of cooking. Crystallization of sugar in interior of *cham-cham* was observed by the judges to be essential for development of desirable texture of *cham-cham*. Adhikari et al. (1992) studied the texture of *rasogolla* (another *chhana*-based sweetmeat of India having similarity in manufacturing techniques with *cham-cham*) with the help of scanning electron microscopy and postulated that on cooking of *chhana* in concentrated sugar syrup, the strong inter-linkages of the coalesced protein particles were severely damaged and the compactness disappeared gradually leading to the development of numerous large and small voids throughout the matrix giving rise to spongy texture. High concentration of sugar resulting in saturation of sucrose solution probably induced crystallization in matrix which provided the typical brittle texture to *cham-cham*. CR and LD samples possessed similar overall acceptability which was significantly different than other two sample groups due to the difference in attributes discussed above.

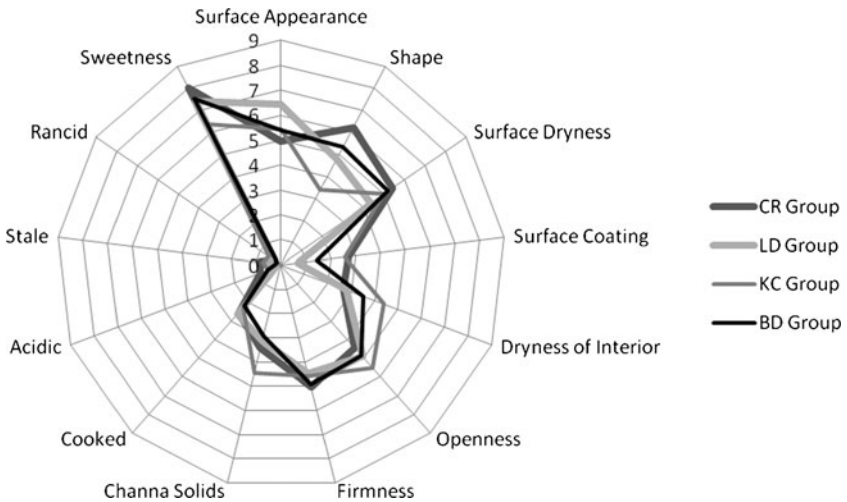

Fig. 1 Sensory profiles of market samples of *cham-cham* from four different groups. Individual attributes are positioned like the spokes of a wheel around a center (zero, or not detected) point, with the spokes representing attribute intensity scales, with higher (more intense) values radiating outward

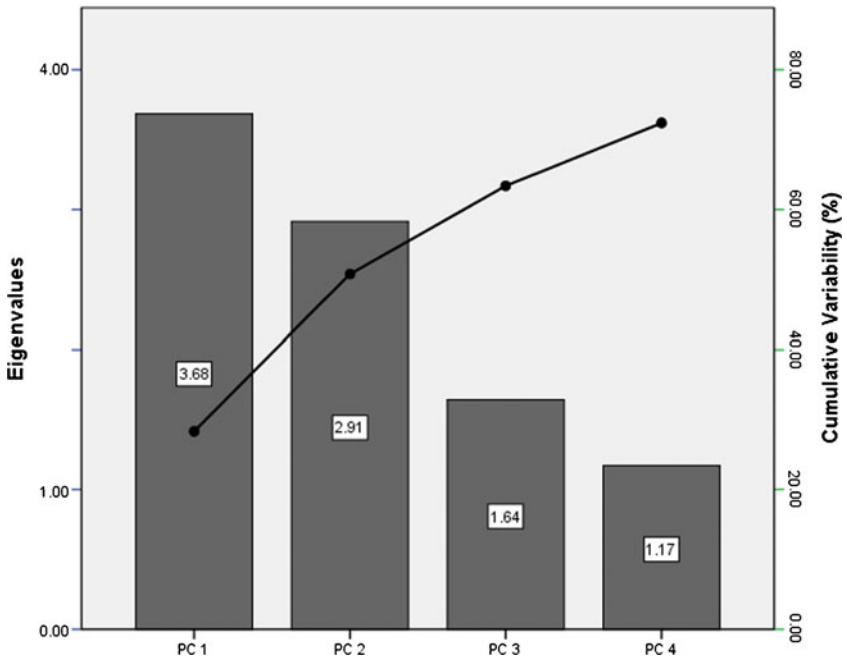

Fig. 2 Cumulative variance plot and eigen values of four extracted principal components generated using PCA

To create a visual profile or "fingerprint" of product attributes, spider plots was created by plotting average intensity values on corresponding scale, and then joining the points (Stone and Sidel 1998). Figure 1 shows attributes of the market samples of *cham-cham* from four different groups. This plot illustrates that "shape" of CR group samples was highly towards elliptical side which is a desirable characteristic of this attribute and samples of KC group obtained lowest scores i.e. the samples had cylindrical shape. As can be seen, surface coating was maximum in case of KC group samples and lowest in LD group. Score for "dryness of interior" was highest for KC group samples due to the coating present on the surface which probably resisted oozing out of syrup. Sweetness was highest in LD group samples and lowest in KC group samples. There was non-significant difference in surface dryness, openness, firmness, *channa* solids, cooked, acidic, stale and presence of rancid flavour. Similar work has been done previously in ultra pasteurized milk (Chapman et al. 2001) and commercial lebneh (strained yoghurt) samples (Kaaki et al. 2012), where author represented the descriptive sensory scores of panellist in pictorial form by creating spider plots, as these plots are often used to represent graphically the data generated by QDA methodology (Murray et al. 2001).

Principal Components Analysis (PCA)

PCA is a multivariate technique of extracting structure from a correlation matrix. Correlation can be done among several dependent variables, scores of which can be obtained by descriptive analysis technique. By identifying the pattern of correlation among dependent variables, PCA substitute a new variable called a factor for group of correlated original attributes. Further second and third group are identified with derivation of factors for each, based on residual variance. PCA provides factor loading and factor scores. The former is represented as correlations of attribute with new dimensions while the latter as values of products on new dimensions. For interpretation of dimensions, factor loadings are essential and the factor scores illustrate the relative positions among the products in a map (Jolliffe 2005). Hence, transformation of

Table 4 Varimax rotated principal component factor loadings for *cham-cham* attributes

Attributes	PC1	PC2	PC3	PC4
Sweetness	0.8616*	0.0943	−0.05492	0.03154
Shape	0.82446*	0.26094	0.28916	−0.08742
Openness	−0.58881	0.19774	0.38287	−0.40364
Channa solids	−0.64055	−0.12887	0.37215	0.07305
Dryness of interior	−0.77735*	0.2595	−0.16201	0.08609
Surface dryness	0.01417	0.82616*	0.14226	0.21344
Surface coating	−0.00173	0.65779	0.33319	−0.39306
Acidic	0.40511	0.53385	0.37723	0.26427
Surface Appearance	−0.00323	−0.89093*	−0.06949	−0.11557
Rancid	−0.11353	0.24206	0.88488*	0.14372
Stale	0.14554	0.19783	0.76051	0.30238
Firmness	−0.01101	0.21109	0.14561	0.78508*
Cooked	−0.07356	0.02673	0.22188	0.76429
Variance explained[a]	28.34 %	22.42 %	12.64 %	9.01 %

Four PC were extracted by applying PCA on the mean values of descriptive sensory scores

* Numbers marked * are believed to be most important

[a] Refers to percent variance explained

Table 5 Factor scores for market samples of *cham-cham*

Shop codes	PC1 Sweetness/Shape/Dryness of interior	PC2 Surface Appearance/Surface dryness	PC3 Rancid	PC4 Firmness
CR1	0.876396	−0.97645	0.761956	−0.94732
CR2	0.885939	0.869201	1.800044	1.590659
CR3	0.944085	−0.00687	−0.43863	0.411358
CR4	0.424202	1.459733	0.033479	−0.13059
CR5	0.37688	0.578295	−0.2438	−0.5917
CR6	0.636018	−0.06988	−0.44133	0.149204
CR7	0.7366	0.674325	−0.96898	1.467509
LD8	1.075232	−1.55693	1.286509	0.417312
LD9	−0.96643	−0.17688	0.041899	0.722076
LD10	0.323293	−1.81144	−0.63935	−1.21919
KC11	0.019084	0.857612	2.163747	−0.75312
KC12	−1.49681	0.850539	0.873518	−1.92557
KC13	−2.23938	−0.61604	1.134561	0.552776
KC14	−1.56771	−0.27208	−0.71071	0.463879
KC15	−0.64031	−0.71459	−1.03325	−0.1246
BD16	0.430227	0.59019	−0.24645	1.067634
BD17	1.273726	−0.94757	−0.40521	−1.3546
BD18	−0.33972	1.678446	−1.27184	−1.08452
BD19	0.242229	0.809875	−1.1138	−0.02095
BD20	−0.99356	−1.21948	−0.58236	1.309767
Variance explained[a]	28.34 %	22.42 %	12.64 %	9.01 %

Factor scores were generated by applying PCA on descriptive sensory score data

[a] Refers to percent variance explained

original dependent variable into uncorrelated dimensions is carried out using PCA to simplify the data and eliminate descriptor redundancies.

PCA was applied to the mean attribute ratings listed in Table 2 to simplify interpretation of data from 13 attributes measured on 20 products of four different groups. To acquire specific knowledge about primitive factors having critical importance among the sensorial descriptors i.e. PCs were extracted based on maximum variance values. Among all the PCs extracted four PCs having eigen values >1 (Kaiser

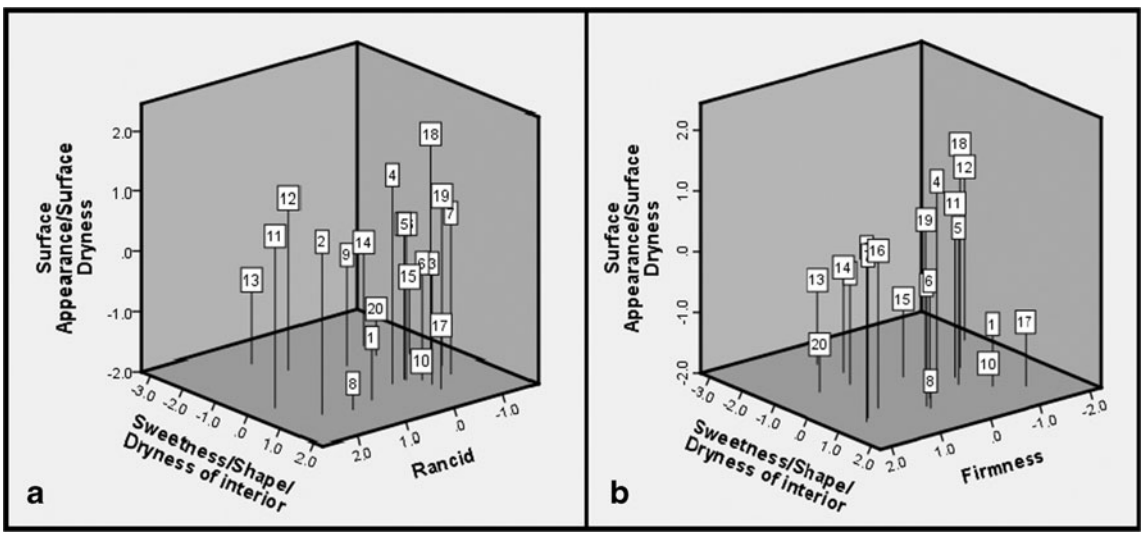

Fig. 3 Three-dimensional plot showing factor scores of market samples of *cham-cham* on Varimax rotated PC axes **a** PC1, PC2, PC3 and **b** PC1, PC2, PC4. Labels: CR (1–7), LD (8–10), KC (11–15), BD (16–20)

criterion) explaining 72.4 % of the total variance in the data set were taken for further analysis. The results revealed that on the basis of eigen vector loadings, first PC with an eigen value of 3.68 was able to explain 28.34 % of the total variation (Fig. 2) whereas second PC with an eigen value 2.91 explained 22.42 % of the variation and both the PC's (PC1 and PC2) explained 50.75 % of the total variation. Third PC with eigen value of 1.64 was able to explain 12.64 % variation and fourth PC having eigen value of 1.17 explained 9.01 % variability. For closer alignment with original variables, PCs were rotated using Varimax rotations (Lawless and Heymann 1998). Rotation of variables resulted in factor loading which represents correlation between PC and the original attribute measured as shown in Table 4. High factor loading values marked with asterisk were of chief importance. As shown in Table 4, absolute value of factor loadings corresponding to each sensory attribute decides the relation between principal component and that specific sensory attribute. PC1 was found to be entirely related to the "sweetness", "shape" and "dryness of interior" as the loadings had maximum absolute values. More than one variable can be explained with the help of one principal component as suggested by Chapman et al. (2001). PC2 had large loadings for "surface appearance" and "surface dryness". PC3 was largely related to "rancid" flavour while PC4 was found to be influenced by "firmness".

With the purpose to position or specify the location of all the samples along the Varimax rotated PC, factor scores (Table 5) values can be utilized (Coxon 1982). Hence, the three dimensional graphs generated depicts the position of different samples along four PC generated (Fig. 3a and 3b). Products that are similar are positioned in close proximity to one another in the graph, and products that are very different are far apart (Jolliffe 2005). It can be observed from Fig. 3a that samples of CR and LD groups are in close proximity with each other having high factor score values for (0.876 to 1.075) for "sweetness/shape/dryness of interior" axis as compared to KC group which had less sweetness, more pronounced cylindrical shape and moderate amount of syrup oozing out from samples as shown by negative factor score values (−0.64 to −2.24). Surface appearance of KC and BD groups was found more desirable as compared to New Delhi market samples (CR 1 = −0.976, LD 8 = −1.56, LD 10 = −1.81) which can be observed to have smaller spike height on graph. At the same time, surface dryness of samples of CR and BD group (CR 2 = 0.87, CR 4 = 1.46, BD 18 = 1.68, BD 19 = 0.81) was found more as compared to LD and KC groups represented by taller spike heights shown in the graph. Most of the samples had no rancid flavour as scrutinized by close association of spikes on graph having very low factor score values for PC3 (rancid). Figure 3b shows each shop location on the "sweetness/shape/dryness of interior" (PC1), "surface appearance/surface dryness" (PC2), and "firmness" (PC4) axis. Samples with the similar firmness of *cham-cham* are grouped together on the graph. Samples with high overall acceptability had lower firmness in *cham-cham*. It was observed that the samples having higher overall acceptability ratings (KC 11 = −0.75, KC 12 = −1.92, BD 17 = −1.35) had factor score values in negative range for PC4 (firmness) axis which was corroborated by the sensory data (Table 2).

The results of the study suggested that PCs sweetness/shape, surface appearance, rancid and firmness had explained much of the variation in descriptive sensory data. It can clearly be observed from the three-dimensional graphs axes that samples positioned in close proximity with one of the axis has more influence of that particular PC which in turn requires attention during technology development and commercialization of optimized product with desired sensory attributes.

Conclusion

For development and marketing of *cham-cham* perceptual mapping in consent of QDA and PCA could contribute in product positioning with correct approach or strategy. It could be concluded from the study that the analysis of sensorial attributes of market samples of *cham-cham* revealed significant differences among samples from different locations. Further, PCA identified key attributes i.e. sweetness, shape, surface appearance, rancidity and firmness, which governed much of the variation in the sensory scores. Hence, these attributes may be given prime importance while developing the product technology for industrial scale production.

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