Sensory characterization of *doda burfi* (Indian milk cake) using Principal Component Analysis

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Abstract Traditional sweetmeats of various countries hold a great and promising scope in their improvement and in order to tap the potential of the same, several companies and co-operative federations have started their organized production. *Doda burfi*, a heat desiccated and popular sweetmeat of northern India, is one of the regional specific, unfamiliarized products of India. The typical sweetmeat is characterized by caramelized and nutty flavour and granular texture. The purpose of this study was to determine the close relationship among various sensory attributes of the product collected from renowned manufacturers located in four different cities and to characterize an overall acceptable product. Individuals from academia participated in a round table discussion to generate descriptive terms related to colour and appearance, flavour and texture. Prior to sensory evaluation, sensory panel was trained and briefed about the terminology used to judge the product involving a descriptive intensity scale of 100 points for describing major sensory attributes. Results were analyzed using ANOVA and principal component analysis. Correlation table indicated a good degree of positive association between the attributes such as glossy appearance, dark colour, caramelized and nutty flavour and cohesive and chewy texture with the overall acceptability of the product.

Keywords Doda burfi · Sensory characterization · Dietary fiber · Caramelization · Principal Component Analysis

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Doda burfi, also known as ‘Doda’ or “Dhoda”, is a heat desiccated sweetmeat, prepared from a mixture of milk, germinated wheat flour and sugar, and garnished with nuts. The product, immensely popular in northern India specially in the states like Punjab, Haryana, and western Uttar Pradesh, is served during special occasions. As the product contains germinated wheat flour, it serves as an excellent source of dietary fiber, which is usually absent in dairy products. However, being prepared at small scale, the hygienic conditions usually are not maintained and thus inferior quality product is often marketed (Patil 2002). Of the total milk commercially processed, about 50–55% is converted by the traditional sector into variety of milk products (Banerjee 1997). Though exact figures for the production and demand of *doda burfi* are not available, the market for traditional dairy products is valued around Rs. 50,000 crores annually (Aggarwal 2007).

The composition of the product available in market varies widely due to lack of any set food standards. Varying manufacturing practices, ingredient quantity and quality and the storage temperature of the final product are major reasons behind wide variation in composition. Also, information on the aspects pertaining to the standard quality product of *doda burfi* and its characteristics is not available till date. Thus, defining the product with its characteristic features is an important criterion to evaluate the product precisely and specifically. Researchers have used descriptive analysis or specific attribute analysis (sensory characterization) to study aging and various processing parameters in cheese (Piggott and Mowat 1991; Drake et al. 2001), whey and soy proteins (Drake et al. 2007), emollients (Parente et al. 2008), Malbec wines (Goldner and Zamora 2007), chocolate milks (Thompson et al. 2004), beverages (Kappes et al. 2006), soy milk (Keast and Lau 2006), and fermented food products (Ghosh and Chattopadhyay 2010)

however, such studies have not been conducted on any of the traditional sweetmeats including *doda burfi*.

In the scenario of rapid globalization and widespread marketing of traditional items, development of a standard descriptive language would enhance communication among research groups and enable more precise profiling of flavour attributes and the same would be useful in niche market identification and in end product application. Keeping the same objective, study was carried out to characterize sensory characteristics of *doda burfi* collected from the market of cities where it is considered as a delicacy, using Principal Component Analysis (PCA).

PCA is a mathematical tool that uses an orthogonal transformation and reduces the set of dependent variables (attributes) to a smaller set of underlying variables (factors) based on patterns of correlation among the original variables (Lawless and Heymann 1998) and convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. PCA is the simplest of the true eigenvector-based multivariate analyses. The objective of this work was to use a multivariate statistical method, viz principal component analysis (PCA) (Massart et al. 1988; Naes et al. 1996), using an equal interval scale of quantitative descriptive sensory analysis (Stone et al. 1974) to find out the attributes without which the product can not be rendered as best in terms of its acceptance. PCA operation makes it possible to distinguish the food samples and also to identify the most important variables in a multivariate data matrix (Díaz and Navaza 2003).

Materials and methods

Sample collection Four cities of northern India namely Karnal, Delhi, Jalandhar and Ludhiana which are known for their excellence in preparing *doda burfi*, were chosen for sample collection. Total 16 different samples of *doda burfi* were collected (four samples from each) thrice, after carefully checking the acceptability of the product along with the complete assurance of intact freshness, so as to reduce any chances of introduction of error in the sensory results. The purpose was to find out the extent of variation in the product collected from different cities as well as in the samples collected from different markets of the same city. The samples were procured, brought hygienically to the laboratory using sterilized pouches so that no physico-chemical and sensory changes took place. The samples were then subjected to sensory evaluation by a panel of trained judges.

Male panelists ($n=12$) and female panelists ($n=7$) between the ages of 30 to 55 years participated in this study and provided informed consent. Prior to sensory

evaluation, sensory panel was trained and briefed about the terminology used to judge the product. Descriptive sensory analysis (DSA) technique was employed to carry out the evaluation of samples and total of nineteen attributes of colour, flavour and texture characteristics were generated which could fully describe the *doda burfi*. An additional attribute to judge the preferability/liking of product (overall acceptability) was added along with other descriptive attributes. Descriptive intensity scale of 100 points was used for describing the attributes. A line of 10 cm ranging from 0 to 100 points was drawn with marking interval of 25 points for evaluation and reporting sensory results. Panelists were asked to mark a vertical linear mark indicating the sample number along the horizontal linear scale for a particular attribute. The main descriptors used for surface appearance were colour and glossy character while the flavour was best described using caramelized, off-flavour, rancid, nutty, doughy, oxidized, stale, bitter and acidic flavour whereas texture descriptors used in the study were crumbli-ness, granularity, firmness, chewiness, cohesiveness and stickiness.

Sensory evaluation Samples were presented with random coding in petriplates, presenting maximum of 2 samples at a time providing enough time to each panelist to report unbiased and error free results. The potential to subdivide a particular character facilitates the usage of more complex and specific language and also provides a tool in descriptive error free sensory analysis when specific need arises.

Statistical analysis Multivariate data was analyzed using principal component analysis (PCA) to reduce the number of dependent variables (attributes) to a smaller set of underlying variables (factors) and factor analysis using sensory rating means to determine how the *doda burfi* could be differentiated and to identify redundant terms. Correlation analysis was also performed to find the degree of correlation of one attribute with other attributes. The results obtained in the present study were subjected to two-way analysis of variance (ANOVA) using MS-Excel software (Version 2003) of Microsoft, USA. To compare the class means two at a time, critical difference (C.D), also called least significant difference (LSD) was calculated as per the method described by Rangaswamy (1995). The same set of data were statistically analyzed using Xlstat software (version 2009) for principal component analysis to find out the components of prime importance, maximum positive loadings and their interaction with other attributes (Thompson et al. 2004). For all statistical analyses, a value of $p<0.05$ was used as the criterion for statistical significance.

Fig. 1 Internal preference mapping of *doda burfi* collected from four cities using PC1 and PC2 where Observation 1, 2, 3, and 4 refers to cities of Karnal, Delhi, Jalandhar and Ludhiana

Results and discussion

The terms generated at roundtable discussion served as a basis for the descriptive sensory analysis (DSA). Many of the terms though sighted as synonym to untrained panel but were quite different for a trained panelist and were helpful in discriminating between the two or more samples. Consensus discussion among the panel refined the list of different lexicons used in evaluation to describe the range of *doda burfi*. Many of these attributes were used to characterize the flavour attributes of soymilks (Keast and Lau 2006). Similar work was carried out by Drake et al. (2007) and Parente et al. (2008). Data obtained after sensory analysis was analyzed using PCA and multivariate analysis of variance for 20 different attributes. PCA also indicated non-redundant terms that clearly differentiated *doda burfi*. Factor analysis was applied on the correlation matrix of different sensory attributes of *doda burfi* means,

in addition to PCA, in order to clarify groups of sensory characteristics of *doda burfi*.

The PCA distinguished and segregated different sensory attributes on the basis of their eigen values. Variables with eigen value over one were taken to explain the total variance. The mean sensory scores of market samples of *doda burfi* from four cities were analyzed using principal component analysis wherein, PCA differentiated cities in four different quadrants (Fig. 1). Similar results were observed by Sabbe et al. (2009) in case of fruit juices with different concentrations of acai, where juices with same characteristics combined in few quadrants while other with different characteristics remained segregated. The results revealed that on the basis of eigenvector loadings, first principal component with an eigen value of 9.81 was able to explain 49.07% of the total variation whereas second PC with an eigen value 6.28 explained 31.43% of the variation and both the PC's (PC1 and PC2) explained 80.50% of the

Fig. 2 Explained variance plot using principal component analysis where F1, F2, F3 refers to factor loadings

total variation (Fig. 2). In PC1, attributes pertaining to colour, glossiness, cohesive texture and caramelized flavour attribute along with overall acceptability were positively loaded. Similarly majority of the undesirable flavour attributes like stale and off-flavour and doughy, acidic, bitter, oxidized and rancid were negatively loaded in PC1 and PC2, respectively, whereas unclean, granularity and firmness were loaded positively in PC2 (Fig. 3). The loadings plot depicts the distance between the location of any two attributes which is proportional to the degree of difference or similarity between them.

Factor analysis revealed component 1 positively and significantly loaded with glossiness (0.789), caramelized and nutty flavour (0.991) and (0.990) respectively, along with cohesive texture (0.802) whereas found negatively loaded with chewiness (−0.929), stale (−0.785), off-flavour (−0.440) and stickiness (−0.527). The characteristics of prime importance were found loaded in Ludhiana city whereas doughy, nutty, acidic, bitter, oxidized and rancid were dominating characteristics in Karnal samples. Cohesive texture and granularity, the identifying and important attributes were found to be the highest in Delhi and Ludhiana samples.

A weaker correlation was observed after recalculating between stickiness and off-flavour and acidic and doughy flavour attributes (Fig. 3). This analysis was performed to illustrate graphically the correlations between ratings given to the different descriptors. Principal component analysis, factor analysis and correlation analysis all indicated relationship among the terms (Tables 1 and 2). Removal of unclean, rancid, off-flavour, bitter terms from data set did not result in a loss of explained variability by PCA, suggesting that these aroma terms could be removed from the sensory language without a

Table 1 Factor loadings for sensory analysis of *doda burfi* employing all attributes

Sensory attributes	Factor 1	Factor 2	Factor 3
Glossy	0.789	0.568	0.233
Surface colour	0.159	0.031	0.987
Caramelized	0.991	0.031	0.128
Doughy	0.921	−0.317	−0.227
Nutty	0.990	−0.034	0.136
Unclean	−0.454	0.707	−0.542
Acidic	0.897	−0.400	−0.188
Rancid	0.086	−0.924	−0.373
Stale	−0.785	−0.607	−0.126
off flavor	−0.440	−0.788	0.431
Bitter	0.426	−0.905	−0.003
Oxidized	0.754	−0.636	0.165
Granularity	−0.312	0.894	0.322
Cohesiveness	0.802	0.582	−0.134
Firmness	−0.821	0.369	−0.436
Chewiness	−0.929	−0.345	0.138
Stickiness	−0.527	−0.821	0.220
Crumbliness	0.678	0.006	−0.735
Gumminess	0.407	−0.230	−0.884
Overall acceptability	0.774	0.122	0.621

Values in bold correspond for each variable to the factor for which the squared cosine is the largest

loss of product differentiation (Table 3). The results obtained after analysis of variance validated the same hence the attributes were omitted from the analysis and data was reanalyzed depicting PC1 and PC2 explaining 57.87 and 23.48% of the variation, respectively. The wide variability among different sensory attributes could be attributed to difference in manufacturing practices, varying ingredient quantity and quality and the storage temperature of the final product.

Correlation matrix (Table 2) revealed many expected correlations and was conducted to determine if linear relationships existed between individual terms of sensory attributes. Rancid was positively correlated with stale, off-flavour, bitter and oxidized flavour and the same were found negatively correlated with overall acceptability. A good degree of correlation was also observed between many other attributes. Texture depicitors such as “chewiness” “stickiness” were correlated to each other. Though these texture descriptors are distinct from each other, but the both were predominate in good quality *doda burfi*. Glossy appearance, dark colour, caramelized flavour showed a positive degree of correlation with overall acceptability while the same has been found to be negatively correlated with attributes such as unclean, rancid, stale and off-flavour. A positive correlation was

Fig. 3 Biplots from the 1st and 2nd principal components of PCA: sensory attributes

Table 2 Matrix showing correlation between different attributes

Variables	GLOSSY	COLOR	CM	DGHY	NUT	UC	ACID	RNCD	STALE	OF	BITR	OX	GRAN	COH	FIRM	CHEW	STICK	CRUM	GUM	OA
GLOSSY	1	0.373	0.830	0.494	0.794	-0.083	0.437	-0.544	-0.993	-0.694	-0.179	0.273	0.337	0.932	-0.540	-0.897	-0.831	0.367	-0.016	0.825
COLOR		1	0.284	-0.088	0.290	-0.584	-0.056	-0.384	-0.268	0.331	0.036	0.263	0.296	0.013	-0.549	-0.022	0.108	-0.618	-0.815	0.740
CM			1	0.874	0.998	-0.498	0.853	0.009	-0.812	-0.405	0.394	0.749	-0.240	0.796	-0.858	-0.913	-0.519	0.578	0.283	0.851
DGHY				1	0.892	-0.520	0.996	0.456	-0.501	-0.253	0.679	0.858	-0.644	0.584	-0.774	-0.777	-0.275	0.789	0.648	0.533
NUT					1	-0.548	0.877	0.066	-0.773	-0.350	0.452	0.791	-0.296	0.756	-0.884	-0.889	-0.464	0.572	0.291	0.847
UC						1	-0.589	-0.490	-0.005	-0.591	-0.832	-0.882	0.600	0.120	0.870	0.103	-0.460	0.094	0.132	-0.602
ACID							1	0.516	-0.437	-0.161	0.744	0.900	-0.698	0.512	-0.802	-0.721	-0.185	0.744	0.623	-0.529
RNCD								1	0.541	0.529	0.873	0.590	-0.973	-0.419	-0.248	0.188	0.631	0.327	0.577	-0.278
STALE									1	0.769	0.216	-0.226	-0.339	-0.966	0.475	0.920	0.884	-0.443	-0.069	-0.759
OF										1	0.524	0.240	-0.428	-0.869	-0.118	0.740	0.973	-0.620	-0.380	-0.169
BITR											1	0.896	-0.943	-0.185	-0.682	-0.084	0.518	0.285	0.383	-0.218
OX												1	-0.750	0.212	-0.926	-0.458	0.161	0.386	0.307	0.609
GRAN													1	0.228	0.446	0.025	-0.499	-0.442	-0.616	0.067
COH														1	-0.385	-0.964	-0.930	0.646	0.311	0.608
FIRM															1	0.575	0.033	-0.234	-0.033	-0.861
CHEW																1	0.803	-0.733	-0.420	0.675
STICK																	1	-0.524	-0.220	-0.371
CRUM																		1	0.924	0.069
GUM																			1	0.262
OA																				1

Where, CM caramelized; DGHY doughy; NUT nutty; UC unclear; ACID Acidic; RNCD rancid; OF off-flavour; BITR bitter; OX oxidized; GRAN Granularity; COH cohesiveness; FIRM firmness; CHEW chewiness; STICK stickiness; CRUM crumbliness; GUM gumminess; OA overall acceptability

Numbers in bold represent significant differences ($p < 0.05$)

Table 3 Factor pattern loadings for sensory analysis of *doda burfi* omitting attributes of null importance

Sensory attributes	Factor 1	Factor 2
Glossy	0.830	0.542
Colour	0.161	0.626
Caramelization	0.991	0.043
Doughy	0.894	−0.444
Nutty	0.985	−0.003
Acidic	0.864	−0.483
Stale	− 0.829	−0.506
Oxidized	0.704	−0.441
Granularity	−0.243	0.918
Cohesiveness	0.844	0.325
Firmness	− 0.791	0.069
Chewiness	− 0.952	−0.129
Stickiness	−0.587	−0.475
Crumbliness	0.676	−0.491
Gumminess	0.388	− 0.751
OA	0.782	0.433

Values in bold correspond for each variable to the factor for which the squared cosine is the largest

observed for cohesiveness and chewiness with overall acceptability whereas negatively correlated with firmness and stickiness (Table 2). These results suggest that high glossy appearance, nutty flavour and cohesive character necessarily drive the consumer liking. Caramelized flavour was found to be positively correlated with doughy and nutty flavor and cohesive and gummy texture indicating intense non-enzymatic reaction between cereal component and sugar in the presence of heat, developing caramelized flavor. A cohesive texture and intact chewiness due to high sugar content, together with the developed intense caramelized flavour resulted in more acceptable product, drove the highest rating and the same was confirmed by correlation matrix. Statistically, location specific analysis indicates (Table 4) that four attributes namely caramelized, nutty, bitter, and crumbliness were found to be significantly different from others ($p<0.05$).

Table 4 shows the mean separation of sensory attributes with respect to texture, colour and appearance and flavour descriptors. ANOVA performed on the various textural attributes revealed only crumbliness significant at $p<0.05$, whereas amongst the flavour attributes, caramelized, nutty and bitter flavour were found significant ($p<0.05$).

Table 4 Colour, flavour and texture profile scores of market samples of *doda burfi*

Characteristics	Attributes	Market areas				CD 5%
		Karnal	Delhi	Ludhiana	Jalandhar	
Surface appearance	Glossy	58.2±4.70	64.5±5.37	65.2±2.95	52.5±3.30	ns
	Surface colour	63.6±4.00	60.0±4.40	69.1±2.95	61.7±4.21	ns
Flavour	Caramelized	63.7 ^a ±2.65	63.5 ^a ±4.08	62.9 ^{ab} ±4.65	48.0 ^b ±6.01	14.50
	Doughy	52.7±3.47	50.0±4.34	45.3±4.07	39.3±6.40	ns
	Nutty	60.1 ^a ±4.64	58.5 ^a ±4.70	58.2 ^{ab} ±3.75	42.1 ^b ±5.80	15.91
	Unclean	3.0±1.13	5.5±3.47	4.0±3.13	5.3±2.68	ns
	Acidic	7.9±2.80	6.6±3.35	5.3±3.14	3.4±1.64	ns
	Rancid	7.9±3.35	3.9±1.44	2.3±0.94	4.8±2.13	ns
	Stale	3.0±1.03	1.0±0.44	1.2±0.48	4.5±2.16	ns
	off flavor	1.6±1.00	0.1±0.12	1.1±0.87	1.5±0.76	ns
	Bitter	4.0 ^a ±1.55	0.5 ^b ±0.22	0.6 ^b ±0.30	0.4 ^b ±0.32	2.720
	Oxidized	9.3±3.30	6.2±2.79	6.8±3.01	4.5±3.11	ns
Texture	Granularity	58.9±4.98	62.1±5.02	63.3±3.75	62.2±3.90	ns
	Cohesiveness	63.8±4.12	73.1±3.31	68.1±3.02	58.0±4.89	ns
	Firmness	50.3±2.95	52.4±4.31	51.0±4.00	54.1±3.76	ns
	Chewiness	53.5±6.09	50.6±6.02	53.0±5.72	58.0±3.38	ns
	Stickiness	54.8±5.80	45.0±5.10	49.5±4.30	54.8±5.09	ns
	Crumbliness	25.4 ^{ab} ±6.70	33.1 ^a ±7.53	12.6 ^b ±4.84	12.6 ^b ±3.81	19.670
	Gumminess	53.3±5.83	55.4±4.14	43.3±5.91	48.0±6.75	ns
	Overall Acceptability	72.4±5.17	70.9±4.41	76.3±4.01	65.2±5.43	ns

Intensity scored on a 100-point line scale, Values are Mean ± S.E

Means followed with the different superscript alphabet within each column are significant $p<0.05$ ($n=19$ panelists)

Conclusion

Doda burfi is a heat desiccated sweetmeat of northern India having high fat content along with the additional benefits of dietary fiber provided by cereal component which otherwise is a deficient component in dairy products. Characterization of this product was carried out using descriptive sensory analysis and PCA was applied as a tool to characterize and standardize *doda burfi* at a commercial scale. The *doda burfi* collected from four different cities and market areas showed a wide variation with respect to its sensory attributes. Among the four cities surveyed, samples collected from Ludhiana city showed maximum positive loadings and scoring for sensory attributes. Attributes which were undesirable were found either negligible or almost completely absent in case of Ludhiana and Delhi samples. Also, component analysis delineated the concentration of desirable attributes present in Ludhiana city compared to the cities surveyed.

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