

## Descriptive sensory profiling of *thandai* using principal component analysis

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Received: 29 June 2020 / Accepted: 08 December 2020 / Published online: 07 June 2021  
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**Abstract:** *Thandai* being nutrient crammed pabulum is relished as a traditional milk-based beverage in India. Being indigenous drink, international and national level research work and the literature pertaining to the same is not available. Thus, the present study was undertaken to investigate and characterize the sensory attributes of commercially available *thandai* using Quantitative Descriptive Analysis (QDA) and Principal Component Analysis (PCA). QDA revealed statistically significant ( $p < 0.05$ ) difference in sensory attributes of *thandai* amongst the market samples. PCA identified three significant principal components that accounted for 93.01 per cent of the variation in the sensory data. Correlation matrix revealed many linear relationships between independent terms of sensory attributes.

**Keywords:** Milk beverage; 100-point scale; Principal component analysis; Quantitative descriptive analysis.

### Introduction

The ancient philosopher has espoused the basic senses of human- sight, hearing, smell, taste and touch as “the windows of the soul.” Sensory properties of products are absolutely necessary for the development of the product and can generally be described using terms defined within the categories of appearance, flavor and texture. *Thandai*, a traditional milk-based

beverage is easily digestible, highly refreshing, thirst quenching, appetizing and nutritionally far superior to many synthetic and aerated drinks. Being prepared from a combination of fruits and nuts with food additives, a proper blend of these is of utmost importance to bestow a peculiar sensory characteristic to the milk. The characterization of product is an important criterion to evaluate the product precisely and specifically. As the sensory quality is driving force for consumer acceptance and consequently demand laden (Desai et al. 2013), present study was undertaken to investigate and characterize the quality of commercially available *thandai* in terms of sensory attributes. The need to develop appropriate sensory characteristics that are product sensitive and specific has emerged in the recent years as the dairy and food industry has grown from the concept of “eat what we produce” to “produce what you want to eat”. The application of statistical tools specifically QDA and PCA to develop these terminologies has been successfully employed in the recent years to characterize the sensory attributes of many food products.

Quantitative descriptive analysis (QDA) has been known as a tool for measurement and optimization of the aesthetically and measurable parameters of various products (Stone and Sidel, 1998). Descriptive sensory analysis of any product requires a descriptive technique and lexicon to describe the sensory properties in detail (Chawla et al. 2014). The principle involved in the QDA is highly dependent on the ability of the panelists to give reproducible results to yield quantitative product description which further can be evaluated statistically (Murray et al. 2001). Piggott and Hunter (1999), and Basker (1988) described screening tests and measures to monitor the performance of panelists for selection in panel. The critical part for any QDA is the scale usage and training of the panelists. Drake and Civille (2003), and Meilgard et al. (2007) reviewed these specifics and suggested that a panel or group of individuals to be employed for descriptive sensory analysis to obtain consistent results.

Principal component analysis (PCA) is a multi-variable analysis statistical tool (Martinez et al. 1998), widely used and involves reducing the original dependent variables (attributes) into a lower number of orthogonal (uncorrelated) synthesized variables

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(factors) based on pattern of correlation among the original variables (Lawless and Heymann, 1998). The application of PCA to the data obtained by QDA can be successfully employed to profile specific product characteristics, comparing and contrasting similar products based on attributes crucial of importance for sensory recognition and thus holding its promising position by altering product characteristics. Many researchers have employed the applications of QDA and PCA for the characterization of many food dairy products *viz.*, ultra-pasteurized milk, cheddar cheese, chocolate and soy flavored milk (Chapman et al. 2001; Young et al. 2004; Thompson et al. 2004; Keast and Lau, 2006), fermented food products like yoghurt (Desai et al. 2013; Ghosh and Chattopadhyay, 2012), labneh (Kaaki et al. 2012), and Indian delicacies like *Doda burfi* (Chawla et al. 2014) and *Cham-Cham* (Puri et al. 2016). In light of the above, considering the degree of success of QDA and PCA to descriptively illustrate the sensory attributes of food products, present study was envisaged to characterize the quality of commercially available *thandai* in terms of sensory attributes with the help of QDA and PCA as a statistical tool.

## Materials and Methods

### Market survey

Five best renowned commercial samples of *thandai* concentrate, in liquid form, were procured from the domestic market. Choosing the market samples was based on the brand image and consequent their sales in the market. Therefore, the brands chosen for the study were procured and coded for further analysis. For uniform product quality, homogenized toned milk was used for reconstitution studies, collected, and standardized to desired fat and SNF content, from the Experimental Dairy plant, College of Dairy Science and Technology for the preparation of *thandai* from market samples.

### Preparation of Thandai from commercial samples (as directed by manufacturer on the label)

All the samples were reconstituted as per the procedure mentioned on the label, adding ice-chilled milk and decoction in requisite amounts. Careful instructions were taken into account while reconstitution as mentioned by the manufacturer.

### Sensory evaluation

The sensory evaluation of the product was carried out by a panel of nine trained faculty members (n= 9) from Dairy Technology Department, working at College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India. The attribute terms adjudicating and characterizing procedures were developed using flavor profile methodology (Keane, 1992). The work done on sensory lexicons by Adhikari et al. (2011), Puri et al. (2016), Chawla et al. (2014), Civile et al. (2010), and Drake et al. (2010) was thoroughly studied

to choose wide range of descriptive attributes, highly regarded for *thandai*. A descriptive language was developed for various attributes of *thandai* with the identified lexicon (Table 1). A total of 17 descriptors were selected under 4 heads. These four heads included color and appearance, flavor, mouthfeel and overall acceptability. Attributes were quantified with an intensity scale of 100 and analyzed using the procedure adopted by Chawla et al. (2014). After the screening of identifiable attributes and suitable terminology, the panelists were briefed and trained to accurately judge the characteristics of the product accordingly. The training period was continued until all the panelists grasped adequate knowledge to differentiate the intensity rates of each characteristic. An approximate sample size of 25 ml was presented to the panelists for its evaluation at its best, keeping in view of judging all the attributes in a precise manner. To achieve reproducible sensory results, random coded samples were served to the panelists with a maximum of two samples served at a time with a temperature of 5°C (in closed cups to ease shaking of contents), and lukewarm water as a white between the different samples. Sensory analysis was performed thrice to eradicate any source of unbiases in the results. All of these triplicate formulations were served on different days to avoid misapprehensions. The environment of test performance was kept pleasant to minimize human errors during sensory analysis.

### Statistical analysis

The data were analyzed with statistical analysis system (SAS) version 9.3.8 (SAS Inc., Cary, NC, USA). One-way analysis of variance (ANOVA) was performed on the descriptive data obtained during the present investigation for difference in means. Duncan's multiple range test was employed to evaluate statistically significant differences in mean values. Further, the mean scores of all 17 descriptors from descriptive analysis of commercial samples of *thandai* was subjected to Principal component analysis (PCA) using XL stat 32-bit software to have in depth understanding of the components of prime importance, maximum positive loadings and their interaction with other attributes in *thandai*.

## Results and Discussion

### Descriptive sensory analysis

Descriptive language for various attributes of *thandai* with the identified lexicon in presented in (Table 1). Puri et al. (2016) showed that the sensorial attributes of *Cham-Cham*, *Doda burfi* and greek yogurt differed with each other except few attributes and thus the need to develop the product specific lexicons to optimally describe the sensory attributes. Similarly, the sensory attributes of *thandai* differs from these products as depicted in Table 1, except for cooked flavor, and thus justifies the need to develop lexicons specific to *thandai*. The lexicon for *thandai* employed in PCA was figured out by finding its most significant

characteristic features by a panel of trained sensory panelists. The attributes were distributed carefully under the main heads such as colour, consistency, sweetness and flavour. Mean sensory scores of market samples of *thandai* for colour and appearance, flavor, mouthfeel and overall acceptability can be fetched from the figure indicating spikes on spider/ radar web (Fig. 1). These plots were used for the graphical representation of the data generated by QDA methodology by plotting average intensity values on corresponding scale and then joining the points to create a visual profile or “fingerprint” of product attributes (Stone and Sidel, 1998) as these plots are often used for the graphical depiction of the data generated by QDA methodology (Murray et al. 2001). PCA not only helps in identifying underlying attributes of acceptance but also provides a means to check adulteration in many cases (Baquiran et al., 2019). Fig. 1 represents graphic representation of the data for five commercial samples of *thandai* in the form of spider web with a branch or spoke from a central point for each attribute. As presented by peaks and loops, sweetness was maximum in case

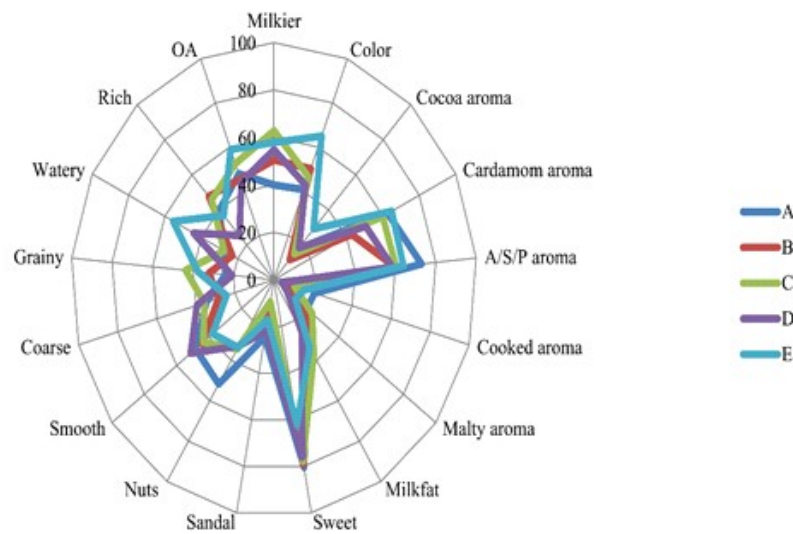
of sample A and lowest in sample E. Similarly, score for watery consistency was highest for sample E and lowest for sample B. Indistinguishable work has been performed earlier in ultra-pasteurized milk (Chapman et al. 2001), commercial lebneh samples (strained yoghurt) (Kaaki et al. 2012), *Cham-Cham* (Puri et al. 2016) and (Singh et al. 2019), where authors represented the descriptive sensory scores of panelists in pictorial form by creating spider plots.

The maximum score for milkier appearance and light brown to pistachio green colour was obtained with sample C (62.85) and E (65.0), respectively. Though, the colour and appearance scores were non-significant ( $p \geq 0.05$ ), these attributes influence food appreciation and quality. The average scores for cocoa, cardamom, almond/saffron/pistachio, cooked, malty, sweet, and sandal and aroma from milk fat and combination of nuts ranged from 11.57-29.0, 42.85-64.85, 58.57-73.0, 4.14-20.71, 8.0-23.57, 62.14-80.42, 9.42-24.57, 26.14-37.28 and 32.85-51.71, respectively. Statistically, non-significant difference ( $p \geq 0.05$ ) was observed

**Table 1** Sensory lexicon developed for *thandai*

Attribute name	Attribute Definition
Milkier Appearance	Having the appearance of milk, whitish, cloudy fluid which can mask other colours and flavours if present in extreme
Colour (Light brown to Pistachio green)	The intensity of colour from light brown to pistachio green
Cocoa aroma	Aromatics that specifically arises from complex biochemical and chemical reactions during the postharvest processing of raw cocoa beans
Cardamom aroma	Aromatics associated with cardamom
Almond/Saffron/Pistachio (A/S/P) aroma	Aroma that arises either due to almonds, saffron, pistachio or a combination thereof
Cooked aroma	Varies in intensity from sweet, pleasant, with slight sulfurous or custard notes, to caramelized or cabbage-like, which may be objectionable. Generally, arises from over cooking/roasting of nuts and milk.
Malty aroma	Malt-like aroma or taste is characteristic of uncooked or roasted grain (including roasted corn, barley or wheat), malt extract
Milk fat	Fat contributed by milk provides a characteristic aroma to the product
Sweet	Sweetness is the most recognized functional property of sugar; intensity depends on amount of sugar added and perceived by taste receptors present on tongue throughout mouth
Sandal	Aromatics associated with sandalwood from trees in genus <i>Santalum</i>
Combination of several nuts	A light, brown, slightly musty and nutty aroma contributed by various nuts infused into the product
Smooth mouth feel	It is the absence of any particles, lumps and bumps in the product.
Coarse mouth feel	Signifies rough mouth feel. The coarseness in the product is resultant of ingredients added and are particularly large in size
Presence of grainy particulates	The extent to which the product is composed of distinguishable pieces or grains of nuts.
Watery consistency	Overly flowing consistency, lacks adequate consistency
Rich mouth feel	Sufficient amount of milk fat, creamy mouth feel
Overall Acceptability	Adequate to satisfy a need, requirement, or standard

**Fig. 1** Descriptive sensory profile of market samples of *thandai* on 100-point scale



**Table 2** Contribution of the variables in factor loadings for sensory analysis of *thandai* employing all attributes

	F1	F2	F3	F4
Milkier	5.74	0.94	8.35	18.30
Colour	12.65	0.73	0.31	8.71
Cocoa aroma	5.63	12.55	0.16	0.16
Cardamom aroma	3.00	3.87	8.77	20.20
A/S/P aroma	0.33	2.18	20.60	0.27
Cooked aroma	0.58	2.18	19.96	1.11
Malty aroma	0.11	12.07	9.10	1.51
Milk fat	5.16	11.35	2.31	0.12
Sweet	10.01	6.02	0.63	0.65
Sandal	3.94	13.34	1.78	0.70
Nuts	2.99	0.63	18.24	0.02
Smooth	14.00	0.24	0.53	2.36
Coarse	8.56	0.00	0.76	33.19
Grainy	9.63	5.80	0.11	5.55
Watery	3.75	13.23	2.29	0.36
Rich	1.07	14.15	4.47	3.93
OA	12.86	0.72	1.64	2.86

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

in the sensory scores of the mentioned attributes except cooked and sweet aroma amongst the five commercial samples of *thandai*. The cooked aroma of sample B and D was observed close to nil with sensory scores of 5.0 and 4.14, respectively. The highest sensory scores for cooked aroma were observed for sample A and were significant ( $p \leq 0.05$ ) w. r. t. sample B and D while non-significant w. r. t. sample C and E. The sweetness scores of sample A was found definite with an average score of 80.42 whereas, in sample E sweetness was found close to moderate

range with an average score of 62.14 and was significant ( $p \leq 0.05$ ) with respect to each other.

Furthermore, the descriptors under mouth feel terminology, were smooth, coarse, grainy/ presence of particulates, watery and rich with their average scores as 37.85-51.42, 24.28-39.42, 20.71-43.71, 22.85-55.42, 25.28-47.57, respectively. The non-significant ( $p \geq 0.05$ ) difference was observed for all the attributes excluding watery

mouth feel. The watery mouth feel scores of sample B and E were significant ( $p \leq 0.05$ ) while non-significant ( $p \geq 0.05$ ) in relation to other commercial samples of *thandai*. The effectiveness of sensory procedure involved in this study can be computed using thorough evaluation of average sensory scores of milk fat aroma, watery mouthfeel and rich mouthfeel. Rich mouthfeel is closely linked with milk fat. Also, the taste, smell, mouth feel, and hedonic properties of fat all contribute to the popular concept of fat “taste” (Drewnowski, 1997). The overall acceptability scores ranged from 44.28-59.0 and were non-significant ( $p \geq 0.05$ ). The maximum sensory scores for overall acceptability were observed with sample E (59.0) while sample D shows the minimum scores with an average of 44.28.

**Principal Component Analysis**

PCA was performed on the 17 attributes measured from five commercial samples of *thandai* to simplify the interpretation of data obtained during QDA methodology. PCs were extracted on maximum variance values to acquire specific knowledge about primeval factors having critical importance among the sensorial descriptors (Puri et al. 2016). The PCA distinguished and segregated brands on the basis of sensory characteristics. The statistical parameters pertaining to the PCA for attributes pertaining to color and appearance, flavor, mouth feel and overall acceptability have been presented in Table 2. The non-redundant terms indicated by PCA clearly differentiated *thandai*. In order to clarify groups of sensory characteristics of *thandai*, factor analysis was applied on the matrix of different sensory attributes. Similarly, distinct and highly reproducible patterns were also reported in soft drinks analysed by Zhang and Suslick (2007). On the basis of the eigen values, PCA distinguished and segregated different sensory attributes and the variables with eigen values over one was taken to explain the total variance. PCA differentiated samples with same characteristics in few quadrants while others with different characteristics remained segregated. Similar results were observed in case of fruit juices with different concentrations of acai (Sabbe et al. 2009) where juices with same characteristics combined in few quadrants while others with different characteristics remained segregated and other products like *Doda burfi* (Chawla et al. 2014), *Cham-Cham* (Puri et al. 2016) and fermented milk products (Ghosh and Chattopadhyay, 2012).

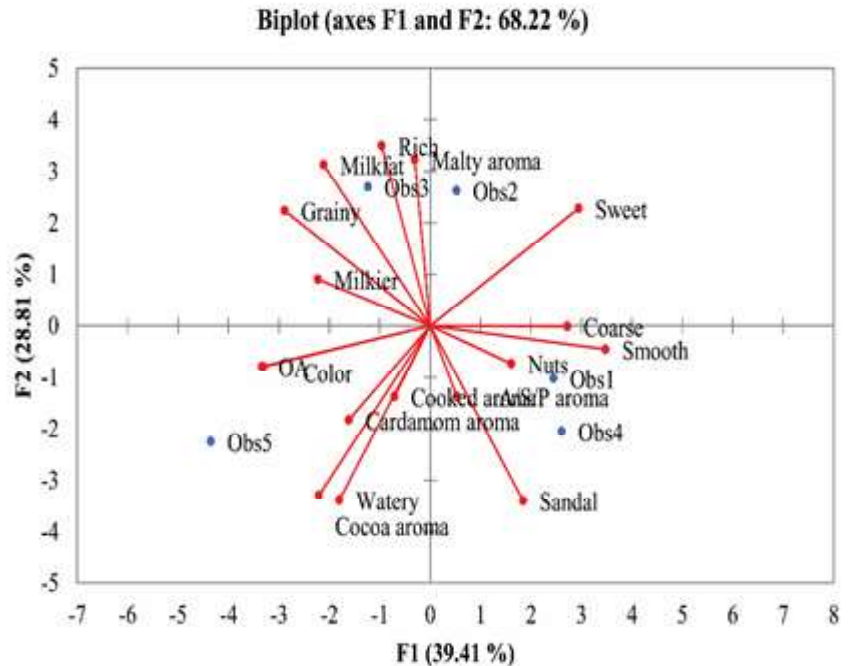
It was clear from the on the basis of eigen vector loadings, four PC’s with an eigen value of 6.7, 4.89, 4.21 and 1.19 were able to explain 39.41%, 28.81%, 24.79% and 6.99% of total variation, respectively. The cumulative variance explained by PC1 and PC2 was 68.22% while 100% of the total variance was explained by cumulating variance of all four PC’s i.e. PC1, PC2, PC3 and PC4. The two PC’s explaining 68.22% of total variation was bi-plotted to study the characteristics that are positively and negatively correlated and also to study the degree of correlation among the attributes. It is evident from the Fig.2 that in PC1, among all the attributes pertaining, sweetness and coarse mouth feel were

**Table 3** Correlation matrix of various variables using Principal Component Analysis (PCA)

Variables	Milkier	Colour	Cocoa aroma	Cardamom	A/S/P aroma	Cooked aroma	Malty aroma	Milk-fat	Sweet	Sandal	Nuts	Smooth	Coarse	Grainy	Watery	Rich	OA
Milkier	1	0.448	0.184	0.052	-0.741	-0.439	-0.086	0.358	-0.447	-0.697	-0.842	-0.457	-0.072	0.692	0.352	-0.013	0.465
Colour		1	0.690	0.267	-0.163	0.100	-0.181	0.352	-0.904	-0.322	-0.475	-0.908	-0.878	0.548	0.628	0.109	0.801
Cocoa			1	0.687	0.238	0.456	-0.494	-0.196	-0.911	0.336	-0.067	-0.514	-0.450	0.092	0.916	-0.462	0.747
Cardamom				1	0.615	0.844	0.146	0.147	-0.461	0.243	0.401	-0.396	-0.139	0.296	0.418	-0.084	0.748
A/S/P					1	0.926	0.306	-0.042	0.091	0.600	0.941	0.030	-0.089	-0.243	-0.105	0.105	0.159
Cooked						1	0.349	0.162	-0.178	0.404	0.772	-0.272	-0.239	0.076	0.084	0.154	0.506
Malty							1	0.822	0.460	-0.508	0.368	-0.237	-0.094	0.556	-0.760	0.903	0.122
Milkfat								1	-0.022	-0.823	-0.121	-0.690	-0.479	0.901	-0.400	0.905	0.494
Sweet									1	0.019	0.413	0.725	0.645	-0.335	-0.893	0.284	-0.803
Sandal										1	0.613	0.529	0.286	-0.848	0.302	-0.672	-0.269
Nuts											1	0.319	0.174	-0.397	-0.357	0.118	-0.155
Smooth												1	0.866	-0.803	-0.341	-0.451	-0.887
Coarse													1	-0.461	-0.281	-0.419	-0.634
Grainy														1	-0.031	0.633	0.711
Watery															1	-0.685	0.547
Rich																1	0.166
OA																	1

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

**Fig.2** Biplots from 1<sup>st</sup> and 2<sup>nd</sup> principal components of PCA



positively loaded, whereas sandal aroma, almond/saffron/pistachio aroma, and smooth mouthfeel were in negative correlation. Similarly, in PC2 major sensory attributes like milk fat, milkier appearance, richness and granularity were positively loaded, whereas watery, cocoa, and cooked aroma was negatively correlated. The degree of difference or similarity between two attributes is proportional to the distance between the location of any two attributes (Chawla et al. 2014).

Factor analysis revealed, component 1 positively and significantly loaded with milkier (5.74), color (12.65), sweet (10.01), smooth (14.00), coarse (8.56), grainy (9.63) and overall acceptability (12.86). Similarly, cocoa aroma, malty aroma, milk fat, sandal, watery and rich were found positive in component 2 with values 12.55, 12.07, 11.35, 13.34, 13.23 and 14.15 (Table 2). The characteristics of prime importance were found loaded in sample C whereas cocoa aroma, watery mouth feel was dominating characters in sample E and were less desired by consumers. Sweetness, the identifying and important attribute was found highest in sample B.

Correlation matrix (Table 3) revealed many expected correlations and was conducted to check if linear relationships existed between individual terms of sensory attributes. Milkier appearance was positively correlated with almond/saffron/pistachio aroma as more of nuts and distinct flavors can mask milkier appearance. Grainy mouth feel was positively correlated with overall acceptability whereas smoothness was negatively correlated with overall acceptability, this provides evidence that panelists liked more granulated product. The same holds true as well, *thandai* being a traditional household preparation people relish coarse particles in this drink to chew in their mouth. The

**Table 4** Enhanced contribution of variables in factor pattern loadings for sensory analysis of *thandai* omitting attributes of null importance

Sensory attribute	F1	F2
Colour	15.69	0.10
Cocoa aroma	8.63	18.57
Cardamom aroma	5.83	9.94
A/S/P aroma	0.011	8.15
Milk fat	6.15	18.27
Sweet	13.15	6.24
Nuts	2.17	4.43
Smooth	17.83	1.14
Grainy	11.46	10.77
Rich	1.21	21.42
OA	17.86	0.93

color showed a positive degree of correlation with cocoa aroma and overall acceptability. A positive correlation was observed for cardamom aroma and cocoa aroma with overall acceptability as well as between milk fat and richness and also between milk fat and graininess (Table 3). These results suggest that high grainy and rich mouth feel, good color and cardamom aroma necessarily drive the consumer liking.

Considering presence of variables with non-significant contributions, few variables like malty, cooked, and sandal aroma, along with coarse, and watery mouthfeel were removed from data set and it did not result in a loss of explained variability by PCA, suggesting that these aroma and mouth feel terms could be safely removed from the sensory language without a loss of product differentiation (Table 4). The results obtained after factor analysis

validated the same hence the attributes were omitted from the analysis and data was reanalyzed depicting PC1 and PC2 explaining 47.50 and 26.08% of the variation, respectively. The three PC's were able to explain 95.57 per cent of the total variation. However, the wide variability among different sensory attributes could be attributed to difference in manufacturing practices, varying ingredient quantity and quality and the processing techniques of the final product.

## Conclusions

The demand to develop consumer specific products has caused the researchers to develop sensory lexicons pertaining to that particular product. *Thandai* being an indigenous drink carries none of the literature available either of the international or national level. Therefore, this necessitates the need to characterize the sensory attributes of commercially available *thandai* using quantitative descriptive analysis (QDA) and principal component analysis (PCA). The five commercial samples of *thandai* showed a wide variation with respect to sensory lexicons defined for *thandai*. Among the five samples surveyed, sample C showed maximum positive loadings and scoring for sensory attributes. Attributes such as milk fat, richness, grainy, and milkier were identified as key attributes by PCA. Hence, these attributes may be regarded as prime sensory quality indicators in *thandai* and may be used for the development of the product.

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