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RESEARCH ARTICLE

Applying sensory and instrumental techniques to evaluate the texture of Paneer (an Indian variety of cheese)

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Abstract: The aim of the work is to investigate the relationship between the instrument and sensory data. Paneer samples from thirty-five manufacturers were evaluated for quality of paneer using texture analyser and perceived sensations through sensory evaluation. The modified sensory scorecard can distinguish the samples well. The correlation between sensory attributes and instrumental parameters was obtained by using Principal component analysis and Pearson correlation analysis. The correlation data showed poor correlation between instrumental parameters and sensory attributes (flavour, body and texture, colour and appearance, and overall acceptability). Instrumental techniques have potential to replace sensory analysis.

Keywords: Paneer, cheese, texture analysis, sensory evaluation, PCA

Introduction

Paneer is a type of soft cheese, usually made from cow or buffalo milk. It is made by heat coagulation of milk with an edible acid such as lemon juice, vinegar, or yogurt. India is the largest producer of *paneer* and the second largest consumer in the world (Kapoor R. et al. 2021). The quality of *paneer* is characterized by fat content, moisture content, colour, flavour, body and texture. A marble white colour, sweetish, slightly acidic taste, nutty flavour, spongy body, and closely knit, smooth texture are all characteristics of good grade *paneer* (Khan and Pal, 2011). The texture can be characterized as a sensory experience which can only be perceived, described, and quantified by humans. It's a multi-parameter trait that's commonly related to mechanical, geometrical, and other qualities (mostly composition of food) that may be recognised through the senses of vision, hearing, and touch (Szczesniak, 2002).

Sensory (subjective) and instrumental (objective) methods are commonly used to assess the *paneer* texture. Although, sensory analysis is a time consuming method but it is a methodical, scientifically-driven process for evaluating characteristics of *paneer* such as extensibility, chewiness, juiciness, flavor, body & texture, and appearance etc. Sensory technique also implies specialized equipment, trained personnel, and calibration standards to guarantee accuracy and consistency. Researchers have invested a lot of time and effort into developing various instrumental approaches and attempting to build a link or model between sensory qualities and instrumental factors for different food products like beef, meat (Pematilleke et al. 2021) and French fries (Li et al. 2020). As far literature does not report the correlation between sensory attributes and instrumental parameters of *paneer*. Therefore, there are some reasons to identify the key drivers for developing correlations between sensory and instrumental measurements to provide valuable insights in: (a) determining a suitable instrument for monitoring changes in food quality; (b) forecasting customer behaviour; (c) comprehending what is experienced in sensory texture assessment; and (d) developing and enhancing instrumental test procedures. Instrumental techniques have been utilised in several investigations to assess the texture of *paneer* samples under various test conditions and probes. On an addition, literature reported the use of different size probes is 75mm (Ahmed and Bajwa, 2018, Kumar et al. 2019, Dey et al. 2019), 25mm (Kapoor R. et al. 2021, Kapoor S. et al. 2021), and 20 mm (Amini et al. 2019) but the most preferred for assessing *paneer* texture is still lacking.

Despite of the widespread usage of the typical instrumental texture analysis of *paneer*, but there is still no clear scientific studies/ agreement on the types of probes to be preferred and their relationship between probe types and with the sensory parameters texture of *paneer*.-It is therefore, the major thrust area

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for the present investigation was to (a) examine the instrumental and sensory texture characteristics of *paneer* samples collected from different manufacturers, and (b) determine the relationship between perceived experiences and instrumental measurements.

Materials and Methods

Sample collection & preparation

The present investigation was carried out on the top 35 different *paneer* manufacturers from two different cities, Moga and Ludhiana of Punjab state. In the coding, alphabet 'M' implies Moga and 'L' implies Ludhiana. These two districts are selected because both are located in centre of Punjab state. The sample numbered from '01' to '17' were collected from Moga and from '18' to '35' were collected from Ludhiana city. The fresh samples, after collection from the manufacturing units were coded for references and delivered to Dairy Engineering Department Laboratory, Guru Angad Dev Veterinary and Animal Sciences University for experimental analysis. The samples were collected on the same day of preparation i.e. freshly prepared and in triplicates but on different days of preparation from same unit of manufacturing. After collecting fresh samples of early morning lot from each manufacturing unit were immediately stored in an insulated boxes with ice packs/gels at the company site to maintain refrigerated conditions (4 °C) during transportation. Further, each sample was preserved in laboratory refrigerator (4 °C) and immediate analysis on same day were preferred by authors keeping delay time (about 5 hours) constant. These samples were immediately tested for both, sensory evaluation and instrumental assessment. Each sample was cut with the dimensions of 20 x 20 x 20 mm (L x B x H) to maintain the uniformity for the experimental purpose.

Sensory Evaluation

The sensory evaluation was conducted by ten semi-trained panellists (males and females, five each), who were dairy professionals having cheese or paneer as their major research field in dairy department of university. Panellists were mostly faculty members selected on the base of their interest, sensitivity towards product parameters and familiarity (knew the production process of *paneer*). The sensory testing was carried out in the sensory analysis laboratory of college having almost five separate seating arrangements with separate, properly focused light, having white coloured table tops and walls along with separate glass water. The samples were presented in disposable cups (one sample in one cup) labelled as three-digit random numbers and evaluated by the ten semi-trained panellists. The sensory evaluation was divided into seven phases and presented randomly.

Sensory evaluation was performed following the suggested scorecard given by Kumar et al (2011) with slight modification as shown in Table 1. The packaging attribute was replaced with the overall acceptability attribute. To each panellist, the separate sensory score card with proper description for scoring pattern against each parameter was provided (Table 1). The different sensory aspects of *paneer* were judged using a 100-point scorecard: flavour (50), body and texture (35), colour and appearance (10) and overall acceptability (5). After evaluation, the scoring sheets were retrieved, and the mean values of ten assessors for all descriptors were used for statistical analysis.

Instrument analysis

The texture was examined in the paneer samples with TA-XT Plus texture analyser from stable micro systems at 20 ± 1°C using Texture Exponent software (version 6.1.1.0, Stable Micro Systems Co. Ltd., UK). The texture evaluation comprised of a texture profile analysis (TPA) test using flat, an aluminium cylinder probe P/75 (75 mm diameter). The tests were carried out by measuring compression force, using a 5 kg load cell and a trigger force of 5.0 g, a test speed of 5 mm/s, and a compression 50% of the sample's original height, as per literature (Kumar et al. 2019). Two cycles of axial compression were applied to the samples in a succession. The typical texture parameters were obtained: hardness (g, peak force of the 1st compression); adhesiveness (g-s, negative force area during the 1st compression); gumminess (product of hardness and cohesiveness); resilience (dimensionless, the ratio of the area before and after deformation at the 1st compression); cohesiveness (dimensionless, the positive force area during the 2nd compression divided by that in the 1st compression); chewiness (g, product of gumminess and springiness); and springiness (dimensionless, the ratio of the height on the 2nd compression to the original height). The samples before analysis were stored at a temperature of 5°C before analysis and removed just before the textural measurements.

Statistical Analysis

The SPSS statistical programme was used to analyse the sensory and instrumental data of *paneer* samples (Version 26.0, SPSS Inc., Chicago, Illinois, USA). The data was checked for significant differences (α =0.05) using a one-way analysis of variance. Using the SPSS statistics software, Pearson's correlation coefficients between the averaged value of sensory attributes and instrumental parameters were obtained to investigate the linear relationship of variables. The Origin-Pro software was used to perform Principal Component Analysis (PCA) (Version 2021b, Origin-Lab Corporation, Northampton, Massachusetts, USA). All variables were centred and scaled to unit variance. The spatial distribution of data and the association between sensory qualities were also determined using PCA. Furthermore, PCA was used to identify the most essential characteristics of the data. The data can be compressed by PCA by restricting the number of dimensions and defining the number of principal components without losing much information (Rodriguez-Campos et al. 2011).

Results and Discussion

Sensory Analysis of texture

The sensory of paneer depends on characteristics, such as its texture (firm, chewy, crumbly, creamy), flavor (nutty, salty, sour, sweet), aroma (grassy, earthy, milky), and appearance (white, yellow, orange), were found to be important in determining sample variability. After analysis, among all the samples ML16 and ML26 have maximum whereas ML07 samples have minimum overall acceptability along with body & texture scores (Table 2).

The ML23 sample had the highest intensity of flavour, while ML03 had the highest intensity of colour and appearance, while other samples, had moderate intensity values for their respective descriptive sensory parameters. The *paneer* processing conditions of different manufacturing units might be responsible for their sensory variances.

Fig. 1(a, b) shows the correlation between loadings and scores of PCA. The first (Principal Component 1, x-axis) and second (Principal Component 2, y-axis) dimensions of the principal component analysis explained 48.54 and 31.59 per cent of the variation in the sensory data, respectively. The two principal components were able to capture the majority of the variance in the data, as they contributed to 80.13% of the total variance. This indicates that the first two principal components were able to explain all the major features of the data, and that any additional components would likely contribute very little additional information. The loading plot is used to identify and visualize patterns in the data, while the scoring plot is used to evaluate the similarity of the samples and separate them into meaningful clusters (Shin et al. 2010). The sensory attributes of PC1, ranging from colour and appearance to overall acceptability correlation loadings, were visualized in Fig. 1a, while PC2 was characterized by body and texture to flavour. On PC1, colour and appearance were found to be inversely related to overall acceptability. The study on PC2 showed that the more cohesive the sample was, the rougher it felt, suggesting a strong positive correlation between the two. This indicates that the two factors are inextricably linked, creating a unique and fascinating relationship. Furthermore, the score plot of the first two components (Fig. 1b) revealed that the 35 samples were projected into four quadrants, demonstrating the differences in sensory texture features between the samples. The samples ML01, ML03, ML06, ML09, ML10, ML11, ML12, ML16, ML19, ML23, ML25, ML26, ML27, ML28, ML29, ML30, and ML31 found in the positive PC1 revealed a stark contrast, with other samples located in the negative region of PC1. The ML09, ML11, ML16, and ML29 samples were located closer to the body & texture, and overall acceptability, indicating respective dominant sensory characteristics of these samples. Similarly, ML01, ML10, ML23, ML26, and ML30 had dominant flavour and overall acceptability. Colour and appearance were major characteristics of ML13, ML18, Ml21, and ML35. The

Table 1: Suggested scores of *paneer* on the basis of degree of defects

Attribute	Defect	Slight	Definite	Pronounced
Flavour (50)	Sour/Acid	42	37	29
	Flat	42	37	29
	Stale	42	37	29
	Smoky/Burnt	42	37	29
	Bitter	42	37	29
	Feed/Weed	42	37	29
	Foreign	42	37	29
	Musty	42	37	29
	Putrid	42	37	29
	Rancid	42	37	29
	Unclean	42	37	29
	Yeasty	42	37	29
Body and texture (35)	Crumbly	32	30	26
	Hard	32	30	26
	Rubbery/chewy	32	30	26
	Weak	32	30	26
	Pasty	32	30	26
Colour and appearance (10)	Dull	9	8	7
	Dry	9	8	7
	Visible dirt	9	8	7
	Uneven surface	9	8	7
	Mouldy	9	8	7
Overall Acceptability (5)	Mean value of other attributes			

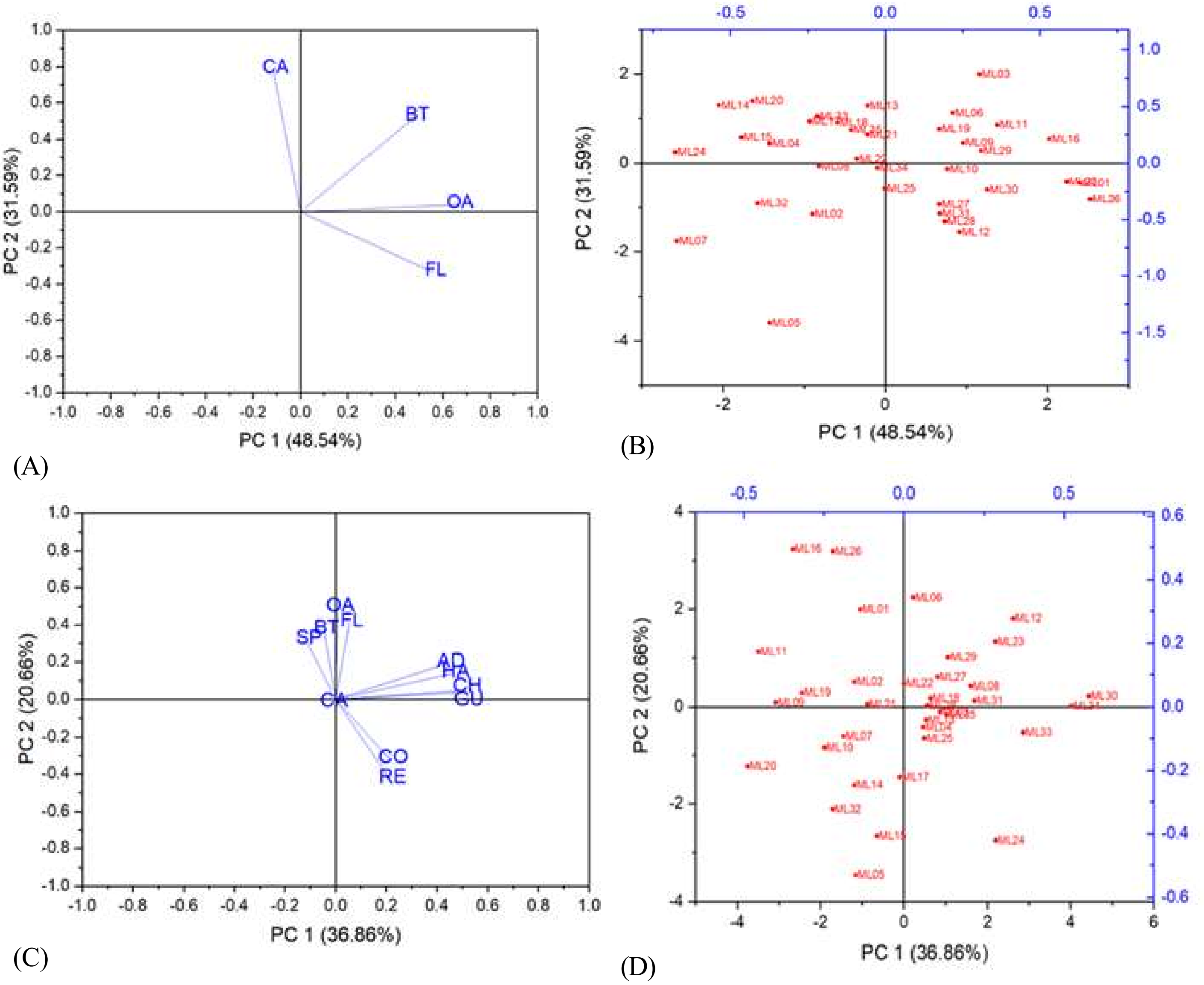

Fig. 1 Principal component analysis of sensory description analysis (a, b) and fused data from sensory and instrument (c, d). Where, FL= Flavour; BT= Body and Texture; CA= Colour and Appearance; OA= Overall Acceptability; HA= Hardness; AD= Adhesiveness; SP= Springiness; CO= Cohesiveness; GU= Gumminess; CH= Chewiness; RE= Resilience.

samples in the IIIrd quadrant (ML02, ML05, ML07, ML08, and ML32) were not found near any of the sensory qualities, indicating the lacked part of a prominent sensory texture characteristic (Meullenet and Gross 1999). Furthermore, ML13, ML21, ML22, ML25, and ML34 exhibited near-zero loadings on PC1, indicating that their sensory intensity scores were lower than other samples, as seen in Table 2.

Instrumental texture

P/75 aluminium probe and adopted test settings generated different average values and the *paneer* samples were differentiated based on instrumental parameters (Table 3 and Table 4). However, in several textural parameters, such as hardness, gumminess, and chewiness, ML12, ML30, and ML34 showed greater textural values. Other samples' instrumental texture values were found to be in the middle range (Table 3 and Table 4). The hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience of 35 *paneer* samples were measured at 1959.96– 3511.23 g, -8.17 - (-0.62) g.sec, 0.83- 0.89, 0.59-0.69, 1268.21-2448.49, 1066.92-2378.39 g, and 0.32-0.43, respectively. The results of hardness, adhesiveness, springiness, cohesiveness, and chewiness were consistent with previous studies (Ahmed and Bajwa, 2018, Kumar et al. 2019). However, the results of gumminess and resilience were lesser than those reported in the previous studies (Ahmed and Bajwa, 2018). These differences were probably caused by different processing and testing conditions.

Table 2 Sensory evaluation scores of various samples of *paneer*

Sample	Flavour	Body and texture	Colour And appearance	Overall acceptability
ML01	$47.20^{b} \pm 1.02$	$32.80^{cde} \pm 0.76$	$8.80^{defghi} \pm 0.51$	$4.55^{a} \pm 0.21$
ML02	$44.50^{ijk} \pm 0.95$	$30.20^{k} \pm 0.80$	$8.85^{bcdefghi} \pm 0.38$	$3.95^{bcde} \pm 0.26$
ML03	$44.40^{jk} \pm 1.06$	$33.70^{ab} \pm 0.73$	$9.60^{a} \pm 0.20$	$4.30^{abcd} \pm 0.34$
ML04	$42.30^{o} \pm 1.36$	$31.50^{fgh} \pm 0.70$	$9.20^{abcde} \pm 0.31$	$3.80^{bcde} \pm 0.33$
ML05	$44.40^{ijk} \pm 1.31$	$29.20^{l} \pm 0.64$	$7.90^{j} \pm 0.4$	$3.80^{bcde} \pm 0.36$
ML06	$44.80^{ij} \pm 1.11$	$32.80^{cde} \pm 0.67$	$9.40^{ab} \pm 0.27$	$4.25^{abcd} \pm 0.33$
ML07	$44.50^{ijk} \pm 1.41$	$28.70^{l} \pm 0.80$	$8.90^{cdefghij} \pm 0.42$	$3.55^{e} \pm 0.34$
ML08	$43.90^{kl} \pm 1.30$	$31.30^{gh} \pm 0.58$	$9.10^{abcdef} \pm 0.54$	$3.90^{bcde} \pm 0.19$
ML09	$44.70^{ijk} \pm 0.95$	$33.20^{bc} \pm 0.70$	$9.00^{bcdefgh} \pm 0.34$	$4.20^{abcd} \pm 0.16$
ML10	$46.30^{ef} \pm 0.93$	$32.40^{cde} \pm 0.76$	$9.00^{bcdefgh} \pm 0.37$	$4.10^{abcde} \pm 0.09$
ML11	$45.90^{efg} \pm 1.40$	$32.50^{cde} \pm 0.86$	$9.40^{abc} \pm 0.27$	$4.40^{ab} \pm 0.28$
ML12	$47.10^{bc} \pm 1.19$	$31.30^{hi} \pm 0.92$	$8.60^{fghi} \pm 0.25$	$4.20^{abcd} \pm 0.24$
ML13	$42.60^{no} \pm 1.04$	$32.50^{cde} \pm 0.69$	$9.40^{abc} \pm 0.21$	$4.10^{abcde} \pm 0.12$
ML14	$39.20^{r} \pm 1.32$	$32.50^{cde} \pm 0.62$	$9.20^{abcde} \pm 0.27$	$3.70^{de} \pm 0.19$
ML15	$41.50^{p} \pm 1.28$	$30.00^{k} \pm 0.67$	$9.50^{ab} \pm 0.34$	$4.00^{abcde} \pm 0.08$
ML16	$46.30^{ef} \pm 1.12$	$33.90^{a} \pm 0.58$	$9.00^{abcdefg} \pm 0.50$	$4.35^{abc} \pm 0.42$
ML17	$43.00^{mno} \pm 1.36$	$32.40^{cde} \pm 0.61$	$9.30^{abcd} \pm 0.37$	$3.80^{bcde} \pm 0.16$
ML18	$43.30^{lmn} \pm 1.14$	$32.40^{cde} \pm 0.66$	$9.30^{abcd} \pm 0.22$	$3.90^{bcde} \pm 0.07$
ML19	$44.40^{ijk} \pm 1.14$	$33.10^{bc} \pm 0.65$	$9.15^{abcde} \pm 0.20$	$4.15^{abcde} \pm 0.06$
ML20	$39.10^{r} \pm 1.18$	$32.90^{cd} \pm 0.73$	$9.15^{abcdef} \pm 0.41$	$3.80^{bcde} \pm 0.14$
ML21	$43.00^{mno} \pm 1.25$	$32.10^{def} \pm 0.83$	$9.20^{abcdef} \pm 0.51$	$4.10^{abcde} \pm 0.18$
ML22	$40.40^{q} \pm 1.21$	$32.90^{cd} \pm 0.85$	$8.60^{efghij} \pm 0.32$	$4.10^{abcde} \pm 0.35$
ML23	$48.30^{a} \pm 1.42$	$32.80^{cde} \pm 0.64$	$8.90^{bcdefghi} \pm 0.47$	$4.40^{abc} \pm 0.32$
ML24	$39.10^{r} \pm 1.40$	$30.45^{jk} \pm 0.78$	$9.10^{abcdef} \pm 0.34$	$3.80^{bcde} \pm 0.25$
ML25	$46.40^{cde} \pm 1.16$	$32.00^{efg} \pm 0.59$	$8.90^{bcdefghi} \pm 0.23$	$3.85^{bcde} \pm 0.20$
ML26	$46.30^{ef} \pm 0.98$	$33.10^{bc} \pm 0.83$	$8.50^{ghi} \pm 0.49$	$4.60^{a} \pm 0.43$
ML27	$44.80^{ij} \pm 1.00$	$30.90^{hij} \pm 0.61$	$8.80^{cdefghi} \pm 0.39$	$4.40^{ab} \pm 0.22$
ML28	$45.20^{ghi} \pm 1.36$	$32.20^{def} \pm 0.80$	$8.40^{hij} \pm 0.31$	$4.15^{abcde} \pm 0.20$
ML29	$47.00^{bcd} \pm 1.09$	$33.10^{bc} \pm 0.68$	$9.10^{abcdef} \pm 0.48$	$4.10^{abcde} \pm 0.09$
ML30	$45.60^{fgh} \pm 1.13$	$32.50^{cde} \pm 0.75$	$8.70^{defghi} \pm 0.33$	$4.30^{abcd} \pm 0.26$
ML31	$44.00^{kl} \pm 1.26$	$32.70^{cde} \pm 0.82$	$8.30^{ij} \pm 0.27$	$4.15^{abcde} \pm 0.13$
ML32	$42.80^{mno} \pm 1.23$	$30.50^{ijk} \pm 0.58$	$8.80^{cdefghi} \pm 0.54$	$3.80^{bcde} \pm 0.22$
ML33	$42.90^{mno} \pm 1.42$	$32.10^{def} \pm 0.88$	$9.40^{abc} \pm 0.29$	$3.90^{bcde} \pm 0.30$
ML34	$44.90^{ghij} \pm 1.11$	$31.50^{fgh} \pm 0.69$	$9.10^{abcdefg} \pm 0.36$	$4.05^{abcde} \pm 0.16$
ML35	$43.40^{lm} \pm 1.32$	$31.50^{fgh} \pm 0.92$	$9.40^{abc} \pm 0.44$	$4.10^{abcde} \pm 0.24$

(N=10, Results are expressed as Mean ± SE, with different small letters superscript (a,b,c) within row differ significantly ($P < 0.05$) among the samples. Where, M denotes Moga and L denotes Ludhiana. The sample numbered from ML01 to ML17 were collected from Moga and from ML18 to ML35 were collected from Ludhiana city)

Relation between sensory and instrumental texture

Pearson's correlation and Principal component analysis were utilised to see if sensory attributes were connected to instrumental parameters. With the application of Principal component analysis, the relation between attributes and significant knowledge of datasets can be acknowledged due to the reduction in the number of variables (Gilbert et al. 2013). Further, the linearity of the relationship among different variables can be quantified by Pearson's correlation analysis (Goldner et al. 2012).

Based on the sensory attributes and instrumental parameters shown in the PCA correlation loadings (Fig. 1c) it was revealed that there was a significant variance between *paneer* samples as presented in the score plot (Fig. 1d). The first two principal components explained 57.52 per cent of the variation, with 1st PC contributing 36.86 per cent and 2nd PC accounting for the rest 20.66 per cent. Correlation loadings projected in Fig. 1c can be used to derive the link between sensory and instrumental texture. Except for body and texture, springiness, and colour and appearance, all characteristics loaded on PC1 were positively associated. Springiness, overall acceptability, flavour, and body

Table 3 Instrumental texture analysis of various samples of *paneer*

Sample	Hardness	Adhesiveness	Springiness
ML01	2575.35^{jk}± 193.24	-5.17^{jk}± 1.07	0.88^{ab} ± 0.02
ML02	2622.38^{hijk}± 254.76	-4.28^{gh}± 0.79	0.87ab ± 0.01
ML03	2767.70^{ghij}± 198.79	-4.35^{gh}± 0.87	0.84^{ab} ± 0.02
ML04	2758.37^{ghij}± 296.04	-3.34^{de}± 0.61	0.88^{ab} ± 0.02
ML05	2137.22^{nop}± 154.55	-6.61^{m}± 1.38	0.85^{ab} ± 0.04
ML06	3034.07^{cdef}± 209.16	-3.16^{cde}± 0.51	0.89^{a} ± 0.04
ML07	2481.10^{kl}± 230.18	-4.23^{gh}± 1.16	0.87^{ab} ± 0.03
ML08	3166.56^{bcd}± 143.17	-2.13^{b}± 0.32	0.87^{ab}± 0.01
ML09	1959.96^{p}± 118.09	-7.28^{m}± 0.96	0.87^{ab} ± 0.01
ML10	2049.71^{op}± 167.66	-6.50^{m}± 0.80	0.85^{ab} ± 0.04
ML11	1964.96^{p}± 139.07	-6.46^{m}± 0.34	0.86^{ab} ± 0.01
ML12	3175.31^{bcd}±441.49	-0.91^{a}± 0.09	0.89^{ab} ± 0.01
ML13	2735.78^{ghij}± 317.86	-3.28^{de}± 0.65	0.85^{ab} ± 0.01
ML14	2599.85^{ijk}± 221.62	-5.98^{l}± 0.97	0.88^{ab} ± 0.03
ML15	2393.22^{klm}± 415.99	-5.90^{l}±1.10	0.85^{ab} ± 0.03
ML16	2314.92^{lmn}±233.39	-4.87^{i}± 0.72	0.88^{ab} ± 0.02
ML17	2594.06^{ijk}± 139.61	-4.59^{hi}± 0.38	0.84^{ab} ± 0.02
ML18	2973.89^{defg}± 218.89	-3.03^{cd}± 0.10	0.85^{ab}± 0.02
ML19	2235.68^{mno}± 97.08	-6.94^{mn}± 0.88	0.88^{ab} ± 0.01
ML20	1984.66^{p}± 367.87	-8.17^{o}± 0.71	0.89^{a} ± 0.01
ML21	2577.43^{jk}± 356.42	-4.60^{hi}± 0.63	0.86^{ab} ± 0.02
ML22	2844.96^{efghi}± 330.67	-3.98^{fg}± 0.07	0.88^{ab} ± 0.01
ML23	2974.55^{defg}± 330.67	-3.00^{cd}± 0.34	0.88^{ab} ± 0.04
ML24	3054.02^{cde}± 385.04	-3.40^{de}± 0.35	0.86^{ab} ± 0.01
ML25	2797.25^{fghij}± 147.53	-5.43^{k}± 0.49	0.88^{ab} ± 0.01
ML26	2612.02^{hijk}± 188.34	-4.32^{gh}± 0.26	0.88^{ab} ± 0.01
ML27	2865.33^{efgh}± 286.11	-2.94^{cd}± 0.33	0.86^{ab} ± 0.03
ML28	2768.66^{ghij}± 356.69	-4.14^{gh}± 0.56	0.85^{ab} ± 0.03
ML29	2979.22^{defg}± 215.86	-3.60^{ef}± 0.51	0.86^{ab} ± 0.02
ML30	3511.23^{a}± 407.38	-1.04^{a}± 0.11	0.84^{ab} ± 0.01
ML31	2799.11^{fghij}± 247.14	-2.66^{c}± 0.35	0.85^{ab} ± 0.01
ML32	2184.44^{mnop}± 98.10	-5.30^{jk}± 1.14	0.83^{b} ± 0.03
ML33	3265.71^{bc}± 298.54	-2.07^{b}± .61	0.87^{ab} ± 0.04
ML34	3315.34^{ab}± 334.81	-0.62^{a}± 0.13	0.85^{ab} ± 0.03
ML35	2954.76^{defg}± 302.67	-3.13^{cde}± 0.77	0.85^{ab} ± 0.01

(N=10, Results are expressed as Mean ± SE, with different small letters superscript (a,b,c) within row differ significantly ($P < 0.05$) among the samples. Where, M denotes Moga and L denotes Ludhiana. The sample numbered from ML01 to ML17 were collected from Moga and from ML18 to ML35 were collected from Ludhiana city)

Table 4 Instrumental texture analysis of various samples of *paneer*

Sample	Cohesiveness	Gumminess	Chewiness	Resilience
ML01	0.65^{abcde} ± 0.03	1603.19^{ij}±172.42	1494.44^{klmno}± 184.09	0.37^{bcdef}± 0.01
ML02	0.61^{cde} ± 0.01	1589.35^{ijk}± 85.15	1577.18^{ghijklm}± 92.57	0.34^{ef}± 0.02
ML03	0.68^{ab} ± 0.03	1974.93^{def}± 78.59	1679.37^{fghijkl}± 46.51	0.39^{abcde} ± 0.02
ML04	0.65^{abcde} ± 0.04	1969.99^{def}± 190.69	1746.85^{defghi}± 228.00	0.37^{bcdef} ± 0.03
ML05	0.69^{a} ± 0.02	1488.29^{ijkl}± 189.55	1344.86^{nopq}± 201.48	0.43^{a} ± 0.01
ML06	0.63^{bcde} ± 0.01	1874.35^{fg}± 237.12	1726.36^{efghij}± 124.21	0.35^{def} ± 0.05
ML07	0.59^{de} ± 0.01	1582.06^{ijk}± 99.94	1571.20^{ghijklm}± 164.23	0.34^{ef} ± 0.02
ML08	0.63^{bcde} ± 0.01	2139.21^{bcde}±251.06	1878.56^{cde}± 167.32	0.36^{bcdef} ± 0.01
ML09	0.64^{abcde} ± 0.02	1375.37^{klm}± 172.98	1163.57^{qr}± 189.40	0.39^{abcde} ± 0.01
ML10	0.68^{ab} ± 0.02	1496.65^{ijkl}± 196.27	1253.33^{pqr}± 168.09	0.38^{abcde} ± 0.01

ML11	0.63^{bcde} ± 0.03	1268.21^{m} ± 127.15	1066.92^{r} ± 115.83	0.35^{def} ± 0.01
ML12	0.65^{abcde} ± 0.06	2280.33^{abc} ± 278.72	2082.59^{bc} ± 215.82	0.37^{bcdef} ± 0.05
ML13	0.66^{abc} ± 0.05	1877.86^{fg} ± 213.64	1698.36^{fghijk} ± 73.77	0.38^{abcde} ± 0.02
ML14	0.65^{abcde} ± 0.05	1642.56^{hij} ± 140.60	1503.48^{jklmno} ± 135.37	0.39^{abcde} ± 0.02
ML15	0.67^{ab} ± 0.04	1626.4^{ij} ± 174.39	1565.85^{hijklmn} ± 187.56	0.41^{abc} ± 0.04
ML16	0.59^{e} ± 0.02	1436.74^{jklm} ± 134.03	1386.05^{mnopq} ± 122.85	0.32^{f} ± 0.01
ML17	0.64^{abcde} ± 0.02	1838.69^{fgh} ± 173.52	1553.35^{ijklmn} ± 169.35	0.40^{abcd} ± 0.01
ML18	0.61^{bcde} ± 0.02	1955.45^{ef} ± 202.95	1711.51^{fghijk} ± 229.72	0.36^{bcdef} ± 0.01
ML19	0.64^{abcde} ± 0.01	1442.75^{jklm} ± 104.12	1304.85^{opq} ± 52.5	0.39^{abcde} ± 0.04
ML20	0.63^{bcde} ± 0.01	1330.16^{lm} ± 99.79	1173.23^{qr} ± 165.20	0.38^{abcde} ± 0.06
ML21	0.65^{abcde} ± 0.01	1698.89^{ghi} ± 173.59	1468.70^{lmnop} ± 44.30	0.35^{cdef} ± 0.02
ML22	0.64^{abcde} ± 0.01	1872.23^{fg} ± 62.34	1726.96^{efghij} ± 74.37	0.37^{bcdef} ± 0.04
ML23	0.67^{ab} ± 0.03	2138.78^{bcde} ± 151.04	2046.27^{bc} ± 44.85	0.42^{ab} ± 0.04
ML24	0.67^{ab} ± 0.05	2188.34^{bcd} ± 289.19	1965.08^{bcd} ± 53.02	0.41^{ab} ± 0.01
ML25	0.67^{ab} ± 0.02	1857.30^{fg} ± 134.03	1754.92^{defghi} ± 161.42	0.41^{ab} ± 0.02
ML26	0.59^{de} ± 0.02	1564.59^{ijk} ± 96.60	1380.14^{mnopq} ± 130.43	0.34^{ef} ± 0.01
ML27	0.64^{abcde} ± 0.02	1933.78^{ef} ± 171.12	1676.40^{fghijkl} ± 52.14	0.38^{abcde} ± 0.01
ML28	0.65^{abcde} ± 0.02	1867.33^{fg} ± 87.23	1732.22^{efghij} ± 99.34	0.39^{abcde} ± 0.03
ML29	0.64^{abcde} ± 0.03	2011.16^{def} ± 168.83	1789.42^{defg} ± 98.92	0.38^{abcde} ± 0.03
ML30	0.69^{a} ± 0.03	2334.67^{ab} ± 315.50	2378.39^{a} ± 49.57	0.41^{abc} ± 0.04
ML31	0.66^{abc} ± 0.03	2106.60^{bcde} ± 258.20	1946.06^{bcde} ± 101.62	0.39^{abcde} ± 0.04
ML32	0.62^{bcde} ± 0.01	1486.08^{ijkl} ± 190.11	1322.80^{opq} ± 193.50	0.39^{abcde} ± 0.02
ML33	0.65^{abcd} ± 0.01	2255.45^{abc} ± 168.83	2151.02^{b} ± 62.78	0.41^{ab} ± 0.01
ML34	0.64^{abcde} ± 0.01	2448.49^{a} ± 232.25	2369.73^{a} ± 55.82	0.41^{ab} ± 0.01
ML35	0.63^{bcde} ± 0.01	1976.42^{def} ± 214.86	1799.86^{defg} ± 175.68	0.38^{abcde} ± 0.01

(N=10, Results are expressed as Mean ± SE, with different small letters superscript (a,b,c) within row differ significantly ($P< 0.05$) among the samples. Where, M denotes Moga and L denotes Ludhiana. The sample numbered from ML01 to ML17 were collected from Moga and from ML18 to ML35 were collected from Ludhiana city)

and texture, on other hand, were strongly positively associated with 2nd principal component.

Pearson's correlation coefficient was utilised to comprehend the strong association between sensory attributes and instrumental parameters. The r value allows researchers to compare correlations of various attributes within a given set of data (Table 5; Philipp et al. 2017). The sensory attributes (flavour, colour and appearance, body and texture, and overall acceptability) had no significant correlation with hardness, springiness, adhesiveness, chewiness, gumminess, cohesiveness, and resilience as their Pearson correlation coefficient ranges between 0.01 and 0.26. The instrumental parameters may not be able to predict the sensory qualities listed above linearly due to the lower correlation value. This finding could be helpful for dairy industry since texture measuring with equipment offers a more objective and cost-effective technique than utilising sensory evaluation, which requires extensive panellist training and takes a lot of time (Mohammadi Moghaddam et al. 2015).

Conclusion

Thirty five different paneer samples from different manufactures were collected and analysed the texture profile using sensory and instrumental technique. The samples show a wide range of texture value and some samples coded as ML06, ML25, ML29, and ML30 showed distinct dominant sensory attributes. Data showed a deprived correlation between sensory attributes and instrumental parameters. This investigation could be helpful for dairy industry as well as dairy entrepreneurs in selection between instrumental and sensory evaluation of paneer samples.

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Table 5 Pearson correlation matrix between sensory attributes and instrumental texture parameters of various samples of *paneer*

		INSTRUMENTAL PARAMETERS							SENSORY ATTRIBUTES			
		HARDNESS	ADHESIVENESS	SPRINGINESS	COHESIVENESS	GUMMINESS	CHEWINESS	RESILIENCE	FLAVOUR	BODY AND TEXTURE	COLOUR AND APPEARANCE	OVERALL ACCEPTABILITY
INSTRUMENTAL PARAMETERS	HARDNESS	1										
	ADHESIVENESS	.92**	1									
	SPRINGINESS	-0.01	-0.11	1								
	COHESIVENESS	0.19	0.05	-.36*	1							
	GUMMINESS	.94**	.90**	-0.15	.36*	1						
	CHEWINESS	.94**	.90**	-0.09	0.33	.96**	1					
	RESILIENCE	0.17	0.02	-.39*	.77**	.36*	.35*	1				
SENSORY ATTRIBUTES	FLAVOUR	0.09	0.20	0.03	-0.03	0.06	0.09	-0.15	1			
	BODY AND TEXTURE	-0.01	-0.08	0.26	-0.07	-0.02	-0.08	-0.13	0.19	1		
	COLOUR AND APPEARENCE	0.04	-0.03	-0.02	-0.07	0.02	-0.03	-0.08	-0.27	0.23	1	
	OVERALL ACCEPTABILITY	0.06	0.12	0.07	-0.02	0.01	-0.01	-0.23	.60**	.56**	-0.10	1

**. Correlation is significant at the 0.01 level (2-tailed) & *. Correlation is significant at the 0.05 level (2-tailed).

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