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# Effect of fruit acidulants and storage conditions on the physicochemical, microbiological and sensory characteristics of *paneer*

[1*]*AHMED A.*, [2]*AGGARWAL P.*, [2]*BAJWA U.*

[1]Mbeya University of Science and Technology, 131-Mbeya, Tanzania
[2]Department of Food Science and Technology, Punjab Agricultural University, 141001-Ludhiana, Punjab State, India

***Corresponding Author**: mimomed88@gmail.com

## Abstract

*Paneer* is an unripened soft cheese mainly used by Indians and Pakistans, and it does not require the rennet enzyme. It is prepared by coagulating heated milk with acid. However, fresh *paneer* has a short shelf life of up to 2 days at ambient temperature. In this study, *paneer* was prepared from lemon and amla fruit acidulants and stored at room and refrigeration temperatures. Then, the *paneer* samples were analysed for their physicochemical properties, texture profile, microbiological counts and sensory attributes during storage at room and refrigeration temperatures. The type of acidulant, storage temperature and time significantly affected the *paneer*'s physicochemical properties ($p<0.05$). However, the changes were rapid in samples stored at room temperature. Moreover, *paneer* coagulated using fruit acidulants had a higher shelf life and retention of functional properties. Furthermore, the *paneer* from fruit acidulants had high acceptability, comparable to the control, usually made from citric acid. Therefore, preparing *paneer* from fruit acidulants with improved functionality, shelf life, and acceptability is possible. Thus, adapting the technology of making *paneer* with acidulant fruits would reduce milk and fruit postharvest loss, promote a sustainable diet and create market potential for the novel milk product in India and the world at large.

**Keywords:** *Fruit acidulants, postharvest loss, paneer, shelf life, sensory evaluation*

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## Introduction

Increased consumer awareness about their health and wellness has resulted in high demand for natural foods (Kumarasamy *et al.,* 2002; Srinivasan *et al.,* 2001). Many natural products are rich in several phytochemical compounds, including antioxidants, which play important roles in the human body tissues (Jayasinghea *et al.,* 2013). One such example is Indian gooseberry (*amla*), which is rich in vitamins (folic acid, niacin, pantothenic acid, pyridoxine, riboflavin, thiamine, vitamins C and A) and minerals (sodium, potassium, calcium, copper, iron, magnesium, manganese and zinc (Ahmed & Bajwa, 2019; Thankitsunthorn *et al.,* 2009). Thus, Indian gooseberry is routinely used in food as a natural remedy for various disorders, including diabetes, atherosclerosis, asthma, constipation, inflammation, and obesity (Thankitsunthorn *et al.,* 2009). On the other hand, lemon fruit is also rich in numerous nutrients and phytochemicals.

There are several phytochemicals present in lemon, such as vitamins, minerals, monoterpenes, limonoids, flavonoids, carotenoids, and hydroxycinnamic acid (Gonzalez-Molina *et al*., 2008; Del Río *et al*., 2004). In addition, lemon is used widely as a natural acidulant in food preparations. Citric acid is the dominant acid in citrus fruits, contributing to their tartness, sourness, and acceptability (Sharma *et al.,* 2014; Sharon-Asa *et al*., 2003).

Ahmed and Bajwa (2019) used *amla* and lemon juices to prepare *paneer*. *Paneer* is a type of unripened soft cheese in India used mainly by vegetarians as its preparation does not require the rennet enzyme (Ahmed & Bajwa, 2019; Kanawjia & Singh, 2000). *Paneer* is generally prepared by acid-coagulating hot milk to form a curd (Chandan, 2007). Several coagulants include lemon juice, synthetic acids such as citric acid, lactic acid, malic acid, hydrochloric acid, fermented milk, sour/cultured whey, yoghurt and lactic cultures have been used in *paneer* preparation (Deshmukh *et al.,* 2009). *Paneer* is consumed alone or with several staple foods. Moreover, several recipes, including culinary dishes, snacks and sweetmeats such as *rasogolla, rasamalai* and *sandesh,* could also be prepared from *paneer* (Khan *et al*., 2012; Yadav *et al.,* 2009).

However, *paneer* is perishable and prone to physiochemical and microbiological changes during storage, limiting its shelf life (Kumar *et al*., 2011). As per FSSAI (2009) specifications, *paneer* should not contain more than 50,000 total bacterial counts, not more than 90 coliform counts, and 250 yeast and mould counts per g of *paneer*. Usually, *paneer* stays fresh within two days at room temperature (Vishweshwaraiah and Anantakrishnan, 1985) or refrigerated for 7 to 10 days (Shukla *et al*., 1984). Therefore, various additives and treatments have been used to extend the keeping time of *paneer*. For example, vacuum packing (Sachdeva and Prokopek, 1992), dipping *paneer* in a brine solution (Sachdeva, 1983), using milk preservatives such as sorbic acid and gamma rays (Singh and Kanawjia, 1990; Modi and Jain, 1988) have been found successful in extending the shelf life of *paneer*.

Nonetheless, substances like aldehydes, phenols, and coumarines in *amla* and lemon may help prevent or delay food spoilage to a certain extent (Jadhav et al., 2020; Aruoma et al. *al.,* 2012; Karimi *et al*., 2012; Nerurkar, 2007). Al-Ani *et al.* (2010) observed an effective antibacterial activity of citrus extracts against *Staphylococcus aureus*, *Proteus vulgaris* and *Pseudomonas aeruginosa*. Patil *et al.* (2012) also reported the antimicrobial activity of *amla* against *E.coli, P. multocida* and *S. aureus*. Therefore, in the present study, *paneer* was prepared using lemon and *amla* extracts and investigated for physicochemical changes, microbiological changes, texture profile changes and sensory properties during storage at ambient and refrigeration temperatures.

**Material and methods**

The investigation was conducted in the Food Science and Technology Department at the Punjab Agricultural University, Ludhiana, India. The factorial design method was used to study the effect of the type of acidulant and storage time on *paneer's* physicochemical, microbiological, sensorial properties and texture profile.

***Extraction of Fruit Acidulants and Paneer Preparation***

Standardised milk (Verka brand), citric acid, lemon and *amla* were obtained from the local market in Ludhiana, Punjab. First, fruit acidulants were extracted, according to Ahmed and Bajwa, 2019. Then, *paneer* was prepared per the standard procedure by De (2015), and whey was collected. Next, milk was heated to 85˚C for 5 minutes, cooled and coagulated at 72°C using a 2% citric acid (control) solution or fruit extracts until a clear whey was separated. After that, the coagulum was strained, pressed, chilled, packed in LDPE bags, heat-sealed and stored at ambient (26±0.5C°) and refrigeration (4.5±0.5C°) temperatures.

***Analysis of Moisture, Titratable Acidity and Total Soluble Solids***

The moisture, total soluble solids (TSS) and titratable acidity contents were determined according to AOAC (2000) method. A weighed sample of *paneer* was dried in a hot air oven at 50±1°C for 8 h, followed by drying at 100±1$^{o}$C till constant weight. The loss in weight was used to calculate moisture content. Fresh and stored *paneer* samples were analysed for total soluble

solids using a hand refractometer of 0-32°B (ERMA, Japan). Distilled water was added to a 10 g sample, swirled, and the final volume was made to 100 ml. After 30 min, it was filtered, from which 10 ml aliquot was used for titration against 0.1 N NaOH. For acidulants, acidity was calculated as anhydrous citric acid, while for milk and *paneer* was calculated as lactic acid, as given in Equation 1.

***Determination of Non-protein Nitrogen Content***

The non-protein nitrogen (NPN) was determined as per the given method by FSSAI (2015). About 0.5g of sample was taken in a preweighed beaker, warmed with water at 40°C, made up to 100 ml and noted the weight. Ten ml was pipetted into a preweighed 125 ml Erlenmeyer flask, and weight was noted. About 40 ±0.5 ml of TCA (15%) was added to the flask with the sample mixture, and weight was noted again. The mixture was swirled and left to precipitate, and the protein components were to settle for 5 minutes. The mixture was filtered through Whatman No1 paper (Nitrogen free), and the entire filtrate was collected. The precaution was that the filtrate should be clear and free from particulate matter. The filtrate was swirled to mix the content, and subsequently, 20 ml was pipetted into a 50 ml beaker and weighed. The filtrate was digested using the Kjeldahl procedure (AOAC 2000). The digestion, distillation and titration were carried out as in protein estimation. Blank was prepared with 16 ml of 15% TCA, and NPN was calculated as per the given formula in Equation 2.

***Determination of Free Fatty Acid Content***

The fat content of the *paneer* was extracted using the Rose-Gottlieb method (AOAC 2000). Then, to determine free fat acid content (FFA), the extracted fat was mixed with 15ml ethanol and diethyl ether in a 1:1 ratio and titrated against 0.02N KOH in the presence of a phenolphthalein indicator until the light pink colour was observed (AOAC 2000). The content of FFA was calculated as shown in Equation 3.

***Analysis of Ascorbic Acid Content***

The standard method given by Ranganna (2001) was followed for ascorbic acid determination. About 2 g was macerated in the presence of 0.06% meta-phosphoric acid, filtered, and volume was made to 100 ml with meta-phosphoric acid. First, ten ml of freshly prepared standard ascorbic acid in a meta-phosphoric acid solution was titrated against 2, 6-dichlorophenol indo-phenol dye. The titre value was used to calculate the dye factor. Then, ten ml aliquot of each sample solution was titrated against dye, and ascorbic acid was calculated, as shown in Equation 4.

***Determination of Total Phenols by Folin–Ciocalteau's Method***

Total phenol content was determined by the Folin–Ciocalteau method by Cindrić *et al.* (2011) with slight modification as indicated by Ahmed and Bajwa (2019). The concentration of phenols in a sample was determined using a standard curve prepared with gallic acid, and total phenol content was calculated using Equation 5. The results were expressed as mg of gallic acid equivalents (GAE) per 100 ml.

***Determination of Tannins by Folin–Denis's Method***

Tannins were estimated using Folin–Denis' method (Ranganna, 2001) with some modifications, as indicated by Ahmed and Bajwa (2019). The concentration of tannins in a sample was determined using a standard curve prepared with tannic acid, and Tannin content was calculated using Equation 5.

***Determination of Antioxidant Activity by the DPPH Method***

The Antioxidant activity of both raw materials and the *paneer* was determined by Alma *et al.* (2003) using DPPH (2, 2-diphenyl-1-picryl-hydrazyl-hydrate) free radical scavenging method based on electron transfer that produces a violet solution in 80% extract-methanol solution. Two grams of each sample were refluxed with 50 ml of 80% methanol solution for two hours, filtered, collected, and refluxed with 50 ml of 80% methanol solution for one hour. Subsequently, the extract was again filtered, and the volume was made to 100 ml with 80% methanol. The reaction mixture consisted of 1 ml of sample, 1 ml of tris buffer and 2 ml of DPPH in methanol solution. The changes in colour (from deep violet to light yellow) after 100 min of reaction were read at 517 nm using a visible spectrophotometer (Hoverlabs, India). Control

was prepared by mixing 1 ml distilled water, 1 ml tris buffer and 2 ml DPPH. The blank solution was prepared by mixing 1 ml of distilled water, 1 ml of tris buffer and 2 ml of 80% methanol solution. DPPH Scavenging activity of samples was measured as a decrease in the absorbance and was calculated using the following Equation 6.

***Measurement of Colour Values***

The colour values of the raw materials, *paneer*, were measured using Mini Scan Xe Plus, USA (Hunter colour lab) in the hunter colour mode and expressed as 'L', 'a' and 'b' values. In the Hunter scale, 'L' measures the brightness band varying from 100 for perfect white to 0 for black. The chromaticity dimensions ('a' and 'b') give a clear designation of colour, i.e. the value 'a' determines redness when positive, grey when zero and green when negative. The value 'b' determines yellowness when positive, grey when zero and blueness when negative.

***Microbiological Analyses***

The paneer samples were packaged in LDPE bags, heat-sealed and stored at ambient (26±0.5C°) and refrigeration (4.5±0.5C°) temperatures. The fresh and stored samples were analysed for microbiological quality at intervals of one day at room temperature and five days for refrigeration temperature for Standard Plate Count (SPC), yeast and mould and psychrophilic count using the APHA method (1992).

***Estimation of Texture Profile Analysis***

Texture profile analysis (TPA) was accomplished on *paneer* samples using Texture Analyser (Model TAXT2i, Exponent Stable Micro Systems, United Kingdom; Software Texture Expert Exceed version 7.1.6) following settings: load cell capacity-25 kg, displacement-0.1–524 mm and speed-20–0.01 mm/s. To place the sample for analysis heavy-duty platform (HDP/90) was used. Stainless steel compression platen (P/75), with a 75 mm diameter, was used throughout the experiments. The *paneer* was cut into (1.5 × 1.5 × 1.5) cm cubes for TPA analysis. The cubes were exposed to TPA using a pre-test of 1 mm/s, 5 g surface trigger force, and 65 % strain, and after that, the probe returned to its original position at a constant speed (5 mm/s). The texture profile curve was interpreted in terms of hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness.

***Evaluation of Sensory Properties of Paneer***

The sample of fresh, cooked and stored *paneer* samples prepared using citric acid, *amla* and lemon extracts were assessed by a semi-trained panel of judges on a nine-point hedonic scale (Larmond, 1977) for the appearance/colour, flavour, body and texture, flavour and overall acceptability.

***Statistical Analysis***

The data obtained were analysed for analysis of variance (ANOVA) using the SPSS® software package with all possible interactions. They were presented as mean ± standard deviation, and the mean difference was compared using the Least Significance Difference (LSD) test at a 95% confidence interval.

$$\text{Acidity (\%Citric acid or lactic acid)} = \frac{\text{Titre value x Normality of NaOH x eq.wt. of acid x Vol. made}}{\text{Weight of sample taken x aliquot taken x 1000}} \text{ x100}$$

***Equation 1***

$$Wn = \frac{1.4007 \times (Vs - VB) \times NWf \times Wm}{(Wt - 0.080\ Wm)}$$

**Where by:**

Wn = NPN content of a sample, expressed as a percentage by mass;
VS = volume in ml of the standard hydrochloric acid used for the sample;
VB = volume in ml of the standard hydrochloric acid used for the blank test;
N = Normality of the standard hydrochloric acid expressed to 4 decimal places;
Wm = mass of test portion in g expressed to nearest 0.1 mg.
Wf = mass of 20 ml filtrate in g, expressed to the nearest 0.1 mg.
Wt = mass of the test portion plus 40 ml of TCA solution in g, expressed to the nearest 0.1 mg.

**Note:** The factor 0.080 in the denominator is derived from per cent fat and true protein (thus 0.045 + 0.035).

***Equation 2***

FFA (%Oleic acid) = (Volume of alkali x Normality of alkali x28.2)/sample weight

**Equation 3**

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre (ml) x dye factor (mg/ml) x Vol. made (ml)}}{\text{Aliquot taken for estimation (ml) x wt. of a sample (g)}} \times 100$$

***Equation 4***

$$\textit{Phenols}/\text{Tannins} = \frac{\text{Concentration in a sample (mg) x dilution x vol. made (ml)}}{\text{ml of sample taken x wt. of sample (g) x 1000}} \times 100$$

***Equation 5***

$$\%\ \text{DPPH inhibition} = \frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

***Equation 6***

**Results**

***Effect of Acidulant and Storage Conditions on the Physico-Chemical Properties of Paneer***

Results on the effect of acidulants and storage conditions on the physicochemical properties of the *paneer* are presented in Table 1. The type of acidulant, storage temperature and time significantly affected the *paneer*'s physicochemical properties ($p<0.05$). The total solids significantly increased while moisture content decreased in all *paneer*s during room and refrigeration temperatures storage. The moisture loss was highest in control, followed by *amla* and lemon for the *paneer* stored at room temperature and in the first five days of those stored in the refrigerator. The coarseness of the *paneer* increased with acidity and was higher in lemon than in *amla* and citric acid. The acidity was highest in control, followed by lemon and *amla paneer*. The NPN significantly increased throughout the storage period of *paneer* at room and refrigeration temperatures. The increase of NPN was highest in control, followed by lemon and *amla paneer*. The free fatty acids (FFA) significantly increased throughout the storage of *paneer* at room and refrigeration temperatures. Again, the increase in FFA was highest in control, followed by *paneer* from lemon and *amla*.

**Table 1**
Effect of acidulants and storage conditions on the physico-chemical properties of *paneer*

| Acidulants | Room temperature | | | | Refrigeration temperature | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Storage time (days) | | | | | | | | |
| | Fresh | 1 | 2 | Mean | 5 | 10 | 15 | 20 | Mean |
| | | | | | **Moisture (%)** | | | | |
| Citric acid | 58.31 ± 0.15 | 55.79± 0.02 | 53.54 ± 0.03 | 55.88$^{x}$ | 57.04 ± 0.27 | 56.67 ± 0.20 | 55.68 ± 0.08 | 52.14 ± 0.04 | 55.97$^{x}$ |
| Lemon | 56.72 ± 0.07 | 54.15 ± 0.03 | 53.66 ± 0.02 | 54.84$^{y}$ | 56.09 ±0.20 | 56.08 ±0.30 | 55.69 ±0.36 | 46.59 ±0.03 | 54.24$^{y}$ |
| *Amla* | 56.77 ±0.24 | 55.03 ± 0.02 | 53.42 ±0.02 | 55.07$^{z}$ | 56.33 ±0.50 | 54.58 ±0.80 | 51.64 ±0.18 | 46.43 ±0.05 | 53.15$^{z}$ |
| Mean | **57.26$^{a}$** | **54.99$^{b}$** | **53.54$^{c}$** | **55.26$^{A}$** | **56.47$^{b}$** | **56.65$^{c}$** | **54.47$^{d}$** | **48.39$^{e}$** | **54.45$^{B}$** |
| | | | | | **Total solids (%)** | | | | |
| Citric acid | 41.69 ± 0.15 | 44.21 ± 0.02 | 46.46 ± 0.03 | 44.12$^{x}$ | 42.96± 0.27 | 43.33 ± 0.20 | 44.32 ± 0.08 | 47.86 ± 0.04 | 44.03$^{x}$ |
| Lemon | 43.28 ± 0.07 | 45.85 ± 0.03 | 46.34 ± 0.02 | 45.16$^{y}$ | 43.91 ±0.20 | 43.92 ±0.30 | 44.31 ±0.36 | 53.41 ±0.03 | 45.76$^{y}$ |
| *Amla* | 43.23 ±0.24 | 44.97 ±0.02 | 46.58 ±0.02 | 44.93$^{z}$ | 43.67 ±0.50 | 45.42 ±0.08 | 48.36 ±0.18 | 53.57 ±0.05 | 46.85$^{z}$ |
| Mean | **42.74$^{a}$** | **45.01$^{b}$** | **46.46$^{c}$** | **47.74$^{A}$** | **43.51$^{b}$** | **44.35$^{c}$** | **45.53$^{d}$** | **51.61$^{e}$** | **45.55$^{B}$** |
| | | | | | **Titratable acidity (Lactic acid %)** | | | | |
| Citric acid | 0.408 ± 0.009 | 0.430 ± 0.009 | 0.531 ± 0.007 | 0.456$^{x}$ | 0.428 ±0.008 | 0.481 ±0.008 | 0.509 ±0.008 | 0.564 ±0.010 | 0.478$^{x}$ |
| Lemon | 0.510 ± 0.005 | 0.517 ± 0.008 | 0.551 ± 0.006 | 0.494$^{y}$ | 0.518 ±0.005 | 0.522 ±0.008 | 0.560 ±0.008 | 0.570 ±0.010 | 0.536$^{y}$ |
| *Amla* | 0.417 ±0.008 | 0.421 ±0.007 | 0.459 ±0.000 | 0.432$^{z}$ | 0.429 ±0.005 | 0.437 ±0.007 | 0.547 ±0.007 | 0.552 ±0.103 | 0.476$^{z}$ |
| Mean | **0.445 $^{a}$** | **0.456 $^{b}$** | **0.482$^{c}$** | **0.460$^{A}$** | **0.458$^{b}$** | **0.480$^{c}$** | **0.539$^{d}$** | **0.562$^{e}$** | **0.497$^{B}$** |
| | | | | | **pH** | | | | |
| Citric acid | 5.87 ± 0.06 | 5.57 ± 0.06 | 4.47 ± 0.06 | 5.63$^{x}$ | 5.77 ±0.58 | 5.63 ±0.58 | 5.33 ±0.58 | 5.03 ±0.58 | 5.53$^{x}$ |
| Lemon | 5.57 ± 0.06 | 5.47 ± 0.06 | 5.43 ± 0.06 | 5.49$^{y}$ | 5.47 ±0.58 | 5.37 ±0.58 | 5.13 ±0.58 | 4.80 ±0.104 | 5.27$^{y}$ |
| *Amla* | 5.77 ±0.06 | 5.67 ±0.10 | 4.63 ± 0.06 | 5.69$^{x}$ | 5.63 ±0.58 | 5.53 ±0.58 | 5.28 ±0.58 | 4.93 ±0.58 | 5.43$^{z}$ |
| Mean | **5.73$^{a}$** | **5.57$^{b}$** | **5.51$^{b}$** | **5.60$^{A}$** | **5.62$^{b}$** | **5.51$^{c}$** | **5.24$^{d}$** | **4.92$^{e}$** | **5.41$^{B}$** |
| | | | | | **Non-protein nitrogen (%)** | | | | |
| Citric acid | 0.094 ±0.03 | 0.105 ±0.006 | 0.180 ±0.008 | 0.126$^{x}$ | 0.112 ±0.07 | 0.178 ±0.004 | 0.195 ±0.009 | 0.220 ±0.003 | 0.160$^{x}$ |
| Lemon | 0.099 ±0.04 | 0.102 ±0.004 | 0.102 ±0.005 | 0.101$^{y}$ | 0.106 ±0.004 | 0.116 ±0.004 | 0.123 ±0.004 | 0.134 ±0.004 | 0.116$^{y}$ |
| *Amla* | 0.099 ±0.01 | 0.106 ±0.002 | 0.108 ±0.002 | 0.104$^{y}$ | 0.110 ±0.002 | 0.119 ±0.004 | 0.133 ±0.007 | 0.149 ±0.036 | 0.122$^{z}$ |
| Mean | **0.097$^{a}$** | **0.104$^{b}$** | **0.130$^{c}$** | **0.110$^{A}$** | **0.110$^{b}$** | **0.137$^{c}$** | **0.150$^{d}$** | **0.168$^{e}$** | **0.132$^{B}$** |
| | | | | | **Free fatty acids (Oleic acid %)** | | | | |
| Citric acid | 0.047 ±0.001 | 0.074 ±0.004 | 0.083 ±0.003 | 0.068$^{x}$ | 0.051±0.003 | 0.057±0.002 | 0.070± 0.002 | 0.084±0.001 | 0.062$^{x}$ |
| Lemon | 0.044 ± 0.001 | 0.051 ± 0.002 | 0.055 ± 0.003 | 0.050$^{y}$ | 0.048 ±0.001 | 0.051 ±0.001 | 0.061 ±0.002 | 0.076 ±0.001 | 0.056$^{y}$ |
| *Amla* | 0.043 ±0.001 | 0.051 ±0.001 | 0.060 ±0.001 | 0.051$^{y}$ | 0.047 ±0.002 | 0.054 ±0.002 | 0.066 ±0.002 | 0.077 ±0.001 | 0.058$^{z}$ |
| Mean | **0.045$^{a}$** | **0.051$^{b}$** | **0.066$^{c}$** | **0.056$^{A}$** | **0.049$^{b}$** | **0.054$^{c}$** | **0.066$^{d}$** | **0.079$^{e}$** | **0.058$^{B}$** |

Mean ± standard deviation. The values with a different superscript in column (x, y and z) or row (a, b, c, d and e) indicated that the mean differed significantly at $p<0.05$ based on the least significance difference test.

**Table 2**

Effect of fruit acidulant and storage condition on the phytochemical components and colour values of *paneer*

| Acidulants | Room temperature Storage time (days) | | | | Refrigeration temperature Storage time (days) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Fresh** | **1** | **2** | **Mean** | **5** | **10** | **15** | **20** | **Mean** |
| | | | | **Antioxidant activity (DPPH inhibition %)** | | | | | |
| Citric acid | 9.59 ± 0.24 | 12.55 ±0.14 | 13.63 ±0.21 | 11.92$^{x}$ | 10.16 ±0.14 | 12.55 ±0.24 | 14.15 ±0.22 | 21.72 ±0.50 | 13.63$^{x}$ |
| Lemon | 24.17 ±0.21 | 43.11 ±0.45 | 41.70 ±0.72 | 36.33$^{y}$ | 46.92 ±0.21 | 36.39 ±0.14 | 33.57 ±0.14 | 34.27 ±1.10 | 34.65$^{y}$ |
| *Amla* | 59.38 ±0.37 | 87.73 ±0.14 | 86.74 ±0.14 | 77.95$^{z}$ | 85.85 ±0.30 | 72.54 ±0.21 | 69.82 ±0.37 | 46.69 ±0.29 | 66.86$^{z}$ |
| Mean | **31.05$^{a}$** | **47.80$^{b}$** | **47.36$^{c}$** | **42.07** | **47.64$^{b}$** | **40.50$^{c}$** | **39.18$^{d}$** | **33.54$^{e}$** | **38.38** |
| | | | | **Ascorbic acid (mg/100g)** | | | | | |
| Citric acid | ND | ND | ND | ND$^{x}$ | ND | ND | ND | ND | ND$^{x}$ |
| Lemon | 1.59 ±0.16 | 1.13 ±0.15 | 0.91 ±0.20 | 1.21$^{y}$ | 1.18 ±0.13 | 0.82 ±0.18 | 0.68 ±0.23 | 0.487 ±0.21 | 0.946$^{y}$ |
| *Amla* | 15.26 ±0.16 | 13.65 ±0.15 | 13.36 ±0.23 | 14.09$^{z}$ | 14.92 ±0.25 | 12.88 ±0.17 | 9.37 ±0.25 | 6.94 ±0.63 | 11.88$^{z}$ |
| Mean | **5.62$^{a}$** | **4.93$^{b}$** | **4.76$^{c}$** | **5.10** | **5.37$^{b}$** | **4.57$^{c}$** | **3.34$^{d}$** | **2.47$^{e}$** | **4.27** |
| | | | | **Total phenols (mg/100g)** | | | | | |
| Citric acid | 56.41 ±4.43 | 37.44 ±+2.23 | 17.93 ±1.55 | 37.26$^{x}$ | 38.56 ±2.27 | 27.20 ±2.10 | 21.12 ±2.11 | 17.58 ±2.20 | 32.18$^{x}$ |
| Lemon | 206.78 ±11.15 | 179.03± 3.14 | 92.33 ±2.89 | 150.09$^{y}$ | 186.96 ±3.01 | 148.86 ±3.46 | 134.47 ±9.57 | 78.21 ±5.88 | 151.06$^{y}$ |
| *Amla* | 2507.70 ±15.39 | 2105.10 ±11.75 | 1917.90 ±11.75 | 2177.00$^{z}$ | 2117.2 ±7.33 | 1744.10±7.62 | 1151.50±10.88 | 853.75±13.13 | 1674.85$^{z}$ |
| Mean | **923.63$^{a}$** | **773.87$^{b}$** | **666.77$^{c}$** | **788.09** | **780.91$^{b}$** | **640.05$^{c}$** | **435.69$^{d}$** | **316.51$^{e}$** | **619.359** |
| | | | | **Tannins (mg/100g)** | | | | | |
| Citric acid | ND | ND | ND | ND$^{x}$ | ND | ND | ND | ND | ND$^{x}$ |
| Lemon | 57.57 ±1.34 | 48.54 ±1.15 | 16.81 ±0.71 | 40.97$^{y}$ | 50.76 ±2.42 | 40.13 ±2.23 | 36.79 ±1.68 | 20.95 ±1.58 | 41.24$^{y}$ |
| *Amla* | 2198.40 ±42.04 | 1861.00 ±152.87 | 1810.90 ±192.61 | 1884.00$^{z}$ | 1952.40±8.25 | 1308.00±9.95 | 816.00 ±8.86 | 618.40 ±5.69 | 1379.00$^{z}$ |
| Mean | **751.99$^{a}$** | **639.96$^{b}$** | **553.47$^{c}$** | **641.81** | **667.71$^{b}$** | **449.37$^{c}$** | **284.26$^{d}$** | **213.12$^{e}$** | **473.29** |
| | | | | **Colour values** | | | | | |
| | | | | **L* value** | | | | | |
| Citric acid | 86.49± 0.97 | 89.73 ± 1.06 | 90.98± 0.75 | 89.06$^{x}$ | 90.85±0.18 | 91.30±0.10 | 90.82b±0.66 | 90.70b±0.29 | 90.03$^{x}$ |
| Lemon | 86.11 ±0.37 | 89.67 ±1.15 | 90.36 ±0.33 | 88.72$^{x}$ | 89.85 ±0.26 | 89.31 ±0.21 | 90.44 ±0.34 | 90.87 ±0.27 | 89.32$^{y}$ |
| *Amla* | 78.92 ±0.35 | 84.47 ±0.85 | 85.10 ±1.18 | 82.83$^{y}$ | 84.40 ±0.71 | 83.86 ±1.20 | 82.98 ±0.55 | 84.43 ±1.47 | 82.92$^{z}$ |
| Mean | **83.84$^{a}$** | **87.96$^{b}$** | **88.82$^{c}$** | **86.87** | **88.37$^{b}$** | **88.16$^{b}$** | **88.08$^{b}$** | **88.67$^{b}$** | **87.42** |
| | | | | **a* value** | | | | | |
| Citric acid | -0.087±0.100 | -1.42±0.26 | -1.37±0.12 | -0.96$^{x}$ | -1.67 ±0.03 | -1.63 ±0.61 | -1.49 ±0.05 | -1.41 ±0.04 | -1.26$^{x}$ |
| Lemon | -0.367 ±0.153 | -1.41 ±0.20 | -1.35 ±0.10 | -1.04$^{x}$ | -1.57 ±0.13 | -1.49 ±0.08 | -1.43 ±0.02 | -1.13 ±0.12 | -1.20$^{x}$ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Amla* | 2.00 ±0.17 | 1.36 ±0.16 | 0.900 ±0.329 | 1.42$^{y}$ | 1.23 ±0.21 | 1.85 ±0.35 | 1.84 ±0.47 | 1.42 ±0.42 | -1.67$^{y}$ |
| Mean | **0.514$^{a}$** | **-0.490$^{b}$** | **-0.609$^{c}$** | **-0.195** | **-0.670$^{b}$** | **-0.422$^{c}$** | **-0.358$^{c}$** | **-0.371$^{c}$** | **-0.261** |
| | | | | | **b* value** | | | | |
| Citric acid | 13.28±0.44 | 11.44±0.35 | 12.85± 0.62 | 12.52$^{x}$ | 11.69 ±0.55 | 11.62±0.46 | 12.17±0.50 | 12.24±0.32 | 12.20$^{x}$ |
| Lemon | 15.66 ±0.70 | 13.31 ±1.20 | 12.42 ±0.60 | 13.80$^{y}$ | 13.06 ±0.47 | 13.15 ±1.17 | 13.28 ±0.48 | 12.94 ±0.45 | 13.62$^{y}$ |
| *Amla* | 10.77 ±0.25 | 9.69 ±0.15 | 10. 04 ±0.35 | 10.17$^{z}$ | 10.02 ±0.04 | 8.99 ±0.26 | 9.78 ±0.87 | 9.99 ±0.10 | 9.91$^{z}$ |
| Mean | **13.24$^{a}$** | **11.48$^{b}$** | **11.77$^{b}$** | **12.162** | **11.59$^{b}$** | **11.25$^{b}$** | **11.74$^{b}$** | **11.72$^{b}$** | **11.91** |

Mean ± standard deviation. The values with a different superscript in column (x, y and z) or row (a, b, c, d and e) indicated that the mean differed significantly at $p<0.05$ based on the least significance difference test. ND indicated that the content of a particular compound was not detected.

**Table 3**

Effect of storage temperature and time on the microbial count (Log No. CFU $g^{-1}$) of *paneer*

| **Acidulants** | | **Room temperature** | | | **Refrigeration temperature** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Storage time (days)** | | | **Storage time (days)** | | | | |
| | **Fresh** | **1** | **2** | **Mean** | **5** | **10** | **15** | **20** | **Mean** |
| | | | | | **Standard plate count (SPC)** | | | | |
| Control | 2.69 ±0.09 | 3.30 ±0.02 | 3.92 ±0.02 | 3.31$^{x}$ | 2.90$^{a}$ ± 0.05 | 3.56 $^{a}$ ±0.71 | 4.34$^{a}$ ±0.05 | 4.63$^{a}$ ±0.41 | 3.67$^{x}$ |
| Lemon | 2.62 ±0.03 | 3.24 ±0.02 | 3.46 ±0.11 | 3.11$^{y}$ | 2.63$^{b}$ ±0.02 | 3.32$^{b}$ ±0.73 | 4.05$^{b}$ ±0.06 | 4.45$^{b}$ ±0.04 | 3.39$^{y}$ |
| *Amla* | 2.67 ±0.06 | 3.27 ±0.01 | 3.73 ±0.10 | 3.22$^{z}$ | 2.73$^{ab}$ ±0.04 | 3.43$^{ab}$ ±0.64 | 4.22$^{ab}$ ±0.05 | 4.53$^{ab}$ ±0.06 | 3.55$^{xy}$ |
| Mean | **2.66$^{a}$** | **3.27$^{b}$** | **3.71$^{c}$** | **3.21** | **2.75$^{a}$** | **3.37$^{b}$** | **4.20$^{c}$** | **4.54$^{d}$** | **3.54** |
| | | | | | **Yeast and mould count** | | | | |
| Control | ND | 1.36 ±0.10 | 1.79 ±0.10 | 1.05$^{x}$ | 1.75$^{a}$ ±0.05 | 1.92$^{a}$ ±0.08 | 2.20$^{a}$ ±0.03 | 2.30$^{a}$ ±0.20 | 1.68$^{x}$ |
| Lemon | ND | 1.10 ±0.17 | 1.75 ±0.05 | 0.95$^{y}$ | 1.10$^{b}$ ±0.17 | 1.56$^{b}$ ±0.07 | 1.90$^{b}$ ±0.05 | 2.06$^{b}$ ±0.06 | 1.40$^{y}$ |
| *Amla* | ND | 1.42 ±0.10 | 1.92 ±0.08 | 1.11$^{x}$ | 1.73$^{c}$ ±0.05 | 1.95$^{c}$ ±0.05 | 2.25$^{c}$ ±0.04 | 2.32$^{c}$ ±0.20 | 1.67$^{x}$ |
| Mean | **ND$^{a}$** | **1.29$^{b}$** | **1.82$^{c}$** | **1.04** | **1.53$^{b}$** | **1.81$^{c}$** | **2.12$^{d}$** | **2.23$^{e}$** | **1.58** |
| | | | | | **Psychrophiles count** | | | | |
| Control | ND | | | | 1.36$^{a}$ ±0.10 | 1.78$^{a}$ ±0.08 | 2.14$^{a}$ ±0.06 | 2.25$^{a}$ ± 0.04 | 1.88$^{x}$ |
| Lemon | ND | | | | 1.10$^{b}$ ±0.17 | 1.26$^{b}$ ± 0.04 | 1.69$^{b}$ ±0.09 | 1.95$^{b}$ ± 0.05 | 1.50$^{y}$ |
| *Amla* | ND | | | | 1.30$^{ab}$ ±0.00 | 1.63$^{ab}$ ±0.06 | 1.86$^{ab}$ ±0.08 | 2.05$^{ab}$ ±0.05 | 1.71$^{z}$ |
| Mean | **ND$^{a}$** | | | | **1.25$^{b}$** | **1.56$^{c}$** | **1.90$^{d}$** | **2.08$^{e}$** | **1.13** |

Mean ± standard deviation. The values with a different superscript in column (x, y and z) or row (a, b, c, d and e) indicated that the mean differed significantly at $p<0.05$ based on the least significance difference test. ND indicated that the content of a particular compound was not detected.

**Table 4**

Effect of fruit acidulant and storage conditions on the texture profile of *paneer*

| Acidulants | Fresh Day | Room temperature Storage time (days) | | | Refrigeration temperature Storage time (days) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | Mean | 5 | 10 | 15 | 20 | Mean |
| | | | | | **Hardness (Kg)** | | | | |
| Control | 1.29 ±0.12 | 0.61 ±0.07 | 0.56 ±0.05 | 0.825$^{a}$ | 1.38 ±0.06 | 17.00 ±2.78 | 17.33 ±2.75 | 17.33 ±2.51 | 10.89$^{x}$ |
| Lemon | 2.31 ±0.19 | 1.33 ±0.37 | 0.86 ±0.12 | 1.50$^{b}$ | 6.61 ±0.70 | 20.33 ±1.04 | 27.00 ±1.73 | 62.47 ±13.06 | 23.74$^{y}$ |
| *Amla* | 1.88 ±0.45 | 0.86 ±0.05 | 0.960 ±0.10 | 1.24$^{c}$ | 2.54 ±0.16 | 18.16 ±1.44 | 33.33 ±2.52 | 56.23 ±10.25 | 22.43$^{y}$ |
| Mean | **1.83$^{a}$** | **0.939$^{b}$** | **0.795$^{b}$** | **1.19** | **3.51$^{a}$** | **18.5$^{b}$** | **25.88$^{c}$** | **45.34$^{d}$** | **19.01** |
| | | | | | **Fracturability (g)** | | | | |
| Control | 10.27$^{a}$ ± 1.72 | 7.95 ±3.07 | 8.49 ±3.25 | 8.91$^{a}$ | 8.94 ±0.55 | 8.67 ±1.26 | 10.33 ±0.32 | 7.47 ±0.55 | 7.27$^{x}$ |
| Lemon | 11.58$^{a}$ ± 0.110 | 8.05 ±0.57 | 1.99 ±0.59 | 7.21$^{a}$ | 8.73 ±0.53 | 9.77 ±1.04 | 13.00 ±1.73 | 9.23 ±0.39 | 10.44$^{y}$ |
| *Amla* | 19.66$^{b}$ ± 4.7 | 8.42 ±5.05 | 6.42 ±4.25 | 11.50$^{ab}$ | 17.02 ±2.53 | 17.02 ±2.53 | 17.83 ±3.01 | 8.74 ±4.91 | 14.48$^{z}$ |
| Mean | **13.84$^{a}$** | **8.14$^{b}$** | **5.63$^{b}$** | **9.20** | **11.56$^{b}$** | **9.17$^{c}$** | **10.62$^{bc}$** | **8.48$^{cd}$** | **10.73** |
| | | | | | **Adhesiveness (g.sec)** | | | | |
| Control | -1.43$^{a}$ ± 0.141 | -33.52 ±8.71 | -24.61 ±12.70 | -19.85$^{a}$ | -5.54 ±2.46 | -5.42 ±2.25 | -5.00 ±3.51 | -1.47 ±0.04 | -3.77$^{x}$ |
| Lemon | -4.40$^{b}$ ± 1.56 | -5.58 ±0.35 | -6.43 ±1.93 | -5.47$^{b}$ | -25.85 ±10.09 | -5.52 ±2.88 | -25.85 ±10.09 | -6.00 ±1.14 | -13.52$^{y}$ |
| *Amla* | -4.78$^{b}$ ± 1.057 | -7.24 ±1.17 | -5.64 ±1.70 | -5.89$^{b}$ | -4.38 ±0.54 | -5.73 ±3.99 | -5.73 ±3.99 | -2.13 ±1.08 | -5.97$^{x}$ |
| Mean | **-3.54$^{a}$** | **-15.45$^{b}$** | **-12.23$^{c}$** | **-10. 40** | **-11.92$^{b}$** | **-7.93$^{abc}$** | **-12.19$^{b}$** | **-3.20$^{ac}$** | **-7.76** |
| | | | | | **Cohesiveness** | | | | |
| Control | 0.497$^{a}$ ± 0.091 | 0.425 ±0.037 | 0.433 ±0.027 | 0.452$^{x}$ | 0.829 ±0.024 | 0.449 ±0.68 | 0.364 ±0.108 | 0.496 ±0.093 | 0.527$^{x}$ |
| Lemon | 0.467$^{a}$ ± 0.015 | 0.497 ±0.035 | 0.410 ±0.016 | 0.458$^{x}$ | 0.462 ±0.064 | 0.483 ±0.110 | 0.462. 0.64 | 0.764 ±0.011 | 0.528$^{x}$ |
| *Amla* | 0.413 $^{a}$ ± 0.032 | 0.424 ±0.063 | 0.370 ±0.019 | 0.403$^{y}$ | 0.416 ±0.031 | 0.453 ±0.578 | 0.504 ±0.167 | 0.765 ±0.107 | 0.511$^{x}$ |
| Mean | **0.459$^{a}$** | **0.449$^{a}$** | **0.404$^{b}$** | **0.437** | **0.569$^{b}$** | **0.462$^{ac}$** | **0.444$^{ac}$** | **0.675$^{d}$** | **0.522** |
| | | | | | **Springiness (mm)** | | | | |
| Control | 0.777$^{a}$ ± 0.085 | 0.760 ±0.017 | 0.710 ±0.11 | 0.790$^{x}$ | 0.370 ±0.108 | 0.496 ±0.032 | 0.750 ±0.043 | 0.776 ±0.085 | 0.634$^{x}$ |
| Lemon | 0.767$^{a}$ ± 0.080 | 0.803 ±0.04 | 0.753 ±0.25 | 0.774$^{x}$ | 0.586 ±0.281 | 0.780 ±0.096 | 0.586 ±0.281 | 0.620 ±0.010 | 0.668$^{x}$ |
| *Amla* | 0.860$^{a}$ ± 0.026 | 0.867 ±0.04 | 0.817 ±0.152 | 0.848$^{y}$ | 0.860 ±0.02 | 0.846 ±0.011 | 0.470 ±0.121 | 0.366 ±0.850 | 0.681$^{x}$ |
| Mean | **0.801$^{a}$** | **0.810$^{a}$** | **0.760$^{a}$** | **0.790** | **0.606$^{b}$** | **0.708$^{abc}$** | **0.602$^{cbd}$** | **0.588$^{bd}$** | **0.661** |
| | | | | | **Gumminess** | | | | |
| Control | 0.647 ±0.145 | 0.263 ±0.55 | 0.240 ±0.100 | 0.383$^{x}$ | 1.14 ±0.03 | 7.68 ±1.81 | 6.21 ±1.62 | 8.75 ±2.93 | 4.88$^{x}$ |
| Lemon | 1.08 ±0.12 | 0.673 ±0.244 | 0.353 ±0.058 | 0.703$^{y}$ | 3.09 ±0.76 | 9.97 ±2.60 | 12.42 ±0.88 | 47.63 ±9.19 | 14.82$^{y}$ |
| *Amla* | 0.783 ±0.25 | 0.370 ±0.072 | 0.357 ±0.416 | 0.503$^{x}$ | 1.05 ±0.03 | 8.19 ±0.74 | 16.79 ±5.71 | 42.32 ±3.69 | 13.83$^{y}$ |
| Mean | **0.838$^{a}$** | **0.436$^{b}$** | **0.317$^{b}$** | **0.530** | **1.76$^{a}$** | **8.58$^{b}$** | **11.80$^{c}$** | **32.91$^{d}$** | **11.18** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Chewiness** | | | | | | | | | |
| Control | 0.493 ±0.81 | 0.200 ±0.46 | 0.173 ±0.35 | 0.289$^{x}$ | 0.423 ±0.126 | 3.78 ±0.81 | 4.63 ±1.02 | 6.62 ±1.49 | 3.91$^{x}$ |
| Lemon | 0.840 ±0.182 | 0.537 ±0.184 | 0.267 ±0.55 | 0.548$^{y}$ | 1.71 ±0.53 | 7.85 ±2.84 | 7.20 ±3.14 | 29.60 ±5.73 | 9.44$^{y}$ |
| *Amla* | 0.677 ±0.223 | 0.320 ±0.07 | 0.287 ±0.032 | 0.428$^{y}$ | 0.910 ±0.051 | 6.93 ±0.57 | 7.70 ±2.97 | 15.40 ±3.08 | 6.32$^{z}$ |
| Mean | **0.670$^{a}$** | **0.352$^{b}$** | **0.242$^{b}$** | **0.421** | **1.07$^{a}$** | **6.19$^{b}$** | **6.51$^{b}$** | **17.20$^{c}$** | **6.32** |
| **Resilience (%)** | | | | | | | | | |
| Control | 0.172$^{a}$ ± 0.027 | 0.117 ±0.115 | 0.140 ±0.017 | 0.143$^{x}$ | 0.403 ±0.035 | 0.143 ±0.032 | 0.113 ±0.032 | 0.173 ±0.025 | 0.201$^{x}$ |
| Lemon | 0.144$^{ab}$ ± 0.013 | 0.157 ±0.021 | 0.117 ±0.006 | 0.139$^{xy}$ | 0.163 ±0.032 | 0.156 ±0.038 | 0.163 ±0.032 | 0.350 ±0.017 | 0.195$^{x}$ |
| *Amla* | 0.126$^{b}$ ± 0.011 | 0.133 ±0.023 | 0.117 ±0.006 | 0.126$^{y}$ | 0.127 ±0.011 | 0.130 ±0.020 | 0.136 ±0.031 | 0.380 ±0.121 | 0.180$^{x}$ |
| Mean | **0.148$^{a}$** | **0.136$^{ab}$** | **0.124$^{b}$** | **1.36** | **0.231$^{b}$** | **0.143$^{a}$** | **0.138$^{a}$** | **0.301$^{c}$** | **0.192** |

Mean ± standard deviation. The values with a different superscript in column (x, y and z) or row (a, b, c, d and e) indicated that the mean differed significantly at $p<0.05$ based on the least significance difference test.

***Effect of Acidulants and Storage Conditions on The Phytochemicals and Colour Values of Paneer***

The effect of acidulants and storage at room temperature on the functional components and colour values ('L', 'a' and 'b') of paneer are presented in Table 2. The type of acidulant, storage temperature, and storage time significantly affected the paneer's functional components and colour values ($p<0.05$). Therefore, the DPPH scavenging capacity was used to test the antioxidant activity of paneer during storage. Generally, the antioxidant activity was highest in amla, followed by lemon and control paneer. Despite the type of acidulant and storage conditions, ascorbic acid, total phenols, and tannins significantly reduced during the storage of the paneer. However, the loss was more in the paneer stored at room temperature than in the refrigerator. Generally, the 'L' values of the paneer increased during storage at all temperatures, even though the increase was higher in refrigerated samples. This is because the increase correlated with the content of phytochemicals, which depleted over time. Although lemon paneer had a high initial 'a' value, it was noticed that the greenness increased more in control than lemon paneer during storage. On the other hand, the amla paneer was characterised by redness ('-a'), and the value declined as storage progressed.

***Effect of Fruit Acidulant and Storage Conditions on the Microbial Count of Paneer***

The type of acidulant, storage condition and time significantly affect ($p <0.05$) the microbial count of paneer (Table 3). The number of SPC colonies increased significantly daily in all paneer samples during storage despite the types of acidulants used. However, the number of bacteria colonies were highest in paneer made from citric acid, followed by amla and lemon extract. For the storage condition, the increase in SPC was higher in paneer stored at room temperature than at refrigeration temperature.

Yeast and mould growth was not detected in all fresh paneer samples. However, the yeast and mould were highest in paneer made from amla, followed by citric and lemon during the storage of paneer at room temperature for three days. A comparable trend was observed for the paneer stored at refrigeration temperature. The number of psychrophiles significantly differed with the acidulant and storage days at 5°C. The highest psychrophile count was found in paneer made from citric acid, followed by amla and lemon.

***Effect of Fruit Acidulant and Storage Conditions on the Texture Profile of Paneer***

The results on the effect of acidulants and storage conditions on the texture profile of *paneer* are presented in Table 4. The type of acidulant, storage temperature and time significantly affected the texture profile of *paneer*. For example, hardness significantly ($p<0.05$) decreased when the *paneer* was stored at room temperature. On the other hand, the hardness of all *paneer* stored in refrigeration temperature significantly increased with storage time. For both storage temperatures, the hardness was highest in lemon, followed by *amla* and control. In addition, there was a decrease in the cohesiveness of the *paneer* stored at room temperature. However, cohesiveness increased for those *paneer* stored in refrigeration temperature except for the control.

The springiness was highest in *amla paneer,* followed by control and lemon. Generally, the springiness of treatments increased after one day and decreased the following days. There was a significant decrease in gumminess, chewiness and resilience in all types of *paneer* throughout the storage period. The gumminess was highest in lemon *paneer,* followed by *amla* and control. However, the change of gumminess in lemon and *amla paneer* was almost similar (Table 4). The chewiness was highest in lemon *paneer,* followed by *amla* and control. The chewiness was significantly increased in all types of *paneer* and showed a linear relationship with hardness, cohesiveness and gumminess. Resilience was highest in control, followed by *paneer* from lemon and *amla* acidulants.

There was a significant variation in the springiness of the *paneer* during the storage of all *paneer* types (Table 4). The springiness of the *amla paneer* decreased continuously, whereas variable change was observed in the lemon and control. There was a marked increase in gumminess of all types of *paneer* during the storage at refrigeration temperature. However, the highest increase of

gumminess was found in lemon *paneer,* followed by *amla* and control. Nonetheless, the change of gumminess between lemon and *amla paneer* was almost similar.

**Table 5**

Effect of fruit acidulant and storage conditions on the sensory scores of *paneer*

| Acidulants | Fresh Day | Room temperature Storage time (days) | | Refrigeration temperature Storage time (days) | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | Mean | 5 | 10 | 15 | Mean |
| **Appearance/ colour** | | | | | | | |
| Citric acid | 8.50 ±0.60 | 8.06 ±0.56 | 8.28$^{x}$ | 8.06 ±0.50 | 7.88 ±0.52 | 7.82 ±0.56 | 8.06$^{x}$ |
| Lemon | 8.50 ±0.60 | 8.06 ±0.68 | 8.28$^{x}$ | 7.88 ±0.79 | 7.86 ±0.83 | 7.68 ±0.84 | 8.00$^{x}$ |
| *Amla* | 7.36 ±0.52 | 7.13 ±0.64 | 7.25$^{y}$ | 7.56 ±0.77 | 7.38 ±0.92 | 6.63 ±0.74 | 7.21$^{y}$ |
| Mean | **8.13$^{a}$** | **7.75$^{a}$** | **7.94** | **7.83$^{a}$** | **7.71$^{b}$** | **7.38$^{b}$** | **7.76** |
| **Body and texture** | | | | | | | |
| Citric acid | 8.38 ±0.58 | 7.87 ±0.99 | 8.13$^{x}$ | 8.06 ±0.73 | 7.93 ±0.68 | 7.25 ±0.76 | 7.90$^{x}$ |
| Lemon | 8.19 ±0.53 | 7.69 ±0.75 | 7.94$^{x}$ | 8.06 ±0.42 | 7.75 ±0.53 | 7.19 ±0.99 | 7.78$^{x}$ |
| *Amla* | 8.00 ±0.71 | 7.94 ±0.50 | 7.97$^{x}$ | 7.56 ±0.73 | 7.50 ±0.16 | 7.44 ±0.73 | 7.69$^{x}$ |
| Mean | **8.19$^{a}$** | **7.83$^{a}$** | **8.01** | **7.90$^{ab}$** | **7.73$^{b}$** | **7.29$^{c}$** | **7.79** |
| **Mouthfeel** | | | | | | | |
| Citric acid | 8.25 ±0.71 | 7.88 ±0.13 | 8.06$^{x}$ | 8.06 ±0.50 | 7.81 ±0.75 | 7.19 ±0.37 | 7.84$^{x}$ |
| Lemon | 8.56 ±0.50 | 8.31 ±0.59 | 8.44$^{xy}$ | 8.12 ±0.35 | 8.06 ±0.56 | 7.25 ±0.69 | 8.06$^{xy}$ |
| *Amla* | 7.88 ±0.69 | 7.50 ±0.80 | 7.67$^{x}$ | 7.63 ±0.92 | 7.56 ±0.90 | 7.50 ±0.10 | 7.61$^{x}$ |
| Mean | **8.23$^{a}$** | **7.90$^{a}$** | **8.06** | **7.94$^{a}$** | **7.81$^{a}$** | **7.31$^{b}$** | **7.84** |
| **Flavour** | | | | | | | |
| Citric acid | 8.06 ±0.68 | 7.69 ±0.70 | 7.94$^{x}$ | 7.94 ±0.72 | 7.93 ±0.68 | 6.63 ±0.92 | 7.68$^{x}$ |
| Lemon | 8.44 ±0.62 | 8.13 ±0.64 | 8.28$^{xy}$ | 8.06 ±0.68 | 7.69 ±0.75 | 7.00 ±0.88 | 7.86$^{x}$ |
| *Amla* | 7.88 ±0.69 | 7.50 ±0.80 | 7.69$^{x}$ | 7.68 ±0.75 | 7.46 ±0.54 | 7.25 ±0.93 | 7.56$^{x}$ |
| Mean | **8.16$^{a}$** | **7.77$^{a}$** | **7.97** | **7.90$^{ab}$** | **7.70$^{b}$** | **7.00$^{c}$** | **7.70** |
| **Overall acceptability** | | | | | | | |
| Citric acid | 8.20 ±0.57 | 7.80 ±0.71 | 8.00$^{x}$ | 8.02 ±0.29 | 7.91 ±0.57 | 7.06 ±0.64 | 7.80$^{x}$ |
| Lemon | 8.52 ±0.48 | 8.14 ±0.72 | 8.33$^{y}$ | 8.00 ±0.59 | 7.88 ±0.47 | 7.31 ±0.67 | 8.00$^{xy}$ |
| *Amla* | 7.81 ±0.50 | 7.56 ±0.66 | 7.69$^{xy}$ | 7.58 ±0.78 | 7.58 ±0.86 | 7.09 ±0.93 | 7.53$^{x}$ |
| Mean | **8.18$^{a}$** | **7.83$^{a}$** | **8.05** | **7.85$^{ab}$** | **7.79$^{b}$** | **7.26$^{c}$** | **7.76** |

Mean ± standard deviation. The values with a different superscript in column (x, y and z) or row (a, b, c, d and e) indicated that the mean differed significantly at $p<0.05$ based on the least significance difference test.

***Effect of Storage at Room Temperature on the Sensory Scores of Paneer***

The sensory evaluation of the *paneer* results are presented in Table 5. The scores for appearance/colour, body and texture, mouthfeel flavour and overall acceptability decreased during the storage of *paneer*. The control and lemon *paneer* were comparable in appearance/colour, whereas the *paneer* from the *amla* extract scored less due to the reddish tinge imparted by phenolic compounds from the *amla* extract. Buch *et al.* (2014) reported a decline in the score of colour/ appearance of *paneer* added with 0.4% and 0.6% turmeric powder and stored at 7 ±1°C.

The body and texture scores also declined with progress in storage in all types of *paneer*. The body and texture score was highest in control, followed by *amla* and lemon *paneer*. The change in score might be due to moisture loss caused by syneresis and low temperature. Buch *et al.* (2014)

reported a change of body and texture score at 7 ±1°C for *paneer* added with 0.4% and 0.6% turmeric powder.

The mouthfeel and flavour scores decreased during storage in all *paneer* samples. However, the flavour score of lemon *paneer* was higher than the rest. The panel reported that the high acceptability of *paneer* from the lemon extract was due to its characteristic flavour. On the other hand, the lower flavour score in *amla paneer* may be attributed to the slight bitterness, as reported by the sensory panel. The bitter flavour of *paneer* is usually associated with rancidity during long-term storage and can easily be detected by the sense of taste and persists even after the sample has been removed from the mouth (Kumar, 2016). Moreover, the excessive proteolysis of curd is reported to cause bitterness in cheese (Nerurkar, 2007). For example, bitterness in cottage cheese is associated with increased insoluble nitrogen and the growth of psychotropic bacteria that produce proteolytic and lipolytic enzymes that break down beta-casein and fat into bitter compounds (Lemieux & Simard, 1991). In addition, the bitter peptides interact with the taste buds at the back of the tongue to give the sensation of bitterness (Iwaniak *et al*., 2016).

The overall acceptability (OA) scores decreased over room and refrigeration storage temperatures. However, the OA score of lemon *paneer* was higher than control and *amla paneer*. Earlier, Bajwa *et al.* (2005) recorded a lowering of OA in 10% coriander (*Coriandrum sativum*), and mint (*Mentha piperita*) incorporated *paneer* stored for 24 h at ambient temperature and 15 days at refrigeration temperature. The factors contributing to the reduced OA of *paneer* are related to changes in physicochemical and texture profiles.

**Discussion**

The type of acidulant, storage temperature and time significantly affected the *paneer*'s physicochemical properties ($p<0.05$). Ahmad *et al.* (2014) observed the moisture decrease in *Kaladhi* (hard and dry acid-coagulated cheese variety of Jammu and Kashmir) stored between 21 to 25°C. Also, Rai *et al.* (2008) observed a moisture loss for vacuum-packed *paneer* with 100% nitrogen gas stored for 15 days at 7 ±1°C. Generally, the moisture loss in the *paneer* is due to syneresis. The rate of syneresis has been associated with *paneer* microstructure (Sinha, 2007). A previous scanning electron microscope study by Ahmed and Bajwa (2019) revealed that the microstructure of *paneer* samples differed with different acidulants.

On the other hand, the increase in the titratable acidity during the storage of *paneer* samples could be highly associated with the growths of microorganisms and biochemical changes causing the hydrolysis of lactose to lactic acid. Earlier, Bajwa *et al.* (2005) recorded increased acidity in the vegetable-impregnated *paneer* during storage for 15 days. Singh *et al.* (2014) also recorded increased acidity in cows, buffalo, and mixed milk *paneer* with turmeric powder stored at 27 ±1°C. Singh *et al.* (2015) observed that the acidity of control samples increased significantly after the first day and the first month for *paneer* with 0.4% formalin during the storage at 37°C for six months. The highest pH decrease in the control could be due to higher microbial growth (Table 1) than *paneer* prepared from fruit acidulants. Rai *et al.* (2008) and Buch *et al.* (2014) reported a decrease in pH for the vacuum-packed *paneer* stored at 7±1°C for 45 days and in *paneer* added with turmeric powder and stored at 7 ±1°C, respectively.

Generally, the milk's NPN constituents include ammonia, urea, creatine, creatinine, uric acid, peptides, amino acids, and other compounds (DePeters and Ferguson, 1992). The high increase in NPN in control during the storage possibly was due to the growth of psychrophiles (Table 3) that have the potential to induce biochemical changes in proteins even at refrigeration temperature. On the other hand, the lower acidity and functional compounds in the fruit acidulant might contribute to the lower formation of NPN in lemon and *amla paneer*. Similarly, Buch *et al.* (2014) noticed a lesser change of soluble nitrogen in *paneer* added with 0.4% and 0.6% turmeric powder than in control stored at 7±1°C.

The increased FFA could be associated with biochemical changes or microbial growth. Singh *et al.* (2015) observed the FFA increase in control

*paneer* after the first day and after the first month of *paneer* with 0.4% formalin during the storage at 37°C for six months. Earlier, Buch *et al.* (2014) reported increased FFA in *paneer* stored at 7±1°C for 12 days. Rai *et al.* (2008) reported an increase in FFA of vacuum-packed *paneer* stored for 15 days at 7±1°C. Therefore, the fruit acidulants have the potential to inhibit the physicochemical changes, such as the formation of NPN and FFA, which are highly associated with spoilage and the safety of the *paneer* during storage.

Phytochemicals, functional components, are plant substances such as phenols and ascorbic acid that have specific pharmacological effects on human health, such as antimicrobial, antioxidants, anti-inflammatory, anti-allergic, anti-cancer, anti-spasmodic, and anti-ageing neuroprotective, hypotensive and diabetes (Unuofin *et al*., 2017; Prakash *et al*., 2012). The high antioxidant activity in lemon and *amla paneer* was due to the high phytochemicals in lemon and *amla* fruit extract (Ahmed and Bajwa, 2019). Moreover, phenolic compounds such as tannins contribute to the antioxidant activity of fruits and plants (Li *et al*., 2007; Pourmorad et al., 2006). The trend showed that the antioxidant activity of all *paneer* stored at room temperature significantly increased, whereas it decreased in *paneer* stored at refrigeration temperature. Gracía-Alonso *et al.* (2008) found that the concentration of different antioxidant compounds was affected by the storage condition of food. Therefore, the decreased antioxidant in lemon and *amla paneer* on the 10$^{th}$ day onward might be attributed to the catalytic action of reactivated phenolases, as elaborated by Xu *et al.* (2015). On the other hand, amino acids or peptides may play significant roles in antioxidant and antimicrobial activities (EFSA, 2009).

Tripathi *et al.* (1988) observed decreased ascorbic acid and phenol content while storing *amla* candy. Generally, temperature and the vitamin's form most affect vitamin C's stability in foods and beverages (Stešková *et al*., 2006). Therefore, the loss of ascorbic acid might be due to the oxidation of L-ascorbic acid to dehydro-ascorbic acid (Reynold, 1965). However, studying structural changes of ascorbic acid in *paneer* during storage was beyond the scope of the study.

On the other hand, the decrease of 'a' values of *amla paneer* might be due to the bleaching/decolourisation of phenolic compounds and tannins. Similarly, Shrivastava *et al.* (2013) observed a decrease of 'L' and 'a' and an increase of 'b' of *paneer* samples packaged under an atmosphere of vacuum, $CO_2$, $N_2$ and a combination after ten days of storage at 3±1°C.

Nevertheless, the SPC was below the maximum limit that FSSAI (2009) prescribed, i.e. the total plate count should not exceed 50,000 $g^{-1}$ of *paneer*. Shashikumar and Puranik (2011) observed that SPC at 30±1°C in fresh and two days stored *paneer* increased from 3.4 to 4.8, 4.64, 4.58 and 4.25 (log $CFUg^{-1}$) for control and *paneer* treated with 10, 15 and 20% lactoferrin, respectively. Lamdande (2012) also noted similar changes in the SPC of edible film-coated *paneer* stored at 5°C for 14 days. Singh *et al.* (2014) reported an increase in SPC from 4.48 to 5.68, 4.51 to 5.69 and 4.80 to 5.61 log CFU $g^{-1,}$ respectively, for cow, buffalo, and mixed milk *paneer* coagulated with citric acid after storage of 16 days below 5°C, and the number decreased when treated with 0.6% turmeric powder. Buch *et al.* (2014) observed that SPC for control and 0.4% turmeric-treated *paneer* with per cent increased from 4.2 to 4.9 and 4.1, respectively, at 7±1°C. According to FSSAI (2009), *paneer* is considered unfit if the yeast and mould count exceeds 250gm-1. The highest number of yeast and moulds count in *amla paneer* might be due to its lower pH. Shashikumar and Puranik (2011) observed that yeast and mould count in fresh and two days *paneer* stored at 30±1°C increased from 1.33 to 1.94, 1.9, 1.74 and 1.68 (log $CFUg^{-1}$) for control and *paneer* treated with 10, 15 and 20% lactoferrin respectively. Singh *et al.* (2014) stored *paneer* for 16 days below 5°C and reported an increase in yeast and mould count from 4.50 to 5.41, 4.41 to 5.44 and 4.4 to 5.43 for cow, buffalo and mixed milk coagulated with citric acid, respectively. Furthermore, they reported a decline in the number of *paneer* treated with 0.6% turmeric powder. Buch *et al.* (2014) reported yeast and mould counts of 2.3 and 0.02, 3.1 and 2.5 and 3.5 and 3.7 (log. $CFUg^{-1}$) for the fresh, six and 12-day storage at 7±1°C, respectively for control and *paneer* treated with 0.4% turmeric powder.

Psychotropic bacteria in milk and milk products include pseudomonads and related aerobic, Gram-negative, rod-shaped bacteria (Ledenbach and Marshall, 2009). The psychotropic microorganisms can survive harsh processing conditions, grow at refrigeration temperatures, and change food composition and quality (de Santana et al., 2020). In addition, they possess several adaptive mechanisms to cope with low temperatures, high UV irradiation levels, elevated pH, salt, and low water content (Aliyu et al., 2014). For example, psychrotrophs limit the shelf life of cottage cheese because the pH (4.5 to 4.7) and salt content of cottage cheese are insufficient to limit their growth (Ledenbach & Marshall, 2009; Cousin, 1982).

On the other hand, the phytochemicals in lemon and *amla* could be highly attributed to the inhibition of the psychrotrophs. For example, Pandey *et al.* (2011) reported that phytochemical compounds found in lemon, including tannins, inhibited the growth of *Pseudomonas aeruginosa.* Citrus fruits contain bioactive compounds such as phenolics, flavonoids, vitamins, and essential oils, which are reported to have several health benefits, including antioxidative, anti-inflammatory, antitumor, and antimicrobial activities (Aruoma *et al.,* 2012; Karimi *et al.,* 2012). Saxena and Patil (2014) also observed that solvent fruit extract of *Emblica officinalis* essential oil had a strong inhibitory effect against *Staphylococcus aureus* compared to gentamicin. Furthermore, Oikeh *et al.* (2016) observed the antifungal activities of lemon juice and lemon concentrate against *Candida albicans* and *Penicillum* spp., respectively, with an inhibition zone of 24 mm and 10 mm. Therefore, it is evident that the *paneer* from the fruit acidulants has a great potential to extend shelf life beyond ten days at refrigeration temperature.

The previous microstructure appraisal study showed that lemon *paneer* had a firmer and more compact structure than *amla* and citric acid (Ahmed and Bajwa, 2019). The decrease in hardness of *paneer* stored at room temperature might be attributed to changes in moisture content and protein structure facilitated by the biochemical changes and growth of microorganisms. Shashikumar and Puranik (2011) observed an increase in hardness during storage of control and *paneer* treated with lactoferrin. Singh *et al.* (2014) observed that the increase of adhesiveness of *paneer*-containing turmeric powder was slower than the control. Moreover, Singh *et al.* (2014) observed increase in the cohesiveness of *paneer* containing turmeric powder was slower than in the control. Shashikumar and Puranik (2011) observed a similar trend earlier, who reported increased cohesiveness of control and *paneer* treated with lactoferrin. The difference in observations might be attributed to the type and strength of the acidulants.

Again, Singh *et al.* (2014) observed that the decrease in the springiness of *paneer* samples containing turmeric powder was slower than control *paneer.* Shashikumar and Puranik (2011) also observed the increase in chewiness of stored control samples and *paneer* preserved with lactoferrin. Resilience was highest in control, followed by lemon and *amla paneer*. Again, Shashikumar and Puranik (2011) observed a slight increase in the springiness of *paneer* treated with lactoferrin at 10 ppm. Similarly, Singh et al. (2014) reported curvilinear changes in turmeric *paneer.*

The control and lemon *paneer* were comparable in appearance/colour, whereas the *paneer* from the *amla* extract scored less due to the reddish tinge imparted by phenolic compounds from the *amla* extract. Buch *et al.* (2014) reported a decline in the score of colour/ appearance of *paneer* added with 0.4% and 0.6% turmeric powder and stored at 7±1°C. Moreover, Buch *et al.* (2014) reported a change in body and texture score at 7±1°C for *paneer* added with 0.4% and 0.6% turmeric powder.

The panel reported that the high acceptability of *paneer* from the lemon extract was due to its characteristic flavour. On the other hand, the lower flavour score in *amla paneer* may be attributed to the slight bitterness, as reported by the sensory panel. The bitter flavour of *paneer* is usually associated with rancidity during long-term storage and can easily be detected by the sense of taste and persists even after the sample has been removed from the mouth (Kumar, 2016). Moreover, the excessive proteolysis of curd is reported to cause bitterness in cheese (Nerurkar,

2007). For example, bitterness in cottage cheese is associated with increased insoluble nitrogen and the growth of psychotropic bacteria that produce proteolytic and lipolytic enzymes that break down beta-casein and fat into bitter compounds (Lemieux & Simard, 1991). In addition, the bitter peptides tend to give the sensation of bitterness when interacting with the taste buds at the back of the tongue (Iwaniak *et al.,* 2016). Earlier, Bajwa *et al.* (2005) recorded a lowering of OA in 10% coriander (*Coriandrum sativum*), and mint (*Mentha piperita*) incorporated *paneer* stored for 24 h at ambient temperature and 15 days at refrigeration temperature. The factors contributing to the reduced OA of *paneer* are related to changes in physicochemical and texture profiles.

**Conclusion**

The type of acidulant and storage conditions significantly affect the physicochemical properties of *paneer*, with an increase in the total solids and a decrease in moisture content during storage. The increase in titratable acidity, NPN, and FFA during storage is associated with microbial growth, causing several biochemical changes. Fruit acidulants have the potential to restrict these changes and improve the quality of *paneer* during storage. In addition, *paneer*'s functional components and colour values were significantly affected by the type of acidulant and storage conditions. The antioxidant activity was high in *amla* and lemon *paneer* due to their high phytochemical content. Ascorbic acid, total phenols, and tannins were reduced during storage, with the loss being more significant at room temperature. The 'L', 'a' and 'b' values of *paneer* changed during storage, with the decrease of 'a' values of *amla paneer* attributed to the bleaching/decolourisation of phenolic compounds and tannins.

Nevertheless, the microbial count of *paneer* was significantly affected by the type of acidulant, storage condition, and time. Although the number of microorganisms increased daily during storage, it remained below the maximum limit prescribed by FSSAI. Nevertheless, the highest psychrophile count was found in *paneer* made from citric acid, followed by *amla* and lemon. Therefore, the phytochemicals in lemon and *amla* could be highly attributed to the inhibition of psychrotrophs. Furthermore, the texture profile of *paneer* is significantly affected by the type of acidulant, storage temperature, and time.

Lemon *paneer* had the firmest and most compact structure, while *amla paneer* had the highest fracturability and springiness. The hardness of the *paneer* stored in refrigeration increased with storage time, while the adhesiveness and cohesiveness increased for the *paneer* stored in refrigeration temperature except for the control. However, all types of *paneer* showed a significant decrease in gumminess, chewiness, and resilience during storage. Therefore, it is important to carefully select acidulants and storage conditions to maintain the desired texture of *paneer*. Finally, the sensory evaluation of *paneer* showed a decline in scores for appearance/colour, body and texture, mouthfeel flavour, and overall acceptability during storage. The decrease in scores could be attributed to moisture loss, syneresis, low temperature, proteolysis, and lipolysis. However, the lemon acidulant *paneer* received higher flavour scores and overall acceptability due to its characteristic taste. Thus, the study suggests that adding natural fruit acidulants improves *paneer*'s physicochemical, functional, shelf life and sensory properties.

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**References**

Ahmad, S. R., Pathak, V., Bhat, Z. F., & Bukhari, S. A. A. (2014). Effect of sorbic acid on the storage quality of Kaladhi-an acid coagulated milk product. *Journal of Food Science and Technology*, *51*, 4040-4046.

Ahmed, A., & Bajwa, U. (2019). Composition, texture and microstructure appraisal of

*paneer* coagulated with sour fruit juices. *Journal of food science and technology*, *56*, 253-261.

Al-Ani, R. A., Diwan, S. N. H., & Adhab, M. A. (2010). Efficiency of Thuja orientalis and Artimisia campestris extracts to control of Potato leaf roll virus (PLRV) in potato plants. *Agriculture and Biology Journal of North America*, *1*(4), 579-583.

Aliyu, H., De Maayer, P., Rees, J., Tuffin, M., & Cowan, D. A. (2014). Draft genome sequence of the Antarctic polyextremophile Nesterenkonia sp. strain AN1. *Genome Announcements*, *2*(2), e00197-14.

Alma, M. H., Mavi, A., Yildirim, A., Digrak, M., & Hirata, T. (2003). Screening chemical composition and in vitro Antioxidant and antimicrobial activities of the essential oils from Origanum syriacum L. growing in Turkey. *Biological and Pharmaceutical Bulletin*, *26*(12), 1725-1729.

AOAC. (2000). *Official Method of Analysis*, 17th edn. Association of Official Analytical Chemists, Maryland.

APHA. (1992). *Methods for the Microbiological Examination of Foods*, 3rd edn. American Public Health Association, Washington D.C.

Aruoma, O. I., Landes, B., Ramful-Baboolall, D., Bourdon, E., Neergheen-Bhujun, V., Wagner, K. H., & Bahorun, T. (2012). Functional benefits of citrus fruits in the management of diabetes. *Preventive medicine*, *54*, S12-S16.

Bajwa, U., Kaur, J., Sandhu, K. S. (2005). Changes occurring during storage of vegetable impregnated *paneer*. *J Food Sci Tech* 42(2):152-57.

Buch, S., Pinto, S., & Aparnathi, K. D. (2014). Evaluation of efficacy of turmeric as a preservative in *paneer*. *Journal of food science and technology*, *51*, 3226-3234.

Chandan, R. C. (2007). Cheese varieties made by direct acidification of hot milk. In: Hui Y H (Ed) *Handbook of Food Products Manufacturing*. Vol-I, pp. 635-50. Wiley-Inter Sci, NJ.

Cindrić, I. J., Kunštić, M., Zeiner, M., Stingeder, G. and Rusak, G. (2011). Sample preparation methods for the determination of the antioxidative capacity of apple juices. *Croat Chem Acta* 84(3):435-38.

Cousin, M. A. (1982). Presence and activity of psychrotrophic microorganisms in milk and dairy products: a review. *J Food Protect 45*:172-207.

de Santana, E. H. W., Luiz, L. L., da Silva Pasquim, P., Pinto, L. D. F. B., Pereira, F. D. A. B., Gasparini, G. B. F. B., ... & Eleodoro, J. I. (2020). Psychrotrophic microorganisms in raw milk and the cheese quality. *Research, Society and Development*, *9*(9), e127997217-e127997217.

De, S. (2015). Outlines of Dairy Technology. Pp 156. 30th edition, Oxford University Press, New Delhi.

Del Rı□o, J. A., Fuster, M. D., Gómez, P., Porras, I., Garcıa-Lidón, A., & Ortuño, A. (2004). *Citrus limon*: A source of flavonoids of pharmaceutical interest. *Food Chemistry*, *84*(3), 457-461.

DePeters, E. J., & Ferguson, J. D. (1992). Nonprotein nitrogen and protein distribution in the milk of cows. *Journal of Dairy Science*, *75*(11), 3192-3209.

Deshmukh, D. S., Zanjad, P. N., Pawar, V. D., & Machewad, G. M. (2009). Studies on the use of acidified and cultured whey as coagulant in the manufacture of *paneer*. *International journal of dairy technology*, *62*(2), 174-181.

El Soda, M., Madkor, S. A., & Tong, P. S. (2000). Adjunct cultures: recent developments and potential significance to the cheese industry. *Journal of Dairy Science*, *83*(4), 609-619.

Fleminger, G., Ragones, H., Merin, U., Silanikove, N., & Leitner, G. (2013). Low molecular mass peptides generated by hydrolysis of casein impair rennet coagulation of milk. *International Dairy Journal*, *30*(2), 74-78.

FSSAI. (2009). Food Safety and Standards Regulations. <http://www.fssai.gov.in/Portals /0/FSSAI%20regulations.pdf> [Visited on 15 May 2016].

FSSAI. (2015). Milk and milk products. *In: Manual of Methods of Analysis of Foods*. Pp 175-78. Food safety and standards authority of India. Ministry of health and

family welfare government of India, New Delhi.

García-Alonso, F. J., Periago, M. J., Vidal-Guevara, M. L., Cantos, E., Ros, G., Ferreres, R., & Abellán, P. (2003). Assessment of the Antioxidant properties during storage of a dessert made from grape, cherry, and berries. *Journal of Food Science*, *68*(4), 1525-1530.

Iwaniak, A., Minkiewicz, P., Darewicz, M., & Hrynkiewicz, M. (2016). Food protein-originating peptides as tastants-Physiological, technological, sensory, and bioinformatic approaches. *Food Research International*, *89*, 27-38.

Jadhav, G. D., Mujawar, T. A. P., Tekale, S. U., Pawar, R. P., & More, Y. W. (2020). Lemon Peel Powder: A Natural Catalyst for Multicomponent Synthesis of Coumarin Derivatives. *Current Organocatalysis*, *7*(2), 140-148.

Jayasinghe, C., Gotoh, N., & Wada, S. (2013). Pro-oxidant/antioxidant behaviours of ascorbic acid, tocopherol, and plant extracts in n-3 highly unsaturated fatty acid rich oil-in-water emulsions. *Food Chemistry*, *141*(3), 3077-3084.

Kanawjia, S. K., & Singh, S. (2000). Technological advances in *paneer* making. *Indian Dairyman*, *52*(10), 45-50.

Karimi, E., Oskoueian, E., Hendra, R., Oskoueian, A., & Jaafar, H. Z. (2012). Phenolic compounds characterisation and biological activities of Citrus aurantium bloom. *Molecules*, *17*(2), 1203-1218.

Khan, S. U., Pal, M. A., Malik, A. H., & Sofi, A. H. (2012). Process optimisation for *paneer* production from milk powder. *Int J Food Nutr Saf*, *2*, 62-71.

Kumar, S., Rai, D. C., Niranjan, K., & Bhat, Z. F. (2014). *Paneer*—An Indian soft cheese variant: a review. *Journal of food science and technology*, *51*, 821-831.

Kumarasamy, Y., Cox, P. J., Jaspars, M., Nahar, L., & Sarker, S. D. (2002). Screening seeds of Scottish plants for antibacterial activity. *Journal of Ethnopharmacology*, *83*(1-2), 73-77.

Kumari, S. (2016). *Enumeration and characterisation of bacillus cereus strains in the dairy environment of the district of Darjeeling, India* (Doctoral dissertation). University of North Bengal.

Lamdande, A., Garud, S. R. & Kumar, A. (2012). Effect of edible coating and different packaging treatments on quality of *paneer*. *Internat J Agric Engg* 5(2):142-46.

Larmond, E. (1977). Laboratory Methods for Sensory Evaluation of Foods. Pp. 163. Deptt Agric Res Branch Canada, National government publication, Ottawa, Ontario.

Ledenbach, L. H. & Marshall, R. T. (2009). Microbiological spoilage of dairy products. In: Sperber, W. H. and Doyle, M. P. (ed.) *Compendium of the Microbiological Spoilage of Foods and Beverages*, *Food Microbiology and Food Safety*. Pp 41-67. Springer, LLC, New York.

Lemieux, L., & Simard, R. E. (1991). Bitter flavour in dairy products. I. A review of the factors likely to influence its development, mainly in cheese manufacture. *Le Lait*, *71*(6), 599-636.

Li, H. B., Cheng, K. W., Wong, C. C., Fan, K. W., Chen, F., & Jiang, Y. (2007). Evaluation of Antioxidant capacity and total phenolic content of different fractions of selected microalgae. *Food Chemistry*, *102*(3), 771-776.

Lore, T., Omore,, A. & Staal, S. (2005). Types, levels and causes of postharvest milk and dairy losses in sub-Saharan Africa and the near East. In: *Phase Two Synthesis Report*. Pp 1-30. Int Livestock Res Inst, Nairobi.

McSweeney, P. L., Ottogalli, G., & Fox, P. F. (2017). Diversity and classification of cheese varieties: an overview. *Cheese*, 781-808.

Modi, V. K. & Jain, S. C. (1988). The preservation of *paneer* by chemical additives. *II Intr Food Conv and Exhibit Feb 18-23*. CFTRI, Mysore.

Nerurkar, A. S. (2007). *Present Status of Applied Microbiology in India*. Pp 1-44. The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat.

Oikeh, E. I., Omoregie, E. S., Oviasogie, F. E., & Oriakhi, K. (2016). Phytochemical, antimicrobial, and antioxidant activities

of different citrus juice concentrates. *Food science & nutrition*, *4*(1), 103-109.

Pandey, A. & Singh, P. (2011). Antibacterial activity of *Syzygium aromaticum* (clove) with metal ion effect against food borne pathogens. *Asian J P Sci Res* 1:69-80.

Patil, S. G., Deshmukh, A. A., Padol, A. R., & Kale, D. B. (2012). In vitro antibacterial activity of Emblica officinalis fruit extract by tube Dilution Method. *Int J Toxicol Appl Pharmacol*, *2*(4), 49-51.

Pourmorad, F., Hosseinimehr, S. J., & Shahabimajd, N. (2006). Antioxidant activity, phenol and flavonoid contents of some selected Iranian medicinal plants. *African Journal of Biotechnology*, *5*(11).

Prakash, D., Gupta, C. & Sharma, G. (2012). Importance of Phytochemicals in Nutraceuticals. *Journal of Chinese Medicine Research and Development (JCMRD)* 1(3): 70 - 78.

Puglisi, I., Petrone, G., & Piero, A. R. L. (2014). A kiwi juice aqueous solution as coagulant of bovine milk and its potential in Mozzarella cheese manufacture. *Food and Bioproducts Processing*, *92*(1), 67-72.

Rai, S., Goyal, G. K., & Rai, G. K. (2008). Effect of Modified Atmosphere Packaging (MAP) and Storage on the chemical quality of *paneer*. *Journal of Dairying, Foods and Home Sciences*, *27*(1), 33-37.

Ranganna, S. (2001). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Vo1. 2, 2nd edn. Tata McGraw-Hill, New Delhi.

Reynold, T. M. (1965). Chemistry of non-enzymatic browning- II. *Adv Food Res* 14:168.

Sachdeva, S. & Prokopek, D. (1992). *Paneer* - an alternative to tofu. *DMZ– Lebensmittel industrie- und- Milchwirtschaft* 113:645-48.

Sachdeva, S. (1983). *Production, packaging and preservation of paneer*. PhD thesis. Kurukshestra University, Kurukshestra, India.

Saxena, R. & Patil, P. (2014). In vitro antibacterial activity of Emblica officinalis essential oil against *Staphylococcus aureus*. *Int J Theoret Appl Sci* 6(2):7-9.

Sharma, H. P., Sharma, S., Vaishali, & Patel, H. (2014). Effect of Storage Conditions on the Bio-chemical Quality of Lemon Drink. *J Food Res Tech* 2(4):158-64.

Sharon-Asa, L., Shalit, M., Frydman, A., Bar, E., Holland, D., Or, E., ... & Eyal, Y. (2003). Citrus fruit flavor and aroma biosynthesis: isolation, functional characterisation, and developmental regulation of Cstps1, a key gene in the production of the sesquiterpene aroma compound valencene. *The Plant Journal*, *36*(5), 664-674.

Shobana, S., & Naidu, K. A. (2000). Antioxidant activity of selected Indian spices. *Prostaglandins, Leukotrienes and Essential Fatty Acids (PLEFA)*, *62*(2), 107-110.

Shori , A. B., and Baba, A. S. (2013). Antioxidant activity and inhibition of key enzymes linked to type-2 diabetes and hypertension by Azadirachta indica-yoghurt. *J Saudi Chemical Soc*, 17(3):295-301.

Shrivastava, S., Goyal, S., & Goyal, G. K. (2013). Effect of Modified Atmosphere Packaging on Colour Profile of *Paneer* Stored at 3±1 $^{o}$ C. *Journal of Agriculture and Sustainability*, *3*(2):195-204.

Shukla, F. C., Madhu, B. & Jain, S. C. (1984). Studies on the technological aspects of processing and preservation of *paneer*. Pp 56–60.A Report on ICAR Project, New Delhi.

Singh, R. R., Singh, R., & Shakya, B. R. (2014). Impact of turmeric addition on the properties of *paneer*, prepared from different types of milk. *International Journal of Current Engineering and Technology*, *4*(3), 1874-1883.

Singh, R., Lal, D., Sharma, V. & Rao, P. S. (2015). Changes in chemical characteristics of market *paneer* samples preserved with formalin. *Indian J Dairy Sci* 68(6): 572-76.

Singh, S., & Kanawjia, S. K. (1990). Effect of hydrogen peroxide and delvocid on enhancement of shelf life of recombined milk *paneer*. *Brief Communications of the XXIII Int Dairy Cong 9–12 October*. Vol. II, p 135. Montreal.

Sinha, N. (2007). Cheese varieties made by direct acidification of hot milk. In: *Handbook of food products Manufacturing*. Pp 635-50. John Wiley and Sons, California.

Srinivasan, D., Nathan, S., Suresh, T., & Perumalsamy, P. L. (2001). Antimicrobial activity of certain Indian medicinal plants used in folkloric medicine. *Journal of Ethnopharmacology*, *74*(3), 217-220.

Stešková, A., Morochovičová, M. & Lešková, A. (2006). Vitamin C degradation during storage of fortified foods. *J Food Nutr Res* *45*(2):55-61.

Thankitsunthorn, S., Thawornphiphatdit, C., Laohaprasit, N., & Srzednicki, G. (2009). Effects of drying temperature on quality of dried Indian gooseberry powder. *International food research journal*, *16*(3), 355-361.

Tripathi, V. K., Singh, M. B. & Singh. S. (1988). Studies on comparative compositional changes in different preserved products of aonla (*Emblica Officinalis* Gaertn.) var. Banarasi. *Indian Food Packer* 42(4):60-66.

Unuofin, J. O., Otunola, G. A., and Afolayan, A. J. (2017). Nutritional evaluation of *Kedrostis africana* (L.) Cogn: An edible wild plant of South Africa. *Asian Pacific Journal of Tropical Biomedicine* 7(5): 443 - 449. DOI: http://dx.doi.org/10.1016/j.apjtb.2017.01.016.

Vishweshwaraiah, L. & Anantakrishnan, C. P. (1985). Quality of market samples of *paneer*. *J Food Sci Technol* 22(6):215-16.

Xu, F., He, S. Z., Chu, Z., Zhang, Y. J., & Tan, L. H. (2016). Effects of heat treatment on polyphenol oxidase activity and textural properties of jackfruit bulb. *Journal of Food Processing and Preservation*, *40*(5), 943-949.

Yadav, Y. N., Singh, C., Dwivedi, B. R., & Gupta, M. P. (2009). Effect of various coagulants on sensory, chemical and microbiological quality of *paneer*. *J. Rural and Agric Res*, *9*(1), 11-14.

Yazici, F., Dervisoglu, M., Akgun, A., & Aydemir, O. (2010). Effect of whey pH at drainage on physicochemical, biochemical, microbiological, and sensory properties of Mozzarella cheese made from buffalo milk during refrigerated storage. *Journal of Dairy Science*, *93*(11), 5010-5019.