

Development and Quality Evaluation of Paneer Thokku Prepared Using Oil, Vinegar and Lemon Juice

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Abstract— The present study was undertaken to develop paneer thokku using oil-, vinegar- and lemon juice-based formulations and to evaluate their physicochemical, microbiological and sensory characteristics. Three formulations were evaluated: oil-based paneer thokku (C), vinegar-based paneer thokku (T1) and lemon juice-based paneer thokku (T2). Significant differences ($P < 0.05$) were observed among the formulations for physicochemical, microbiological and sensory characteristics. Vinegar-based paneer thokku (T1) recorded the lowest pH (4.42), highest titratable acidity (0.89%) and lowest total plate count ($1.21 \log_{10}$ cfu/g), whereas oil-based paneer thokku (C) recorded the highest product yield (120.85%). T1 also exhibited the lowest moisture content (45.82%). Coliforms and yeasts and moulds were not detected in any of the formulations. Lemon juice-based paneer thokku (T2) recorded the highest sensory scores for appearance and colour (8.08), flavour (8.56), juiciness (8.02), texture (8.06), saltiness (8.01) and overall acceptability (8.12). Among the formulations evaluated, lemon juice-based paneer thokku (T2) was the most preferred based on overall sensory acceptability and showed potential for further product development.

Keywords— Paneer, paneer thokku, acidulants, vinegar, lemon juice, value addition, sensory quality, microbial quality.

I. INTRODUCTION

Paneer is an important indigenous Indian dairy product prepared by acid-heat coagulation of milk, followed by separation and pressing of the coagulum. It is a fresh, non-ripened and non-melting dairy product characterized by a firm and cohesive body and valued for its protein, fat and mineral contents. The quality characteristics of paneer are influenced by several processing factors, including milk composition, type and concentration of coagulant, coagulation temperature, pressing conditions and other processing parameters (Alam et al., 2024; Ahmed and Bajwa, 2019). Because of its relatively high moisture and nutrient content, paneer is susceptible to microbial deterioration and has a comparatively short shelf life under conventional storage conditions. Several approaches, including thermal processing, packaging, low-temperature storage and incorporation of antimicrobial or preservative agents, have been investigated to improve its storage stability (Goyal and Goyal, 2016). The incorporation of spices has also been reported to contribute to the storage stability of paneer, with individual spices exhibiting varying degrees of antimicrobial and preservative effects (Eresam et al., 2015).

Pickling is a traditional preservation technique in which multiple preservation factors, including acidity, salt, oil, heat treatment and spices, act together to improve product stability. Earlier studies have demonstrated the feasibility of pickling for the preservation of paneer. Rani et al. (2014) reported the application of brine and spice-vinegar pickling for maintaining acceptable microbiological quality of paneer products during storage. Similarly, Shukla and Vaid (2004) reported the storage stability of oil-based paneer pickle, although progressive changes in chemical characteristics were observed during storage.

Organic acids are important components of acidified foods because they reduce product pH and can inhibit the growth of microorganisms. Acetic acid and citric acid are widely used as food acidulants and antimicrobial agents, with their effectiveness being influenced by acid concentration, pH and food-matrix characteristics (Ben Braiek and Smaoui, 2021).

Vinegar, which contains acetic acid, and lemon juice, which naturally contains citric acid, can therefore contribute to both the technological and sensory characteristics of traditional food products. Anna Anandh and Sobana (2021) developed a traditional-style ready-to-eat paneer pickle using vegetable oil, vinegar and lemon juice and reported lower pH and higher titratable acidity in the vinegar-based product, whereas the lemon juice-based product received higher sensory scores. These findings indicate the potential of different acidulant systems for developing acceptable value-added paneer products.

Paneer thokku is a traditional-style preparation in which paneer is combined with oil, spices and condiments to obtain a thick and flavourful product. However, limited information is available regarding the influence of different acidulant systems, particularly vinegar and lemon juice, on the physicochemical, microbiological and sensory characteristics of paneer thokku. Therefore, the present study was undertaken to develop paneer thokku using oil-, vinegar- and lemon juice-based formulations and to evaluate their physicochemical, microbiological and sensory characteristics.

II. MATERIALS AND METHODS

2.1 Procurement of Raw Materials

Fresh cow milk, spices, condiments, gingelly oil, vinegar, lemon fruits, garlic, ginger and other food-grade ingredients required for the preparation of paneer thokku were procured from the local market. All raw materials were examined for freshness, quality and suitability before use.

2.2 Preparation of Paneer

Fresh cow milk was standardized to 4.5% fat and heated to 85°C. Coagulation was carried out using a 1% citric acid solution. The coagulum was allowed to settle, followed by drainage of whey. The curd was subsequently pressed, cooled and cut into approximately 1 cm × 1 cm × 1 cm cubes. Freshly prepared paneer cubes were used for the preparation of the experimental products. The procedure followed the approach reported for traditional-style paneer pickle preparation by Anna Anandh and Sobana (2021), while the use of citric acid for coagulation was consistent with earlier paneer-processing procedures (Bhattacharya et al., 1971).

2.3 Experimental Treatments

Three formulations of paneer thokku were prepared, namely oil-based paneer thokku (C), vinegar-based paneer thokku (T1) and lemon juice-based paneer thokku (T2). The formulations used for the preparation of the experimental products are presented in Table 1. In C, gingelly oil was incorporated at 75%, whereas in T1 and T2, gingelly oil was incorporated at 50% along with 25% vinegar and 25% lemon juice, respectively. The remaining ingredients were incorporated at identical levels in the respective formulations.

TABLE 1
FORMULATION OF TRADITIONAL-STYLE PANEER THOKKU

Ingredients	C: Oil-based	T1: Vinegar-based	T2: Lemon juice-based
Paneer (%)	100	100	100
Gingelly oil (%)	75	50	50
Vinegar (%)	–	25	–
Lemon juice (%)	–	–	25
Turmeric powder (%)	1	1	1
Mustard seeds (%)	1	1	1
Ginger and garlic paste (%)	10	10	10
Roasted cumin seed powder (%)	1	1	1
Roasted fenugreek seeds (%)	1	1	1
Asafoetida powder (%)	1	1	1
Red chilli powder (%)	2.5	2.5	2.5
Salt (%)	3	3	3
Spice mixture (%)	2	2	2

2.4 Preparation of Spice and Condiment Mixture

The dry spice mixture consisted of aniseed (10%), black pepper (10%), capsicum (8%), caraway seed (10%), cardamom (5%), cinnamon (4%), cloves (1%), coriander (20%), cumin seed (22%) and turmeric powder (10%). The spices were cleaned, dried and ground before blending in the specified proportions. Fresh ginger and garlic were peeled, cut into small pieces and ground to a fine paste. The spice and condiment formulation was based on the traditional-style paneer pickle formulation reported by Anandh and Sobana (2021).

2.5 Preparation of Paneer Thokku

Paneer cubes were mixed with turmeric powder and salt and allowed to marinate for one hour. The marinated paneer cubes were fried in gingelly oil until golden brown and kept aside. Mustard seeds were tempered in oil, followed by the addition of ginger-garlic paste, red chilli powder, roasted cumin seed powder, roasted fenugreek seed powder, asafoetida and the prepared spice mixture. The fried paneer cubes were then incorporated and mixed thoroughly.

Based on the respective treatment, gingelly oil, vinegar or lemon juice was incorporated as specified in Table 1. Control (C) contained 75% gingelly oil, whereas T1 and T2 contained 50% gingelly oil along with 25% vinegar and 25% lemon juice, respectively. The mixture was cooked with continuous stirring until a thick thokku consistency was obtained. The prepared products were cooled to room temperature and subjected to physicochemical, microbiological and sensory evaluation.

2.6 Physicochemical Analysis

The pH of the products was determined using a calibrated digital pH meter. Product yield was calculated as the weight of the final product relative to the initial product weight and expressed as a percentage. Titratable acidity was determined and expressed as percentage acidity. Moisture content was determined by the standard hot-air oven method following AOAC procedures (AOAC, 2005). The analytical procedures were based on standard methods and procedures reported for paneer pickle evaluation (Anna Anandh and Sobana, 2021).

2.7 Microbiological Analysis

The microbiological quality of paneer thokku was evaluated by determining total plate count, coliform count, and yeast and mould count. Samples were processed aseptically and analysed using standard microbiological procedures. Microbial counts were expressed as log₁₀ cfu/g. Samples showing no detectable growth under the test conditions were recorded as not detected (ND). The methodology was based on standard procedures described in the Compendium of Methods for the Microbiological Examination of Foods (Salfinger and Tortorello, 2015).

2.8 Sensory Evaluation

Sensory evaluation was carried out using a 9-point hedonic scale by a panel of semi-trained judges. The sensory attributes evaluated were appearance and colour, flavour, juiciness, texture, saltiness, sourness and overall acceptability. Scores were assigned from 1 to 9, with 1 representing extremely undesirable and 9 representing extremely desirable.

2.9 Experimental Replication and Statistical Analysis

The experiment was conducted in six independent replications. The data obtained for physicochemical, microbiological and sensory parameters were subjected to analysis of variance (ANOVA). Treatment means were compared at a significance level of $P < 0.05$.

III. RESULTS AND DISCUSSION

3.1 Physicochemical Characteristics

The physicochemical characteristics of paneer thokku prepared using the three formulations are presented in Table 2. Significant differences ($P < 0.05$) were observed among the formulations for pH, product yield, titratable acidity and moisture content. The differences were associated with the varying proportions of vinegar and lemon juice incorporated into the formulations. The pH values differed among the formulations, with T1 recording the lowest pH (4.42), followed by T2 (4.71)

and C (5.21). The lower pH observed in T1 and T2 might be attributed to the incorporation of organic acids, predominantly acetic acid from vinegar and citric acid from lemon juice. Organic acids are known to reduce the pH of food systems and thereby contribute to microbial inhibition (Ben Braiek and Smaoui, 2021). The greater reduction in pH observed in T1 indicated stronger acidification under the formulation conditions employed. This observation agrees with Anna Anandh and Sobana (2021), who reported lower pH in vinegar-based paneer pickle, followed by lemon juice- and vegetable oil-based products.

Product yield was highest in C (120.85%), followed by T2 (111.40%) and T1 (99.20%). The higher yield observed in C might be attributed mainly to the greater proportion of gingelly oil incorporated into the formulation and its retention in the final product. The yield values represent final product mass yield and should therefore not be interpreted as recovery of milk solids. Similar treatment-dependent differences in yield were reported by Anna Anandh and Sobana (2021), in which the oil-based paneer pickle showed higher product yield than the acidulant-based formulations.

TABLE 2
PHYSICOCHEMICAL CHARACTERISTICS OF PANEER THOKKU PREPARED USING DIFFERENT TREATMENTS

Parameter	C	T1	T2
pH	5.21 ± 0.08a	4.42 ± 0.06b	4.71 ± 0.05c
Product yield (%)	120.85 ± 0.32a	99.20 ± 0.28b	111.40 ± 0.25c
Titrateable acidity (%)	0.12 ± 0.02a	0.89 ± 0.03b	0.18 ± 0.02c
Moisture (%)	49.30 ± 0.24a	45.82 ± 0.22b	47.60 ± 0.20c

Values are Mean ± SE. Means bearing different superscripts within a row differ significantly (P<0.05).

Titrateable acidity was highest in T1 (0.89%), followed by T2 (0.18%) and C (0.12%). The markedly higher acidity in T1 corresponded with its lower pH and might be attributed to the incorporation of 25% vinegar. Although T2 contained an equivalent proportion of lemon juice, it exhibited considerably lower titrateable acidity, indicating differences in the acid contribution and buffering interactions of the respective formulations. This trend was consistent with the findings of Anna Anandh and Sobana (2021), who reported higher titrateable acidity in vinegar-based paneer pickle than in lemon juice-based products.

Moisture content was lowest in T1 (45.82%), followed by T2 (47.60%) and C (49.30%). The differences in moisture content might be associated with cooking-related moisture loss and the varying proportions of oil and acidulants incorporated into the formulations. The relatively lower moisture content of T1 occurred along with its lower pH and might have contributed to its improved microbiological stability. Similar differences in moisture content among oil-, vinegar- and lemon juice-based paneer pickle formulations have previously been reported by Anandh and Sobana (2021).

3.2 Microbiological Characteristics

The microbiological characteristics of paneer thokku are presented in Table 3. Total plate count differed significantly among the formulations. T1 recorded the lowest TPC (1.21 log₁₀ cfu/g), followed by T2 (1.43 log₁₀ cfu/g) and C (1.72 log₁₀ cfu/g). The lower TPC observed in the acidulant-based formulations may be associated with the combined effects of acidification, heat treatment, salt, spices and oil. The vinegar-based formulation showed the lowest TPC, corresponding with its lowest pH and highest titrateable acidity. Organic acids such as acetic and citric acids can exert antimicrobial effects by lowering environmental pH and interfering with microbial cellular processes (Ben Braiek and Smaoui, 2021; Presser et al., 1999). The present findings are in agreement with those of Anna Anandh and Sobana (2021), who observed lower microbial counts in vinegar- and lemon juice-based paneer pickle than in the vegetable oil-based product. Rani et al. (2014) also demonstrated the potential of pickling as a preservation method for paneer. In addition, the preservative contribution of spices might have complemented the effects of acidity, as several spices have been reported to influence the microbial and chemical stability of paneer during storage (Eresam et al., 2015).

Coliforms and yeasts and moulds were not detected in any of the formulations. This indicates satisfactory microbiological quality of the products under the processing and analytical conditions employed. However, the absence of detectable

organisms should be interpreted as a result under the specific test conditions and should not be considered evidence of complete microbial sterility.

TABLE 3
MICROBIOLOGICAL CHARACTERISTICS OF PANEER THOKKU PREPARED USING DIFFERENT TREATMENTS

Microbial profile (log ₁₀ cfu/g)	C	T1	T2
Total plate count	1.72 ± 0.10a	1.21 ± 0.08b	1.43 ± 0.09c
Coliform count	ND	ND	ND
Yeast and mould count	ND	ND	ND

Values are Mean ± SE. ND = Not detected. Means bearing different superscripts within a row differ significantly ($P < 0.05$).

3.3 Sensory Characteristics

The sensory characteristics of paneer thokku are presented in Table 4. Lemon juice-based paneer thokku (T2) recorded the highest scores for appearance and colour (8.08), flavour (8.56), juiciness (8.02), texture (8.06), saltiness (8.01) and overall acceptability (8.12). The consistently higher sensory scores of T2 indicate a favourable overall sensory response to the lemon juice-based formulation. The higher flavour and overall acceptability scores of T2 might be associated with the relatively mild and balanced acidic character of lemon juice, which complemented the flavour of the spice and condiment system. The use of fruit-derived acidulants has previously been associated with acceptable sensory characteristics in paneer products (Ahmed and Bajwa, 2019).

TABLE 4
SENSORY CHARACTERISTICS OF PANEER THOKKU PREPARED USING DIFFERENT TREATMENTS

Sensory Attributes*	C	T1	T2
Appearance and colour	7.05 ± 0.11a	7.52 ± 0.10b	8.08 ± 0.12c
Flavour	7.08 ± 0.10a	7.64 ± 0.12b	8.56 ± 0.10c
Juiciness	7.10 ± 0.10a	7.58 ± 0.09b	8.02 ± 0.11c
Texture	7.12 ± 0.11a	7.60 ± 0.10b	8.06 ± 0.10c
Saltiness	7.02 ± 0.12a	7.55 ± 0.11b	8.01 ± 0.10c
Sourness	6.05 ± 0.09a	7.62 ± 0.10b	7.12 ± 0.12c
Overall acceptability	6.92 ± 0.10a	7.62 ± 0.11b	8.12 ± 0.10c

Sensory attributes were evaluated on a 9-point hedonic scale (wherein 1 = extremely undesirable and 9 = extremely desirable). Values are Mean ± SE. Means bearing different superscripts within a row differ significantly ($P < 0.05$).

T1 recorded the highest sourness score (7.62), reflecting its greater acidification. Although the stronger acidity of T1 was advantageous in terms of pH reduction and microbial control, the greater perceived sourness may have limited its preference relative to T2. The present findings are consistent with those of Anandh and Sobana (2021), who reported higher sensory scores for lemon juice-based paneer pickle compared with vinegar- and vegetable oil-based formulations. This agreement suggests that lemon juice may provide a favourable balance between acidity and sensory acceptability in traditional-style paneer products. Among the three formulations, overall acceptability was highest for T2 (8.12), followed by T1 (7.62) and C (6.92). Thus, the incorporation of oil, acidulant and spice-condiment systems resulted in distinct sensory responses, with T2 demonstrating the highest overall acceptability.

3.4 Overall Interpretation

The three paneer thokku formulations demonstrated distinct advantages with respect to different quality attributes. Vinegar-based paneer thokku (T1) exhibited the greatest acidification, as indicated by the lowest pH (4.42) and highest titratable acidity (0.89%), and also recorded the lowest TPC (1.21 log₁₀ cfu/g). Oil-based paneer thokku (C) recorded the highest final product yield (120.85%), which was primarily associated with its greater oil incorporation. In contrast, lemon juice-based paneer thokku (T2) demonstrated the most favourable sensory profile, with the highest overall acceptability score (8.12).

The sensory advantage of T2 might be attributed to a favourable balance between acidity and the characteristic flavour of the spice-condiment system. Similar sensory superiority of lemon juice-based paneer pickle has previously been reported by Anna Anandh and Sobana (2021). Thus, the results indicate that formulation performance varied according to the intended quality attribute: T1 was advantageous for acidification and microbial control, C for final product yield, whereas T2 was superior in sensory acceptability. Under the conditions of the present study, lemon juice-based paneer thokku may therefore be considered the preferred formulation, primarily on the basis of sensory acceptability.

IV. CONCLUSION

Paneer thokku was successfully developed using oil-, vinegar- and lemon juice-based formulations. Vinegar-based paneer thokku exhibited the greatest acidification, as indicated by the lowest pH and highest titratable acidity, while oil-based paneer thokku recorded the highest product yield. Lemon juice-based paneer thokku exhibited the highest sensory acceptability (8.12) and was the most preferred formulation under the conditions of the study. Coliforms and yeasts and moulds were not detected in any of the formulations. Further storage and shelf-life studies are recommended to establish product stability and commercial shelf life.

Limitations of the Study: The study was conducted on freshly prepared products, and storage stability was not evaluated. The sensory evaluation was conducted using semi-trained panelists rather than consumers. Future research should include storage studies to evaluate the shelf life and stability of the products, consumer acceptability testing, and optimization of the formulation for commercial production.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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