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Original Research Article

Comparative evaluation of anti-cariogenic effect of various dairy products in pediatric patients: a randomized clinical trial

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ABSTRACT

Background: Dairy products support overall and dental health due to their anticariogenic properties. Rich in calcium, phosphorus, and casein phosphopeptides, they aid enamel remineralization, strengthen teeth, and form a protective barrier that neutralizes acids. Regular consumption helps prevent cavities, enhance tooth structure, and promote better oral hygiene. The aim of the study was to compare and evaluate the anti-cariogenic effect of various diary products in pediatric patients - a randomized clinical trial.
Methods: Ninety children aged 6–12 years (45 with caries and 45 caries-free) visiting the Department of Pediatric and Preventive Dentistry were included after abstaining from oral hygiene for 24 hours. Participants were randomly assigned to three groups: milk, curd, and paneer. Baseline plaque pH was recorded using a digital pH meter. Following consumption of the assigned test food (milk 50 ml, curd 50 g, paneer 50 g), plaque pH levels were measured at 10, 20, and 30 minutes.
Results: Paneer showed the highest plaque pH at 10, 20, and 30 minutes followed by yogurt and milk. Children aged 6–12 years showed no significant age or gender differences. Paneer maintained stable pH, yogurt showed no significant changes, while milk exhibited group differences but no significant pH shifts. Group A displayed higher baseline pH than group B, with yogurt subgroup showing significant differences at 10 and 20 minutes ($p<0.001$).
Conclusion: The findings of our study indicate that paneer consumption may play a beneficial role in promoting remineralization and improving caries management.

Keywords: Dental caries, Plaque pH, Paraffin Wax, Paneer, Yogurt, Milk

INTRODUCTION

Dental diseases represent a major global health challenge, impacting a large portion of the global population, regardless of socioeconomic status or geographic location. A landmark report by the US general surgeon characterized dental health as a "silent epidemic," emphasizing its severe impact on children and adults.[1] Dental caries is a multifaceted bacterial disease, characterized by its infectious and transmissible nature, and resulting from the intricate interplay of various factor.[2]

The identification of tooth decay typically begins with the appearance of a small, chalky area on a smooth tooth surface. Untreated caries can lead to severe complications including: pulpitis, chronic infection, abscess formation, tooth loss, and cellulitis.[3]

The World Health Organization (WHO) Global Oral Health Status Report (2022) further highlighted that 2 billion people suffer from caries in permanent teeth, while 514 million children experience caries in their primary teeth.[4] The prevalence of dental caries exhibits significant

variability, affected by many factors including: ethnicity and cultural background, socioeconomic status, dietary patterns and nutrient intake, oral hygiene practices and genetic predisposition, particularly inherent developmental defects in enamel formation.[2]

Dental caries and gingivitis are prevalent plaque-induced dental diseases that often originate in childhood, underscoring the importance of early preventive measures. Effective plaque control requires a comprehensive understanding of the oral biofilm's structural and pathophysiological properties, as well as identification of the factors that disrupt the delicate balance of the oral microbiome.[5]

The complex interplay between nutrition, diet, and dental health has been a subject of ongoing interest, as vital nutrients interact with oral tissues to impact overall oral health.[1]

Dairy products are generally considered non-cariogenic and some have even demonstrated anticariogenic properties, actively helping to prevent tooth decay. The dairy products derived from milk have been found to possess a low cariogenic potential, thereby exhibiting anticariogenic properties.[6] The incorporation of milk and dairy products into one's diet has been found to have a positive impact on calcium and phosphate levels, thereby reducing tooth demineralization and promoting remineralization. Tooth decay can be prevented when plaque on the teeth has high levels of calcium and phosphate, and the pH is specific. The binding of calcium ions to proteins within the plaque matrix serves as a calcium reservoir. However, acidogenesis-induced pH reductions within the plaque trigger enamel demineralization.[7]

Probiotics can be defined as "live microorganisms that, when consumed in sufficient amounts, provide a health benefit to the host." Probiotics also possess numerous oral health benefits, including the capacity to lower salivary pH and produce antioxidants that neutralize free radicals, thereby preventing plaque mineralization and formation. It has also shown to impede the colonization of *Streptococcus mutans* on tooth surfaces, a key factor in preventing dental plaque formation and subsequent dental caries development.[8]

Paneer is produced by adding lime juice to milk, effectively preserving milk's non-cariogenic properties. It contains more protein and phosphate than regular cheese, but its effect on the potential for causing cavities still remains uncertain. As a sugar-free and unaged cheese alternative, paneer's unique nutritional profile sets it apart from other types of cheese.[9]

Dairy products have consistently been associated with strong oral health because of high levels of calcium and phosphate ions, along with their proven anticariogenic effect.[7]

While numerous studies and clinical trials have demonstrated the remineralizing potential and success of products containing CPP amorphous calcium phosphate (CPP ACP) with or without fluoride, there is limited research comparing naturally occurring Ca/P based foods that may restore lost Ca/P ions in enamel in a similar manner.[10]

The purpose of our present study was to assess the changes in plaque pH following the consumption of various dairy products, including probiotic yogurt, paneer, and milk, with the aim of evaluating their anti-cariogenic effects in pediatric patients.

Aim and objectives

The aim of the study was to compare and evaluate the anti-cariogenic effect of various dairy products in pediatric patients.

Objectives of the study were to compare the anti-cariogenic effect of milk with yogurt, to compare the anti-cariogenic effect of milk with paneer, to compare the anti-cariogenic effect of yogurt with paneer, and to determine the most effective dairy product among milk, yogurt, and paneer in reducing dental caries.

METHODS

This study was carried out in the Department of Pediatric and Preventive Dentistry, Shree Bankey Bihari Dental College and Research Centre, Ghaziabad, Uttar Pradesh. A total of 90 children, aged 6-12 years were selected randomly based on selection criteria. It was reviewed and approved by the institution ethical committee. Informed consent was obtained from each subject’s parents before enrolling them in study. They were divided into 2 major groups (45 caries free and 45 caries active) and they were further randomly assigned into three groups (milk, curd and paneer group) each comprising 15 children.

Group A included caries free subjects. Subgroups included: paneer (Amul fresh paneer 50 g), yogurt (Amul yogurt 50 ml), and milk (Amul fresh milk 50 ml).

Group B included caries active subjects. Subgroups included: paneer (Amul fresh paneer 50 mg), yogurt (Amul yogurt 50 ml), and milk (Amul fresh milk 50 ml).

Inclusion criteria

Children between 6-12 years of age, healthy subjects with no systemic diseases, and 45 subjects with DMFT and def scores <0 were included.

Exclusion criteria

Children younger than 6 years of age or older than 12 years of age, children suffering from any systemic disease or on any kind of medication for the last three months, lactose

intolerant subjects, and children undergoing orthodontic treatment were excluded.

Informed consent was obtained from parents two days before the examination, and demographic data was collected using a specifically designed form. Subsequently they were given written as well as verbal instructions requesting them to refrain from all oral hygiene measures for 48 hours, in order to ensure adequate plaque accumulation, and abstain from eating or drinking (except water) on the day they report to the Department for the study to ensure a controlled environment.

"First, the pH meter was calibrated according to the manufacturer's instructions using buffer standards of pH 7 and pH 4. The intrinsic pH of the dairy products was then measured using the calibrated digital pH electrode. For each measurement 50 ml of milk, 50 g of curd, and 50 g of paneer (crushed in a grinder placed in a beaker) and stirred until a stable reading was achieved. The electrode was then inserted directly into each solution. Between readings, the electrode was rinsed with distilled water to prevent cross-contamination. The estimation of the endogenous pH of the dairy products was carried out before plaque accumulation occurred.

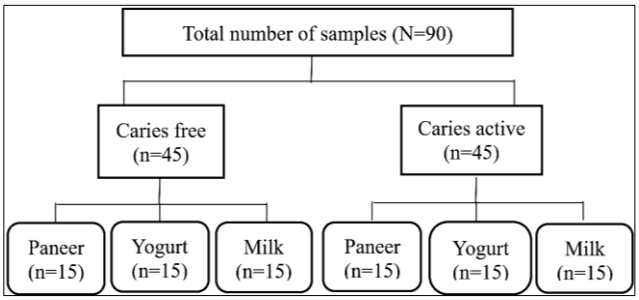

Figure 1: Study design.

The subjects were asked to chew one gram of paraffin wax for 3 minutes and plaque samples were collected in glass beakers. The pH of plaque was recorded as the baseline score on the proximal surfaces of first molars for all selected subjects with the help of a universal hand scaler and then dissolved in distilled water taken in a beaker. (Figures 6-8) The pH was then measured with the standard electrode pH meter. (Figures 4 and 5). The subjects in each sub-group were then asked to consume their respective dairy product. They were asked to rinse with distilled water. Plaque pH measurements were then repeated after 10, 20, and 30 minutes, using the same procedure for all subjects. After collection of plaque samples i.e., after 30 min, subjects were made to rinse vigorously with distilled water to prevent pooling of the test samples in their mouth. In order to eliminate inter-examiner variability all measurements were made by the same examiner while an assistant was recording the pH values. The electrode was rinsed in distilled water between readings recorded at different time intervals in order to rule out erroneous measurements. The tabulated data was then sent for statistical analysis.

RESULTS

Comparison of mean pH at different time intervals in group A and group B in subgroup paneer

Table 1 shows the comparison of mean pH at different time intervals in group A and group B in subgroup paneer group A (subgroup paneer) remained relatively stable over time, with baseline pH of 7.20±0.04, decreasing to 7.00±0.08 at 10 minutes, 7.10±0.06 at 20 minutes and 7.00±0.04 at 30 minutes. In contrast, group B (paneer) a lower baseline pH of 6.40±0.04, which further decreased over time indicating a significant intergroup difference ($p<0.05$).

Table 1: Comparison of mean pH at different time intervals in group A and group B in subgroup paneer.

Time interval	Group A	Group B	P value
Baseline	7.2000±0.04158	6.4000±0.04142	0.027
10 min	7.0000±0.08220	6.2000±0.04546	0.034
20 min	7.1000±0.06499	6.4000±0.03945	0.039
30 min	7.0000±0.04061	6.5000±0.02667	0.025

Comparison of mean pH at different time intervals in group A and group B in subgroup yogurt

Table 2 shows the comparison of mean pH at different time intervals in group A and group B in subgroup yogurt. The baseline pH was 7.00±0.04 in group A (yoghurt) and 6.20±0.02 in group B (yoghurt) ($p=0.035$). Over time, group B exhibited a consistently lower pH compared to group A, with significant differences at all-time intervals. The lowest pH was observed at 10 minutes (6.10±0.05 versus 5.50±0.02, $p=0.047$).

Table 2: Comparison of mean pH at different time intervals in group A and group B in subgroup yogurt.

Time interval	Group A	Group B	P value
Baseline	7.0000±0.04158	6.2000±0.02470	0.035
10 min	6.1000±0.05662	5.5000±0.02132	0.047
20 min	61.3000±0.04254	5.7000±0.02547	0.047
30 min	6.5000±0.04423	5.9000±0.05147	0.049

Comparison of mean pH at different time intervals in group A and group B in subgroup milk

Table 3 shows the comparison of mean pH at different time intervals in group A and group B in subgroup milk. At baseline, the mean pH for group A (milk) was 6.90±0.21, while for group B (milk) it was 6.30±0.24. At all-time points, a significant difference was observed between the groups ($p<0.05$), with group A maintaining a higher pH than group B.

Table 3: Comparison of mean pH at different time intervals in group A and group B in subgroup milk.

Time interval	Group A	Group B	P value
Baseline	6.9000±0.21205	6.3000±0.24001	0.040
10 min	7.3000±0.39295	6.6000±0.07367	0.022
20 min	7.2000±0.40170	6.4000±0.19246	0.032
30 min	7.3500±0.40095	6.3500±0.19466	0.039

Comparison of mean pH at different time intervals in each group in subgroup paneer

Table 4 present the comparison of mean pH at different time intervals in each group in subgroup paneer. In group A (paneer), the pH remained relatively stable, decreasing slightly from 7.20±0.04 at baseline to 7.00±0.04 at 30 minutes. In contrast, group B (paneer) showed a significant pH drop, decreasing from 6.40±0.04 to 6.50±0.02 over the 30-minute period. The p values for both groups were <0.05 when compared to baseline, indicating significant intragroup changes.

Table 4: Comparison of mean pH at different time intervals in each group in subgroup paneer.

Time interval	Group A (paneer)	Group B (paneer)
Baseline	7.2000±0.04158	6.4000±0.04142
10 min	7.0000±0.08220	6.2000±0.04546
20 min	7.1000±0.06499	6.4000±0.03945
30 min	7.0000±0.04061	6.5000±0.02667
P value from baseline	0.022	0.027

Comparison of mean pH at different time intervals in each group in subgroup yogurt

Table 5 shows the comparison of mean pH at different time intervals in each group in subgroup yogurt. In group A (yoghurt), the pH decreased from 7.00±0.04 at baseline to 6.50±0.04 at 30 minutes, but this change was not statistically significant (p=0.121). Similarly, in group B (yoghurt), the pH dropped from 6.20±0.02 to 5.90±0.05 over 30 minutes, with no significant difference observed (p=0.167).

Table 5: Comparison of mean pH at different time intervals in each group in subgroup yogurt.

Time interval	Group A (yogurt)	Group B (yogurt)
Baseline	7.0000±0.04158	6.2000±0.02470
10 min	6.1000±0.05662	5.5000±0.02132
20 min	6.3000±0.04254	5.7000±0.02547
30 min	6.5000±0.04423	5.9000±0.05147
P value from baseline	0.121	0.167

Comparison of mean pH at different time intervals in each group in subgroup milk

Table 6 illustrate the comparison of mean pH at different time intervals in each group in subgroup milk. In group A (milk), the pH slightly increased from 6.90±0.21 at baseline to 7.35±0.40 at 30 minutes, but this change was not statistically significant (p=0.145). In contrast, group B (milk) showed a pH drop from baseline to 30 min, but no statistically significant change was observed (p=0.146).

Table 6: Comparison of mean pH at different time intervals in each group in subgroup milk.

Time interval	Group A (milk)	Group B (milk)
Baseline	6.9000±0.21205	6.3000±0.24001
10 min	7.3000±0.39295	6.6000±0.07367
20 min	7.2000±0.40170	6.4000±0.19246
30 min	7.3500±0.40095	6.3500±0.19466
P value from baseline	0.145	0.146

Correlation of mean pH among subgroups in group A and group B (caries-free) (caries active)

Table 7 shows comparison of mean pH among all subgroups in both caries-free (group A) and caries-active (group B) subjects, paneer showed the highest baseline pH, followed by milk and yoghurt, with no significant differences (p>0.05). Over time, Milk demonstrated the highest pH at 10 and 30 minutes, while yoghurt consistently exhibited the lowest values. Significant differences were observed among subgroups at 10 and 20 minutes (p<0.05), whereas differences at 30 minutes were not statistically significant (p>0.05).

Table 7: Correlation of mean pH among subgroups in group A and group B (caries-free) (caries active).

Time interval	Paneer, group A	Paneer, group B	Yoghurt, group A	Yoghurt, group B	Milk, group A	Milk, group B	P value, group A	P value, group B	Post hoc, group A	Post hoc, group B
Base-line	7.2000± 0.04158	6.4000± 0.04142	7.0000± 0.04158	6.2000± 0.02470	6.9000± 0.21205	6.3000± 0.24001	0.121	0.435	1>2>3	1>3>2
10 min	7.0000± 0.08220	6.2000± 0.04546	6.1000± 0.05662	5.5000± 0.02132	7.3000± 0.39295	6.6000± 0.07367	0.034	0.021	3>2>1	3>1>2

Continued.

Time interval	Paneer, group A	Paneer, group B	Yoghurt, group A	Yoghurt, group B	Milk, group A	Milk, group B	P value, group A	P value, group B	Post hoc, group A	Post hoc, group B
20 min	7.1000± 0.06499	6.4000± 0.03945	6.3000± 0.04254	5.7000± 0.02547	7.2000± 0.40170	6.4000± 0.19246	0.021	0.041	3>1>2	3>1>2
30 min	7.0000± 0.04061	6.5000± 0.02667	6.5000± 0.04423	5.9000± 0.05147	7.3500± 0.40095	6.3500± 0.19466	0.211	0.442	3>2>1	1>3>2

DISCUSSION

Nutrition and oral health are intricately linked with diet playing a crucial role in the development and maintenance of healthy teeth and surrounding structures. Conversely, a healthy dentition enables individuals to consume a balanced diet throughout their lives.[19]

Dairy products play a crucial role in providing essential micronutrients (calcium, phosphorus, magnesium, vitamins A, B12, and D) and macronutrients (including proteins and nonessential fatty acids) which are vital for overall daily functioning. Therefore, including dairy products in an individual's daily diet, beginning in childhood, can help reduce the risk of caries.[13] In our study we are comparing various dairy products (paneer, milk, yogurt) to evaluate the anticariogenic effect of each one.

Paneer, a soft, non-fermented cheese, is known for its high levels of protein, phosphate, calcium, fats, and vitamins.[18] Moynihan et al emphasized that paneer can be recommended as protective foods during diet counseling, especially for young individuals. Supporting this, studies by Jenkins and Hargreaves, Moynihan et al, and Ravishankar et al observed an increase in plaque calcium concentration within 5–10 minutes of consuming paneer, further underlining the oral health benefits of dairy products.[20,21]

The finding of present study indicated that there is significant difference in the mean pH at different time intervals for the groups A and B. In group A, paneer subgroup confirms significant intragroup changes, with group A pH decreasing slightly while group B pH dropped significantly with p values <0.05 for both groups compared to baseline. The results of this study demonstrate that paneer offers comparable protection to paneer against acidogenic challenges (Tables 1 and 4).

Paneer proved to be as protective as cheese against acidogenic challenge. The anti-acidogenic properties of paneer were confirmed in this study, aligning with the findings of Tayab et al.

Similarly, Jensen and Wefe et al in their study highlighted the protective effect of processed cheese against acidity following a sucrose rinse. Similarly, findings regarding plaque pH changes after paneer consumption were reported by Sonmez and Aras et al, as well as Telgi et al.[6,16,21]

Probiotic microorganisms are naturally present in certain dietary products such as yogurt. It exerts a profound impact on oral health by interfering with biofilm formation through direct and indirect interactions. Thus, reduction in salivary pH following the consumption of both probiotic and regular curd was mainly due to the acidic properties of the curds. Ferrazzano et al suggested that probiotics can be delivered through milk-based products, as the CPPs present in these products help prevent demineralization and promote the remineralization of dental enamel.[23]

In this current study, the consumption of yogurt led to an initial rapid drop in plaque pH, which aligns with findings by Sonmez and Arasi. The early decrease in plaque pH was likely due to the yogurt's acidic nature, with a pH ranging between 4.0 and 4.5. However, after 20 minutes, an increase in pH was noted, possibly attributed to the buffering capacity of stimulated saliva and the lower lactose content in yogurt resulting from fermentation. Moreover, the naturally occurring CPP in yogurt, which are present in higher amounts compared to milk due to proteolytic activity, may have played a role in the pH rise and helped prevent demineralization (Tables 2 and 5).[16]

Poureslami et al showed that probiotic yogurt resulted in a more substantial increase in salivary calcium levels when compared with plain yogurt. This implies that youngsters who are susceptible to tooth decay are not at risk from curd, even though it is acidic. Conversely, because of its vitamin, protein, phosphorus, and calcium content, it might be advantageous.[24]

The results of the current study in contrast to the study by Sudhir et al, who reported a statistically significant decrease in salivary pH after 30 days of consumption in the probiotic group, but not in the normal curd group. Similar studies have also indicated that consuming products with probiotic lactobacilli or bifidobacteria can reduce the number of Mutans Streptococci in saliva.[12] In contrast, various studies have found that sugar-free yogurt did not reduce plaque pH below 5.7. It was also observed that different fruity yogurts can lower plaque pH to levels ranging from 5.54 to 5.61. This could be attributed to the fact that fruity yogurts have a lower pH compared to sugar-free yogurt.

Milk is a rich source of nutrients, including calcium, phosphorus, and CPPs, which may help protect tooth surfaces. Levine's hypothesis proposes three primary mechanisms: adsorption of milk proteins onto the enamel

surface, thereby inhibiting demineralization; adsorption of milk fat onto the enamel surface, exerting a p-rotective effect; and enzymatic inhibition of acidogenic plaque bacteria proliferation and multiplication.[8] The cariogenic potential of milk is influenced by its lactose content which oral microorganisms can metabolize to produce organic acids that may promote demineralization.[15,16]

This finding suggests that milk consumption does not contribute to dental caries development and supports the potential protective role of dairy products in preventing caries development during childhood and adolescence. Aimutis et al demonstrated that the CPPs and glycol macro-peptide components found in dairy products provide a protective effect on tooth enamel by inhibiting demineralization. This dual mechanism of action promotes oral health by mitigating the risk of tooth decay. The findings of Ferrazzano et al support this conclusion.[17,60] The intake of milk and dairy products has been connected to a decreased likelihood of developing dental caries and the benefits of these products can be attributed to several principal mechanisms, including the remineralization of tooth enamel, the prevention of bacterial attachment to the tooth surface, and the inhibition of bacterial biofilm formation (Tables 3 and 6).

According to Levine's study, milk is a rich source of calcium and phosphate, and its consumption leads to a significant reduction in plaque pH. Moreover, plain milk has been found to be non-cariogenic. The anticariogenic properties of milk can be attributed to its high buffering capacity and the presence of calcium, phosphate, proteins, and phosphoproteins.[6] while, studies by Masih et al and Danchaivijitr et al suggest that milk has cariostatic properties, its consumption with cariogenic foods can override this effect.[25,26]

Research conducted by Merrttis et al has highlighted the significance of milk consumption for dental health. The study demonstrated that calcium, phosphorus, and bioactive peptides present in milk exhibit enamel protective and anticariogenic effects, emphasizing the importance of milk as a nutritional component of oral health.[26]

Likewise, studies by Nase et al, Ahola et al, Caglar et al, Busscher et al, and Petti et al found that milk products led to a significant reduction in salivary *S. mutans*, which contributed to a lower occurrence of dental caries.[22]

Although previous research has explored the effects of various foods on plaque pH, no studies have specifically examined the changes in plaque pH following the consumption of milk, yogurt, and paneer in combination with paraffin wax, particularly comparing caries-active and caries-free individuals. Therefore, this study was undertaken to evaluate the anticariogenic potential of these dairy products.

CONCLUSION

The findings of our study indicate that paneer consumption may play a beneficial role in promoting remineralization and improving caries management.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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