



Evaluation of salivary pH after consumption of black coffee and lemon tea: A randomised controlled clinical study

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DOI: <https://doi.org/10.66856/ijds.2026.8.4.8141>

Abstract

Background: Saliva contributes to oral homeostasis through lubrication, clearance and buffering of dietary acids. Acidic beverages can produce transient changes in salivary pH, although the magnitude and duration of the response vary with beverage composition and salivary factors. ^[1, 6]

Aim: To compare changes in salivary pH after consumption of black coffee and lemon tea, using water as a control.

Materials and Methods: A three-arm, parallel-group randomised controlled trial was conducted among 90 healthy adults aged 20–30 years, with 30 participants in each group. Unstimulated whole saliva was collected at baseline, immediately after consumption of 20 mL of the assigned beverage, and 15 minutes later. Salivary pH was measured using a digital pH meter with a precision of 0.01. Between-group differences at each time point were assessed using one-way ANOVA followed by Tukey HSD post-hoc testing.

Results: Immediately after consumption, mean salivary pH decreased from 6.92 ± 0.25 to 6.11 ± 0.10 in the Black Coffee group and from 6.91 ± 0.27 to 5.62 ± 0.15 in the Lemon Tea group. In the Water group, pH increased slightly from 6.89 ± 0.26 to 6.94 ± 0.16 . Between-group differences were significant immediately after consumption ($F=672.506$, $p<0.0001$) and at 15 minutes ($F=72.899$, $p<0.0001$). Repeated-measures ANOVA showed significant changes across the three time points in the Black Coffee group ($F(2,58)=376.662$, $p<0.0001$), Lemon Tea group ($F(2,58)=1135.009$, $p<0.0001$) and Water group ($F(2,58)=4.232$, $p=0.019$). At 15 minutes, pH had increased to 6.58 ± 0.10 after black coffee and 6.42 ± 0.11 after lemon tea, but remained below baseline.

Conclusion: Black coffee and lemon tea were associated with marked short-term reductions in salivary pH, with a greater reduction after lemon tea. Salivary pH showed partial recovery over 15 minutes but did not return completely to baseline.

Keywords: Salivary pH, lemon tea, black coffee, acidic beverages, saliva

Introduction

Saliva is a complex biological fluid that supports several aspects of oral homeostasis. It lubricates the oral mucosa, facilitates mastication and swallowing, assists the clearance of food and microorganisms, contributes to antimicrobial defence, and helps protect dental hard tissues. ^[1, 2] Its buffering systems also limit changes in oral acidity following dietary acid exposure. ^[3]

Dietary acids are recognised contributors to erosive tooth wear. The effect of an acidic beverage is not determined by pH alone; acid type, titratable acidity, drinking behaviour and biological factors, including salivary flow, buffering and the acquired pellicle, can influence the oral response. ^[4]

^[6] Dental erosion is distinct from dental caries, although both are influenced by the chemical environment of the oral cavity and repeated acid exposure. ^[4, 5]

Following an acidic challenge, salivary pH may decrease temporarily and subsequently rise as the beverage is cleared and salivary secretion and buffering act on the acid load. The principal salivary buffer systems include bicarbonate, phosphate and proteins. ^[3, 6] Recovery of pH, however, should not be equated with a direct measurement of

buffering capacity, which requires a specific analytical assessment.

Coffee and tea are commonly consumed beverages, but their effects on salivary pH may vary according to preparation, composition, serving volume and additives. Clinical studies have reported changes in salivary pH following beverage consumption, but the direction and magnitude of these responses have not been uniform. ^[7, 10]

The available evidence therefore provides a rationale for examining specific beverage formulations rather than treating coffee or tea as uniform exposures. In particular, direct evidence comparing a standardised volume of black coffee with lemon tea in healthy young adults is limited. Lemon may add an acid load, but beverage pH and titratable acidity were not measured in the present study; therefore, any explanation based on citric acid remains mechanistic rather than directly demonstrated. ^[5, 11]

The present randomised controlled study was undertaken to compare changes in salivary pH after consumption of black coffee and lemon tea, with water used as a control. Salivary pH was assessed at baseline, immediately after consumption and 15 minutes later to evaluate the immediate response and early recovery.

Methodology

Study Design and Setting

A three-arm, parallel-group randomised controlled trial was conducted in the Department of Public Health Dentistry, M.A. Rangoonwala College of Dental Sciences and Research Centre, Pune. Institutional ethics (Helsinki) approval was obtained before recruitment, and written informed consent was obtained from all participants.

Study Participants

Healthy adults aged 20–30 years were screened according to the predefined eligibility criteria. Individuals were excluded if they reported allergy or hypersensitivity to tea, lemon or coffee; were pregnant or lactating; had a known systemic disease; had used antibiotics or immunosuppressive medication during the preceding two weeks; had chronic dental conditions such as periodontitis; or had undergone dental treatment during the preceding two weeks.

Sample Size and allocation

A total of 90 participants were included, with 30 allocated to each study group. The manuscript states that sample-size estimation was based on comparison of mean salivary pH using one-way ANOVA. The numerical assumptions used for the expected effect, standard deviation, significance level and statistical power should be reported explicitly before submission so that the calculation can be reproduced.

$$n=2\sigma^2(Z_{\alpha/2}+Z_{\beta})^2 / d^2$$

Results

Table 1: Demographic Characteristics of Participants in the Three Study Groups

Demographic characteristic	Black Coffee (Group A), n=30	Lemon Tea (Group B), n=30	Water (Group C), n=30	Total (N=90)
Age (years), Mean $\pm$ SD	24.70 $\pm$ 2.71	24.17 $\pm$ 2.80	24.93 $\pm$ 2.63	24.60 $\pm$ 2.70
Gender, n (%)				
Male	17 (56.7%)	12 (40.0%)	17 (56.7%)	46 (51.1%)
Female	13 (43.3%)	18 (60.0%)	13 (43.3%)	44 (48.9%)
Total	30 (100%)	30 (100%)	30 (100%)	90 (100%)

All 90 participants were included in the analysis, with 30 participants in each group. The overall mean age was 24.60 $\pm$ 2.70 years. The age range was 20–30 years in each group. The sample

The participants were randomly allocated to three groups of 30: Group A, black coffee; Group B, lemon tea; and Group C, water (control).

Study Procedure

To reduce the influence of diurnal variation, saliva collection was performed between 8:30 AM and 10:00 AM. Participants were seated comfortably and allowed to relax before collection. Approximately 5–10 mL of unstimulated whole saliva was collected at baseline by allowing saliva to accumulate naturally in the mouth and then expectorating it into a sterile collection container. No chewing or deliberate salivary stimulation was permitted. After baseline collection, each participant received 20 mL of the assigned beverage and was instructed to consume the entire portion. Group A received black coffee, Group B received lemon tea and Group C received water. A second saliva sample was obtained immediately after consumption and a third sample was collected 15 minutes later. Participants were instructed not to consume additional food or beverages during the observation period. Salivary pH was measured using a digital pH meter with a precision of 0.01.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS. Descriptive statistics were summarised as mean and standard deviation. Between-group differences at each assessment time were examined using one-way ANOVA followed by Tukey HSD post-hoc testing. A two-sided p-value <0.05 was considered statistically significant.

comprised 46 males (51.1%) and 44 females (48.9%). The Black Coffee and Water groups each included 17 males and 13 females, whereas the Lemon Tea group included 12 males and 18 females.

Table 2: Mean salivary pH at baseline, immediately after beverage consumption, and 15 minutes after consumption

Group (n = 30)	Baseline pH (Mean $\pm$ SD)	Immediately After (Mean $\pm$ SD)	15 Minutes After (Mean $\pm$ SD)	Mean Change (Baseline– Immediate)	Mean Change (Baseline–After 15 min)
Group A - Black Coffee	6.920 $\pm$ 0.249	6.110 $\pm$ 0.105	6.584 $\pm$ 0.101	–0.81	–0.336
Group B - Lemon Tea	6.910 $\pm$ 0.271	5.624 $\pm$ 0.147	6.416 $\pm$ 0.107	–1.28	–0.494
Group C - Water	6.890 $\pm$ 0.259	6.943 $\pm$ 0.164	6.867 $\pm$ 0.207	0.05	–0.023

Baseline salivary pH values were closely comparable among the three groups. Lemon tea produced the largest immediate fall in pH, followed by black coffee, whereas water

produced only a small change. At 15 minutes, pH had increased in both beverage groups but remained below baseline.

Table 3: Comparison of mean salivary pH between study groups at each assessment time point using one-way ANOVA

Time Interval	Group A Black Coffee (Mean ± SD)	Group B Lemon Tea (Mean ± SD)	Group C Water (Mean ± SD)	F-value (df = 2,87)	p-value
Baseline	6.92 ± 0.25	6.91 ± 0.27	6.89 ± 0.26	0.101	0.904
Immediately after consumption	6.11 ± 0.10	5.62 ± 0.15	6.94 ± 0.16	672.5060	<0.0001
15 minutes after consumption	6.58 ± 0.10	6.42 ± 0.11	6.87 ± 0.21	72.8986	<0.0001

Table 4: Within-group comparison of salivary pH across the three assessment time points using repeated-measures ANOVA

Group	Baseline Mean ± SD	Immediately after Mean ± SD	15 min Mean ± SD	F (2,58)	p-value
Black Coffee	6.920 ± 0.249	6.110 ± 0.105	6.584 ± 0.101	376.662	<0.0001
Lemon Tea	6.910 ± 0.271	5.624 ± 0.147	6.416 ± 0.107	1135.009	<0.0001
Water	6.890 ± 0.259	6.943 ± 0.164	6.867 ± 0.207	4.232	0.019

Table 4. states that Black Coffee: significant difference in mean salivary pH across the three time points, $F=179.047$, $p<0.0001$. Lemon Tea: significant difference across the

three time points, $F=356.359$, $p<0.0001$. Water: no statistically significant difference across the three time points, $F=0.990$, $p=0.3757$.

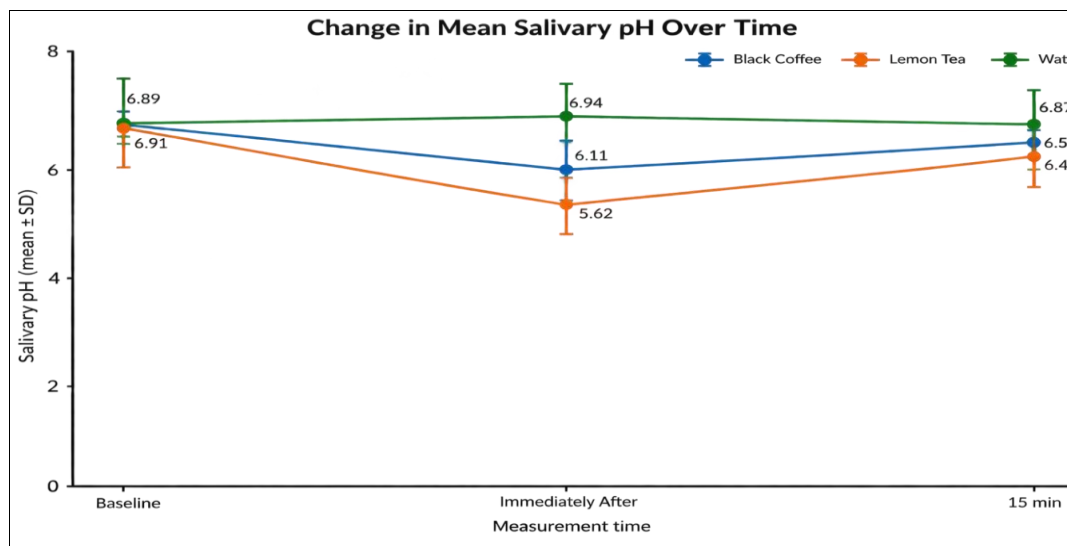
**Fig 1:** Mean salivary pH at different assessment time points in the three study groups.

Figure 1: The line graph shows changes in mean salivary pH at baseline, immediately after beverage consumption, and 15 minutes later. Salivary pH decreased markedly after both black coffee

and lemon tea, with a greater reduction following lemon tea, followed by partial recovery at 15 minutes. The water group showed only minor changes in salivary pH throughout the observation period.

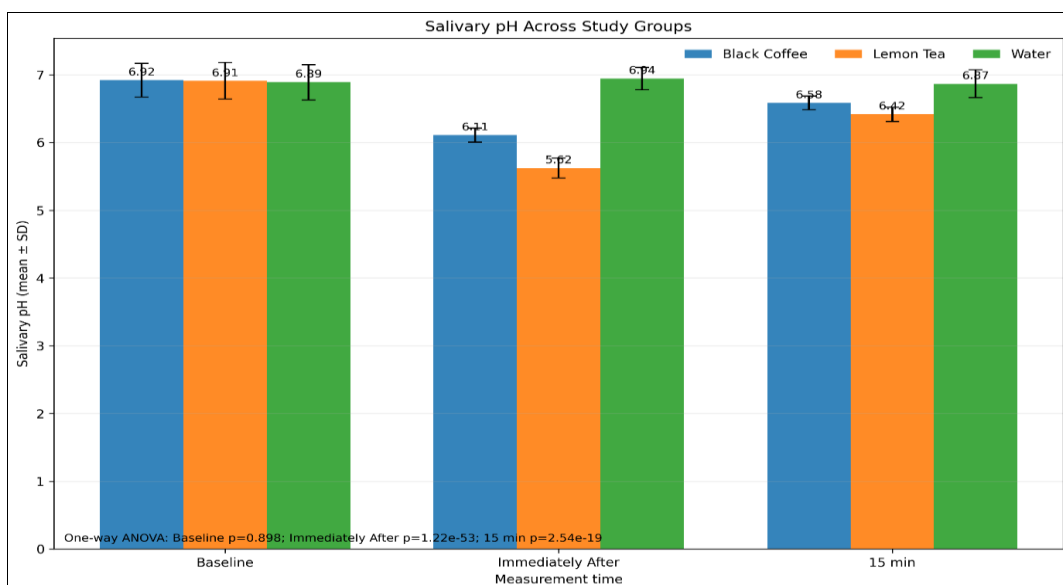
**Fig 2:** Mean salivary pH in the three study groups at baseline, immediately after consumption, and 15 minutes after consumption.

Figure 2: The graph compares mean salivary pH across the three study groups at baseline, immediately after beverage consumption, and after 15 minutes. Baseline pH values were comparable among the groups. A marked reduction in salivary pH was observed immediately after black coffee and lemon tea consumption, with the greater reduction following lemon tea, whereas the water group showed minimal change. At 15 minutes, salivary pH showed partial recovery towards baseline in both beverage groups, although it remained lower than baseline. Between-group differences were statistically significant immediately after consumption and at 15 minutes ($p < 0.001$).

Ninety participants were included in the analysis. Baseline mean salivary pH was 6.92 ± 0.25 in the Black Coffee group, 6.91 ± 0.27 in the Lemon Tea group and 6.89 ± 0.26 in the Water group. Between-group analysis showed no statistically significant baseline difference ($F=0.101$, $p=0.904$).

Immediately after consumption, mean salivary pH decreased to 6.11 ± 0.10 after black coffee and 5.62 ± 0.15 after lemon tea, while the water group showed 6.94 ± 0.16 . The between-group difference was significant ($F=672.506$, $p<0.0001$), and all three Tukey-adjusted pairwise comparisons were significant ($p<0.001$).

At 15 minutes, mean salivary pH had increased to 6.58 ± 0.10 in the Black Coffee group and 6.42 ± 0.11 in the Lemon Tea group. The Water group had a mean pH of 6.87 ± 0.21 . The groups remained significantly different at 15 minutes ($F=72.899$, $p<0.0001$), with all pairwise comparisons significant after Tukey adjustment ($p<0.001$).

Repeated-measures ANOVA demonstrated significant changes across the three time points in the Black Coffee group ($F(2,58)=376.662$, $p<0.0001$), Lemon Tea group ($F(2,58)=1135.009$, $p<0.0001$) and Water group ($F(2,58)=4.232$, $p=0.019$). Bonferroni-adjusted paired comparisons showed significant changes across all three time points in the Black Coffee and Lemon Tea groups. In the Water group, only the immediate-after versus 15-minute comparison was statistically significant; the baseline-to-immediate and baseline-to-15-minute comparisons were not significant.

The repeated-measures findings therefore support a pronounced transient response to black coffee and lemon tea, followed by partial recovery at 15 minutes. The smaller changes observed after water should be interpreted separately from the larger beverage-related changes.

Discussion

The principal finding of this randomised controlled study was that both black coffee and lemon tea were followed by an immediate reduction in salivary pH, with the reduction being greater after lemon tea. Mean pH decreased by 0.81 units after black coffee and by 1.28 units after lemon tea. At 15 minutes, pH had increased in both beverage groups but remained below baseline. Water produced only a small change. These findings indicate an acute change in the measured salivary pH response followed by partial early recovery, rather than a persistent change.

The present findings are broadly consistent with clinical research showing that beverage consumption can alter salivary pH. Hans *et al.* reported reductions in salivary pH after several commercially available beverages, including coffee, together with changes in salivary flow.^[7] The study

involved 120 adults and repeated salivary measurements, making it relevant to the short-term response observed here. Direct numerical comparison is nevertheless inappropriate because beverage formulations, volumes and sampling schedules differed.

Virk *et al.* evaluated the effects of several beverages, including tea, in adults and observed a reduction in salivary pH immediately after tea consumption followed by recovery during subsequent measurements.^[8] The direction of the early response is compatible with the present findings, although the absolute pH values differed. The larger reduction observed with the lemon tea formulation in the present study may reflect differences in formulation, including the addition of lemon. Because beverage pH and titratable acidity were not measured, this remains a plausible explanation rather than a demonstrated mechanism.

Evidence concerning tea is not uniform. Shirzaiy *et al.* reported an increase rather than a decrease in salivary pH after black and green tea in a double-blind crossover study.^[9] Pallepati *et al.* also reported differences in salivary response according to the sweetener used with tea.^[10] These findings emphasise that tea should not be regarded as a single standardised exposure. Brewing method, temperature, volume, sweeteners and added ingredients may influence the oral response. The lemon tea used in the present study should therefore be interpreted as a specific beverage formulation rather than as representative of all tea consumption.

The reduction observed after black coffee is also consistent with the findings of Levrini *et al.*, who monitored oral pH after coffee consumption and observed an initial fall followed by recovery.^[11] Their study used continuous monitoring and also examined the effect of sugar, whereas the present study used discrete saliva samples and a different beverage protocol. These methodological differences limit direct comparison of the magnitude and timing of the response.

The greater reduction after lemon tea may be related to the additional acid load associated with lemon. Beverage acidity is influenced by both pH and titratable acidity. Tenuta *et al.* demonstrated that titratable acidity influences the duration of salivary pH recovery after acidic beverage exposure.^[12] Fernández *et al.* likewise reported that beverage pH and titratable acidity influence the response to acidic beverages.^[13]

The recovery observed by 15 minutes is compatible with the known protective functions of saliva. Saliva dilutes and clears dietary acids, while bicarbonate, phosphate and protein systems contribute to buffering.^[3, 6] The present study measured salivary pH rather than buffering capacity itself. Therefore, the increase in pH should be described as evidence of recovery of the measured pH response, not as a direct quantitative assessment of buffering capacity. This distinction is important because buffering capacity requires a specific acid-titration or equivalent analytical method.^[3, 6] Within the limitations of this study, both black coffee and lemon tea produced an immediate decrease in salivary pH, with a more pronounced reduction following lemon tea. Salivary pH showed a gradual recovery towards baseline over the next 15 minutes, whereas water caused only minor changes. These findings suggest a temporary effect of beverage consumption on salivary pH rather than a direct alteration in buffering capacity. Interpretation is limited by

the short follow-up period, the absence of direct measurements of beverage pH, titratable acidity, temperature, preparation characteristics, salivary flow and buffering capacity, and the inclusion of healthy young adults from a single centre. Further studies with longer observation periods and direct assessment of these factors are needed to better understand the persistence and potential clinical significance of these changes.

Conclusion

Within the limitations of the present study, consumption of black coffee and lemon tea was followed by a significant immediate reduction in salivary pH, with a greater reduction after lemon tea. Salivary pH showed partial recovery at 15 minutes but did not return completely to baseline during the observation period. Water produced only minimal changes. The findings indicate a transient change in salivary pH after the two test beverages; they do not constitute a direct assessment of salivary buffering capacity.

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